5 Project Description

The reconnection and gradual incremental increase in tidal exchange between the Herring River estuary and Wellfleet Harbor is the primary proposed process for tidal restoration envisioned for the Herring River floodplain and its adjoining tributary stream basins. Increased tidal exchange will result in several important beneficial changes to the Herring River's estuarine characteristics and floodplain features, which include improvements to water and sediment quality, coastal wetland habitats, and fisheries and shellfish habitat. The restoration project comprises the following objectives:

- Restoration of the natural tidal range and salinity throughout the floodplain including all tributary stream basins.
- Reestablishment of the physical connection with the marine environment for exchange of sediment, nutrients, organic matter, and biota.
- Restoration of a natural sediment budget to counter wetland subsidence and sea level rise.
- Improvement of water quality realized by increased salinity, alkalinity, and pH, and decreased metals and coliform bacteria.
- Elimination of salt-intolerant plants including non-native species, especially common reed (*Phragmites autstralis*).
- Reestablishment of native saltmarsh plants and animals.
- Improvement of estuarine finfish and shellfish habitats and physical access to those habitats.
- Improvement in the natural control of mosquitoes and other nuisance insects.
- Improvement of recreational access: boating, finfishing, shellfishing, bird-watching, etc.

5.1 Targeted Level of Restoration

Restoration of the full natural tidal range has been considered the ecological goal throughout as much of the Herring River floodplain as practicable, including up to the 100-year flood level (9.1 feet NAVD88). However, in certain areas, tidal flooding must be limited to protect existing land uses. Where such land use considerations prevent full tidal range restoration, the goal is to restore the maximum high tide up to the mean spring high-tide level, an elevation of 5.1 feet NAVD88. This elevation has ecological significance as it corresponds with the average elevation of existing high saltmarsh habitat seaward of the

Chequesset Neck Dike. Before the system was diked, the area at or below the 5.1-foot contour would have encompassed about 1100 acres of estuarine wetlands.

Examples of existing land use that might preclude full tidal restoration include, but are not limited to, the Chequesset Yacht and Country Club (CYCC) property in the Mill Creek sub-basin, segments of low-lying roads at several stream crossings, residential properties, and existing wells or septic systems. These issues are discussed in greater detail in Sections 2, 5.4, and 6. Detailed planning for these areas will be subject to comprehensive hydrologic modeling and input from the affected landowners and other residents of the Wellfleet and Truro communities. However, throughout much of the floodplain, current land use may not be in conflict with full tidal restoration to 9.1 NAVD88. For these areas, the tentative plan is to remove all artificial restrictions to tidal flow to restore natural physical, chemical and biological estuarine functions. This would allow storm tides to deposit sediment on the surface of the saltmarshes, allowing them to naturally accrete as sea level continues to rise (Orson et al. 1987).

5.2 Hydrodynamic Modeling

Any modification to the tidal regime of the Herring River requires design and evaluation using sophisticated hydrodynamic modeling. Initial hydrodynamic assessments were conducted in the 1980s (Roman, 1987). More recent studies, *Hydrodynamic and Salinity Modeling for Estuarine Habitat Restoration at Herring River, Wellfleet, Massachusetts* (Spaulding and Grilli 2001) and *Simulations of Wide Sluice Gate Restoration Options for Herring River* (Spaulding and Grilli 2005) provide one-dimensional hydrodynamic modeling (see glossary) information for the Herring River. The 2001 and 2005 reports were prepared as part of the planning for the river restoration project, specifically the planned opening, reconstruction, or replacement of the dike.

The one-dimensional models were developed and applied to evaluate water levels, flows and salinities in the Herring River under a series of alternative sluice and tidal gate configurations in the dike at Chequesset Neck Road. The 2001 study evaluated potential changes in management of the existing Chequesset Road Dike structure, while the 2005 update evaluated potential changes including larger openings in the dike (up to 100 feet), fitted with sluice gates to allow for incremental openings of the culvert. A peer review of these modeling studies, largely substantiating their conclusions, was also conducted in 2006 (Woods Hole Group, Inc. July 2006).

The 2005 hydrodynamic evaluation included data collection by the NPS to measure water levels and salinities on both sides of the dike and flows up the river. Data were collected to characterize flow, as well as salinity and temperature, upstream and downstream of the dike under varying tidal conditions. Data collected were used to develop the model and to compare with model predictions.

To validate the predictions of the alternative scenarios, the model was first applied to current openings at the existing dike and water levels within the Herring River floodplain.

Model predictions were compared with measured values and the report provided several comparisons of observed and predicted water level values that indicated model predictions were well matched to observed data. The model was then applied to predict water levels in the river with several alternative configurations of the sluice and tidegates, ranging from minor modifications to the existing structure to removal of all culvert restrictions. This series of model runs used an average tide to drive water levels throughout the model. Presented in the report are predicted high and low water levels for each alternative configuration. A 100-year storm was applied to a subset of configurations to predict the maximum water level under extreme storm conditions.

The results of these model runs were used in the assessment of restoration alternatives. In general, the hydrodynamic modeling indicated that use of the existing culverts, even if opened to their maximum 18-foot wide capacity, would not result in sufficient tidal flushing to promote estuarine restoration due largely to the inability of the system to drain adequately during the ebb tides. However, installing wider culverts of at least 100 feet in total width in the dike would allow the potential restoration of a tidal regime in the Herring River comparable to that in Wellfleet Harbor (Figure 15).

Comprehensive two-dimensional hydrodynamic modeling (see glossary) is now being completed utilizing recently obtained, detailed topographic and bathymetric data from the Herring River and adjacent floodplain. Unlike the previous one-dimensional modeling, water levels, salinities and velocities at all road crossings and other impediments to tidal exchange will be included in the model. Updated modeling results are expected by spring 2008 and will be used interactively with design alternatives to evaluate multiple scenarios of tidal flows throughout all portions of the Herring River floodplain. In this manner the alternative will be selected that best addresses the appropriate balance between restoring the natural hydrology of the Herring River estuary while protecting existing land uses.

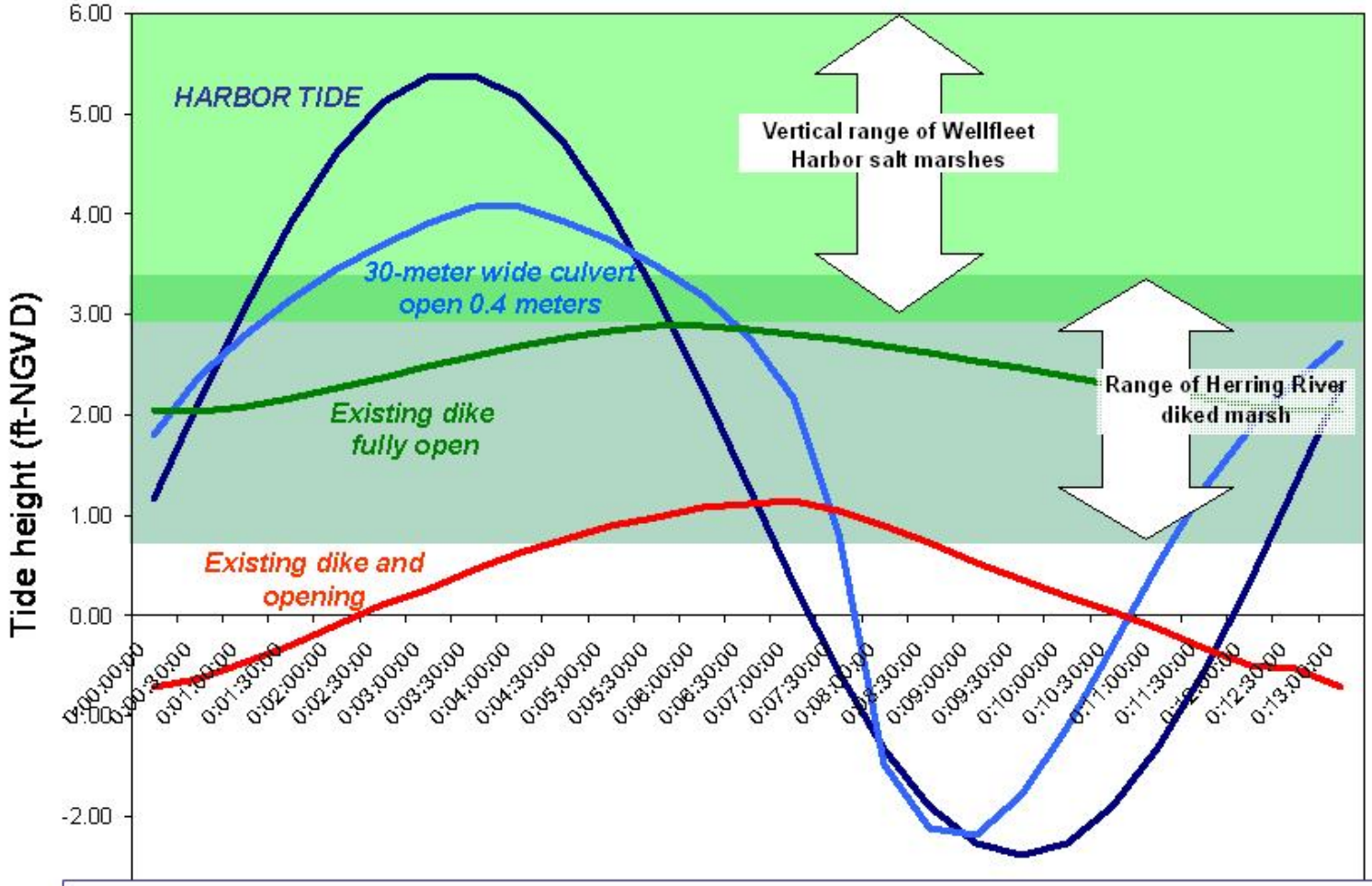
5.3 Description and Assessment of Alternatives

The basic goal of the Herring River Restoration Project is to increase the amount of tidal exchange between the Herring River and Wellfleet Harbor. All alternatives under consideration would allow for the gradual incremental increase in tidal exchange to restore saltmarsh systems and other ecological functions in the river and its floodplain. To accomplish this, significant modifications to the existing dike structure are necessary. Over the past several years four basic alternatives have been considered:

1. No Action: leaving the existing tidegates in place and managing tide heights in the Herring River under existing conditions.

2. Complete opening of the existing culverts to their maximum (18-foot) extent;

Figure 15. One-Dimensional Hydrodynamic Modeling Results



The existing (2007) Herring River dike and culvert opening reduce Wellfleet Harbor's seven-foot tidal range to about 1.5 feet. Hydrodynamic modeling shows that fully opening the existing culverts raises both low and high tide heights, and actually reduces tidal range. In contrast, a much wider culvert system (here 30 meters or about 100 ft) achieves moderately higher high tides, much lower low tides, and thus a six-foot tidal range. Salt marsh productivity increases with tidal range.

Source: Spaulding and Grilli 2005

3. Replacement of the existing dike with a structure with a total opening width of 100-130 feet, fitted with sluice gates to allow to full tidal control and management. The options evaluated for replacing the existing culvert structures include:

- Option 1: Cast-in-place culverts with 8-foot wide cells.
- Option 2: Pre-cast arch spans.
- Option 3: A 2-span bridge structure.
- Option 4: A trestle bridge structure

4. Constructing an open bridge span with no tidal control at the existing Chequesset Neck Road Dike and establishing tidal control with several smaller structures at strategic upstream locations to regulate the limit of tidal flooding as deemed necessary by further hydraulic analyses and public input.

5.3.1 Factors Evaluated During Review of Alternatives:

All alternatives and options under consideration must be evaluated along the following criteria:

- Project costs
- Logistics of construction
- Hydraulics/structural/geotechnical engineering considerations
- Public access to Griffin Island: during and after construction
- Management implications, such as controlling incremental tidal level increases and protection of properties from flooding
- Project aesthetics
- Recreational access for boating, fishing, etc.

5.3.2 No Action Alternative

The No Action Alternative does not achieve the project purpose and need of restoring the estuarine ecological functions to the Herring River system and therefore did not fulfill the mission of the HRTC. Taking no action would result in the continued degradation of the Herring River system including:

- continued encroachment of invasive plant species,
- loss of native plant communities and habitats,

- adverse impacts to water quality and associated effects to finfish, shellfish, and other aquatic biota,
- high populations of nuisance mosquitoes,
- continued subsidence of former saltmarsh peat soils,
- continued decoupling of the coastal floodplain from nearshore waters, depressing the export of energy, nutrients and biota that sustain nearshore productivity (e.g. Wellfleet Harbor) and,
- loss of other natural functions provided by this estuary as described within Section 4.0 of this CRP.

Consequently, the No Action alternative is not considered viable.

5.3.3 Opening of existing culverts to maximum extent

Earlier modeling studies (Roman 1987, Spaulding and Grilli 2001) evaluated the option of completely opening the existing three culverts in the Chequesset Neck Road Dike. The modeling showed that although this would result in a substantial increase in tide heights and area of inundation upstream of the dike, drainage on the ebb tides would be impeded at the dike. Accordingly, opening the existing structure would actually decrease both the tidal range and flushing and therefore not achieve the goal of restoring the functions of the Herring River estuary, while increasing the likelihood of harmful flooding.

5.3.4 Modified tidegate controls at Chequesset Neck Road dike

The more recent hydrodynamic modeling effort (Spaulding and Grilli 2005) indicated that increasing the width of the tidal control openings at Chequesset Neck Road would be needed to attain sufficient ebb and flow for tidal flushing of the estuary. This is logical considering the original width of the mouth of the Herring River across the entire Chequesset Neck is nearly 500 feet. The modeling indicated that a total opening width of at least 100 to 130 feet (versus the current 18-foot width of the existing tidegates) would be sufficient to restore greater than 80% of the tidal regime above the Chequesset Neck Road Dike (see Photo 10). Additionally, the

Photo 10: Digital Image of potential culvert expansion at Chequesset Neck Road.

modeling report recommended that the culvert opening at High Toss Road should be increased to at least 30 feet to remove the restriction to tidal flow at that crossing.

Maintaining primary tidal control at Chequesset Neck Road has a number of advantages. Most notably, it would limit the control, management, operation and maintenance of the tide control structures to one location. It also would limit design efforts and construction-phase impacts to one location. Consequently, this alternative is anticipated to be generally the most efficient and cost-effective when compared to multiple upstream control structures.

A number of options for the design of the modified tidal control structure at Chequesset Neck Road have been developed in a report entitled *Preliminary Analysis for Alternatives for Modifying Tidal Flooding Controls at Chequesset Neck Road Dike* (June 22, 2007) prepared by ENSR and DMJM Harris. The following discussion is taken from that report. The conceptual plans/figures that are referred to in the text are provided in Appendix D of this report.

Four options have been evaluated to a conceptual design level for the alternative that modifies tidegate controls at the Dike. All options assume that the existing culverts will remain in place and in use, although possibly with new sluice gates. The four options are:

- Option 1: Cast in place culverts with eight-foot wide cells
- Option 2: Pre-cast arch spans
- Option 3: A two-span bridge structure
- Option 4: Trestle bridge

The trestle bridge option, comprised of multiple short spans with solid bent structures, was also originally investigated. However it was eliminated from further analysis due to high construction costs and lengthy construction duration associated with additional substructure elements.

5.3.5 Design/construction considerations

Modification of the existing dike and tidal control structures at Chequesset Neck Road requires a detailed understanding and assessment of numerous factors, including:

- the condition of the existing structures, geotechnical conditions at the site,
- traffic control and public access,
- construction duration and logistics,
- aesthetics, recreational suitability, etc.

Preliminary site investigations and previous reports indicate that the visible components of the existing culvert are in good condition and acceptable for continued use (MacBroom 2003). Therefore it has been assumed that the existing culvert would remain in place and would account for 18 feet of the necessary total opening dimension required to achieve the desired the tidal restoration. An evaluation of optional alignments to the existing Chequesset Neck Road Dike showed there were no obvious advantages to altering the alignment or footprint of the dike/roadway. Geotechnical conditions as reported from previous investigations in the 1970s were reviewed and considered in the evaluation of options (Christo Engineers, 1973). Additional geotechnical studies eventually will be needed but will be dependent on the design alternative/option that is ultimately selected.

Initially, building two openings of equal length on either side of the existing culvert was considered to maintain the center of the existing channel. However, for the arch (Option 2) and two-span bridge (Option 3), this meant doubling the construction of abutment units and cofferdams and lengthening the construction duration. This approach was abandoned and the alternative of building all openings on the north side (toward Griffin Island) of the existing structure currently is believed to be the most cost effective.

Due to the light traffic volumes encountered in the off season (September through May), it was assumed that Chequesset Neck Road could be closed for the duration of construction of all options. Traffic would be detoured to an alternate route and construction would be completed in the off season. This would allow for significantly shorter construction duration, due to the lack of staging that would be required if Chequesset Neck Road had to remain open to traffic. Construction costs would also be reduced by eliminating additional support of excavation provisions that would be necessary to keep one lane of traffic open at all times. Closure of the entire roadway precludes the need for placing excavation support at the centerline of the roadway that would be required to maintain one lane of traffic open. The estimated savings of complete road closure during construction is approximately 15% of the total cost of the entire structure.

Many issues could affect the decision of which option should be selected. Without consideration to priority, these include:

Aesthetics – Sluice gates to control tide levels in the Herring River will be placed on the Wellfleet Harbor side of the structure. From a structural stand point, it is far more practical and less expensive to take the hydrostatic force exerted on the sluice gates in the form of pushing force causing bearing pressure on the structure rather than pulling force causing tension on the structure. All three options will be fitted with similar sluice gates. Therefore from the Wellfleet Harbor side, all options have nearly similar aesthetics; however, the Herring River side of the structures will vary in appearance.

Cost – according to preliminary estimates, initial construction costs of all the three options are approximately the same (within 10 percent). All costs shown are based on a 100 foot opening and will increase should a larger opening is selected. Costs given in the following

paragraphs only are for the construction of the structure(s) and do not include the affiliated site work which may cost another $2,000,000. The structure cost estimate includes items such as: superstructure and substructure concrete, reinforcing steel, structural steel, bridge bearings, bridge expansion joints, bridge deck membrane waterproofing, asphalt, protective screen, excavations, ordinary and gravel borrows, temporary earth support system, and the sluice gates. The affiliated site work includes: adjustment of the roadway profile and alignment, repavement, reconstruction of roadway slope protections, signage, lighting, drainage, adjustments to sidewalks/shoulders, and landscape/site improvements.

Lifetime cost – this is a function of the future maintenance cost and harder to quantify, however certain options have more maintenance costs over the lifetime of the structure.

Construction Duration – It is currently anticipated that construction of all options would be feasible within one, six to nine-month season (September-May) if the roadway were closed to traffic.

Ease of opening up channel completely in the future – Options 2 and 3 are most conducive to any future decision that completely eliminates tidal controls at the Chequesset Neck Road Dike. However, all alternatives can be designed to accommodate complete removal of tidal control structures in the future should it be warranted.

Consequences of selecting a 130-foot versus 100-foot total opening – Options 1 and 3 easily accommodate the selection of a larger opening without increasing the cost of the structure significantly, whereas increasing the total opening under Option 2 (precast arches), will increase costs significantly.

Allowance for future recreational boat navigation to and from the Herring River and Wellfleet Harbor. The long, dark, relatively narrow and shallow channels inside culverts (Option 1) likely would not be suitable for small canoes or kayaks for safety reasons. Even inspection crews likely would have to treat the culvert channels as confined space and inspect them following established safety protocols. Option 2 (precast arches) and Option 3 (two-span bridge) would lend themselves well to recreational boat uses when the sluice gates are open or removed.

Hydraulics – deep foundations may be required for some options to resist the hydrostatic pressure created by channelizing the water flow. Although all options have a similar total opening, for the box culvert (Option 1), significant friction would develop between the concrete boxes and the surrounding soil that is anticipated to fully resist the hydrostatic pressure. The backfill soil weight placed on top of the culvert boxes further increases the resisting frictional force, making it likely that deep foundation (piles) would not be required. For Options 2 and 3, the friction developed between their foundations and soil may not be sufficient to take the hydrostatic force and thus deep foundation (piles) may be required.

5.3.6 Description of options for modifying the tidegate controls at the existing Chequesset Neck Road Dike

Three options have been evaluated for modifying the tidegate controls. All options assume that the existing culvert remains in place and in use. The plans referenced below are provided in Appendix D.

Option 1 – Culvert

This option involves the use of cast-in-place culverts with 8 foot-wide cells. This option is similar to the existing condition and can easily accommodate any length of total opening selected by adding as many cells as are necessary. The approximate cost of this option is estimated at $2,200,000 (structure only). As noted above, affiliated site work is estimated to cost another $2,000,000. The advantages and disadvantages of this alternative are summarized below:

Advantages:

- Low maintenance cost
- Most conventional
- Adding extra cells could accommodate opening increase from 100 feet to 130 feet.
- No deep foundations required

Disadvantages:

- Aesthetics
- Longest construction duration (approximately nine months)
- Difficult to inspect interior of structure
- No possibility to completely open channel
- No possibility of future recreational boat traffic (due to safety reasons)

Option 2 – Precast Arch

This option consists of either a two or three-span precast arch structure (depending on the size of opening required by the hydraulic analysis). Arch segments are proprietary items that are 8-foot wide segments and can vary in length from 12 to 48 feet (48 feet shown for Option 2). (Please note that the 8-foot wide segments refer to the width in the same direction as the width of the roadway (perpendicular to roadway traffic) as opposed to the length of each arch [48 feet]). Therefore, the entire structure is made of several 8-foot wide segments placed side by side. Wingwall and headwall panels are also precast and would be placed on cast-in-place footings. Cast-in-place channel beds also would be used. Deep

versus shallow foundations would be evaluated when additional geotechnical information becomes available, but would most likely be similar to the bridge option. If a structure longer than 100 feet is required, a three-span arch will be required. The approximate cost of this option is estimated at $2,200,000 (two-span structure only). Similar to the other options under evaluation, an additional $2,000,000 is estimated as the cost for affiliated site work. The major advantages and disadvantages of this option are summarized below:

Advantages:

- Aesthetics
- Low maintenance cost
- Shortest construction timeline due to the precast arch elements (approximately 6 to 7 months)
- Can be opened up completely (without gates) in the future
- Possibility of opening for recreational small boat traffic

Disadvantages:

- Gate dimensions are a function of predetermined arch span lengths
- Cost of this option increases significantly if the total opening size is increased to greater than 114 feet (two 48-foot arches plus existing 18-foot wide culverts) as three arches would be required instead of two.
- Not as easy to open to boat traffic as bridge option (Option 3)
- May require pile (battered or vertical) foundation.

Option 3 – Bridge

This option consists of a two-span bridge with either precast concrete box beams or steel girders. Cast-in-place abutments, pier and channel beds would be used. Abutments and piers would be supported by either spread footings or pile foundations, depending on geotechnical requirements. The bridge can easily be lengthened to accommodate an increased opening size without increasing the number of spans. Also, if it is determined later that the existing culvert is not viable for future use, the bridge may be built directly over the existing culvert and the culvert demolished at a future date. The approximate cost of this option is estimated at $2,400,000 (structure only, again with an additional $2,000,000 estimated for affiliated site work). The major advantages and disadvantages of this option are summarized below:

Advantages:

- Aesthetics
- Easiest to completely open up in the future
- Easy to inspect
- Flexibility of accommodating larger openings by increasing span lengths with the least amount of cost increase.
- Easiest to open to boat traffic (highest vertical clearance)
- May be constructed over existing culverts if existing culverts are deemed not viable

Disadvantages:

- Longer construction duration than Option 2 (approximately seven to eight months)
- Higher lifecycle cost (due to larger future maintenance cost estimated at 10 - 15% of construction cost)
- May require pile (battered or vertical) foundation.

5.3.7 Open Bridge Alternative with tidegate control at selected up-stream locations

An Open Bridge Alternative with no tidal controls at the existing Dike on Chequesset Neck Road would provide the potential for full tidal restoration (up to 9.1 feet NAVD88) in portions of the Herring Creek floodplain. This alternative also would necessitate the construction of several smaller structures in the upper watershed that would include tidegate controls to regulate the limit of tidal flooding within specific sub-basins (Figure 16). This alternative has been less comprehensively evaluated when compared to the previous alternatives/options. Hydraulic analyses would have to be completed and cost estimates would need to be generated to adequately evaluate the Open Bridge Alternative for comparison with the options that include tidal regulation at Chequesset Neck Road Dike. If this alternative is pursued there also will be additional costs associated specifically with the evaluation. However, in general terms, if this alternative is selected it is thought to have the following advantages and disadvantages:

Advantages:

- There would be unrestricted access under the Chequesset Neck Open Bridge allowing recreational boating and other unrestricted access to and from Wellfleet Harbor and the Herring River Lower Basin.

USGS Topographic Quadrangle
Wellfleet, MA

N

Feet
0 875 1,750 3,500 5,250 7,000

Potential Upstream Tidegate Control Locations under Open Bridge Alternative

Herring River Tidal Restoration Project
Wellfleet and Truro, MA

SCALE	DATE	PROJECT NO.
1:30000	June 2007	04479-003-300

ENSR | AECOM

Figure Number

16

J:\Water\ProjectFiles\P40\4479_CZM\4479003\GIS_May2007\Projects\FigB_UpsTidegate_OpenBridgeAlt.mxd

- An unobstructed bridge span likely would be more aesthetically pleasing from the Wellfleet Harbor side.

- With tidal control now installed at multiple upstream locations, tidal management for an individual sub-basin that needs infrastructure protection, may not limit tidal restoration elsewhere in the system, e.g. Mill Creek likely has a potential maximum tide height to 5.1 feet NAVD88.

- The Lower Basin and any other sub-basin that would not be adversely impacted by tide heights greater than 5.1 feet NAVD88, would gain significant additional sediment accumulation on storm tides, allowing the floodplain wetlands to more effectively keep pace with rising sea level rise, in turn providing increased storm surge protection for surrounding development.

Disadvantages:

- The overall cost of this alternative may be higher than other alternatives because it necessitates the construction of a bridge at Chequesset Neck Road and several structures with tidal regulation at key locations in the upper watershed.

- Without a control structure in place at the mouth of the river, road segments adjacent to the Lower Basin may have to be raised and fortified and the control structures will have to be larger and more robust in order to withstand exposure to storm tides and surges.

- Increased effort and coordination would be required to manage tidegates at more than one location.

Without control gates at Chequesset Neck Road, there would be free tidal flow into and out of the Lower Basin. However, the Herring River restoration plan is built around the concept of "adaptive management", a controlled step-by-step process (see Section 7).

Simply constructing and opening an open bridge in one step would not be consistent with adaptive management, unless it is constructed with temporary control gates that could be removed when no longer needed.

The process of constructing and managing the open bridge option needs further study.

5.4 Known Restoration Design Concerns

5.4.1 Mill Creek

Mill Creek is an 80-acre sub-basin located east of the Herring River and just south of Old Chequesset Neck Road and north of the CYCC. Because Mill Creek is just upstream of the Chequesset Neck Dike, and portions of the drainage are very low, this sub-basin needs special consideration.

The presence of portions of five CYCC fairways and several private residences, near or below proposed maximum spring tide heights (5.1 feet NAVD88) necessitates either the construction of a dike with some degree of tide control at the mouth of Mill Creek or that these features be relocated (CYCC fairways) or protected from increased tidal flooding. In addition, four of the five domestic water-supply wells within the river floodplain that are thought to be sensitive to saltwater intrusion occur in the Mill Creek watershed and may need to be relocated.

All restoration options with tidal control at Chequesset Neck Dike (managed to a maximum tide height of 5.1 feet NAVD88) and the open bridge alternative (full tidal restoration) would permit tidal restoration in Mill Creek. For the open bridge alternative, a new dike and control structure would need to be constructed at the mouth of Mill Creek. Additionally, because of other project constraints (see below), this new dike and structure may have to be managed to mimic existing water level conditions in Mill Creek.

Project partners, including the CYCC, have worked together over the last couple of years and the CYCC now has tentative plans to relocate low fairways above the proposed spring tide heights of 5.1 feet NAVD88. However, funding for this large construction project is uncertain. Further, although engineering studies of the affected private residences have identified several alternatives for flood-protection of the properties, agreement with the owners and funding are not yet attained. These high and potentially prohibitive costs compel a serious analysis of the costs and benefits of including 80-acre Mill Creek in the 1100-acre restoration project and may necessitate consideration of the construction of a dike and water control structure that prevents any increased tidal flooding in the Mill Creek watershed. The type (and eventual cost) of any dike and control structure constructed at the mouth of Mill Creek will be dependent on whether tidal control is implemented at the Chequesset Neck Road Dike.

Blocking all tidal exchange into Mill Creek will avert tidal-flooding effects to low-lying lands within the CYCC and to private residences. However, those portions of the golf-course fairways that were built on the original saltmarsh will still flood during periods of high water table and precipitation. These impacts will increase over the long term as the diked floodplain continues to subside and groundwater rises along with sea level. The Mill Creek floodplain also includes acid-sulfate soils, which presently release acidity and metals into receiving waters. This discharge will continue and may worsen with the blockage of all seawater entry. Tidal restoration in Mill Creek would restore normal saltmarsh geochemical cycling which would cause toxic metals (from acid-sulfate soils) or old pesticide applications to be immobilized. Continued diking and drainage of Mill Creek will cause these toxins to remain active and toxic to aquatic life. Without tidal flushing, mosquito control in Mill Creek will remain difficult and will be exacerbated by the sub-basin's poor water quality. Recent hydrologic work by the U.S. Geological Survey, which may be pertinent to Mill Creek, indicates that wells adjacent to artificially restricted saltmarshes are more vulnerable to saltwater intrusion under diked conditions than with tides restored (Masterson & Garabedian 2007). Most fundamentally, diking off Mill Creek

disconnects 80 acres of original tidal wetlands from the marine environment, blocking the exchange of materials, energy and biota that sustain nearshore coastal productivity.

A detailed updated topographic survey of the area around the Mill Creek confluence with the Herring River is needed to initiate the process of an engineering design for a dike/tidegate control at this location. A dike was apparently located across Mill Creek near the confluence with the Herring River as part of a historical tidal gristmill operation. The feature is still identifiable, but the extent to which it is serviceable for the anticipated future needs of tidal control is unknown. Additionally, if the location is deemed to be culturally sensitive, an archeological assessment will have to be completed before construction is initiated. A previous investigation that considered the prospects of a dike across Mill Creek to protect low-lying portions of the CYCC and other developed portions of the Mill Creek floodplain indicated that a pumping system likely would be needed during high precipitation and runoff events to remove impounded fresh water from behind the dike (Nuttle 1990). The option of a Mill Creek Dike will be evaluated in greater detail by the ongoing two-dimensional hydrologic modeling that is occurring as a component of planning for the Herring River Restoration Project (Woods Hole Group 2007).

5.4.2 High Toss Road

High Toss Road extends across the Herring River roughly one mile upstream of the Chequesset Neck Road Dike. It is a key location in the Herring River system to evaluate potential options for controlling tidal flooding, but also has to be evaluated for its importance for maintaining public access to Griffin Island (Figure 16). This unpaved, single-lane road extends across approximately 1000 feet of Herring River floodplain. Currently, a 60-inch diameter, 24-foot long culvert conveys the Herring River beneath High Toss Road near the western end of the dike. Except for the Mill Creek sub-basin, tidal control at High Toss Road could provide a tidal regime for both saltmarsh restoration as well as flood protection for large portions of the upper Herring River basin.

Dependent on the decision on the size and type of tidal control at Chequesset Neck Dike, additional hydraulic analyses would need to be completed for this location. Previous, hydrodynamic modeling (Spaulding and Grilli 2001) has indicated that the culvert opening at High Toss Road will need be increased to at least 30 feet to remove the restriction on tidal flow. Should the Open Bridge Alternative be selected at Chequesset Neck Road, High Toss Road (where it crosses the floodplain from Rainbow Lane west to Griffin Island), would need to be raised from the current elevation of 3-4 feet to between 10-12 feet (NAVD88). To ensure protection from major coastal storms and to prevent flood damage to areas upstream of this location, it is also likely that the entire High Toss Road Dike structure would have to be widened and have appropriately sized tidal sluice gates installed. Engineering designs and the costs for such a structure, although thought to be significant, have not been evaluated.

5.4.3 Pole Dike Road

Pole Dike Creek extends east from the Herring River just upstream of the High Toss Road crossing. Pole Dike Road crosses the creek at a relatively narrow (approximately 400 feet wide) wetland crossing, providing linkage from West Main Street to Bound Brook Island Road. This road crossing is a key location when considering future conditions relative to tidal flooding in the Upper Pole Dike Creek system to the east of this crossing (see Figure 18). Currently, Pole Dike Creek is conveyed under the road crossing via a 32-inch diameter, 40-foot long culvert. It should be noted that the 172-acre Pole Dike Creek wetland area upstream of Pole Dike Road was not included in the 2005 hydrodynamic modeling due to the lack of bathymetric data. The recently updated topographic mapping includes this sub-basin, and further evaluation of this area can now be completed during the two-dimensional hydrodynamic modeling. If warranted, the Pole Dike Road crossing would appear to be a suitable location for controlling tidal flows to the east (upstream). The old railroad dike could also be the site of a tidal control structure; it crosses Pole Dike Creek immediately to the west of the present road crossing.

5.4.4 Bound Brook Island/Old County Roads

As indicated in Figure 18, the Herring River flows under this roadway between the mid- and upper-basin portions of the Herring River floodplain. As such, it is another key location that warrants further evaluation during the consideration of potential tidal restoration options. Tidal controls could be installed at the road crossing over the Herring River just north of Merrick Island, which would regulate tidal inundation over all upstream areas. Alternatively tidal control could be installed at the Bound Brook crossing north of this location which could regulate inundation in the Bound Brook wetlands up into Truro. The recently updated topographic mapping permits further evaluation of this area that can now be completed during the two-dimensional hydrodynamic modeling.

5.4.5 Chequesset Neck Road Dike - Sluice gate considerations

For the application of modified tidegate controls at the Chequesset Neck Road Dike, a series of sluice gates six to eight feet wide and six to ten feet tall, positioned across the width of the channel is anticipated (see Figure 17). A total of 13 to 17 units would be required to span a 100 foot width.

The sluice gates would be fabricated of a cast iron/nickel alloy or stainless steel, with hardware of stainless steel or nickel/copper alloy. Higher quality materials (stainless steel or nickel/copper alloy) are more expensive but more resistant to corrosive environments. Self-contained actuators would limit the amount of ground space needed for installation, and can be hydraulically, electrically, or manually powered. The operating stem and stem cover would extend approximately 14 feet above the top of culvert. Sluice gates may be constructed with a combined flap gate feature to allow for increased flexibility of operating the structure. Flap gates are likely to be useful only when the sluice gates are fully, or nearly fully, closed after a coastal storm when the gates could remain closed and still allow drainage from the inland areas. However, flap gates may also complicate incremental

Figure 17. Sluice Gate Schematic

Sluice Gate Schematic

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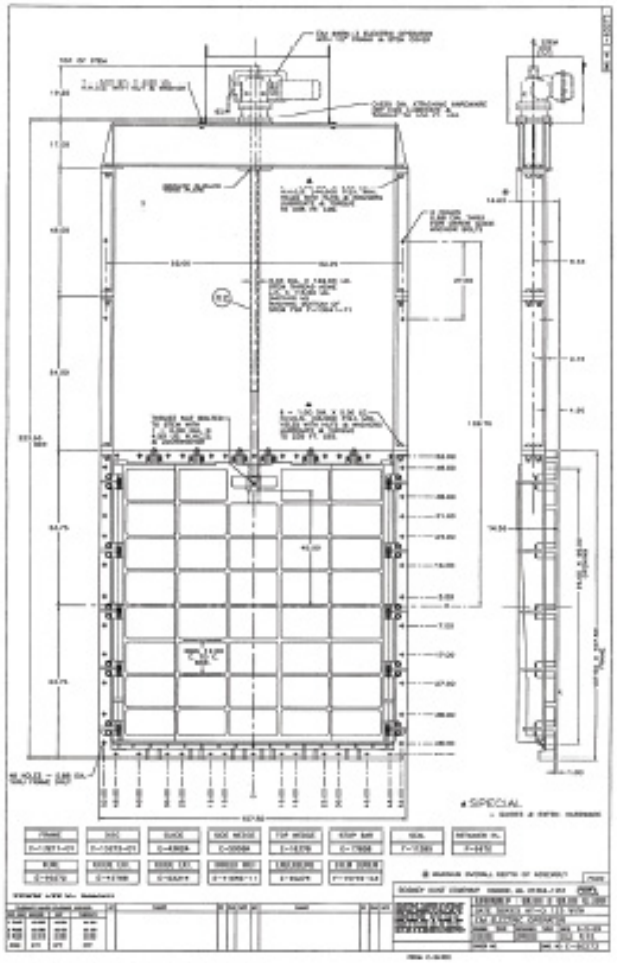

Chesquessett Neck Road Dike Sluice Gate Application

For this application, ENSR recommends a series of sluice gates 6 to 8 feet wide and 6 to 10 ft tall positioned across the width of the channel. A total of 13 to 17 units will be required to span a 100 ft width.

The sluice gates will be fabricated of a cast iron/nickel alloy or stainless steel, with hardware of stainless steel or nickel/copper alloy. Higher quality materials are more expensive but more resistant to corrosive environments.

Self-contained actuators will limit the amount of ground space needed for installation, and can be hydraulically, electrically, or manually powered. The operating stem and stem cover will extend approximately 14-ft above the top of culvert.

Sluice gates may be constructed with a combined flap gate feature to allow for multiple uses of the structure.

restoration, as they would tend to let high volumes of water out at ebb tides and considerable less in at flood tides. Again, an interactive hydraulic model will be needed to assess the needs and operations of the tidegate controls.

5.5 Restoration of Herring River Sinuosity

As described in Section 2, the Herring River was channelized during the first half of the 20th century, in order to enhance drainage for mosquito control. Recent studies (French and Stoddart 1992, Reed et al. 1999, Desmond et al. 2000, Williams et al. 2002) have indicated that restoration of natural sinuosity and channel geometry has significant benefits to the ecological health of channelized tidal river systems. Any restoration of the river's sinuosity likely will occur in the latter phases of the Herring River Restoration Project after comprehensive analysis including hydrologic modeling and construction of new tide control structures.

5.6 Selection of a Preferred Alternative

The selection of a preferred alternative for this large restoration project currently is deferred until all parameters, including the completion of two-dimensional hydrodynamic modeling, have been fully evaluated and the public input required under MEPA and NEPA has been completed (see Section 8 for additional details). Using recently obtained detailed topographic mapping, comprehensive hydrodynamic modeling will be applied to the various alternatives to more fully evaluate the effectiveness of each option. Associated issues, such as those related to low-lying roads, public access, effects on private properties, recreational uses, aesthetics, costs, etc., will continue to be assessed in the selection of a preferred alternative to carry forward into more detailed design phases.

The prescribed process (through the MOUs between CCNS and the Towns of Wellfleet and Truro) includes the formation of the Herring River Restoration Committee (HRRC) and the development of a Detailed Restoration Plan as part of concurrent MEPA and NEPA processes. These environmental review procedures ensure a thorough public process of assessing alternatives and minimizing/mitigating environmental impacts. Subsequent to these reviews, the project will be subject to specific local, state, and federal permitting requirements.

5.7 River Access

The Herring River Restoration Project including its adjacent saltmarshes will create new opportunities for use and enjoyment of the valley. Historically, the Herring River was much used by the local citizenry, including shellfishing, finfishing and recreational boating (canoeing/kayaking; Photo 11). Much of this use is well-remembered by many of the current residents of Wellfleet and Truro. The continued degradation of the river has now made most of these historic uses unappealing, difficult, or impossible.

Photo 11: Recreational boating opportunities are anticipated to improve with tidal restoration.

Restoration of access will be necessary to allow enhanced use of the restored Herring River system. Project design is anticipated to take advantage of the construction phases of the restoration project to create additional access. This access will be balanced with the other important project goals including preserving ecological health of the river and marshes and minimally disturbing wildlife. Any changes in river access will be part of the environmental review of the project.

5.7.1 River Access Locations

Locations where roads cross the Herring River provide potential sites for access to the river for shellfishing, finfishing and a diversity of recreational purposes. These points include enhanced access (including fishing piers) on both the upstream and downstream sides of the Chequesset Neck Road Dike, High Toss Road, Pole Dike Road and Bound Brook Island Road. Each of these crossing points could be the site of construction during the restoration project. There will also be construction projects for low-lying roadways and culvert enlargements. During this construction, river access sites likely could be created and could involve nothing more that a kayak/canoe put-in site with a small area for parking.

5.7.2 Walking Trails

The restoration of the river valley will create many open sites and vistas of great natural beauty. A set of walking trails and view points along the Herring River valley would allow visitors to enjoy those vistas (see Photos 12 and 13).

The creation of a trail system will be a component of the Herring River Restoration Plan and will be consistent with the need to preserve natural ecosystems and the concerns of adjacent landowners.

Photos 12 and 13: Activities such as fishing and hiking will be promoted by the restoration project, and natural vistas of the estuary will be enhanced.