6 Project Impact Assessment and Management Needs

6.1 Introduction

Planning for the implementation of this complicated tidal restoration is arguably the most critical component of the larger project. Sustained management will be needed to minimize the potential for impacts to infrastructure, private property, and existing floodplain habitats as increased tidal flooding is implemented.

As an example, and as discussed below in detail, mature woody vegetation presently existing on former saltmarsh habitats and comprising a very large amount of biomass on the river floodplain, will die as a result of incremental salt water inundation. Without active management, some of this standing dead wood will eventually fall to the ground and likely would enter into waterways, perhaps impeding the movements of river herring and other finfish. The shade produced by standing dead shrubs and trees may also reduce the growth of recolonizing saltmarsh plants, which require high light levels. Finally, the occurrence of an extensive stand of dead woody vegetation, which could persist for many years, may be unacceptable to the public. Therefore, appropriate measures to address this specific type of impact are integral components of project planning.

6.2 Incremental Approach to Restoring Tidal Flow as Part of an "Adaptive Management" Strategy

The modified tidal control structure at Chequesset Neck Road (or at alternative locations) will be designed so that planned tidal flows can increase incrementally over a relatively long time period. A carefully planned monitoring program will be implemented to document changes to floodplain characteristics within the Herring River basin and the smaller sub-basins within the project area. The project design will include easy adjustments to tidal flow in the event of unanticipated and unacceptable changes. The approach of monitoring changes as tidal flows are gradually increased and assessed and reacting to these changes defines an "adaptive management" strategy for this project. Section 7.0 outlines the adaptive management plan anticipated for the Herring River restoration project. Issues that have been anticipated and planned for as part of the adaptive management strategy include impacts to low-lying roads, private residences and the CYCC.

6.3 Private Property and Infrastructure Protection and Mitigation

In the hundred years since the Herring River dike was constructed, there has been considerable intrusion into the old floodplain by roadways, private residences and a golf course. This CRP reflects a decision by the HRTC to work in good faith with any abutter – private or public - affected by the restoration to mitigate and remediate adverse impacts.

In many cases, this process is already well underway. Meetings have been held with private homeowners in Wellfleet to discuss issues concerned with affected residences, septic systems and wells. Similar meetings are planned for homeowners in the Ryder Beach area of Truro. The effects of restoration on low-lying roadways have been explored with the Departments of Public Works of Wellfleet and Truro as well as the Maintenance Division of the CCNS. Concerns of the Wellfleet shellfish community are also reflected in this Plan.

6.3.1 Low-lying public roadways

Following dike construction, the roadways were built within the river floodplain at relatively low elevations. These roads were constructed as public access roadways across streams and adjacent wetland areas.

Planned tidal restoration will ultimately result in a significant increase in the high-tide elevations throughout the expansive Herring River floodplain. A number of low-lying public roadways and private properties have elevations below the targeted tidal restoration elevation of 5.1 feet (NAVD 88, see Figure 18). A review of the low-lying roadways in the floodplain has been performed (ENSR July 2007) and the following summary is provided from that report. There are a number of different options to consider for each roadway area that could be affected by restored tidal flows; these include:

- Raising the roadway elevation in its current location
- Realigning the horizontal location of the road to higher ground
- Tolerating a certain degree or frequency of roadway flooding
- Abandoning a specific road or portion of road, subject to Town approvals

Hydraulic analysis would be necessary before any road crossing the river is realigned or raised. Some of these roadways are generally well-traveled and provide important access for residents. Well-made plans for alternative travel routes during any reconstruction work are critical. In several locations the opportunity to restore wetland functions where the roadway may be relocated or abandoned will also be a consideration.

Road Raising

Raising a road involves placing fill to create new road beds with paved or unpaved surfaces above a specific elevation. A number of the low-lying roads in the Herring River are not adjacent to higher ground, but may need widening. This is the case with High Toss Road, Old County Road, and Pole Dike Road. In order to raise these roadways and avoid costly retaining wall construction, the toe of each roadway embankment would need to extend horizontally into adjacent wetland resource areas, such as Bordering Vegetated Wetland (310 CMR 10.55) and Riverfront Area (310 CMR 10.58), which would alter these areas. In addition, raising a road that traverses a wetland area would likely adversely affect tidal

Cumulative lengths of road segments that may be affected by flooding as part of the proposed Herring River Restoration Project in Wellfleet and Truro, Massachusetts (units of length given in feet)

	Elevation of roadway[1]	< 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	> 10
1	Bellamy Lane	-	-	-	-	-	-	-	-	340
2	Black Pond Road	-	-	-	-	83	42	16	13	112
3	Bound Brook Island Road	1,131	1,994	3,130	1,000	799	325	88	44	4,130
4	Bound Brook Way	250	813	334	19	10	8	7	15	4,180
5	Chequessett Knolls Drive	-	-	-	-	16	24	7	11	1,590
6	Chequessett Neck Road	-	-	-	-	97	84	28	28	9,407
7	Chris' Way	-	-	-	-	109	55	26	17	12
8	Cobb Road	-	-	-	-	-	-	-	-	100
9	Duck Harbor Road	1,960	2,240	2,624	1,791	1,494	598	373	254	566
10	Former Railroad Right of Way	-	62	461	727	1,029	407	542	573	1,327
11	Freeman Road	-	-	91	80	139	11	42	46	130
12	Griffin Island Road	-	-	-	-	-	20	26	22	4,813
13	Gull Pond Road	-	-	-	-	-	-	122	65	5
14	High Toss Bridge Road	5	1,167	362	208	108	2	-	2	35
15	Highmeadow Road	-	-	-	-	-	-	-	-	892
16	Newcomb Hill Road	-	-	-	-	-	-	-	-	1,626
17	Newcomb Hill Way	-	-	-	-	-	-	-	-	710
18	Old Chequesset Neck Road	-	-	-	460	368	192	74	58	531
19	Old County Road	38	344	367	464	619	536	507	388	5,593
20	Pamet Point Road	-	-	-	7	13	33	67	105	16
21	Pole Dike Road	-	214	65	61	57	-	-	-	129
22	Prince Valley Road	-	-	-	7	15	168	152	53	958
23	Quail Run	-	-	-	-	-	-	-	-	144
24	Ryder Beach Road	11	65	389	653	255	254	172	39	1,740
25	Snake Creek Road	52	753	1,210	1,280	508	88	-	-	-
	Road Name Blank[2]	119	852	939	906	469	399	270	386	25,564
	Total	3,566	8,504	9,972	7,663	6,189	3,246	2,519	2,117	64,650

1. Units of elevation are presented in feet NAVD 88. Add 0.86 feet to NAVD 88 elevations to obtain NGVD 29 elevations.
2. Road without a name in the Massachusetts EOT road database

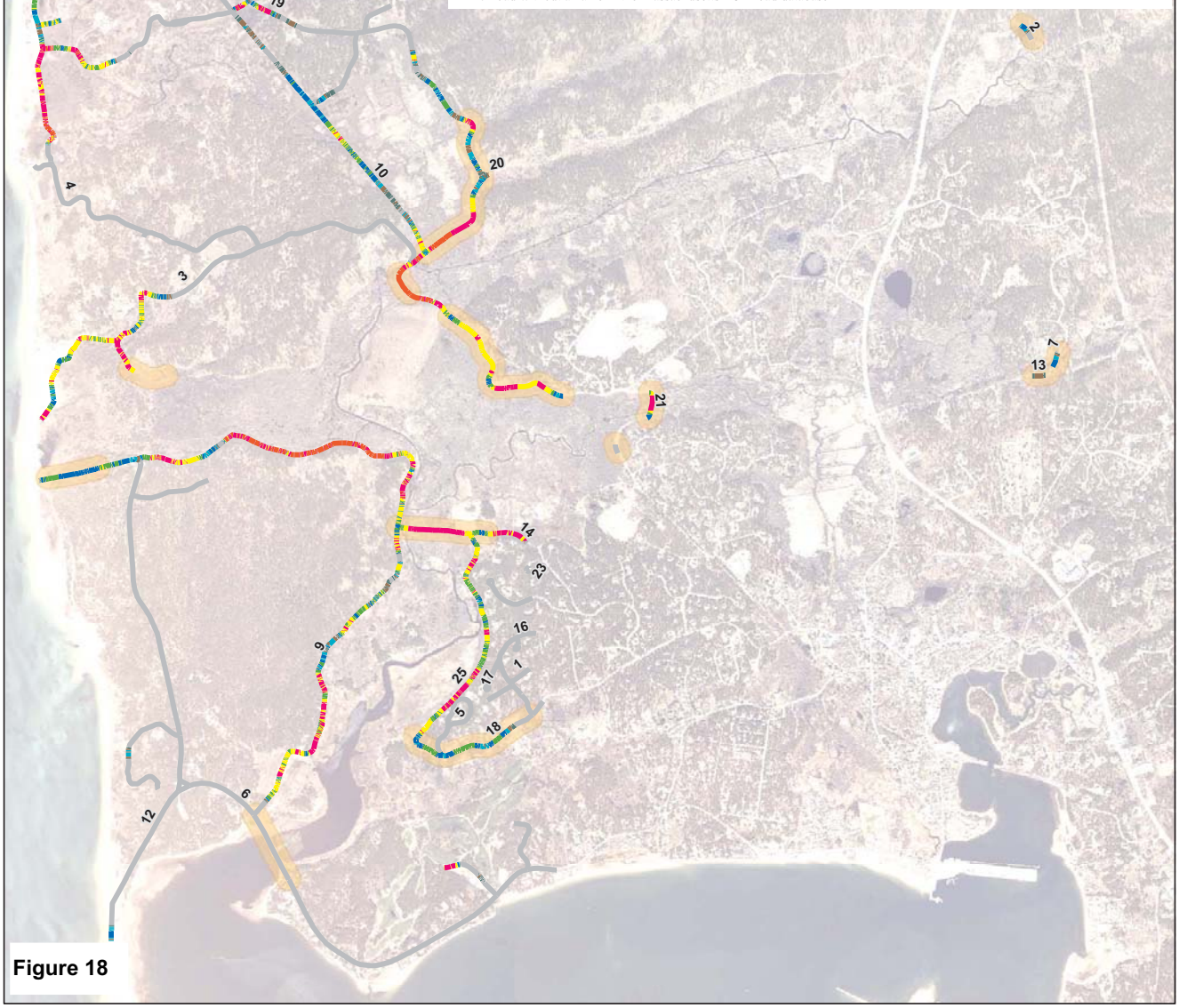


Figure 18

Herring River Restoration Project
Summary of Low-Lying Roads Analysis

< 3 ft, 3 - 4 ft, 4 - 5 ft, 5 - 6 ft, 6 - 7 ft, 7 - 8 ft, 8 - 9 ft, 9 - 10 ft, > 10 ft
Road Elevations (NAVD 88)

ENSR | AECOM

Roads analyzed using December 2006 survey points, all other roads analyzed using ACOE 2005 LiDAR survey.

0 2,500 5,000 Feet

exchange between areas upstream and downstream of the road by creating a causeway. Including supplemental surface water conveyance(s) along the raised road would mitigate this type of adverse effect to a degree and be in the interest of the habitat restoration goals of the larger project. In addition, if certain roadways have stormwater collection facilities, then the rims of the structures would need to be raised, or the structures would need to be re-set to match proposed grades.

Road Realignment

Realignment of roads involves relocating segments of road that will be inundated frequently to nearby higher ground. Realignment would entail tasks such as acquiring new rights-of-way for the roads, transitioning relocated road segments into remaining segments, relocating stormwater facilities and other utilities. A prime example of where this approach might be implemented is along Bound Brook Island Road east of Merrick Island, where the existing landscape slopes upward adjacent to the existing road location, and moving the roadway to that higher ground would be a logical consideration. Note that one possibility for a roadway realignment of Pole Dike Road would be to relocate a portion of it to the old rail road grade that extends across the wetland just east of the Pole Dike Creek crossing.

Tolerating Some Degree of Flooding

Some low-lying roadways along the coast have historically been subjected to varying degrees of flooding during coastal storms. When such flooding occurs infrequently, such as during rare-event storms (e.g., 10- to 100-year storm events), the affect on public use may be minimal and can be accommodated. Issues to consider in such instances include public health and safety relative to access. There may be instances where such infrequent flooding could be tolerated. This will require further assessment as more detailed hydrologic analyses are conducted.

Roadway Abandonment

In addition to the low-lying infrequently traveled roadways discussed above, there are several locations where road abandonment is a consideration. These include Snake Creek Road which runs north from Old Chequesset Neck Road along the east side of the Herring River, Duck Harbor Road from High Toss Road to Griffin Island Road, High Toss Road from Snake Creek Road (Rainbow Lane) to Griffin Island, and an unnamed road that runs south from the Ryder Beach parking area toward Bound Brook in Truro. Any decision on such roadway abandonment would be subject to public hearings in the respective towns.

6.3.2 High Toss Road

High Toss Road is an infrequently traveled, unpaved, single-lane road that provides an access from Pole Dike Road to Griffin Island. For the portion of High Toss Road west of its intersection with low-lying Snake Creek Road (Rainbow Lane) and nearest the Herring River channel, wetland habitat abuts both the northern and southern margins of this road. This portion of road is at elevations between 4.0 and 5.0 feet (NAVD 88). Much of the surrounding wetland area is at or just below the road surface elevations. It appears that

raising this portion of High Toss Road west of Rainbow Lane to an elevation several feet above the existing elevation would necessitate construction of sloped roadway embankments. This construction would result in substantial alteration to vegetated wetland areas and create a more substantial causeway.

Avoiding or minimizing wetland impacts by road relocation or lateral realignment in this section would not be possible due the lack of adjacent land at higher elevations and a close proximity to existing wetland areas. Using vertical retaining walls in place of embankments to minimize direct wetland alteration, while possible, will very likely be considered cost prohibitive and the causeway that would result may not serve the interests of the larger restoration project.

The elevations along the portion of High Toss Road between Rainbow Lane and Pole Dike Road are primarily near or above 5.0 to 6.0 feet. This portion of road has wetland habitat immediately abutting its northern margin, but generally lacks wetland habitat along its southern margin where lateral realignment onto adjacent higher ground can avoid wetland alteration.

A 60-inch diameter, 24-foot long culvert conveys the Herring River beneath High Toss Road near its western end. Replacing this pipe culvert with a larger conveyance structure, such as an open-bottom arch or box culvert, would alleviate the apparent flow restriction caused by the existing culvert and create better conditions for fish passage. As noted previously, the hydrodynamic modeling conducted to date has indicated that the hydraulic capacity required to provide sufficient ebb and flow at High Toss Road for estuarine restoration warrants a new culvert roughly 30 feet wide. Under the open bridge with upstream control option, this culvert structure at High Toss Road may require a tidegate control that limits upstream tidal flooding and protects private properties.

Another consideration relative to High Toss Road involves its potential use as a temporary access road to Griffin Island and Great Island should Chequesset Neck Road be closed for a period to expedite construction at the dike. Should this use be warranted, upgrades to High Toss Road (as well as Duck Harbor Road) should be evaluated in combination with both this temporary use and long-term needs.

6.3.3 Pole Dike Road

Pole Dike Road is a frequently traveled, paved public road, the northernmost portion of which crosses Pole Dike Creek (see Photo 14). This portion of roadway, which is a relatively short length of road, is at elevations below 5.0 feet (NAVD 88). The densely vegetated wetland areas that border the creek are close to both margins of the road. Avoiding or minimizing wetland impacts by road relocation or lateral realignment would not be possible here due to both the lack of adjacent land at higher elevations and proximity to existing wetland resource areas (although as noted below, the use of the nearby railroad bed is a consideration). It appears that raising the roadway by the necessary number of feet would result in some amount of wetland alteration from construction of sloped roadway

embankments. If retaining walls were used in place of sloped embankments, wetland alteration could be greatly reduced or unnecessary.

Photo 14: Pole Dike Creek at Pole Dike Road

A 32-inch diameter, 40-foot long culvert conveys Pole Dike Creek beneath the road. Replacing this pipe culvert with a larger conveyance structure, such as an open-bottom arch or box culvert, would alleviate the apparent flow restriction caused by the existing culvert and create better conditions for fish passage. Again, this structure may be considered another control point for regulating tidal inundation within the 172-acre wetland system upstream of this location along Pole Dike Creek.

The HRTC has also discussed the potential of relocating a portion of Pole Dike Road to the old railroad grade that extends across the wetland just east of the creek crossing. This relocation would actually be a more direct route for a roadway connecting Wellfleet village with the Bound Brook area. The viability of this option is not currently known.

6.3.4 Bound Brook Island Road

Bound Brook Island Road crosses the Herring River where the river changes from a north-south orientation to an east-west orientation (see Photo 15). This paved road is frequently traveled as compared to High Toss Road. The 60-inch concrete culvert, which conveys the Herring River beneath Bound Brook Island Road, would very likely impose a flow restriction with tidal restoration at this point along the river.

Photo 15: Herring River along Bound Brook Island Road

Elevations of the roadway between Pole Dike Road and Old County Road are predominantly below 5.0 feet. The portions at the lowest elevations (below 3.0 feet) are just south of the Herring River crossing where wetlands are in close proximity to both margins. Avoiding or minimizing wetland impacts by road relocation or lateral realignment would not be possible in these locations

due to the lack of adjacent land at significantly higher elevations and a close proximity to existing wetlands. Raising the roadway by the necessary number of feet would result in substantial wetland alteration from construction of sloped roadway embankments. If retaining walls were used in place of sloped embankments in these lowest road segments, the potential for wetland alteration would be greatly reduced.

The two segments of Bound Brook Island Road that are at slightly higher elevations -- the portion that abuts Merrick Island and west of the Pole Dike Road intersection – abut lands that are at higher elevations. It may be possible to realign these road segments onto higher ground so that wetland impacts are avoided or minimized. A 60-inch concrete culvert conveys the Herring River beneath Bound Brook Island Road. This culvert may be adequately sized for current conditions. Replacing this pipe culvert with a larger conveyance structure, such as a wide box culvert, may be necessary to accommodate increased tidal flooding. This location is another point where an upstream tide control structure may be considered to control tidal inundation in the upper reaches of the Herring River system.

6.3.5 Old County Road

Old County Road is a frequently traveled, paved public road that crosses the Truro-Wellfleet town boundary. In Wellfleet, this road has two stream crossing locations, one at Bound Brook and the second located to the north at Paradise Hollow. Each is discussed separately below.

Bound Brook Crossing

Along its southernmost portion in Wellfleet this road crosses Bound Brook and the densely vegetated wetland areas that border this stream. This wetland is close to both margins of the road. The elevations of the road in this segment are between 3.0 and 4.0 feet (NAVD 88) and the abutting wetland areas appear to be at elevations just below this range. The 24-inch diameter culvert that conveys Bound Brook beneath the road appears damaged and/or otherwise obstructed.

Avoiding or minimizing wetland impacts by road relocation or lateral realignment would not be possible in this segment of Old County Road due to close proximity of existing wetland resource areas. It appears that raising this section of roadway would result in substantial wetland alteration from construction of sloped roadway embankments. Using vertical retaining walls in place of embankments to minimize direct wetland alteration, while possible along this segment of roadway, will likely be considered cost prohibitive and the causeway-like structure that would result may not serve the interests of the larger project.

Paradise Hollow Crossing

The northernmost portion of Old County Road in Wellfleet crosses a stream within Paradise Hollow, which is tributary to Bound Brook. The low-lying length of roadway at

this crossing point is minimal compared to other segments. The elevation at the centerline of the road was surveyed to be 3.37 feet (NAVD88). As with other LLR segments that cross streams, completely avoiding or minimizing wetland impacts by road relocation or lateral realignment would not be possible here due to lack of adjacent land at higher elevations. Using vertical retaining walls in place of embankments to minimize direct wetland alteration and increase the road elevation may be practical in this location.

The existing culvert in this location is an eight-inch diameter pipe. The pipe appears partially obstructed by sediment and other debris. Replacing this pipe culvert with a larger conveyance structure, such as an open-bottom arch or box culvert, may be appropriate here.

6.3.6 Alternative public access routes and emergency access

Planning for reconstruction of the dike at Chequesset Neck Road must also include an assessment of impacts to fire department (FD) and emergency medical technician (EMT) vehicle access routes and alternative access options. Wellfleet's fire chief has raised a number of issues pertaining to FD and EMT vehicle access needs. As presented to the HRTC, these issues are:

- Bypass fire and EMT access will be needed to Griffin Island using High Toss Road and Duck Harbor Road during dike reconstruction. This will require the widening of both roads, strengthening the roads and crossings and ensuring adequate turning radii for fire truck passage.

- To reduce inconvenience to residents and visitors, winter is the preferred time for dike reconstruction.

- Access will be needed to Bound Brook Island as well as maintaining traffic flow on Bound Brook Road, during reconstruction of the Herring River culvert at Bound Brook and at the crossing of Bound Brook itself.

- A detailed survey is needed from Merrick Island north to determine where Bound Brook Island and Old County Roads may need to be raised to avoid flooding at 5-foot tides. Old maps (c. 1890) show a way running north from Pole Dike (starting about where the transfer station is now) to cross the Herring River at the present crossing near Bound Brook, but avoiding the valley north of that point.

- Snake Creek Road, (on the east side of the river, south of the occupied housed down to Old Chequesset Neck Road), is not needed for fire or EMT access (HRTC 2006).

6.3.7 Private Residences

During the past several years of research and consideration of the Herring River restoration proposal, topographic and survey investigations have been directed at locating any private residences that may have structures located at elevations low enough to be directly affected

by tidal restoration up to the spring high tide elevation. Several such residences have been located, and studies have been conducted at two locations to identify the potential impacts and recommend mitigation measures.

The same survey searched for on-site wastewater leaching fields/pits that occurred within the 100-year floodplain and thus might be sensitive to increased tide heights (Slade Associates 2006).

Nearly all residences surrounding the river floodplain derive their water supply from private wells set in the fresh groundwater aquifer. There have been concerns that the restoration of seawater flow across the floodplain could cause saltwater intrusion into some of these wells; however, work by US Geological Survey and National Park Service hydrogeologists has shown that very few of these wells could be adversely affected (Fitterman & Dennehy 1990, Martin 2004, Masterson 2004). In fact, most recent modeling indicates that restoring tides to diked marshes, and thereby increasing their average surface-water level, actually causes the adjacent freshwater aquifer to thicken (Masterson & Garabedian 2007), providing even more protection from saltwater intrusion than exists under today's tide-restricted conditions. Further, hydrogeologic studies of fresh/saline groundwater relationships around coastal marshes (summarized in Martin 2004) have shown that saline tidal water does not intrude into the freshwater aquifer, even in unrestricted marshes (See Figure 19). A nearly complete inventory and analysis of all private properties (nearly 200) within 250 feet of the expected spring-tide flooding height in Herring River (See Figure 20) have at the date of this writing found only five vulnerable wells. Meanwhile, the USGS has installed and periodically monitors seven wells that penetrate the freshwater/saltwater interface in groundwater below developed uplands adjacent to Herring River; this monitoring will continue both to test model predictions and to ensure that any rise in the fresh/salt interface, however unlikely, is documented.

6.3.8 Mill Creek Property Owners (Including the Chequesset Yacht and Country Club)

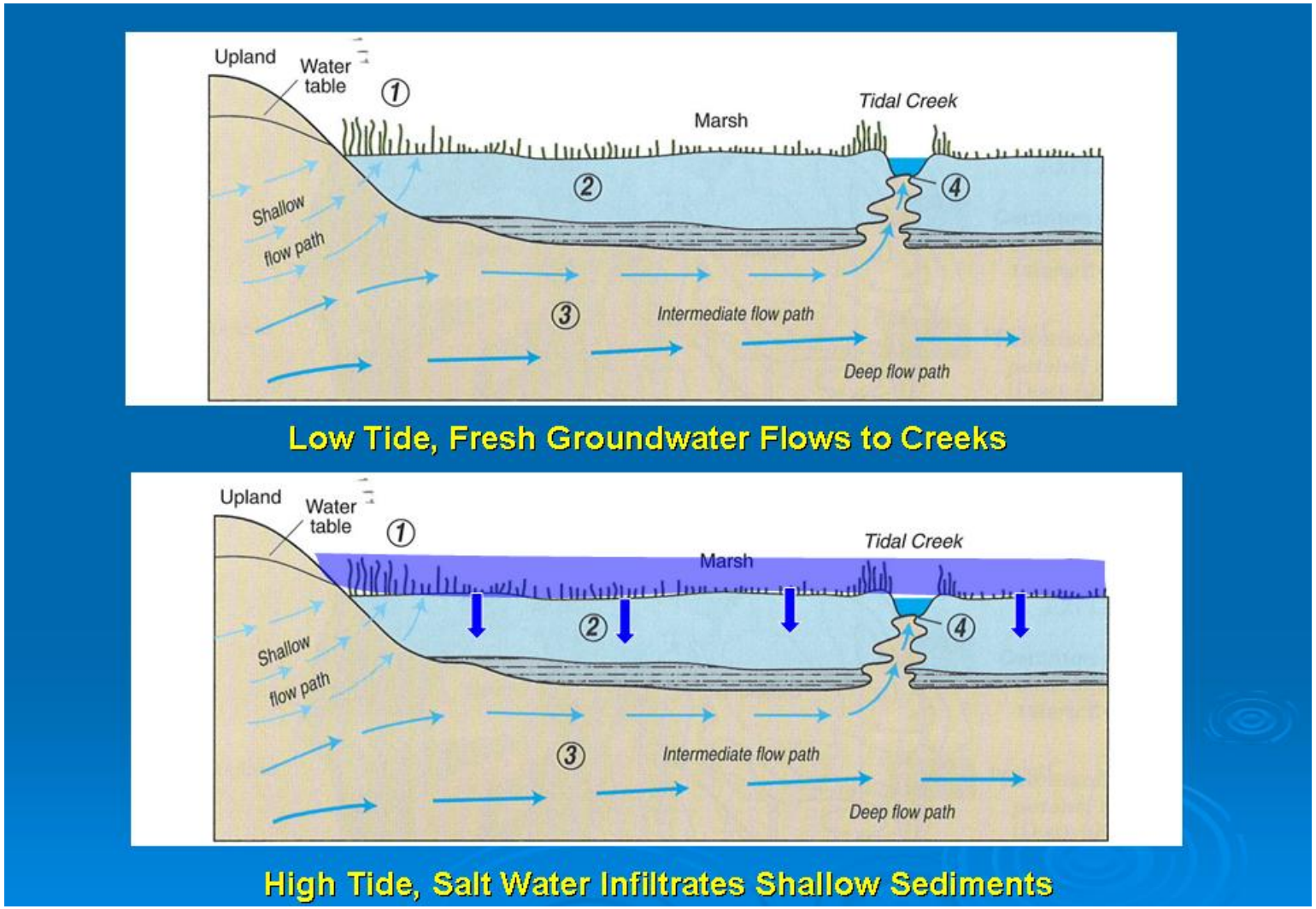
Mill Creek is a tributary of the Herring River, joining the main river stem from the east between Chequesset Neck and Newcomb Hill. As noted in Section 4, there has been significant construction in or adjacent to the Mill Creek floodplain in the past 100 years.

Mitigation plans for private residences – including those in the Mill Creek basin – have been outlined above.

Also in the Mill Creek basin is the Chequesset Yacht and Country Club (CYCC). CYCC is a semi-private, nine hole golf course. It was constructed between 1929 and 1933. The property currently occupies about 106 acres on Chequesset Neck. Property elevations range from below mean sea level to approximately 60 feet.

As a portion of the course lies within the Mill Creek floodplain, reconfiguration of the course has been considered to maintain a playable layout given increased tide heights with

Figure 19. Hydrogeology of Seawater/Freshwater Flows in Unrestricted Salt Marshes



Hydrogeologic studies on Cape Cod and elsewhere show that, even at high tide in unrestricted salt marshes, seawater intrusion is limited to shallow wetland sediments, and does not penetrate the underlying freshwater lens. Freshwater discharges into the estuary mostly along the upland/wetland border and through permeable creek bottoms.

Figure 20. 250-Foot Zone from Anticipated Spring-Tide Elevations

Examination of water quality results from properties near Herring River and from wells close to other nearby Cape Cod embayments, and computations based on the known relationship between water-table height and the depth of the freshwater aquifer (Martin 2004), concluded that only those properties within 250 feet of the Herring River estuary had any chance of being affected by tidal restoration. Further hydrologic analyses showed that only those wells placed within or very close to the original coastal flood plain (less than ten wells) had the potential for saltwater intrusion with tidal restoration.

river restoration. Planning studies have been undertaken and preliminary course plans developed to address this issue (Horsley Witten Group 2006). Plans have considered the construction of four new golf holes in the higher elevations located in the western half of the property to replace areas in the historic floodplain portions of the course that could be impacted by certain proposed tidal regimes. (Partial funding for this move, via Town acquisition of 25 acres using Land bank funds, was approved at Wellfleet Town Meeting, Spring 2005). Discussions and assessments are continuing concerning this area as well as the larger Mill Creek basin area in terms of proposed tidal regimes and selection of the most appropriate alternative. Construction of a new flood protection dike across Mill Creek remains an alternative to afford tidal controls for this sub-basin (See 5.4.1). As described in a previous section, a historic dike was located across Mill Creek extending north of the golf course that could be considered as a location for a new control point, with a separate tidegate structure installed to regulate tide levels in the Mill Creek basin.

6.4 Habitat Management During Project "Transition" Phase

6.4.1 Vegetation management on tidal floodplain

Purpose and Need

The increased tidal exchange between the Herring River estuary and Cape Cod Bay will result in gradual changes to numerous tidal floodplain characteristics. The planned increase in tidal exchange and flooding will be achieved in incremental steps over a number of years. One of the most significant, noticeable, and desirable changes to occur during this period will be to the composition of existing plant communities. There will be a gradual transition from one set of plant community types to another as adjustments to environmental parameters, such as tidal inundation, frequency, soil saturation, and, most notably, salinity occur. The plant community transition from one type to another can be referred to as the "transition sequence". Management of floodplain vegetation, specifically the removal of dead shrubs and trees, during the transition sequence will have the following objectives:

- Encourage restoration/reestablishment of *Spartina*-dominant marsh;
- Improve floodplain aesthetics;
- Removal of woody debris that might impede fish passage;
- Removal of large trees that will eventually die, topple and leave holes on the wetland surface for mosquito breeding.

Predominantly shrubland and woodland plant communities exist on areas of the river floodplain that were once vegetated with salt-marsh plants including salt meadow grass (*Spartina patens),* smooth cordgrass (*S. alterniflora),* black grass (*Juncus gerardii*), and spike grass *(Distichlis spicata)*. Woody plants will not tolerate flooding with seawater, however

gradually these effects occur and will ultimately result in standing dead woody debris covering a large portion of the floodplain.

Large volumes of woody debris on the floodplain surface will create two problems. First, much of it could be deposited in the Herring River channel and in the river's numerous tributary streams and ditches. Fallen woody debris and the additional material it will trap could impede the passage of migratory fish and other animals to and from spawning habitats. Second, woody debris laying on the surface of the floodplain may retard the establishment of marsh grasses by preventing seed access to soil surface, preventing germination, and shading or smothering young seedlings when debris is rearranged by tidal flow. More aggressive invasive plants may not be so inhibited and thus could become established first. Therefore, appropriate measures will be needed to manage woody plants in order to protect the fishery habitat and to promote the establishment of natural saltmarsh flora. A vegetation management program will be an integral part of the overall comprehensive incremental restoration management plan.

Defining Vegetation Management Zones

The six individual basins of the Herring River floodplain serve as logical units for planning vegetation management: Mill Creek, Lower Basin, Lower Pole Dike, Duck Harbor, Upper Basin, and Bound Brook (Table 1 and Figure 4). Together, these basins comprise nearly 600 acres in which vegetation management activities are likely necessary. The Upper Pole Dike basin and areas to the east of Route 6 are not included in this estimate, pending results of hydrologic studies that will include these areas.

Table 1: Summary of River Sub-basins in which Vegetation Management Activities will be Occur

Name	Approximate Size (acres)*	Vegetation Communities Present
Mill Creek Basin	26	Predominantly hardwood tree and shrub species with a few acres of pines. *Phragmites* expanses.
Lower Basin	60	Mix of hardwood tree and shrub species. *Phragmites* expanses.
Lower Pole Dike Basin	172	Mix of hardwood tree and shrub species
Duck Harbor	120	Predominantly hardwood tree and shrub species with approximately 12 acres with a mix of pine
Upper Basin	121	Mix of hardwood tree and shrub species
Bound Brook Basin	85	Approx. 85 acres of hardwood tree and shrub species and approx. 6 acres with a mix of pine

*The estimated area of each respective basin which is anticipated to require vegetation management

The NPS has developed mapping based on 2001 MassGIS orthophotography that shows vegetated habitats and the 6-foot and 10-foot contour elevations within the National Seashore boundary (Figure 11). This mapping, along with detailed topographic data and additional hydrologic modeling will be used to target and quantify areas where specific management activities, such as tree removal, will be necessary, identify ecologically sensitive areas, such as rare species habitat, and prioritize areas for management.

6.4.2 Vegetation Management Prioritization, Options, and Considerations

Potential techniques for dealing with woody vegetation include cutting, chipping, and burning. Combining techniques will be considered as part of a flexible vegetation management approach.

Primary and Secondary Management

The vegetation management protocols consist of "primary management" techniques and "secondary management" techniques. Primary management is the cutting of the vegetation, while secondary management is the processing and removal of the biomass that has been cut. Primary management will be accomplished using mechanized tools such as hand-held loppers, chain saws, mowers, brush hogs, or larger, wheeled or treaded machines that both cut and chip. Woody vegetation with diameters of three or more inches could be sold as biofuel, either as chips or logs. Appropriate options for smaller diameter cut woody vegetation will need to be developed.

Secondary management will be accomplished by a number of techniques including the sale of cut hardwood, removal of wood chips, and burning brush and branches. With respect to burning, a plan for disposal or dispersion of ash will be necessary. Access, substrate type, and other factors will need to be considered to determine the most appropriate vegetation management technique.

Vegetation Community Types and Biodegradation

Vegetation cover types mapped in Figure 11 can be grouped into two categories with respect to their management during the tidal restoration process: 1) woody vegetation, i.e. shrubs and trees and 2) herbaceous / reedy vegetation. Woody species include highbush blueberry (*Vaccinium corymbosum*), northern arrowwood (*Viburnum dentatum*) black cherry (*Prunus serotina*), red maple (*Acer rubrum*) and pitch pine (*Pinus rigida*). Herbaceous species comprise common reed (*Phragmites*), cattail (*Typha*), and a wide variety of salt-sensitive sedges, grasses and forbs.

Generally, herbaceous plant species decompose more rapidly without active management, with the possible exception of *Phragmites,* which may require a combination of cutting, mowing, disking, burning, flooding, or herbicide application.

Prioritization and Timing Considerations for Vegetation Removal

Prioritizing the different management zones for vegetation management as well as

prioritizing activities within each of the zones will depend primarily upon land elevation. The lower the land elevation within a management zone, the earlier the area will be affected by tidal inundation.

The timing of all vegetation management activities will require careful planning. It will be critical to avoid or reduce unintentional adverse impacts to animal activities, such as seasonal fish migration (begins mid-March) and bird nesting. Tide heights will also determine when certain vegetation removal activities can and cannot occur.

Access Issues and Privately-owned Lands

Portions of the river floodplain where restoration is proposed are on privately owned lands. For this reason, vegetation management activities on certain private lands may not be permitted. Specific protocols for notification, access, and liability need to be developed for management operations on privately owned properties.

Habitat Refuge Areas

To minimize sudden impacts to important habitats, wildlife habitat refuge areas on the river floodplain will be maintained. The purpose of these refuge areas will be to provide an undisturbed buffer for wildlife during the transition phase of the project. The quantity and proposed locations of these refuge areas have not been determined.

Preventing Erosion along upland fringes

Shrubs and trees that vegetate the upland/wetland interface at the edges of the Herring River floodplain provide habitat for many songbirds, mammals and other animals, and stabilize the soil against the erosive forces that may accompany tidal restoration. Because these plant communities occupy a zone of continual freshwater discharge from the freshwater aquifer to the coastal wetland, there is good reason to predict that their roots will remain in freshwater even after tidal restoration and this woody fringe will survive. Therefore, operations to remove woody vegetation from the floodplain should not be extended into this zone.

6.5 Tidal Restoration and Nuisance Mosquitoes

6.5.1 Background

Proposed tidal restoration will be undertaken in steps, but ultimately will cause spring tides to reach at least 5.1 feet NAVD88, inundating a large portion of the wetlands upstream of the Chequesset 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 the seasonal mosquito nuisance.

Complicating the situation even more is the fact that 80% of the Herring River wetlands are under the management responsibility of the National Park Service, a federal agency that protects native insect populations unless they threaten human health or safety by, for example, vectoring disease as determined by the US Public Health Service. Unless a public health threat develops (unlikely on outer Cape Cod), the Seashore does not have the authority to allow any actions solely intended to control native mosquitoes.

The Cape Cod Mosquito Control Project (CCMCP) does have special authority to undertake mosquito control on NPS lands that were conveyed from the state (Pilgrim and Province Lands State Parks); however, no such authority exists for the Herring River system, where CCMCP has reportedly done no work since the 1980s, except for monitoring adult mosquitoes. Nevertheless, CCMCP remains concerned about currently high mosquito production from Herring River marshes (documented in Portnoy 1984) and is supportive of ongoing efforts to restore tidal flushing, along with water quality and predatory fish populations, as ways to reestablish natural mosquito control. In addition, CCMCP represents the Massachusetts Department of Public Health in monitoring outer Cape mosquito populations for the very insect-vectored diseases that would trigger a US Public Health Service determination of a health emergency justifying active mosquito control. Thus, there appears to be considerable commonality of interests between CCMCP's duties and the restoration project, both in terms of restoring wetland hydrologic and ecological function, and in protecting human health.

6.5.2 Planning for Integrated Mosquito Control

The overarching goal of the restoration project is to restore natural hydrography, an action that should in general improve water quality, tidal flushing, fish access to the wetland surface and, thus, floodwater mosquito control. A well-recognized overarching difficulty is considerable uncertainty, despite hydrodynamic modeling, of wetland flooding depth and duration throughout spring-neap tidal cycles and after major rain events, particularly at small spatial scales. Because tidal restoration is planned to take place in steps, through incrementally opening restricting structures, system hydrology and nuisance insect production can be both monitored and adaptively managed.

Most of the public-nuisance mosquitoes on outer Cape Cod breed in flood waters, which form as pools after heavy rains or high tides on a wetland surface. These pools of floodwater can contribute to a substantial mosquito nuisance if they are inaccessible to fish predators. Because of 100 years of wetland drainage and subsidence, stream channelization, and the invasion of *Phragmites*, shrubs and trees, we are today dealing with a profoundly altered landscape. In this context, habitat manipulations, which would be inconsistent with NPS policy in an unaltered saltmarsh, may be appropriate interim measures to both 1) reestablish some semblance of natural hydrography at Herring River and 2) promote predatory fish access to mosquito breeding sites that have been created artificially by decades of wetland drainage, spoil disposal and wetland subsidence.

6.5.3 Mosquito Monitoring

Monitoring of adult mosquitoes by CCMCP will continue. In addition, CCMCP staff will identify existing (pre-restoration) larval habitat and species composition as well as monitoring both larvae and adults throughout the restoration process to assess the effects of changing hydrography and salinity on mosquito species composition, abundance and habitat use.

Water chemistry within the Herring River marshes is expected to change profoundly with restored tidal exchange, and in ways that greatly affect both immature mosquitoes and their predators; therefore, NPS water-quality staff will work closely with CCMCP in assessing developments in mosquito breeding ecology.

6.5.4 Mosquito Control and Hydrologic modeling

A first step in addressing hydrography and potential mosquito breeding is acquisition of fine-spatial-scale topographic data, accomplished in spring 2007 with aerial photogrammetric survey and mapping of the floodplain at one-foot contour intervals. This will be followed by two-dimensional modeling of tide heights and salinity throughout the 1100-acre floodplain, providing an excellent tool for identifying potential breeding sites and for focusing future surveillance.

Before tidal restoration is initiated, topographic mapping and larvae sampling will be used to map current and potential mosquito breeding sites. Not all can be anticipated, but enough is known of the species composition and breeding ecology of mosquitoes of the outer Cape to predict which species will be favored or suppressed by a predicted change in flooding period or salinity. Success in managing the restoration will depend on the following predetermined contingency plan that is responsive to hydrologic, water chemistry and mosquito monitoring data.

6.5.5 Mosquito Control Plan Implementation

The basic elements of the hydrographic and mosquito contingency plan are as follows:

- Effective mosquito control will be realized as a consequence of restored tidal flushing, water quality and predatory fish habitat. Conversely, poor mosquito control can be seen as one indicator of poor flushing and water quality, and incomplete habitat restoration.

- All work will be undertaken to restore natural tidal flooding and drainage and not solely for the purpose of nuisance mosquito control.

- Because of the long history of tidal restriction, sedimentation and stream channelization, the reestablishment of native saltmarsh tidal flow may require re-digging of filled and/or cut off creek meanders, especially during the period of incremental tidal restoration.

- Because of substantial sediment subsidence, the present wetland surface cannot be considered "natural"; therefore, the reestablishment of natural hydrography may include the digging of creeks where they did not exist before diking.

- As a result of many years of channelization, the river main stem from High Toss Road to Route 6 has a nearly continuous spoil pile along its east bank. This artificial levee will impede water flow onto and off of the wetland surface once tides are restored; therefore, it should be at least interrupted with openings allowing unimpeded water movement.

- No excavation will be allowed in Herring River marshes until pore-water salinity has been restored to at least 15 ppt, to avert production of acid sulfates and mobilization of toxic metals.

- All excavation work will be done using low-ground-pressure equipment, with excavated material spread to a depth of not more than 2 inches to avoid the formation of levees that impede water flow. Some of this material may be used to fill subsided marsh on a trial basis.

- Larvicides will be limited to those with least effect on non-target species (e.g. presently *Bti*) and used only as an interim measure. All pesticide use must be logged and promptly reported per NPS integrated pest management guidelines. If pools of standing water and intense floodwater mosquito breeding occur on the artificially subsided wetland surface, those areas will be subsequently studied and targeted for measures to make future pesticide applications unnecessary.

- The planned removal of vegetation, including invasive *Phragmites*, shrubs and trees, from the floodplain will improve both water and predatory fish movement over the wetland surface and will further promote floodwater mosquito control.

As this strategy for dealing with nuisance mosquitoes is implemented, it will be subject, like all the other actions included in the upcoming detailed restoration plan, to regulatory compliance, oversight, and public input.

6.6 Water Quality

Given poor water quality, including low pH, metals, low dissolved oxygen and high fecal coliform in the river above the dike, there have been public concerns that tidal restoration would extend these problems to harbor waters and shellfish beds below the dike; however, waters seaward of the dike are actually much more vulnerable under existing conditions than with tides restored. The tidal restriction creates all of the above water-quality problems in the diked river, e.g. generating acidity, leaching toxic aluminum, concentrating fecal coliform, and releases these pollutants into harbor waters during ebb tides. With tidal restoration, the volume of clean water will increase by at least a factor of 13, overwhelming (i.e. diluting) any pollutants that flow out of the river during the ebb. Thus, the influence of river water on harbor water should radically <u>decrease</u> with tidal restoration. Also,

experiments have shown that resaturating Herring River's acid sulfate soils with seawater will restore normally high sediment pH, eliminating the acidity and metals problem in the river proper within weeks to months (Portnoy & Giblin 1997b).

6.7 Harbor Shellfish Resource Protection Concerns

The potential for water quality changes and sedimentation as a result of increasing tidal exchange between Wellfleet Harbor and the Herring River basin is a very serious concern for restoration advocates, the Town, and shellfish growers, many of whom make a living by raising shellfish on the tidal flats of Wellfleet Harbor. The tidal flats, which occupy a large portion of the harbor, are critical to shellfish habitat protection and aquaculture interests because of the commercial and recreational opportunities they provide (see Figures 13 and 14).

These interests must be protected; however, recent hydrodynamic (Giese, McSherry and Spencer 1994) and sediment-transport studies (Dougherty 2004) specific to Wellfleet Harbor and Herring River should relieve concerns about sediment transport to shellfish beds. Like any tidal embayment, Wellfleet Harbor is flood-tide-dominated. The flood tide velocities are greater than the ebbing velocities. This fundamental fact means tidal borne sediments are naturally carried upstream and are eventually deposited on the marshes. Harbor geomorphic features such as the Gut and Egg Island predated the original dike construction and would not, therefore, be affected by restoration. Thus, the risk of downstream transport of Herring River sediments is small. The design and operation of the new Herring River dike must include consideration of avoiding sediment transport into the harbor. On-going monitoring is in place to provide additional assurance.

6.7.1 Sedimentation monitoring program

The CCNS Natural Resources staff, in cooperation with the Wellfleet Shellfish Department, has baseline data for sediment below the dike and on aquaculture grants at Egg Island, Power's Landing, Mayo Beach, and the town's shellfish propagation bed. The existing monitoring program is expected to continue for the duration of the restoration project as part of the adaptive management approach to impact mitigation for this project. In addition, the marina/harbor sedimentation monitoring program will continue; however, marina/harbor sedimentation is not expected to be affected by the restoration.

6.8 Fisheries Habitat Impact Mitigation

While the restoration project will benefit estuarine fish in the long-run by restoring habitat and a connection with the marine environment, there may be adverse short-term effects, especially to migratory species. The following information and protection strategies are recommended prior to the commencement of the project.

6.8.1 Characterization

The Herring River is the largest estuary on the outer Cape, and therefore provides important spawning, nursery, and foraging habitat for many migratory and resident finfish

(Roman 1987, Wellfleet Comprehensive Plan 1994). Both anadromous herring and catadromous American eels must migrate through the dike and river system to spawn. Currently there is a small (twelve square feet) opening through the dike structure during flood tides, and a larger cross-section during ebb tides when two clapper valves are open; however, these openings are small, compared to the unrestricted river channel, and current velocities are rapid at times through the tidal cycle. Both of these factors limit fish passage (P. Brady, Division of Marine Fisheries, personal communication). Protection of river herring is of great concern during the restoration process. The adults' migration generally peaks in April and May, but can stretch from March to June. After spawning, the adults move seaward between May and June. Fry will move seaward from July through October, but can extend into early December (HRTC Migration Subcommittee Final Report 2006).

6.8.2 Protection Strategies

Restoration activities must be scheduled so as to avoid spring spawning migrations of adults that occur between March and June. The fry can also be protected by holding them back in Herring Pond until potentially harmful construction activities are complete (HRTC Migration Subcommittee Final Report 2006), as has been done during main stream oxygen depletions (Portnoy et al. 1987). Another alternative would be waiting to complete construction in the river until November, when most fry have completed their seaward migration. This would also avoid exposing fish and other wildlife to construction activities and potential sediment resuspension. Water monitoring as well as fish counts could be done to observe river conditions (US Department of the Interior 2007).

Also, as discussed in a previous section, there are habitat impact issues associated with the accumulation of woody debris on the river floodplain that will result during the transition phase of the project. Because woody debris might enter river channels and impede fish passage, the tentative plan is to remove dead woody vegetation from the floodplain.

6.8.3 Structural Considerations

It is imperative that each design option for the replacement tidal control structure at Chequesset Neck Road dike allow for relatively unimpeded, if not entirely unimpeded, passage of migratory fish. This must also be a consideration for the design of any upstream tidal control structure constructed along critical fish passage routes. The options that have been presented in Section 5 each provide a design concept that allows for unimpeded fish passage.