

Massachusetts Coastal Zone Management

Review of Potential Impacts of Herring River Restoration on Rosenberg Property, Wellfleet, Massachusetts



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1.0 INTRODUCTION

ENSR prepared this report to summarize the results of our review of the potential effects to the Rosenberg property in Wellfleet, Massachusetts from anticipated hydrological changes associated with the restoration of tidal flooding in the Herring River system. The National Park Service (NPS) has been evaluating the potential for removing existing barriers to tidal flooding of the Herring River to restore salt marsh ecosystem functions from Wellfleet Bay inland to Route 6, restoring an estimated 1100 acres of wetland to salt marsh. The Rosenberg property is located along the Herring River roughly 4,500 feet from the lowest dike at Chequesett Neck Road. The Rosenbergs have expressed concerns over the effects of the restored tidal flows, including storm surges, on their property. ENSR has contracted with the Massachusetts Coastal Zone Management-Wetland Restoration Program to conduct a review of pertinent background materials describing and analyzing the proposed tidal regime change, conduct site reviews and interviews with the Rosenbergs, and prepare this report summarizing our findings.

1.1 Information/Material Reviewed by ENSR

As part of the investigation, ENSR conducted two site reviews of the Rosenberg parcel, both including direct discussions with the Rosenbergs regarding their conditions and concerns. Site reviews occurred on April 8, 2005 and July 8, 2005. Information on site topography was provided to ENSR from existing survey information by Slade Associates, Inc. as well as other reports. Information on existing water supply and wastewater disposal conditions was gathered from local contractors familiar with the site and supplemented by field observations. On-site inventories of vegetation/landscaping as well as soil conditions were conducted by ENSR. During the site reviews, brief reconnaissance of the larger Herring River watershed was also conducted.

As part of the investigation, the following documents were among those reviewed by ENSR:

- Martin, Larry. 2004. Salt Marsh Restoration at Herring River: An Assessment of Potential Salt Water Intrusion in Areas Adjacent to Herring River and Mill Creek, Cape Cod National Lakeshore. Technical Report NPS/NRWRD/NRTR-2004/319.
- Masterson, John P. 2004. Simulated interaction between freshwater and saltwater and effects of ground-water pumping and sea-level change, Lower Cape Cod aquifer system, Massachusetts: U.S. Geological Survey Scientific Investigations Report 2004-5014, 72 p.
- Spaulding, Malcolm L., and Annette Grilli. 2001. Hydrodynamic and Salinity Modeling for Estuarine Habitat Restoration at Herring River, Wellfleet, Massachusetts.
- Spaulding, Malcolm L., and Annette Grilli. 2005. Simulations of Wide Sluice Gate Restoration Option for Herring River.

- Fitterman, David V. and Kevin F. Dennehy. 1991. Verification of Geophysically Determined Depths to Saltwater Near the Herring River (Cape Cod National Seashore), Wellfleet, Massachusetts. U.S. Geological Survey Open-File Report 91-321.
- Letter from EarthTech to Tim Smith, Wetland Scientist, Massachusetts Coastal Zone Management. June 29, 2004. Regarding Floodproofing Feasibility Analysis of Rosenberg Parcel – Wellfleet, Herring River Restoration Project.

1.2 Caveats and Limitations

This findings and conclusions of this report are subject to the following caveats and limitations:

- All conclusions are based upon the information identified above, provided by NPS, CZM and the Rosenberg's as well as conditions observed during ENSR's two visits to the property.
- The conclusions of this report are relevant for the current restoration alternatives proposed by the NPS only.
- Assessment of proposed impacts inherently requires projections of potential conditions. For this analysis these projections have been based on best professional opinions using the available information and were not developed from precise calculations.

1.3 Report Contents

The remainder of this report is organized into the following sections:

- Background Summary and Description of Property (Section 2.0)
- Hydrodynamic Model Review (Section 3.0)
- Structure Review and Impact/Mitigation Assessment (Section 4.0)
- Well Impact Evaluation (Section 5.0)
- Septic Impact Evaluation (Section 6.0)
- Vegetation/Landscaping Impact Evaluation (Section 7.0)
- Summary, Conclusions and Recommendations (Section 8.0)
- References Cited (Section 9.0)

2.0 BACKGROUND SUMMARY AND DESCRIPTION OF PROPERTY

The Herring River extends from Wellfleet Harbor northeast for nearly four miles to Herring Pond near Newcomb Hollow Beach. An estimated 1,100 acres of marshes and other wetlands border the River or are hydrologically connected via other streams (e.g., Mill Creek and Bound Brook). In 1909 a dike was constructed across the roughly 100-meter wide channel just above where the River discharges into Wellfleet Harbor; Chequesset Neck Road passes over the existing dike. Flow through the dike is restricted, with three 6-foot wide box culverts remaining to pass flow; two of the culverts contain flapper-style tide gates that allow flow only into the Harbor, while the third culvert contains an adjustable sluice gate. An additional culverted dike occurs at High Toss Road, roughly 5,200 feet north (upstream) of the main dike. The NPS has been evaluating the hydrologic and ecological conditions created by the existing dikes. According to the NPS, *“the restriction in flow imposed by these hydraulic control structures has resulted in the conversion of hundreds of hectares of the original inter-tidal salt marshes into upland vegetation, eliminating habitat for estuarine plants and animals, including fish and shellfish. In addition, it has resulted in adverse impacts on water quality including acidification of river waters, leaching of metals from the sediments and episodic anoxia. It has also resulted in subsidence of the wetlands.”* Consequently, the NPS has been evaluating various options for reducing the tidal restrictions to promote restoration of the Herring River and adjoining salt marshes. ENSR's review is not intended to cover a comprehensive assessment of the overall restoration project, but rather to assess the potential affects to the Rosenberg property and to consider potential mitigation measures, if warranted.

The Rosenberg property is located along the east side of the Herring River roughly 4,500-feet upstream of the Chequesset Neck Road dike. The property is approximately 1 acre in area, with roughly 200-feet directly bordering the channel of the Herring River. Based upon available survey information, the edge of the Herring River along the east edge of the site is roughly at elevation 2 feet (the existing mean high tide elevation is elevation 1.5 feet). The Rosenberg house is set back from 60 to 80 feet from the edge of the River and a thin band of wetland alongside of it. The elevation of the yard between the River and the house is generally between 4 and 5.5 feet (the lowest point of ground adjacent to the house is surveyed at 5.4 ft). The yard generally contains mowed lawn with roughly 15 small-to-moderate size trees scattered around the yard (see Section 7 for detailed vegetation description, as well as pictures in Appendix A). The potable well for the home is located just east of the house (at approximately elevation 8 feet), near to the access drive (Rainbow Lane) for the land (which is roughly at elevation 9.6 feet). Wastewater leaching areas (cesspools) are located 30 to 40 feet east and north of the house, both at approximate elevations 5 to 5.5 feet. Figure 1 provides a plan of the Rosenberg property, as adapted from Slade Survey. Section 4 provides a detailed description of the Rosenberg house itself, which contains first floor elevations of 7.56 feet (addition on west side) and 9.28 feet (main portion of house).

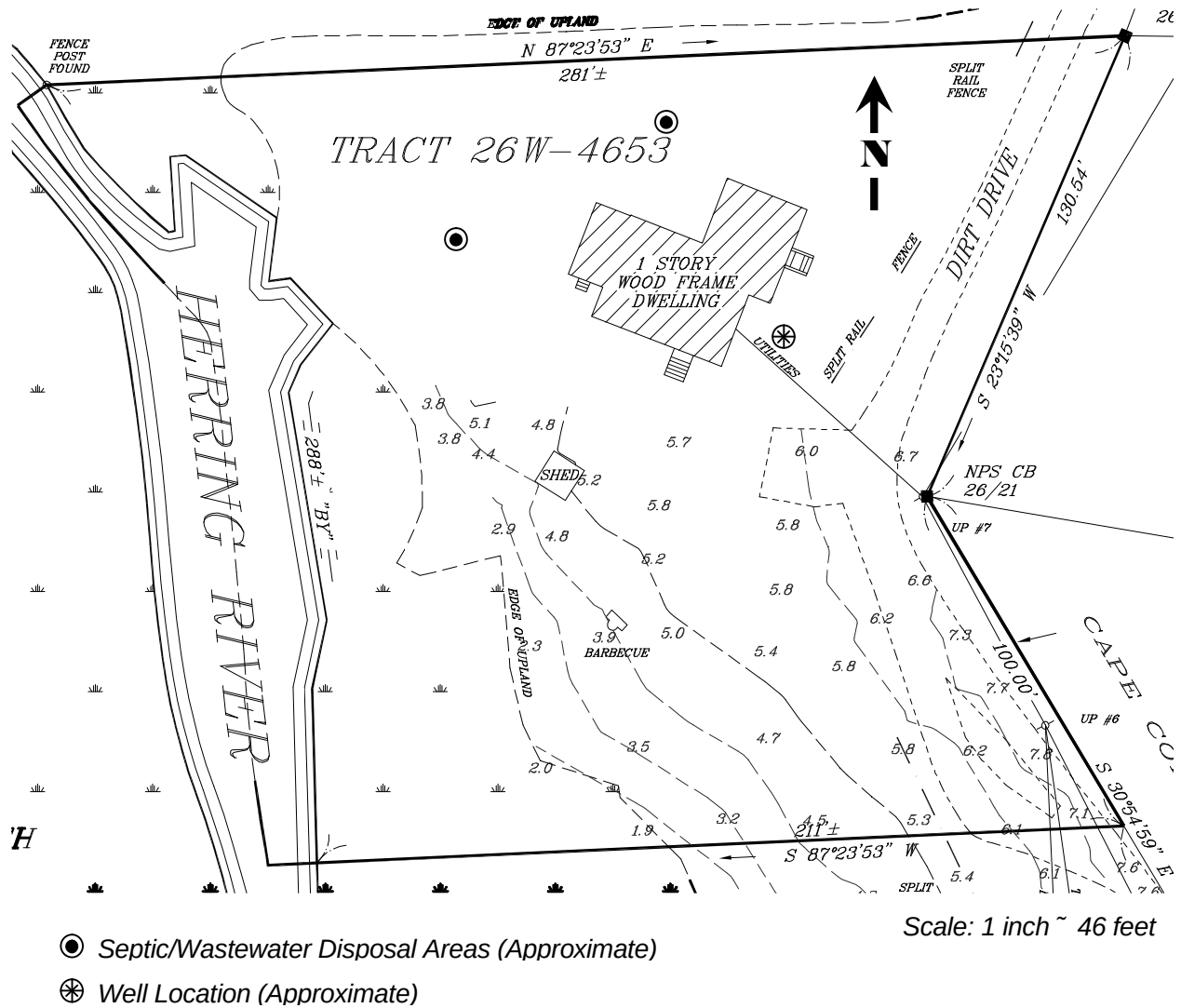


Figure 1: Rosenberg Property Site Plan

3.0 HYDRODYNAMIC MODEL REVIEW

This section summarizes ENSR's review of the hydrodynamic modeling used conducted on behalf of NPS to develop and assess the proposed Herring river restoration alternatives.

3.1 Hydrodynamic Model Summary

ENSR reviewed the Herring River hydrodynamic modeling, documented in *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). The model was 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 to the existing structure, while the 2005 update evaluated potential changes with wider openings in the dike, fitted with sluice gates to allow for incremental vertical openings in the culvert.

The evaluation by the NPS included a field program to measure water levels on both sides of the dike and flows up the river. Data was collected to characterize flow conditions upstream and downstream of the dike under varying tidal conditions and salinity and temperature fields in the Herring River. Data collected during the field program were used to develop the model and to compare with model predictions.

To ensure that the model predictions of the alternative scenarios were realistic, the model was first applied to model the existing dike. Model predictions were compared with measured values. The report provides several comparisons of observed and predicted water level values that indicate model predictions are well matched to observed data.

The model was applied to predict water levels in the river with several alternative configurations of the sluice and tide gates, 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 flood conditions.

3.2 Hydrodynamic Model Review Findings

Spaulding and Grilli selected and applied a numerical model primarily to evaluate water level changes across the existing and proposed modified culverts and/or gated opening. Had the goal of the original study been determination of flood elevations at specific locations along the river, a more detailed model of the estuary would likely have been developed. However, their modeling effort is consistent

with the goals of the study. Overall, it is ENSR's opinion that the model predictions are well matched to observed data at the upstream end of the inlet. Following are ENSR's concerns and comments regarding the selection and application of the present model to flood elevation predictions upstream of the dike:

- The model assumes that the water level in the Herring River rises and falls uniformly over the river. It does not include energy losses due to friction or flow changes within the river. This assumption has the potential to result in overprediction of high water levels in the upstream reaches of the river system, particularly above High Toss Road. Due to the relatively small size of the Herring River system and its large conveyance capability relative to the tidal opening, this assumption appears reasonable.
- Field data was collected to determine the flow volumes and elevations at the dike for use in calibrating and validating the model. However, the observed ebb-flood tide mass balance is off by up to 20 percent and this discrepancy is not fully resolved in the report. Also, modeled flow volume predictions differ from the observed values by up to 35 percent. The model is well calibrated to observed elevations, but it is difficult to fully assess model calibration/validation with the discrepancy in the observed flow data. Further investigation into this matter is warranted.
- The model is validated and calibrated to a narrow range of sluice and gate configurations, based on available data. Model predictions for configurations that are significantly different from these conditions may not be as realistic as those for which the model was calibrated. This is true for most modeling studies.
- There is some uncertainty in the surface area versus water level relationship for the Herring River; this could affect predicted water levels. The authors recommended that additional surveying be performed to reduce this uncertainty.
- It is not clear if freshwater inflows were modified in the 100-year flood scenarios from the dry weather values used for the other scenarios. Although field observations indicated that freshwater inflow was nominal during dry weather conditions, the volume of freshwater inflow could be substantially increased during a large rain storm if this occurs in conjunction with a tidal event, resulting in higher water levels in the river.
- Spring and neap tide events were not simulated for the 100-foot wide culvert option.

3.3 Restoration Scenarios Reviewed

ENSR understands that at present there has been no definitive determination made as to the final culvert configuration. We anticipate that the design implementation will afford an iterative approach of openings based upon observed conditions, with increased sluice gate height openings across a

roughly 100-foot wide culvert over time. Consequently, for the purposes of this evaluation, ENSR has evaluated conditions under four potential scenarios:

- Scenario 1. existing structure fully open
- Scenario 2. 100-foot wide culvert with 4-inch sluice gate opening
- Scenario 3. 100-foot wide culvert with 16-inch sluice gate opening
- Scenario 4. 100-foot wide culvert with 118-inch (10-foot) sluice gate opening

Table 1 provides the water level elevations predicted upstream of the Chequesett Neck Road for the scenarios discussed above for mean tide, mean low tide, mean high tide, and the 100-year flood event. Figure 2 through Figure 5 present schematic transects of the Rosenberg property depicting these tidal event elevations for each scenario.

Table 1: Hydrodynamic Model Prediction Summary

Tidal Event	Wellfleet Harbor	Scenario ?				
		Existing Culvert		New 100-Foot Culvert w/Gate Opening (inches)		
		Current Configuration	Fully Open	4	16	118
100-Year (ft-NGVD)	10.3	1.9	6.0	5.5	5.7	8.4
Mean Low Tide(ft-NGVD)	-2.4	-0.3	0.8	-2.0	-2.2	-2.3
Mean High Tide (ft-NGVD)	5.4	1.6	4.2	4.1	4.2	5.4
Mean Tide (ft-NGVD)	1.5	0.7	2.5	1.0	1.0	1.6

Scenario 1 represents the least tidal flow restriction possible with the existing culvert configuration. We understand that this may not be the optimum alternative ecologically. A superior alternative, in terms of restoring tidal range, would be to replace the exiting culvert with a significantly wider one (approximately 100-feet wide) to allow for greater tidal flushing volumes than possible with the existing culvert. Note that this culvert is still a concept and if implemented, would actually required multiple smaller culverts place in parallel with a total width of 100-feet. If a 100-foot wide culvert alternative is ultimately implemented, it would be fitted with an adjustable sluice gate(s) to control the opening height. This would allow for a gradual phasing in of restored tidal flushing over several years. Scenario 2 represents the 100-foot culvert with a minimal (4-inch) opening, which might be used at the start of the restoration implementation. Scenario 3 represents the 100-foot culvert with a moderate (16-inch) opening that might be used several years into restoration implementation. Scenario 4 represents the 100-foot culvert with an un-restricted (100-foot) opening that might be used in the full restoration condition.

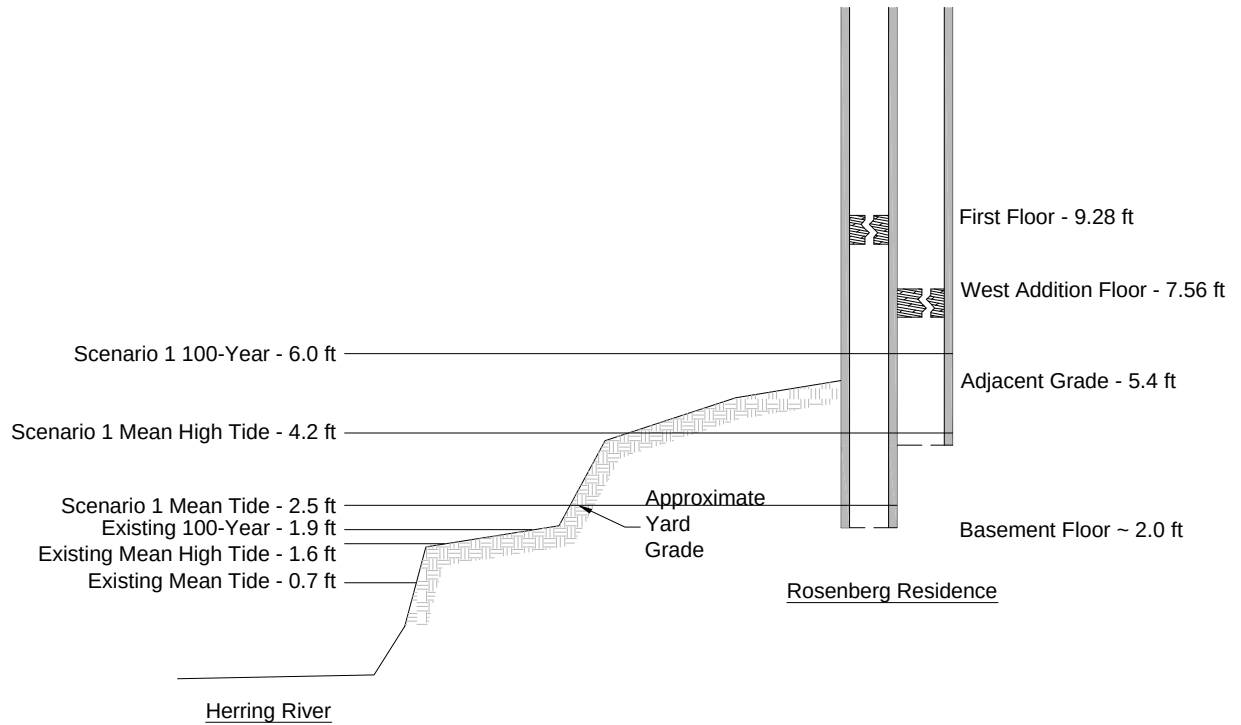


Figure 2: Scenario 1 (Existing Structure Fully Open) Transect

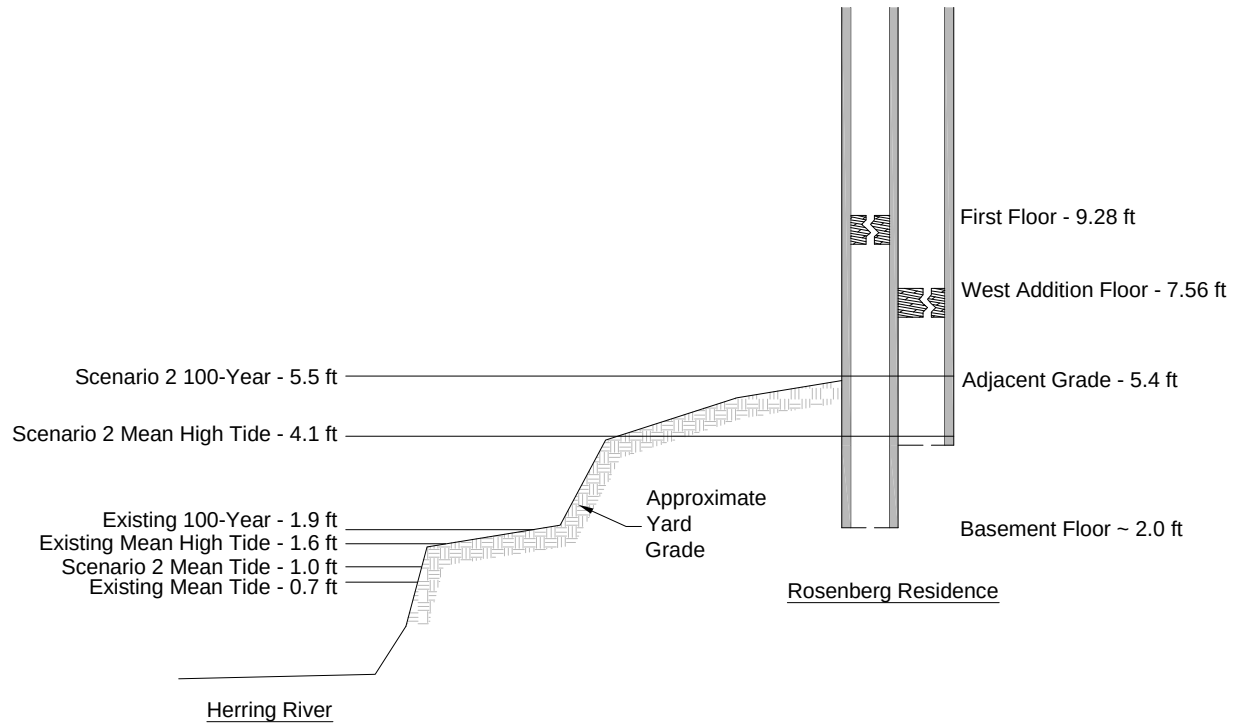


Figure 3: Scenario 2 (100-Foot Culvert Open 4 Inches) Transect

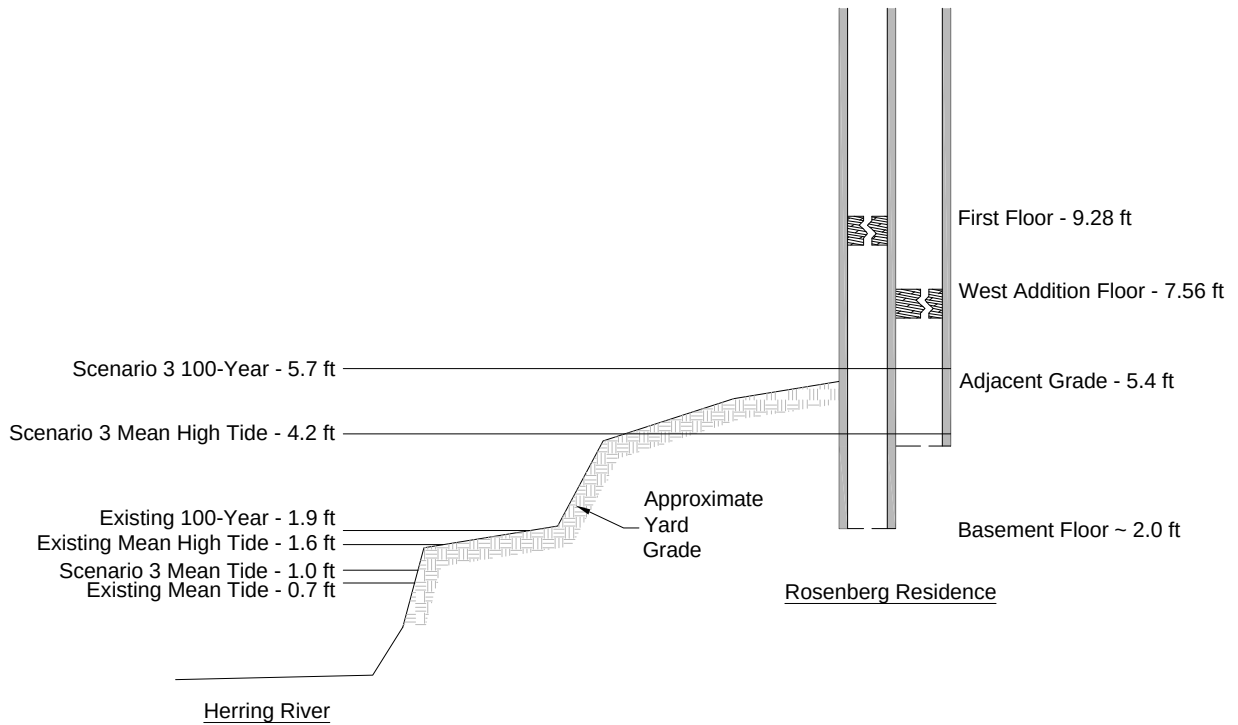


Figure 4: Scenario 3 (100-Foot Culvert Open 16 Inches) Transect

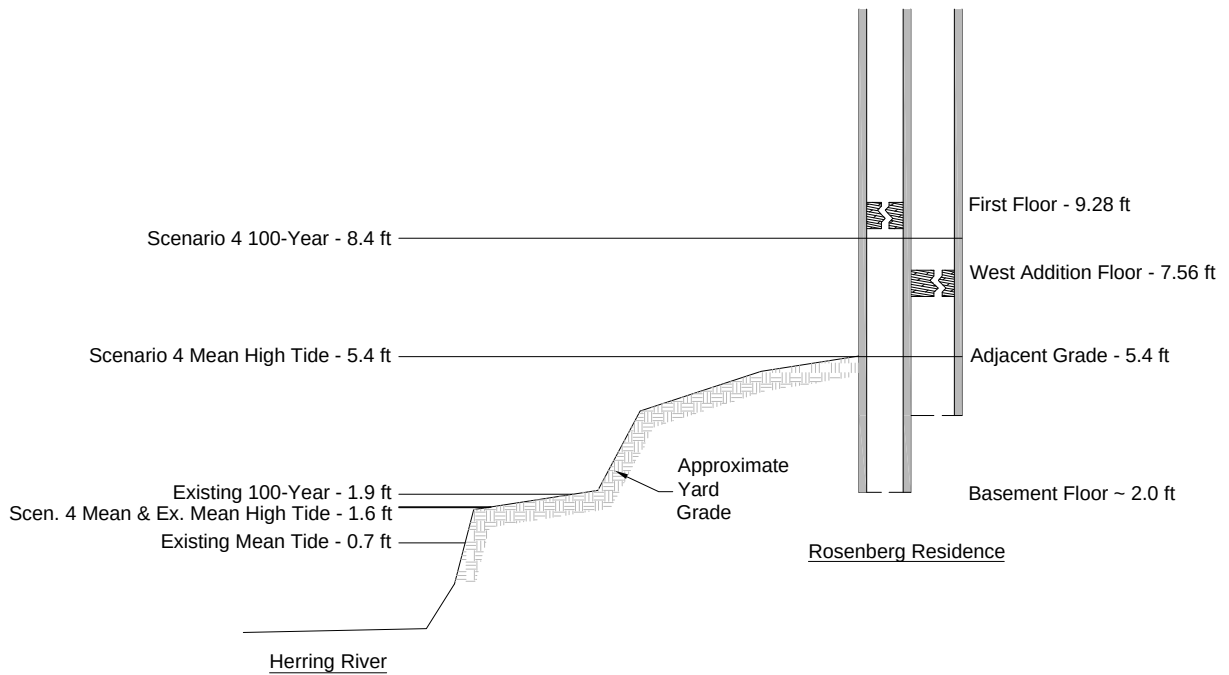


Figure 5: Scenario 4 (100-Foot Culvert Open 10 Feet) Transect

4.0 STRUCTURE REVIEW AND IMPACT/MITIGATION ASSESSMENT

This section describes ENSR's evaluation of the potential impacts of water level changes associated with restoration alternatives to the Rosenberg's house. This section also identifies potential mitigation alternatives to address these impacts.

4.1 Structure Impact Assessment

During ENSR's site reviews we verified the structural descriptions and measurements provided by EarthTech's Structural Engineer in their letter dated June 29, 2004; we are in agreement with those descriptions, and they are summarized below. The Rosenberg house is a single-story wood frame structure supported on a masonry block foundation. The house consists of a main, original structure as well as several additions. The main structure is roughly 26-feet long by 22-feet deep, with a first floor elevation of 9.28 feet. The structure is supported by a 6-foot high, 8-inch thick non-reinforced masonry block foundation wall. A masonry block chimney foundation support structure also exists. An unfinished basement with a concrete floor of unknown thickness is found beneath the main structure, accessed by wood stairs from the first floor. The basement floor slab is roughly 4 feet below the outside grade. The basement has a slight pitch into a central sump, and a sump pump is in place to pump seepage water into the basement. Indications of water seepage into the basement and accumulation in the sump were noted during both of ENSR's site reviews. Utilities located in the basement include a furnace/water heater, water pump for potable water drawn from the well, and a sanitary wastewater pipe that exits to the northeast roughly 29 inches below the sill. The first floor is supported by 2 x 8 wood joists spanning to a built-up timber beam supported by 4-inch diameter steel lally column, wood posts and a masonry wall at the chimney foundation.

Several wood frame additions have been added to the west and south sides of the house. These are supported on either 8-inch masonry block walls with a 3-foot deep crawl space or 8-inch by 16-inch by 3-foot masonry block piers. The 20-ft by 10-ft western addition has a depressed first floor level (at 7.56 ft) with a nominal crawl space, while the southern addition (roughly 10 by 36 feet) is supported on masonry block piers with no accessible crawl space.

4.2 Potential Changes/Impacts Under Proposed Regimes

ENSR compared predicted tidal event elevations for existing conditions and the four restoration scenarios to critical elevations on the Rosenberg property and structure including lowest yard elevation, basement elevation, west addition first floor elevation, and main first floor elevation. Table 2 summarizes the results of this evaluation. For each scenario, the table identifies whether or not the predicted mean, mean high and 100-year flood tidal event elevation, in the Herring River, is higher than these critical elevations. Table 3 summarizes the predicted elevation difference between critical elevations and tidal events for cases where predicted elevations exceed critical elevations.

Table 2: Summary of Potential Impacts on Rosenberg Property

Tidal Event	Potential Impact by Scenario				
	Existing	1	2	3	4
Mean Tide					
Yard*	No	Yes	No	No	No
Basement	No	Yes	No	No	No
West Addition Floor	No	No	No	No	No
Main First Floor	No	No	No	No	No
Mean High Tide					
Yard	No	Yes	Yes	Yes	Yes
Basement	No	Yes	Yes	Yes	Yes
West Addition Floor	No	No	No	No	No
Main First Floor	No	No	No	No	No
100-Year Flood					
Yard	No	Yes	Yes	Yes	Yes
Basement	No	Yes	Yes	Yes	Yes
West Addition Floor	No	No	No	No	Yes
Main First Floor	No	No	No	No	No

* Yard at approx. elevation 2 ft-NGVD (lowest elevation of mowed yard at river edge)

Table 3: Predicted Elevation Difference Between Tidal Event and Critical Elevation

Tidal Event	Elevation Difference by Scenario(feet)				
	Exist	1	2	3	4
Mean Tide					
Yard	--	0.5	--	--	--
Basement	--	0.5	--	--	--
Mean High Tide					
Yard	--	2.2	2.1	2.2	3.4
Basement	--	2.2	2.2	2.2	3.4
100-Year Flood					
Yard	--	4.0	3.5	3.7	6.4
Basement	--	4.1	3.6	3.8	6.4
West Addition Floor	--	--	--	--	0.8

Scenario 1 = Existing culvert with gates fully open.

Scenario 2 = New 100-foot culvert with gate open 4 inches.

Scenario 3 = New 100-foot culvert with gate open 16 inches.

Scenario 4 = New 100-foot culvert with gate open 10 feet.

Under existing conditions the Rosenberg property and structure does not experience flood problems for any of the tidal events considered. For potential restoration scenarios, the tidal events evaluated are predicted to primarily impact the yard and basement. For all restoration scenarios, the mean high tide elevation would exceed the lowest yard and basement elevation by at least 2-feet. Surface

flooding at mean high tide would extend to within about 40 to 45 feet of the house for Restoration Scenarios 1 through 3 and to the house for Scenario 4. Since there is no direct hydraulic connection between the basement and river, impacts to the basement would be experienced via groundwater level increases. However, given the sandy soils and close proximity of the surface water and the fact that mean tide elevation is within 1-foot of the basement floor under all scenarios, it is likely that groundwater would exceed the basement floor elevation at high tide. For Scenario 1, the mean tide elevation exceeds the basement floor elevation.

For the 100-year flood tidal event under all scenarios, water elevations would significantly exceed both the basement elevation and grade elevations adjacent to the foundation. This could potentially cause hydrostatic pressures resulting in failure of the foundation walls. However, it is likely that the basement would fill with groundwater to equalize this pressure. Predicted 100-year flood elevations exceed the finished floor elevation of the western addition for Scenario 4. Predicted 100-year flood elevations do not exceed the finished floor elevation for the main structure.

4.3 Potential Mitigation

Predicted 100-year flood elevations do not exceed the finished floor elevation for the main structure and exceed the finished floor elevation of the western addition for Scenario 4 only. Assuming that Scenario 4 is not likely to be implemented while the Rosenberg residence remains occupied, mitigation should not be required to address potential flooding of the either main or addition first floor. However, all four restoration scenarios have the potential to cause impacts to the basement of the Rosenberg residence during normal tidal events as well as infrequent ones such as the 100-year flood. ENSR has identified the following potential mitigation activities to mitigate the basement flooding impacts:

- Footing drain
- Relocate utilities to first floor and add equalization ports to basement
- Other flood proofing of basement

Each of these mitigation alternatives is discussed in greater detail below.

4.3.1 Footing Drain (Dry Floodproofing)

A footing drain would function to prevent groundwater from entering the basement. This drain would consist of a perforated pipe installed around the outside perimeter of the house at or below the footing level. This pipe would be embedded in crushed stone to allow for rapid drainage. Sealing of the foundation wall from the outside would be advisable at this time, as well. The footing drain would need to be directed to a sump fitted with a submersible pump to allow for drainage when tide levels exceed the drain elevation. Given the relatively remote location of the property, a back-up power source should

also be considered for the sump pump. Installation of a footing drain would actually address existing seepage issues in the basement, improving conditions from the current status.

A footing drain could be effective for normal tidal events for all scenarios evaluated. However this footing drain would likely provide less benefit for more infrequent events like the 100-year flood, particularly for Scenarios 1 and 4, where flood predicted elevations significantly exceed ground elevations adjacent to the house.

4.3.2 Utility Relocation (Wet Floodproofing)

Generally, elevating all living space above the 100-year flood elevation is the preferred method of protecting residences from flood damages. This living space includes all utilities (e.g., water heater, furnace, electrical panels, etc.). For example, National Flood Insurance Program (NFIP) regulations do not allow flood proofing as a valid means of protecting residential structures from floods. These regulations require that all finished spaces, including all utilities, for new construction be placed above the 100-year flood elevations. Since the Rosenberg's utilities are currently located in the basement, the space would be considered living space. For the Rosenberg residence utility relocation would entail:

- Construction of a new utility room to house the furnace, water heater and electrical panel on the same level as the Rosenberg's current first floor.
- Either filling in the basement to adjacent grade elevations or adding open ports at grade on the exterior to allow flood waters to enter the basement to equalize hydrostatic pressure. The second option would allow for continued use of the basement for storage of non-water sensitive materials but would also require means for removing accumulated flood waters from the basement.

In ENSR's opinion utility relocation with basement filling would be most viable alternative for protecting the Rosenberg structure for the range of potential flood conditions.

4.3.3 Other Flood Proofing Methods

EarthTech's letter report identified two additional floodproofing alternatives for the Rosenberg property. These include:

- Elevating the Structure
- Levees and Floodwalls

Please refer to the Earthtech letter for a full description of each of these options. The following is a brief summary of the potential applicability of these measures for the Rosenberg property.

Elevating the structure would be needed for only Scenario 4 (unrestricted tidal flow) where the predicted 100-year flood elevations (8.4 feet) exceed the west addition floor elevation (7.6 feet). For this Scenario, the predicted flood elevation would not affect the main structure floor elevation (9.3 feet). Therefore, only the addition would need to be raised, if viable. Note that for this option to provide full protection from a 100-year event, utilities would need to be relocated to above the 100-year elevation. See the previous section for addition detail regarding utility relocation. Structure elevation would not mitigate for water levels in the Rosenberg's basement.

Levees and floodwalls would provide similar protection to structure elevation and like structure elevation would not protect against basement flooding, which is and will be the primary issue for the Rosenberg residence.

5.0 WELL IMPACT EVALUATION

This section describes ENSR's evaluation of potential impacts of water level and salinity changes associated with potential restoration alternatives on the Rosenberg's on-property potable water well. This section also identifies potential mitigation alternatives to address these potential impacts.

5.1 Well Description

Potable water is supplied to the Rosenberg house from a shallow well installed in 1980. While there is no surface indication of the well location, it is believed to be just east of the southeast corner of the house. This location is approximately 100 feet from the edge of the Herring River channel, and about 80 feet from the edge of the wooded wetland bordering the River just south of the house. This location has been indicated by the Rosenbergs, supported by conversations with the well driller (Cappello Well), and is consistent with the orientation of the water supply piping entering the house in the basement. The ground surface elevation in the vicinity of the well is approximately 8 feet. According to Frank Cappello, there are no documents recording the details of the well installation. It is believed that the well consists of a small diameter (6-8") screened pipe driven into an augered well hole. The depth of the well is unknown. A more intrusive investigation of the well could be undertaken to define the depth, but this was not considered warranted at this time.

5.2 Potential Surface Water Impacts

Comparing the ground surface elevation at the well to the predicted tide elevations under the proposed conditions suggests that future surface water levels will not directly affect the well at maximum high tide events (i.e., 5.4 feet < 8.0 feet), but that under the worst case 100 year tidal event the ground at the well may be flooded (i.e., 8.4 feet > 8.0 feet). Only scenario 4 will bring mean high tide levels up to the grade of the yard adjacent to the Rosenberg house.

5.3 Freshwater – Saltwater Interface Evaluation

ENSR evaluated the potential for reduction of the existing fresh water lens surrounding the Rosenberg's well due to future increased salinity in the Herring River. The freshwater saltwater interface (FWSI) is the boundary at which the freshwater aquifer lens transitions to a saltwater aquifer. In this case, the primary factor that could affect the depth/elevation of the FWSI is the re-introduction of salinity to Herring River.

The USGS studied the freshwater saltwater interface (FWSWI) on Cape Cod and published their findings in a 2004 report (Masterson, 2004). One component of this report specifically models the Herring River under 4 scenarios, each of which vary the water level elevation and the salinity distribution in order to predict the FWSWI.

Water level elevations were set to 1.5 and 2.5 feet; the former representing the elevation measured at the seaward side of the Herring River tide-control structure, the latter representing the simulated average water level under the current conditions if the sluice gate were opened 51 inches (referred to as Case 5 in S&G, 2001). Then, for each of these water level elevations, the initial distribution of salinity in the river was either set to be equal to seawater or was given a spatially variable distribution.

The conclusion from this report is that with a water level elevation in the Herring River equal to 1.5 feet it did not matter what the distribution of the salinity was: there was only a moderate predicted rise (3 to 10 feet) in the FWSWI as calculated at 5 select sites. If the water level elevation in the Herring River equaled 2.5 feet and the salinity varied spatially, the FWSWI may rise between 9 and 36 feet; if the salinity was equal to seawater throughout the river the FWSWI may rise as much as 80 feet.

Of the five sites discussed, of interest is Site 1, which is near the Rosenberg Property. In the worst-case scenario, where the water levels rise 2.5 feet and all the water has salinity commensurate with seawater, the FWSWI was predicted to rise 80 feet. According to Masterson (2005), the current FWSWI is -111 feet (i.e., 111 feet below ground surface). The predicted FWSWI therefore would be -31 feet (-111+80). With the land surface at the well estimated to be 8 feet, therefore, the well could be 39 (8-(-31)) feet deep and not intersect the FWSWI. Practically, there is uncertainty with the model and a mixing zone that the well should probably not intersect. It can be safely said that if the well is 25 or less feet deep, under the worst-case, unlikely circumstances, the well would not be affected by a rise in the FWSWI.

Note also that Masterson does two runs using water level elevations of 2.5, consistent with Spaulding and Grilli's Case 5. However, the worst case scenario simulated by Spaulding and Grilli is Case 10, where the average water level for the case where there is no control structure is predicted to be 3.1 feet. Masterson does not complete a simulation that indicates the rise in the fresh water-salt water interface for a case where the water level is 3.1 feet. A run with this elevation may be interesting to see where the model predicts the fresh water-salt water interface.

Fitterman and Dennehy (1991) studied the "Verification of Geophysically Determined Depths to Saltwater Near the Herring River (Cape Cod National Seashore), Wellfleet Massachusetts." They completed a study at WNW-115, which is very near the Rosenberg Property, that the salinity was below 1800 $\mu\text{S}/\text{cm}$ (generally considered the upper limit for conductivity of freshwater) up to 64 feet below land surface. Below 64 feet the water would probably be too brackish to be potable.

If Masterson's worst-case scenario prediction (i.e., 80 feet of rise) is applied to this value, 64, the FWSWI would be above the land surface - a slightly ridiculous suggestion, but consistent with the worst-case scenario. In the simulation where the water elevation rises to 2.5 feet, but that the salinity distribution is spatially variable, presumably more natural, there is a predicted 18 foot rise in the FWSWI at Site 1 (in the vicinity of the Rosenberg property). An 18 foot rise would change the FWSWI from 64 feet below land surface to 46 feet below land surface, suggesting that a well could be up to 46

feet deep and still draw in potable water. Again, a safety factor may be employed such that a recommendation of a well no deeper than 35 feet below land surface may be made. This second evaluation compares fairly well to the evaluation based on Masterson's data.

Martin (2004) further evaluates the FWSWI in a document specifically dealing with the Herring River. This report uses the Ghyben-Herzberg principle to estimate the depth to the FWSWI. Our review indicates that this approach was used appropriately. Martin states that "There may be some thinning of the freshwater lens [as a result of restoration of tidal flow in Herring River] where the upland areas meet the river valley if the groundwater underlying the valley becomes predominantly salty. However, a short distance inland (100-200 feet) the freshwater lens should remain thick enough to provide water or private or domestic wells."

Uncertainties should be kept in mind. The estimates of the water surface elevations are made based on model simulations. Inherent in the modeling are assumptions that may affect the modeling conclusions. One limitation was that Masterson's model runs only simulated the freshwater-saltwater interface for the case where the water levels were 2.5 feet; Spaulding and Grilli present a simulation which would result in a rise in water levels up to 3.1 feet. Masterson's model would likely predict a rise in the freshwater saltwater interface given this water level; it is unlikely that resultant rises would affect the Rosenberg well, but it would be good to do this to be thorough.

5.4 Summary and Recommendations

To summarize, we compared Masterson's simulations, Fitterman and Dennehy's measured data, and Martin's evaluation and can conclude that restoring tidal flows to the Herring River should not alter the freshwater-saltwater interface such that the well at the Rosenberg property would be impacted by saltwater provided the well is not screened deeper than 35 feet below land surface. This assumes that water use remains generally the same into the future.

Should the Herring River undergo a restoration such as that proposed, a monitoring well may be considered somewhere downgradient of the Rosenberg drinking water well and up gradient of the Herring River. This well can be a 2-inch diameter pvc monitoring well and should be screened deeper than the supply well, perhaps 40-50 feet deep. A more detailed inspection of the existing well is recommended prior to the installation of the monitoring well to ensure the depth is appropriate. The monitoring well can then be periodically monitored for increase in conductance, which will be an indicator of increasing salinity in groundwater. This well is a precautionary measure; no increases in salinity within the well water is expected.

5.5 Other Studies

Martin (2004) details the findings of a few other studies that focus on the changes in the FWSWI due to the restoring tidal flow to streams or estuaries. They are briefly summarized here.

- Fitterman and others (1989) conducted a geophysical survey of the highlands east of the Herring River and concluded that opening the downstream tidal gates would not affect wells because the water level in the river would not change much and any changes that did occur would not affect water levels except in the first tens of meters from the river.
- Fitterman and Dennehy (1991) concluded that a small increase in the Herring River water levels compared to the large thickness of the freshwater aquifer makes it unlikely that the thickness of the freshwater aquifer or the FWSWI would change at wells in the highlands east of the Herring River.
- Eichner and others (1987) conducted their study at the Pamet River in Truro and observed that the marsh peat deposits served to dampen the tidal influences on groundwater such that only 0.1 feet change in water levels in the groundwater were observed 500 feet from the ocean.
- Walter and others (1996) studied the effect tidal restoration may have on a municipal water supply well in Sagamore Beach. Again local peat deposits played a part in dampening the tidal effects on groundwater. Under worst-case scenarios, tidal fluctuations would effect groundwater elevations by less than 0.1 feet for distances approximately 100-400 feet from the channels.
- Neidoroda and April (1975) conducted an investigation of the FWSW transition zone beneath coastal marshes. Data from one site leads to the conclusion that the salt marshes can change the shape and location of the transition zone, but that they have little effect on the depth to the transition zone. .

6.0 SEPTIC SYSTEM EVALUATION

Wastewater disposal on the Rosenberg property appears to be directed to two areas for leaching into the ground. Although there is no apparent recorded information documenting the status of the two disposal areas, conditions have been assessed by discussion with a local plumber (Garry Davies) who has direct familiarity with the on-site discharge pipes, as well as observations of both the pipes from the basement and review of as the ground conditions in the yard. Discharges from the house appear to be split between one area 30-40 feet north of the house, and another area 30-40 feet east of the house. Both areas are likely to consist of cesspool areas where exfiltration into the surrounding sandy fill soils occurs. The surface elevation at both locations is estimated at between 5-5.5 feet. Assuming 2-3 vertical feet for the disposal area depth, the bottom of the leaching area in each case would be between elevation 2-3.5 feet. Accordingly, there is likely to be little separation between the bottom of the leaching area and the groundwater table under most existing conditions.

Under proposed conditions it is unclear what changes will occur to groundwater levels on the Rosenberg property. As noted previously, Walter and others (1996) found that local peat deposits played a part in dampening the tidal effects on groundwater. Under worst-case scenarios, tidal fluctuations would effect groundwater elevations by less than 0.1 feet for distances approximately 100-400 feet from the channels. However, ENSR's observations of soil conditions on the Rosenberg property did not encounter peat deposits, but rather a sandy loam topsoil over medium sands. These soil deposits are more likely to transmit groundwater, which could be more influenced under proposed conditions by the rise and fall of the tides in the Herring River.

Given that proposed Scenarios 1-3 will create mean high tide levels to elevations 4.1-4.2 feet, roughly one foot lower than the ground surface grade at the septic disposal areas, and that soil conditions are relatively sandy with at least moderate permeability, it is likely that the disposal areas will become more saturated as the capacity to exfiltrate wastewaters is reduced by the higher water tables. Scenario 4 will establish a mean high tide level that will inundate the ground surface at the disposal areas, rendering them non-functional for most uses.

Accordingly, it is ENSR's opinion that implementation of any of the four scenarios will warrant a modification in the wastewater disposal system. The most likely resolution to this impact is the installation of a tight tank system with periodic pumping to a disposal truck and discharge off-site at a municipal disposal area. Alternatively, if higher ground were available for use to the east of the site, a new disposal area might be considered there and wastewater pumped from the Rosenberg site.

7.0 VEGETATION/LANDSCAPING EVALUATION

This section addresses the potential impacts of the proposed restoration scenarios on the vegetation and landscaping of the Rosenberg property.

7.1 Existing Vegetative Conditions

Vegetated cover on and in the vicinity of the Rosenberg property ranges from emergent marsh bordering the Herring River to shrub/woodland thickets around the landscaped portion of the site. Directly bordering the River there tends to be a band of narrow-leaved cattail (*Typha angustifolia*) with other subdominant marsh emergents such as sedges (*Carex crinita*), marsh mallow, and cow parsnip. On the west side of the River the cattail band is bordered by an extensive stand of tall reed (*Phragmites australis*). During ENSR's site reviews the water in the River was clear and flowing freely within a well-defined channel. Based upon the vegetative composition, the salinity level in the River and marsh along this stretch would appear to be near zero.

Directly bordering the Herring River along the west side of the Rosenberg property there is a band of dense shrubs and trees that fall within the irregularly flooded wetland or adjacent upland fringe. Species found within this wooded edge include Bebb's willow (*Salix bebbiana*), elderberry (*Sambucus canadensis*), swamp rose (*Rosa virginiana*), multiflora rose (*Rosa multiflora*), arrowwood (*Viburnum dentatum*), winterberry holly (*Ilex verticillata*), and honeysuckle (*Lonicera morrowii*). Associated herbaceous species include goldenrod (*Solidago rugosa*), jewelweed (*Impatiens capensis*), cinnamon fern (*Osmunda cinnamomea*), and poison ivy (*Toxicodendron radicans*). The estimated elevation of this woodland thicket along the River ranges from 1.5 to 3 feet.

Between the wooded edge of the river and the Rosenberg house (a distance of 60-80 feet), a wooded lawn condition is present that also extends over to the north and east sides of the house. Black cherry (*Prunus serotina*) is by far the most abundant species, with several specimens of pitch pine (*Pinus rigida*), sycamore maple, and pin oak (*Quercus palustris*) also present. This wooded lawn is largely between elevations 4-5.5 feet, based upon available information. As shown in Table 1, a tree inventory list of the Rosenberg property (and also indicated in the site photographs in Appendix A), the existing trees are of moderate diameter and form a significant characteristic of the yard.

Table 4: Tree Inventory

Tree Species	Tree Diameter (in)	Total Number
Black cherry (<i>Prunus serotina</i>)	5,5,10,11,8,5, 10, 14,12,6,6,7	12
Pitch pine (<i>Pinus ridgida</i>)	12, 20	2
Sycamore maple (<i>Acer pseudo-platanus</i>)	8, 12	2
Pin oak (<i>Quercus palustris</i>)	6	1

7.2 Vegetative Impact Assessment and Potential Mitigation

It is anticipated that the most important variable likely to affect the vegetative impact and determine vegetative changes on the Rosenberg parcel is the elevation of mean high tide. Spring high tide is typically the elevation that high salt marsh (or irregularly flooded salt marsh) develops at; areas at a slightly higher elevation often support other coastal vegetative species that can tolerate sporadic flooding and some salt influence, but salt marsh tends not to be supported more than a few tenths of a foot above mean high tide. Note that the existing mean high tide level at the Rosenberg site is 1.6 feet; as described above the shrub/wooded wetland fringe along the Herring River in front of the Rosenberg yard is estimated to range in grade from 1.5 feet to three feet, or just above the mean high tide level. Under proposed Scenarios 1-3, the mean high tide level will be at elevation 4.1-4.2 feet, well above the grade of this wooded fringe. Accordingly, it is anticipated that under all scenarios this wooded fringe will convert into salt marsh (consistent with the goal of the project). The grade of 4.1-4.2 feet appears to run roughly 25-30 feet into the maintained yard of the Rosenberg's, such that this entire portion of the yard will convert from mowed lawn with scattered trees and shrubs into salt marsh. ENSR estimates that salt marsh development will occur to within approximately 40 feet of the Rosenberg house under Scenarios 1, 2, and 3. Scenario 4 will have a mean high tide of 5.4 feet, which corresponds to the lowest grade adjacent to the dwelling; accordingly, salt marsh will develop fairly close (within 10 feet) to the house under that scenario.

Most of the trees listed in the table above occur along the west side of the yard below elevation 5 feet. Given that the major portion of the root zone of these trees extends roughly two feet below ground surface, and that the surface soils are relatively sandy with at least moderate permeability, the mean high tide events of Scenarios 1-3 are expected to bring higher salinity waters through most of the root zone of these trees. Therefore, it is unlikely that these trees will survive more than several years of

such tidal levels. Scenario 4 will irregularly flood the ground surface around most of these trees, and tree mortality is likely to occur in a short time period.

In addition to direct impacts cited above, the conversion of the existing emergent marsh community around the Rosenberg residence will significantly change the landscape views as they are affected by vegetative cover. Tree mortality will reduce the shading of the lot, particularly during the afternoon as the sun moves to the west and will no longer be shielded by the tree foliage cover on that side of the house. The views from the house will change considerably, as the taller emergent marsh species (*Phragmites* and *Typha*) yield to the *Spartina* grasses of the salt marsh.

7.3 Potential Mitigating Measures

It is difficult to prescribe meaningful mitigation measures for the impacts described above. Other plantings of more salt tolerant plant species could be considered to slow the changes forecast above. For example, red cedar (*Juniperus virginiana*) trees and salt spray rose (*Rosa rugosa*) planted along the west side of the house could compensate for some of the losses of shrubs and trees anticipated in that area. Some plantings could occur on elevated mounds to prolong their survival as tidal levels are incrementally increased.

8.0 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

ENSR evaluated the impact of anticipated hydrological changes associated with the restoration of tidal flooding in the Herring River system on the Rosenberg property in Wellfleet, Massachusetts. ENSR's evaluation was based a review of material and prepared by the National Park Service, visits to the property, and discussion with the Rosenberg's. As part of this evaluation, ENSR reviewed the hydrodynamic model developed to support selection of restoration alternatives. ENSR also evaluated the impacts of proposed activities to the following areas of the Rosenberg property:

- House structure
- Potable water well
- Septic system
- Vegetation/Landscaping

ENSR's review indicated that the hydrodynamic model developed to evaluate restoration scenarios was suited for this purpose and that it generally conforms to accepted modeling practices. Based on the hydrodynamic modeling results, four restoration scenarios were identified for evaluation of impacts:

- | | |
|-------------|---|
| Scenario 1. | existing structure fully open |
| Scenario 2. | new 100-foot wide culvert with 4-inch sluice gate opening |
| Scenario 3. | new 100-foot wide culvert with 16-inch sluice gate opening |
| Scenario 4. | new 100-foot wide culvert with 118-inch (10-foot) sluice gate opening |

For each restoration scenario, ENSR compared predicted elevations for mean and 100-year tidal events to critical elevations (e.g. first floor, well head, basement, etc.) on the Rosenberg property. This comparison was used as the basis for evaluating the impacts to the Rosenberg property. The following summarizes ENSR's findings and recommendations

- All proposed restoration scenarios are likely to worsen the Rosenberg's current basement flooding problem. The recommended mitigation strategy for this would be to relocate all utilities from the basement of the residence to the first floor and fill the basement to the adjacent grade elevation.
- None of the proposed restoration scenarios are predicted to result in flooding of the main structure first floor in a 100-year flood.

- Only Scenario 4 would result in flooding of the west addition first floor during a 100-year flood. This scenario represents unrestricted tidal conditions and would not likely be implemented while the Rosenberg residence remains occupied.
- Only scenario 4 would result in surface flooding in the area of the Rosenberg's well.
- Restoration of tidal flushing to the Herring River could raise the freshwater saltwater interface in groundwater at the Rosenberg residence to about 46 feet below the ground surface. So long as the Rosenberg's well does not extend below about 35 feet below ground, their potable water supply should not be impacted. There is some uncertainty, however regarding the depth of the Rosenberg's well. A precautionary measure would include constructing a monitoring well deeper than the Rosenberg's well located between the Herring River and the Rosenberg's well to periodically check for saltwater encroachment.
- All restoration scenarios are likely to significantly impact the operation of the Rosenberg's septic system. Mitigation would include installation of a tight tank or potentially construction of a new mounded system a higher elevation.
- The Rosenberg yard has a notable component of moderate-sized trees and associated shrubbery that forms a significant characteristic of the site. Under most scenarios, it is anticipated that this wooded condition will not survive for more than a few years of increased water levels and salinity. Plantings of more salt tolerant plant species could be considered to slow the changes forecast above. For example, red cedar (*Juniperus virginiana*) trees and salt spray rose (*Rosa rugosa*) planted along the west side of the house could compensate for some of the losses of shrubs and trees anticipated in that area. Some plantings could occur on elevated mounds to prolong their survival as tidal levels are incrementally increased.

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APPENDIX A

ROSENBERG SITE PHOTOGRAPHS



1. View of Herring River marsh from north side of Rosenberg residence. July 8, 2005.



2. View of Herring River from edge of Rosenberg yard, looking downstream. July 8, 2005.



3. View of Herring River from edge of Rosenberg yard, looking upstream. 7/8/2005.



4. View of Herring River and marsh from northwest edge of Rosenberg yard. 7/8/2005.



5. View of Rosenberg yard and house from edge of Herring River. July 8, 2005.



6. View of east side of Rosenberg yard and house from north edge of property. 7/8/2005.