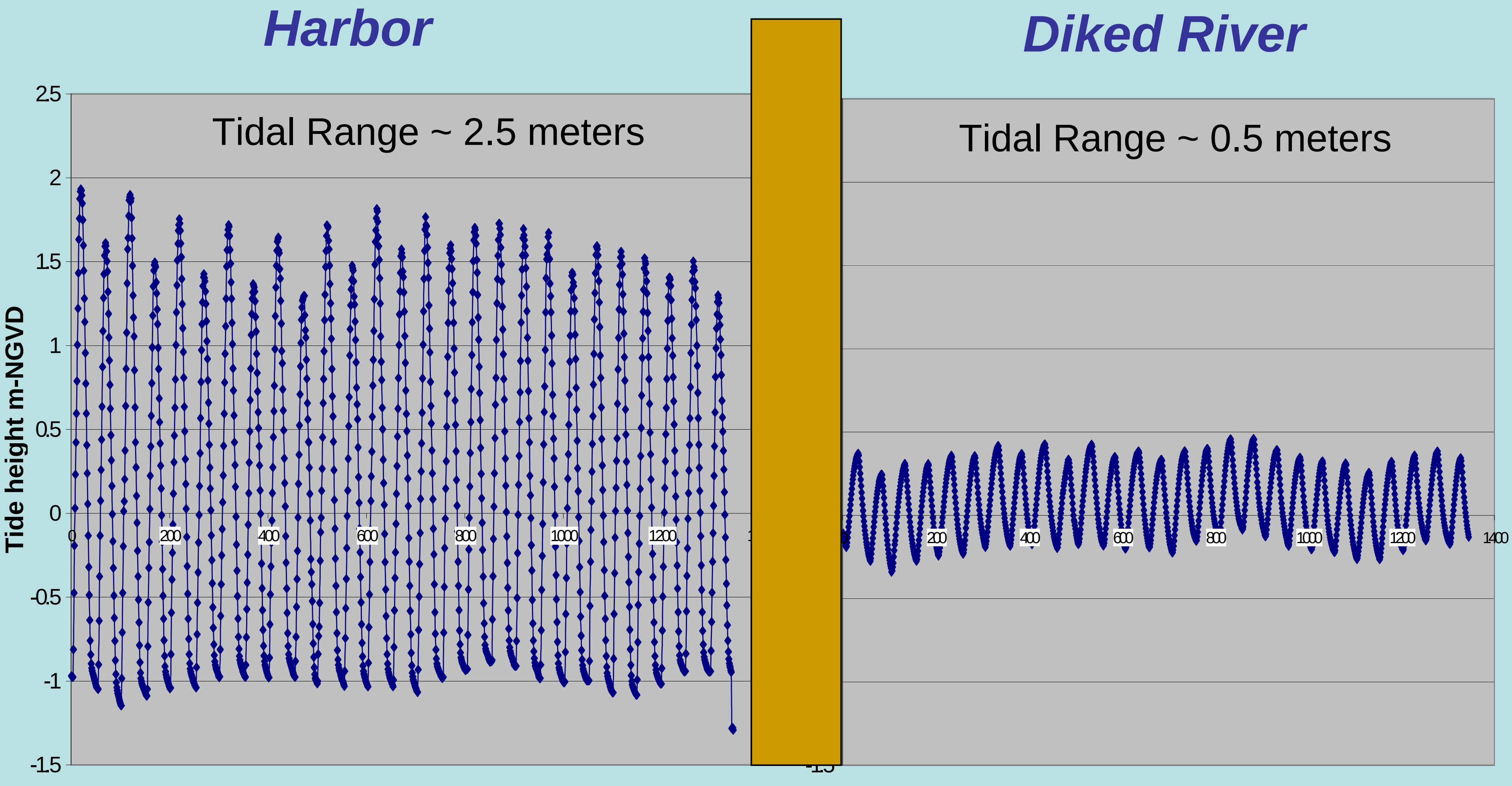
Herring River tide heights and salinity

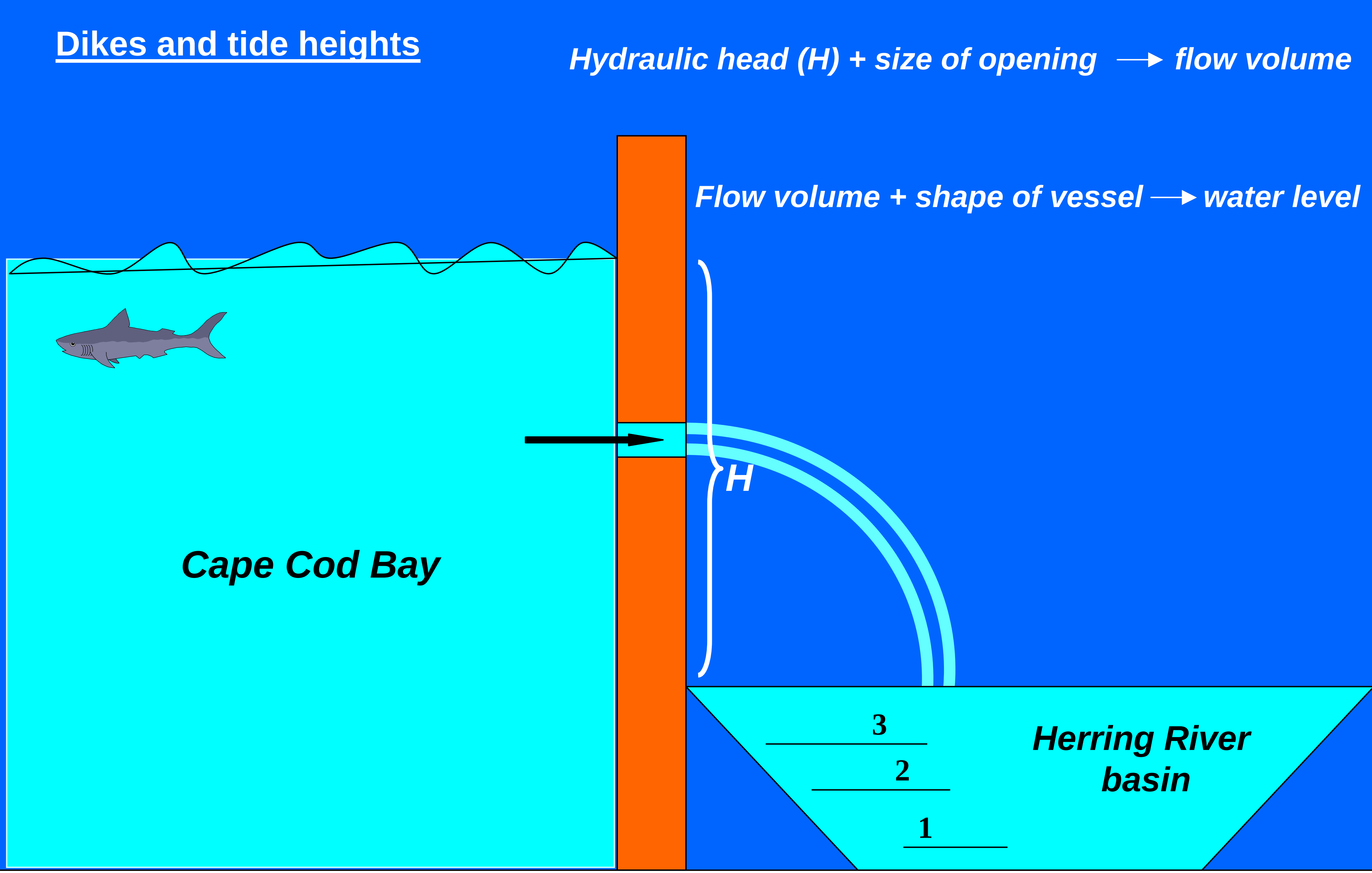
Since 1909, tidal exchange into Wellfleet’s Herring River has been restricted by a dike fitted with three six by six ft culverts: two culverts are fitted with clapper valves to allow drainage but block the inflow of seawater; the third culvert has a partially open sluice gate that allows some seawater to flow into the river.

The 1100-acre Herring River flood plain comprises at least eight lobes or sub-basins separated by natural topography, roads and the railway grade. Culverts have been installed at road crossings to allow freshwater to flow toward the river mouth.

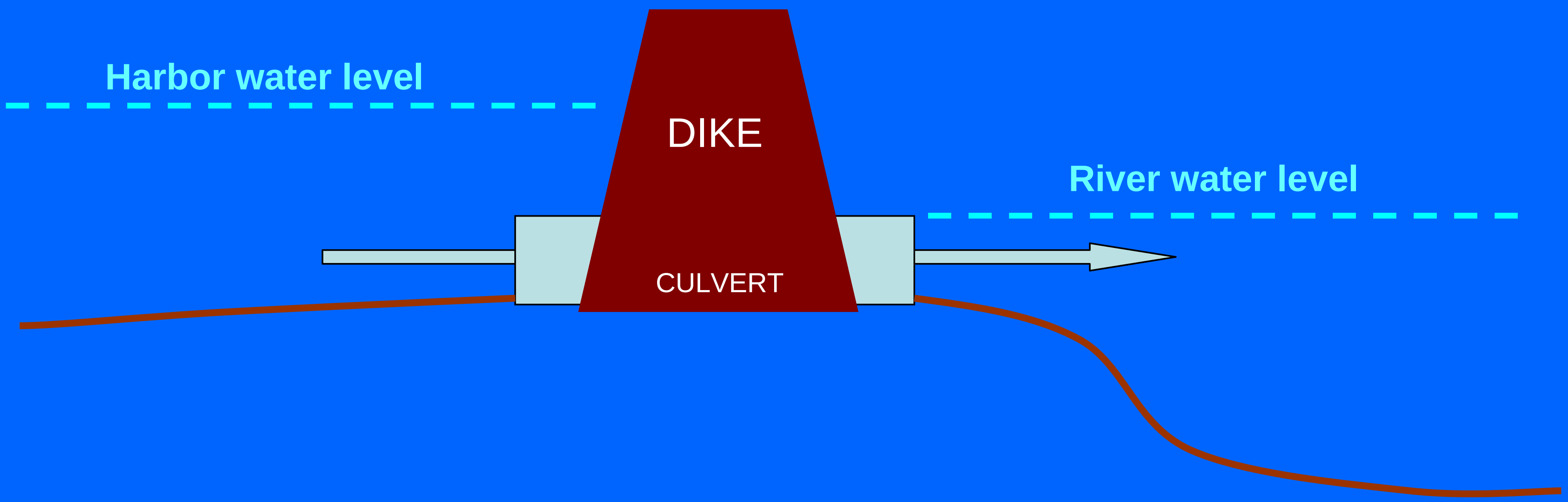
Before 1909 diking, tides, salt water and salt marsh habitats extended well east of modern Route 6. The ecosystem includes four headwater ponds where migratory river herring still spawn after negotiating the diked river.

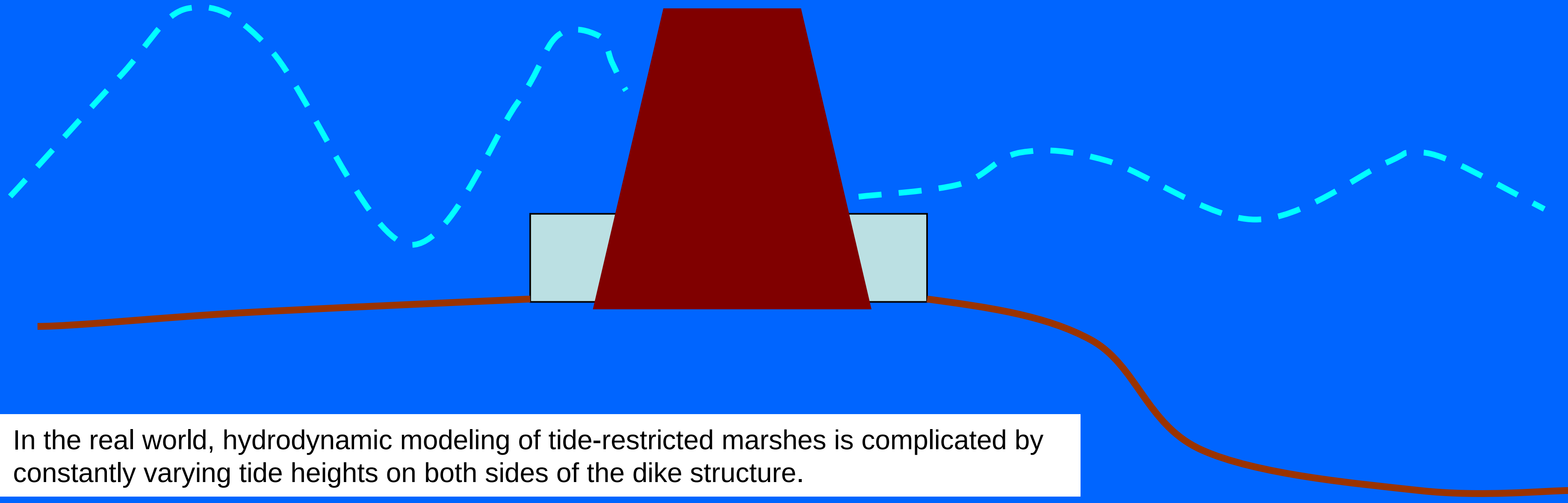


Tides above and below the present Herring River dike. The dike both reduces high-tide height and impedes low-tide drainage, thereby reducing tidal range in the river. Salt marsh productivity is directly related to tidal range. Large differences in water levels above and below the dike cause very rapid flows and impede fish passage.



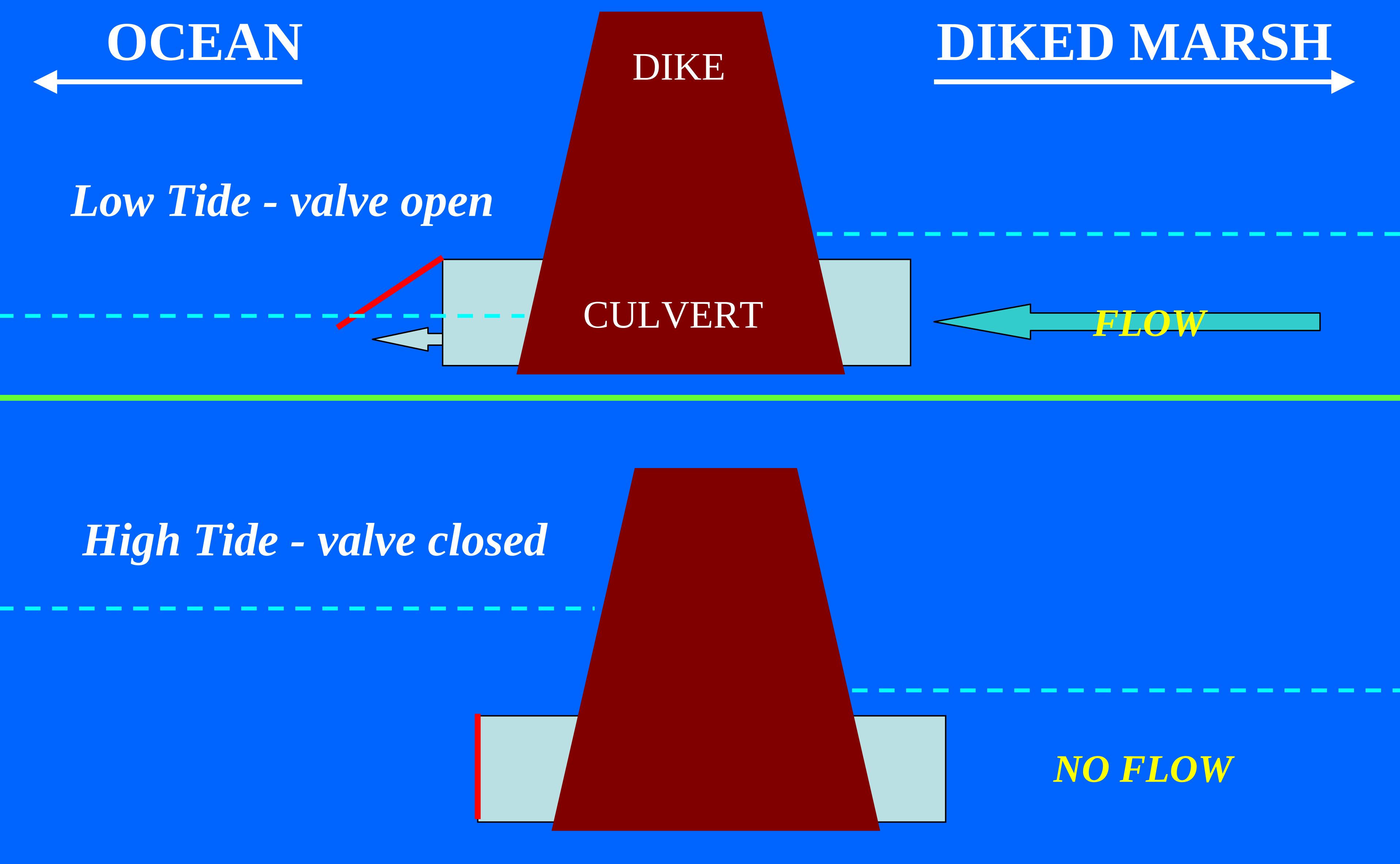
A cartoon depicting the basic components of a hydrodynamic model to predict tide heights given flow through a tide restriction. The flow volume per unit time is dependent the hydraulic head difference between the water on downstream and upstream sides of the dike, the size, shape and elevation of the opening, and friction imposed by the opening. The resulting water level in the diked Marsh is dependent on this flow volume and the shape of the "vessel", i.e. the volume capacity of the flood plain.

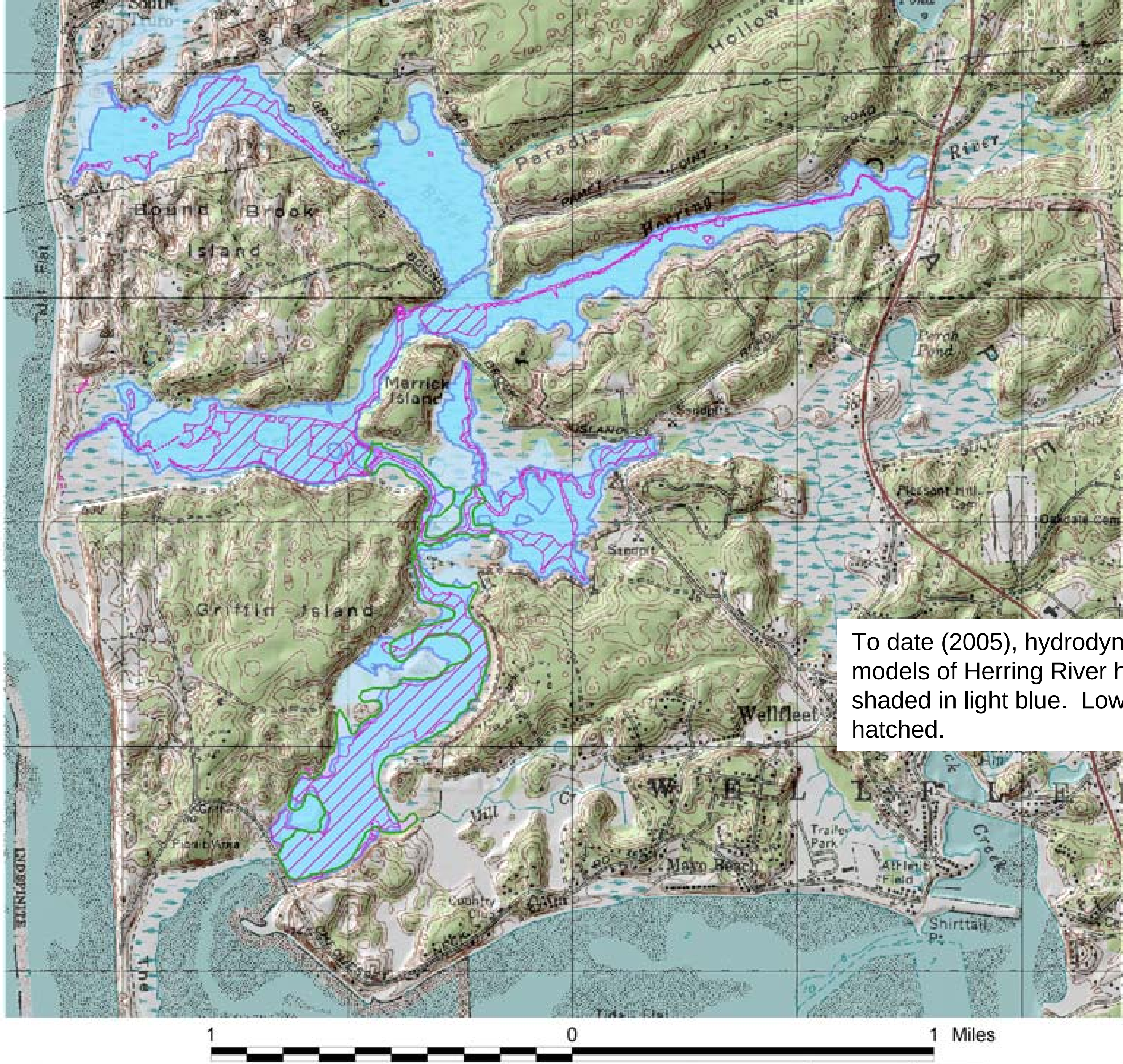




In the real world, hydrodynamic modeling of tide-restricted marshes is complicated by constantly varying tide heights on both sides of the dike structure.

In addition to constantly varying hydraulic heads on either side of a dike, culverts usually have clapper valves which are open only when the seaward water level is lower than the diked-marsh water level. And at Herring River, one of the three culverts has a partially open sluice gate. Given these complications, and the need to model tide heights dynamically over time, make it necessary to build and calibrate a sophisticated numerical hydrodynamic model for reliable predictions and planning.

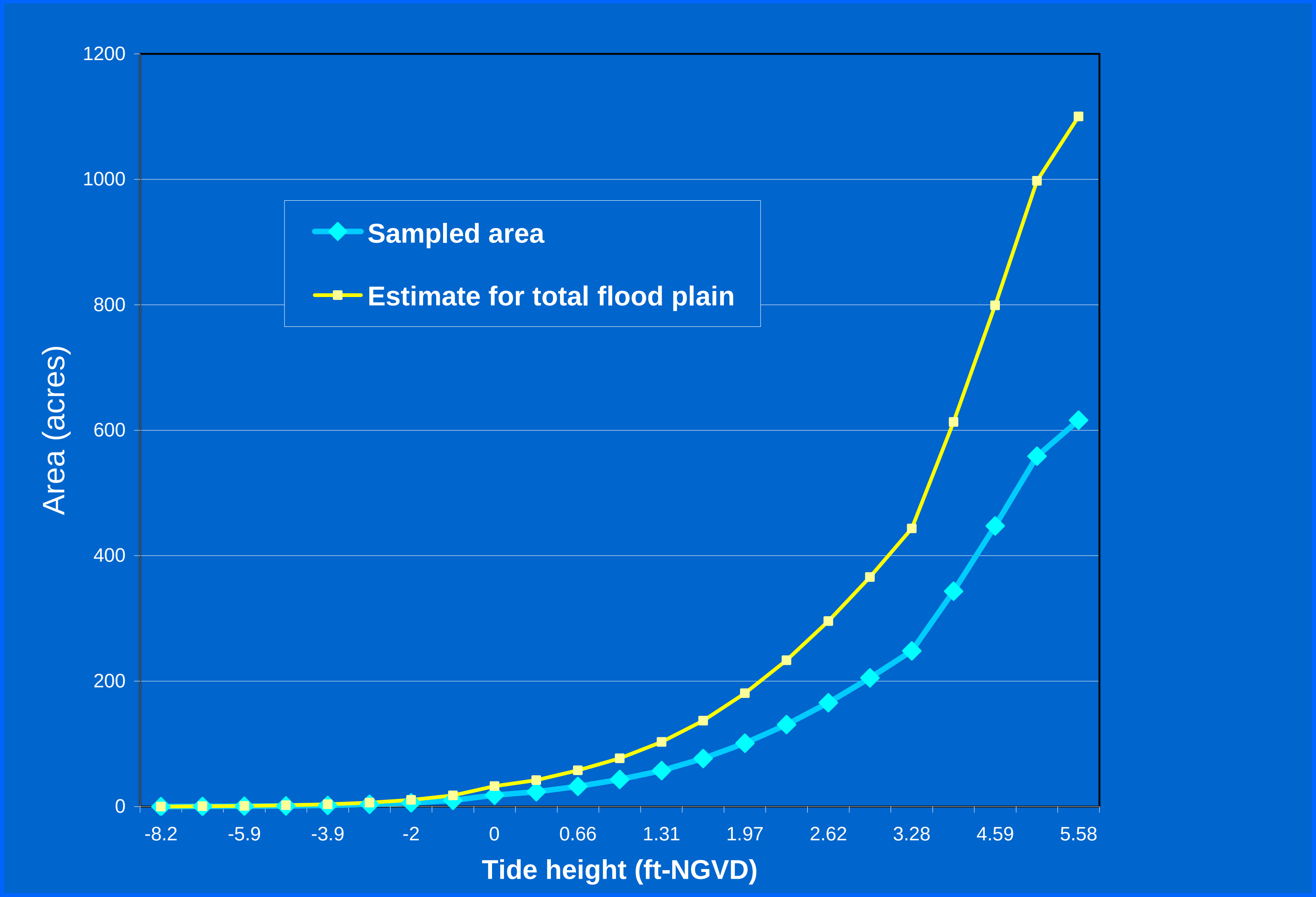




To date (2005), hydrodynamic tide-height and salinity models of Herring River have included the area shaded in light blue. Lowest elevations are cross-hatched.

Legend

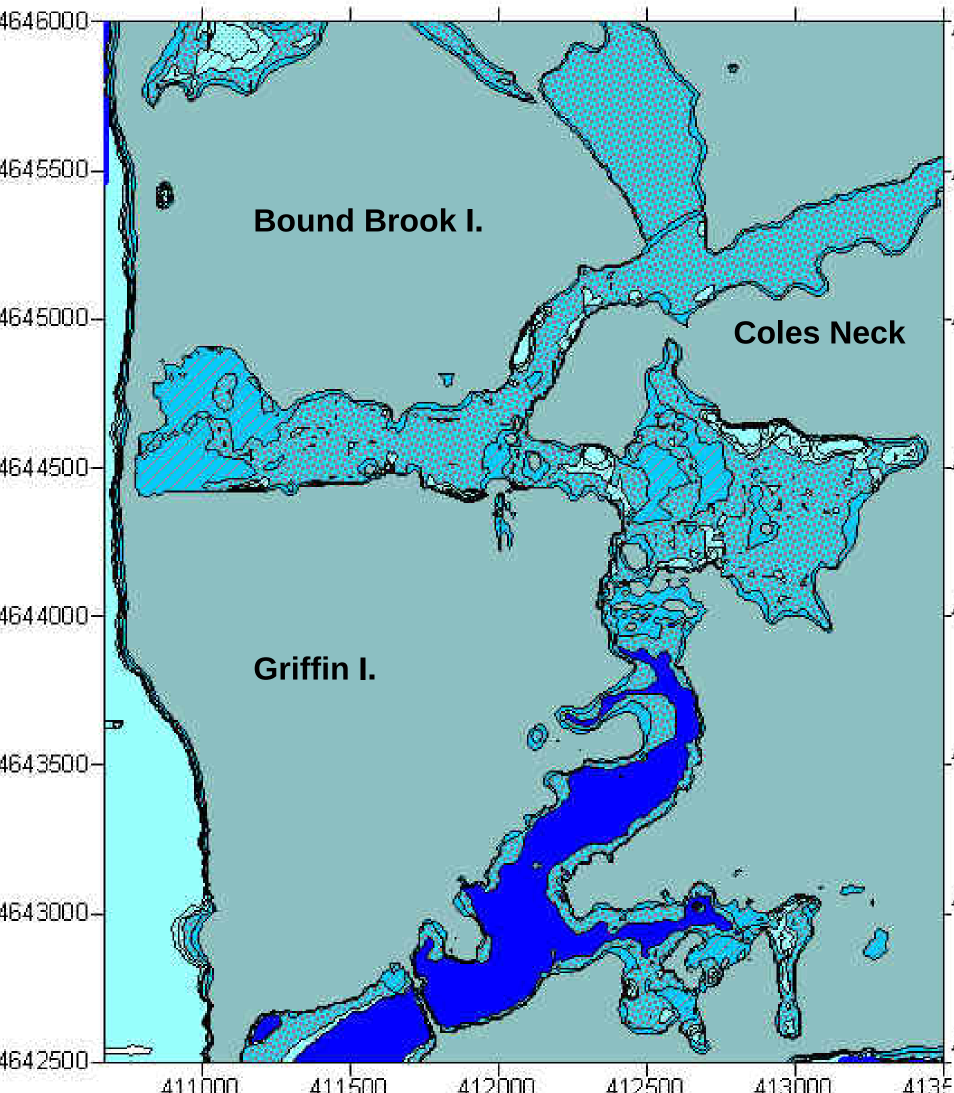
Water-depth / flooded-area curve for Herring River flood plain



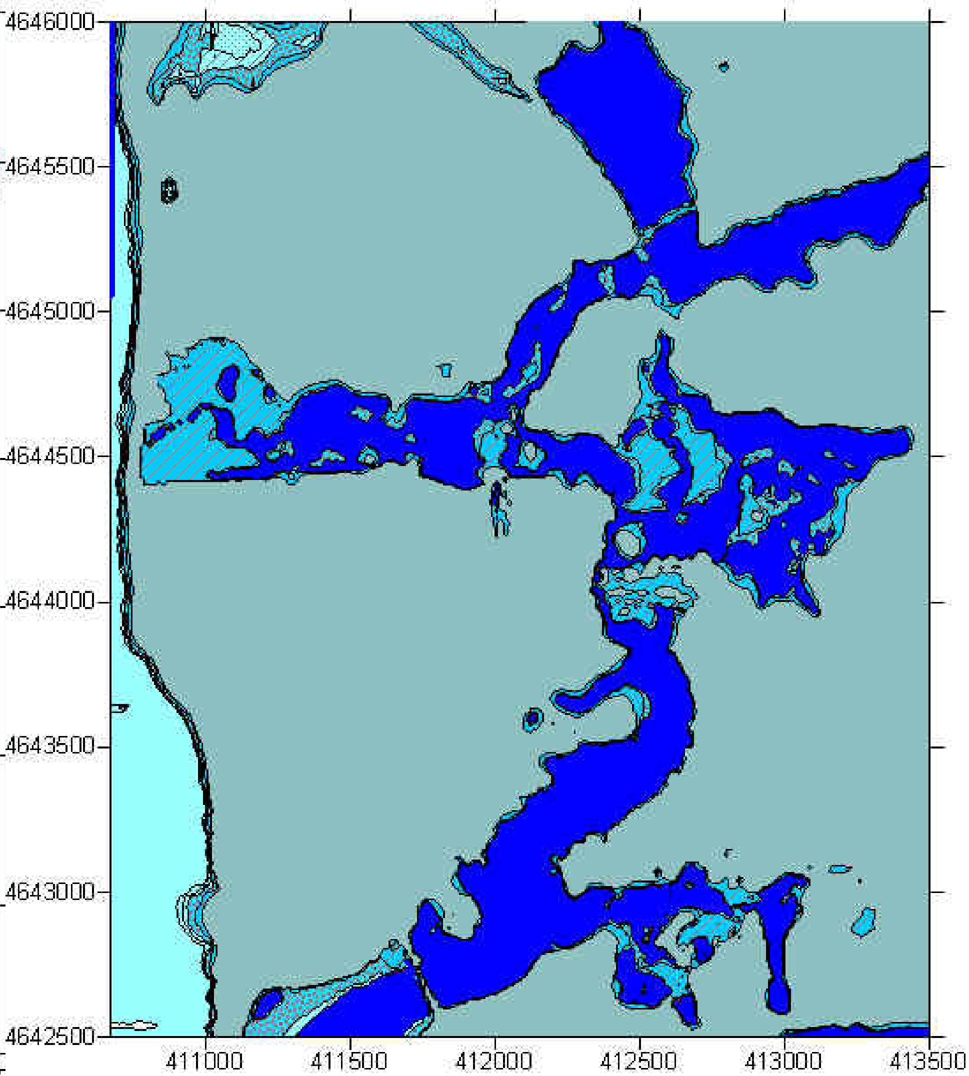
This graph shows that flooded wetland area increases greatly when tide heights reach above 1.5 ft-NGVD (roughly 1.5 feet above mean sea level) in the 1100-acre Herring River coastal flood plain. Little flooded-area increase is realized once tide heights approach 6 ft-NGVD. Natural salt marshes extend up to this elevation, 6 ft-NGVD, in the unrestricted marshes seaward of the dike.

<u>River high tides with the existing dike</u>: The extent of flooding at high tide is shown on these maps in dark blue for: left, currently observed conditions; and right, for the river modeled with all three of the dike culverts wide open. Fully opening the existing structure does greatly extend the area flooded at high tide.

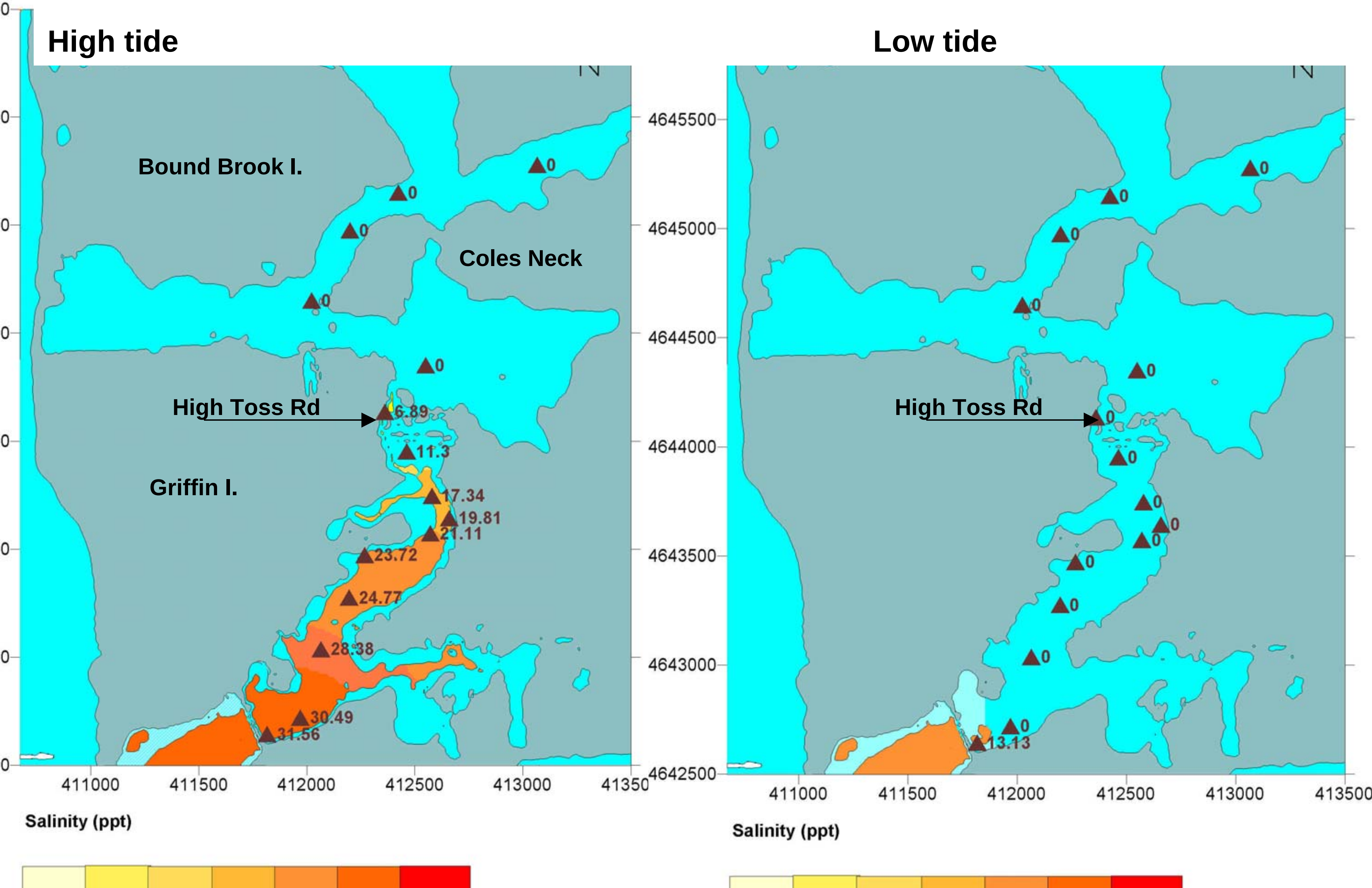
Current conditions (observed 2005)



All gates open (modeled)

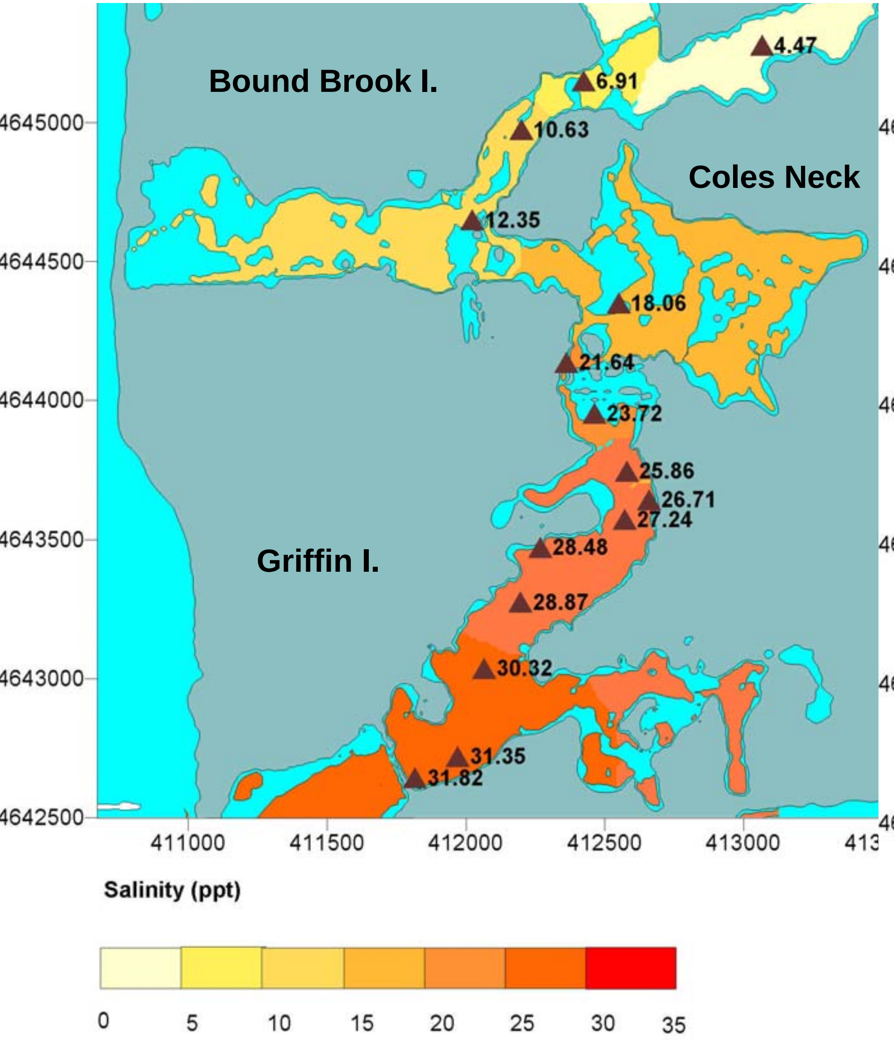


Current salinity distribution in the Herring River flood plain. At high tide, brackish water extends only about 3000 feet upstream of the dike, and does not reach High Toss Road. Low tide salinity is near zero throughout most of the river above the dike structure. Thus, estuarine animals and plants are severely limited.

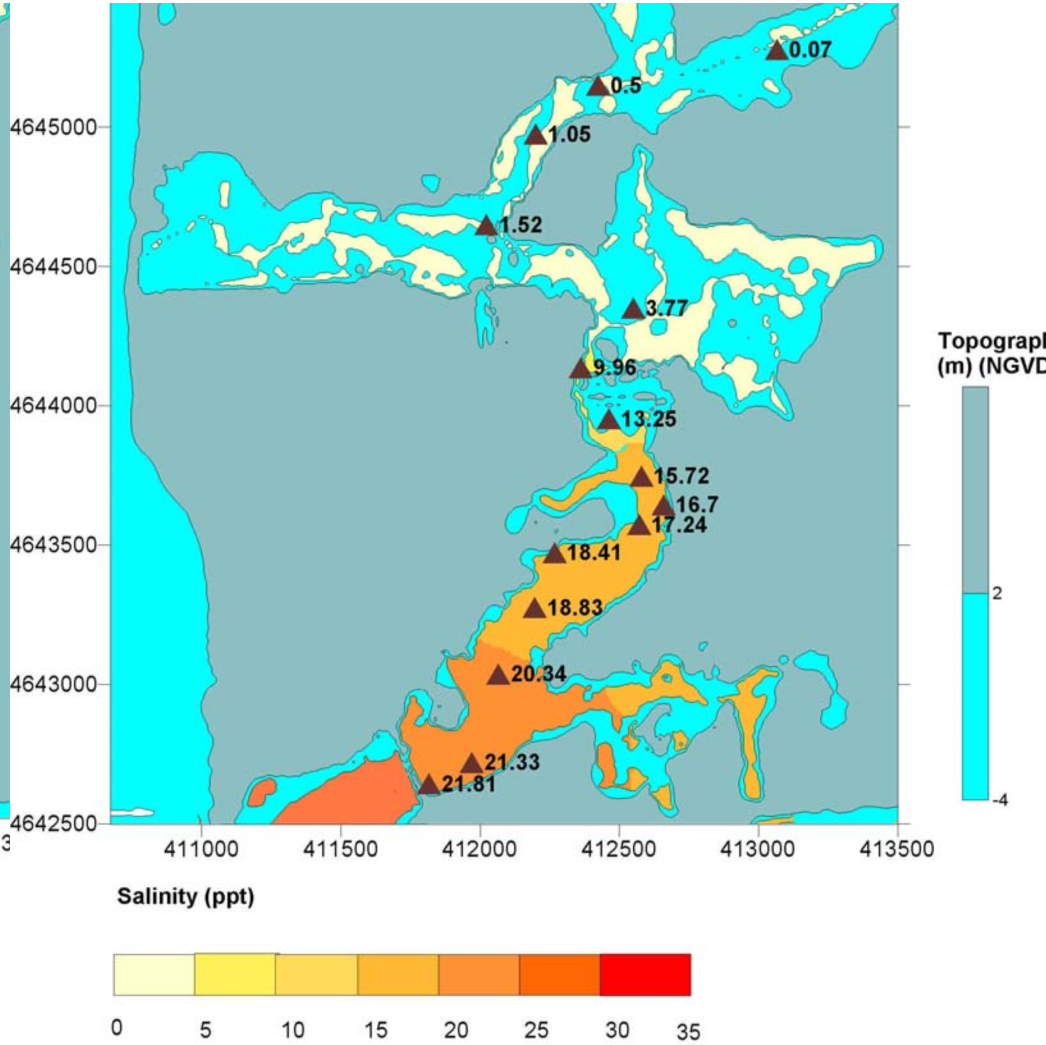


Model results showing salinity distribution with present dike fully open. Opening the existing dike increases salinity well past High Toss Road to Bound Brook Island. Note, however, that tidal water still floods the lower basin (dike to High Toss Road) during low tide; this limits the restoration of exposed (intertidal) habitat at low tide.

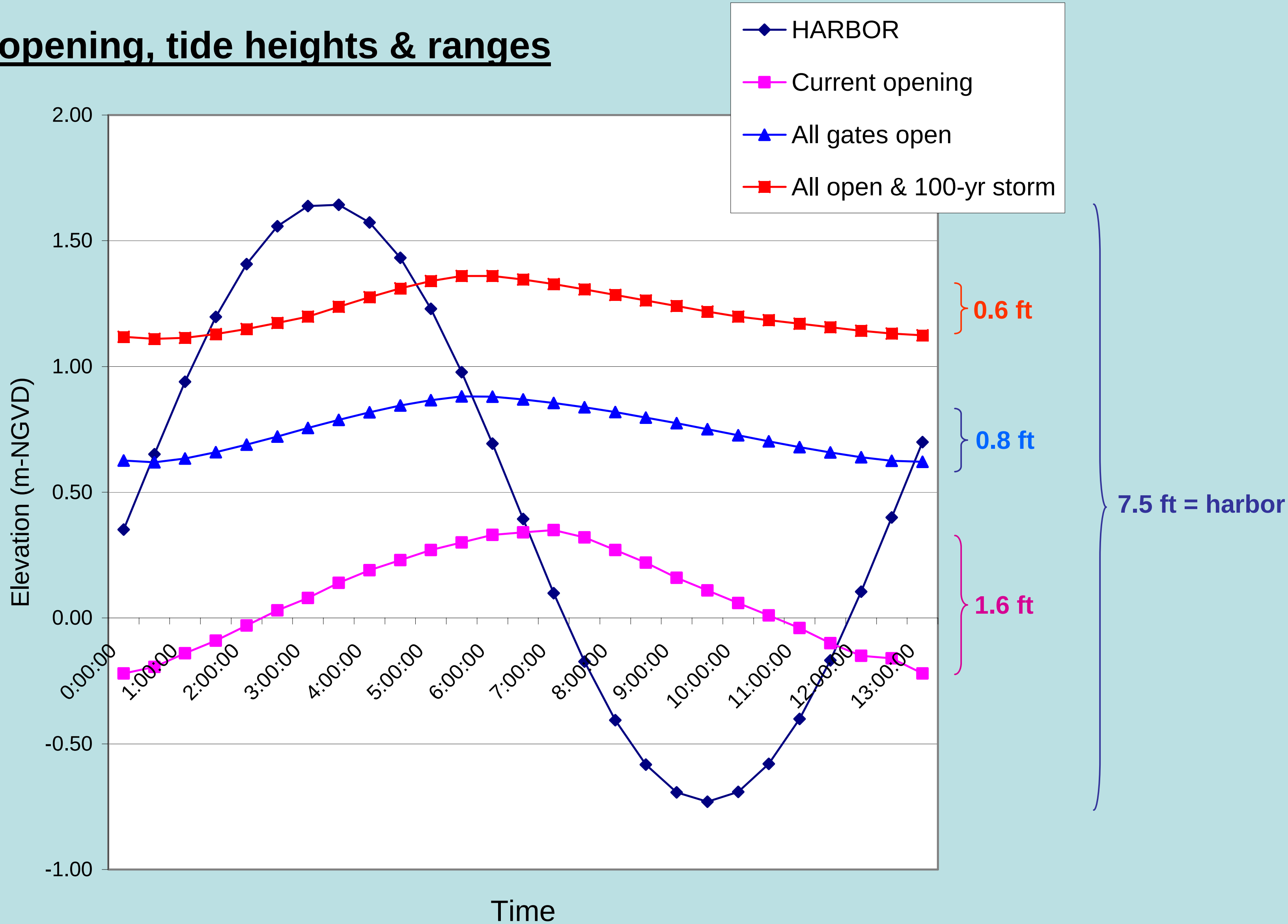
High tide



Low tide

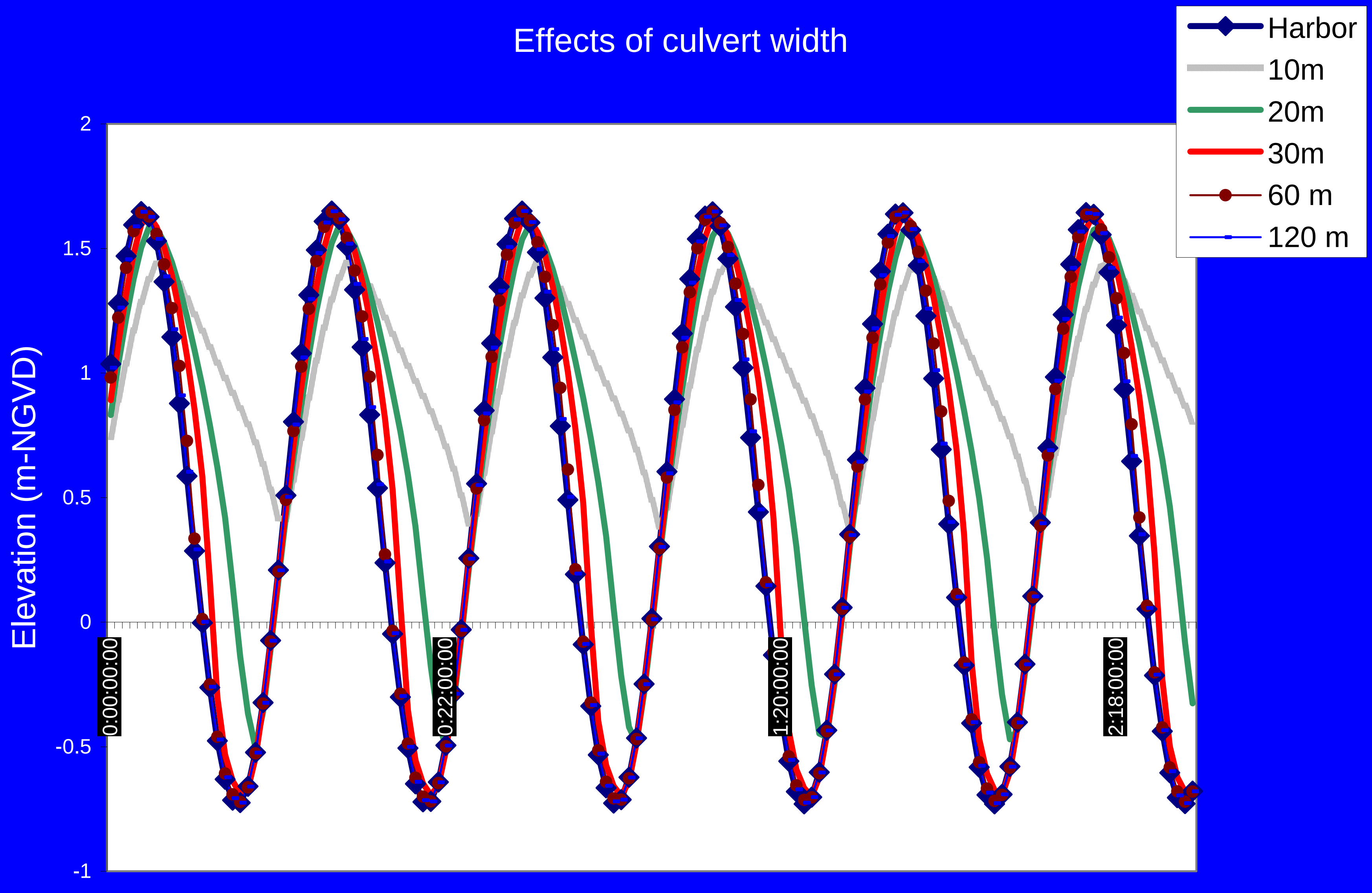


Dike opening, tide heights & ranges

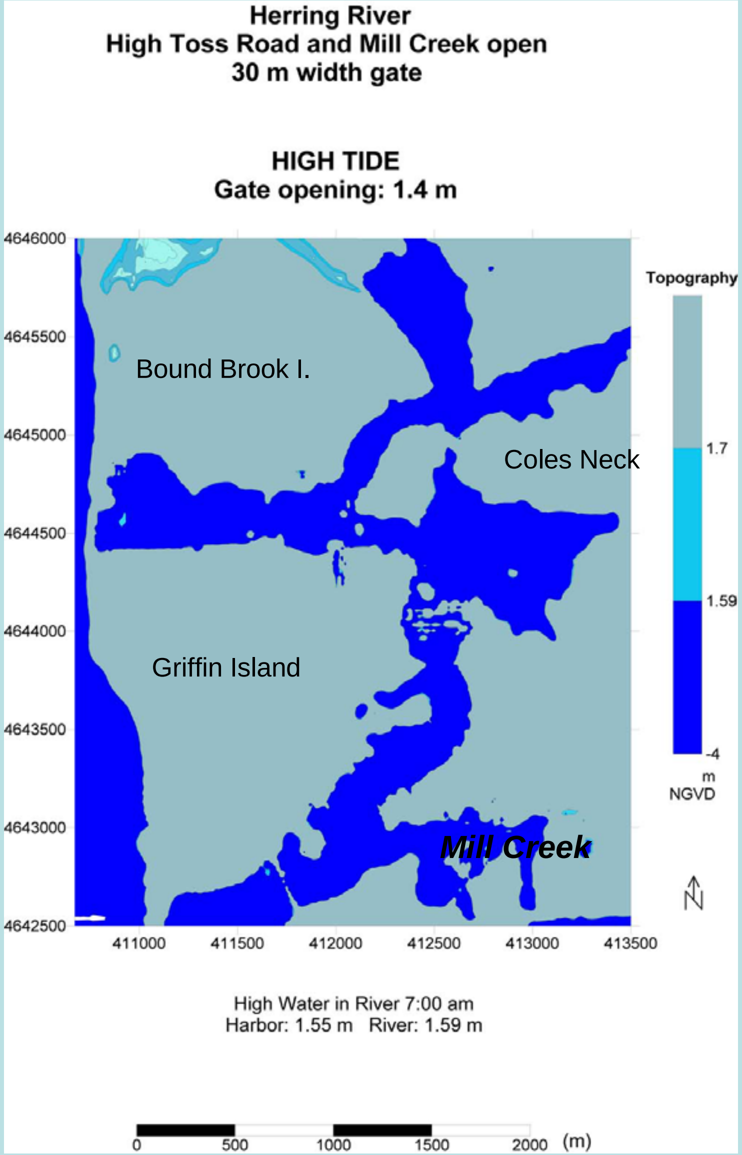


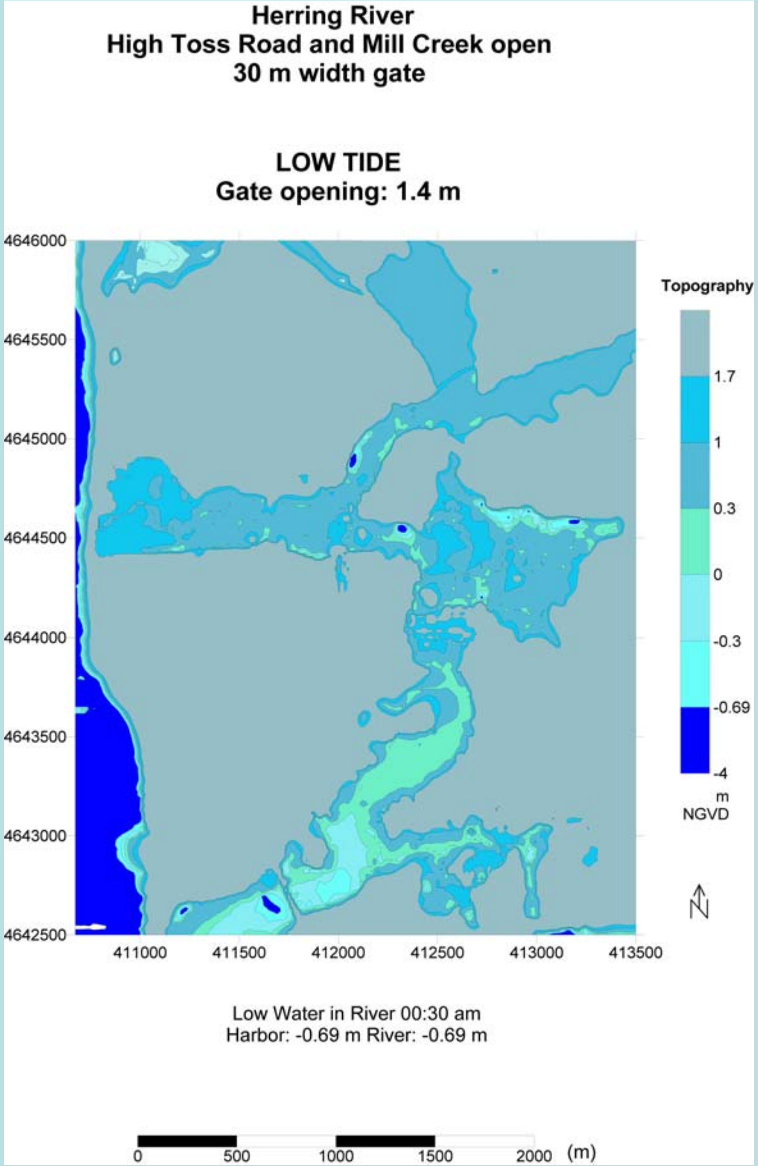
Model results show that opening the existing Herring River dike causes high tide height to increase, but low tide height increases even more, i.e. water is impounded in the river; thus, tidal range actually decreases from the present 1.6 ft to only 0.8 ft, compared to 7.5 ft just seaward of the dike. Reduced tidal range causes flushing time to increase, exacerbating current water quality problems, e.g. summertime dissolved oxygen stress.

A better alternative than the existing opening at Herring River would likely be wide, low culverts as at Hatches Harbor (Provincetown); these culverts, installed in 1999 and opened gradually over six years, have resulted in high tides that flood the marsh surface plus excellent low-tide drainage – to the benefit of salt marsh plants, animals and water quality.
Inset image shows how these culverts would look emplaced in the Herring River dike.

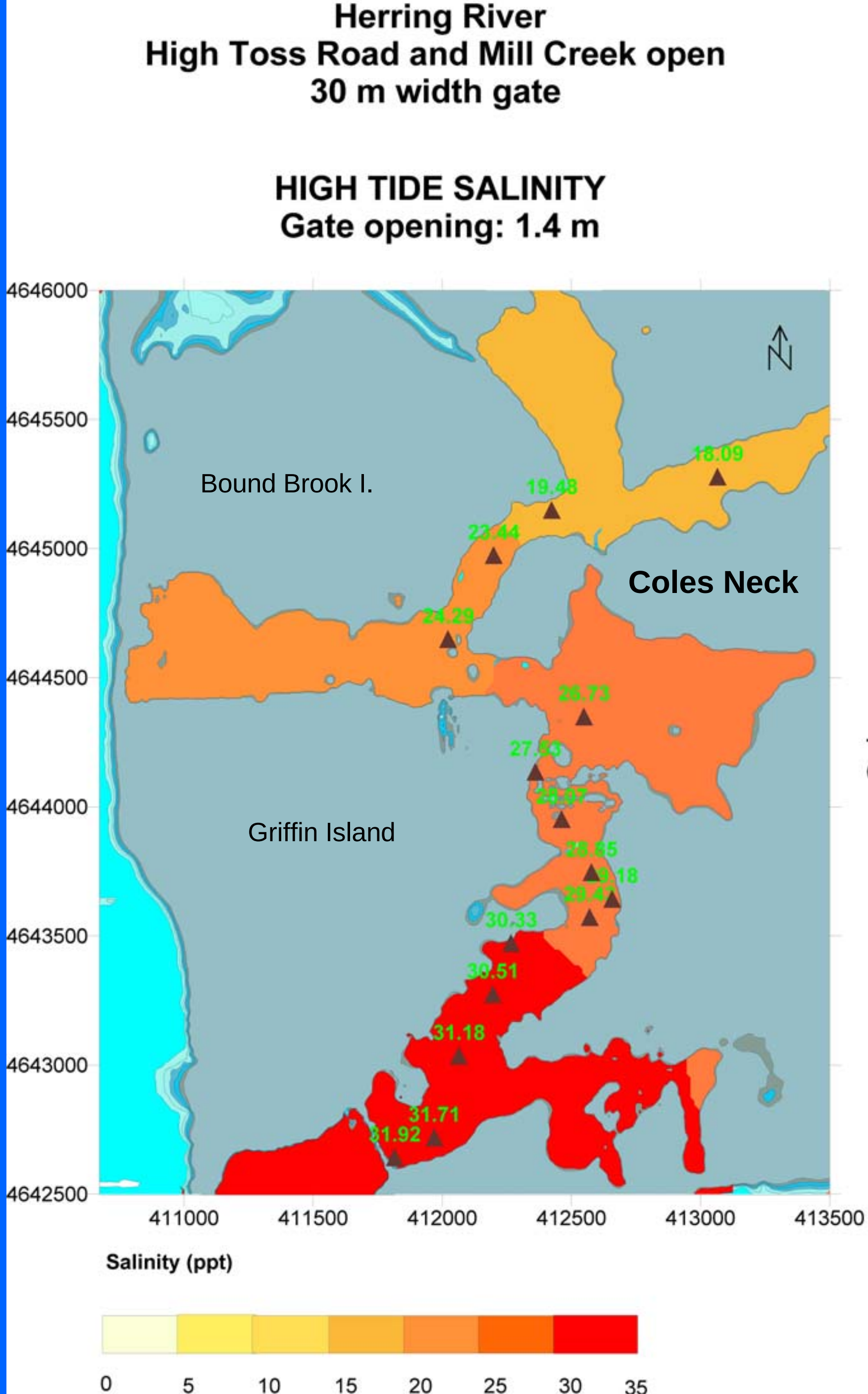


The first step in testing the performance of the wide-culvert option for Herring River. The hydrodynamic model was run with the dike opening set at various widths to determine the minimum width required to achieve near-complete tidal restoration. The graph shows that a culvert 30 meters wide (about 100 ft, red line) produces tides that are very close to those of the unrestricted harbor (dark blue line).

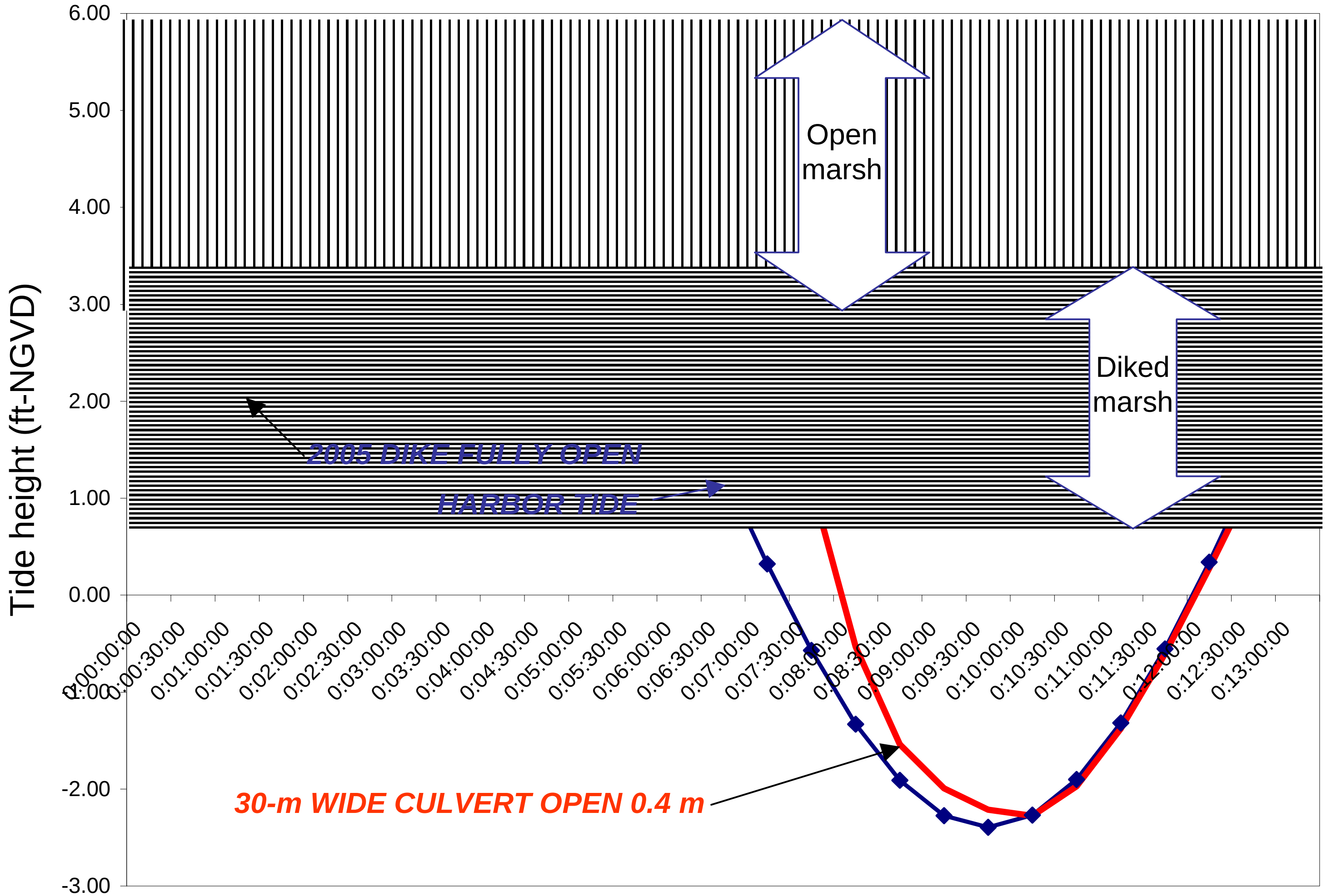




Model results: Extent of tidal flooding at high and low tide with the wide-culvert option in the Herring River Dike. This shows an average harbor tide, with 30-meter wide gate open 1.4 m high. Note how the system drains almost completely at low tide.

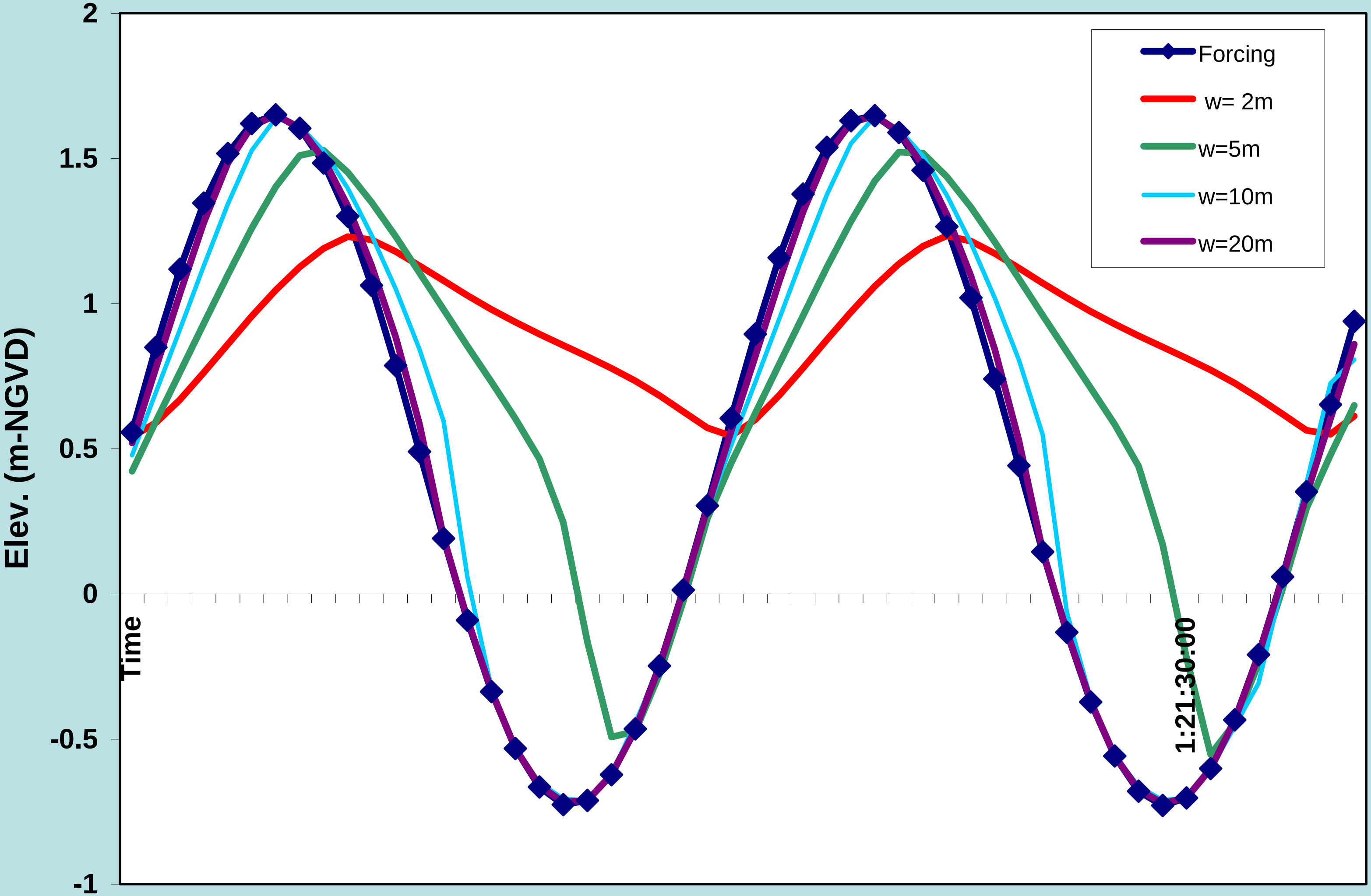


Model results: High-tide salinity distribution with the wide-culvert option in the Herring River dike. Note that salinity is sufficient to support most estuarine plants and animals, include softshell clams and oysters, well beyond Old County Road and Pamet Point. No low-tide salinity plot is shown because the system drains almost completely at low tide.

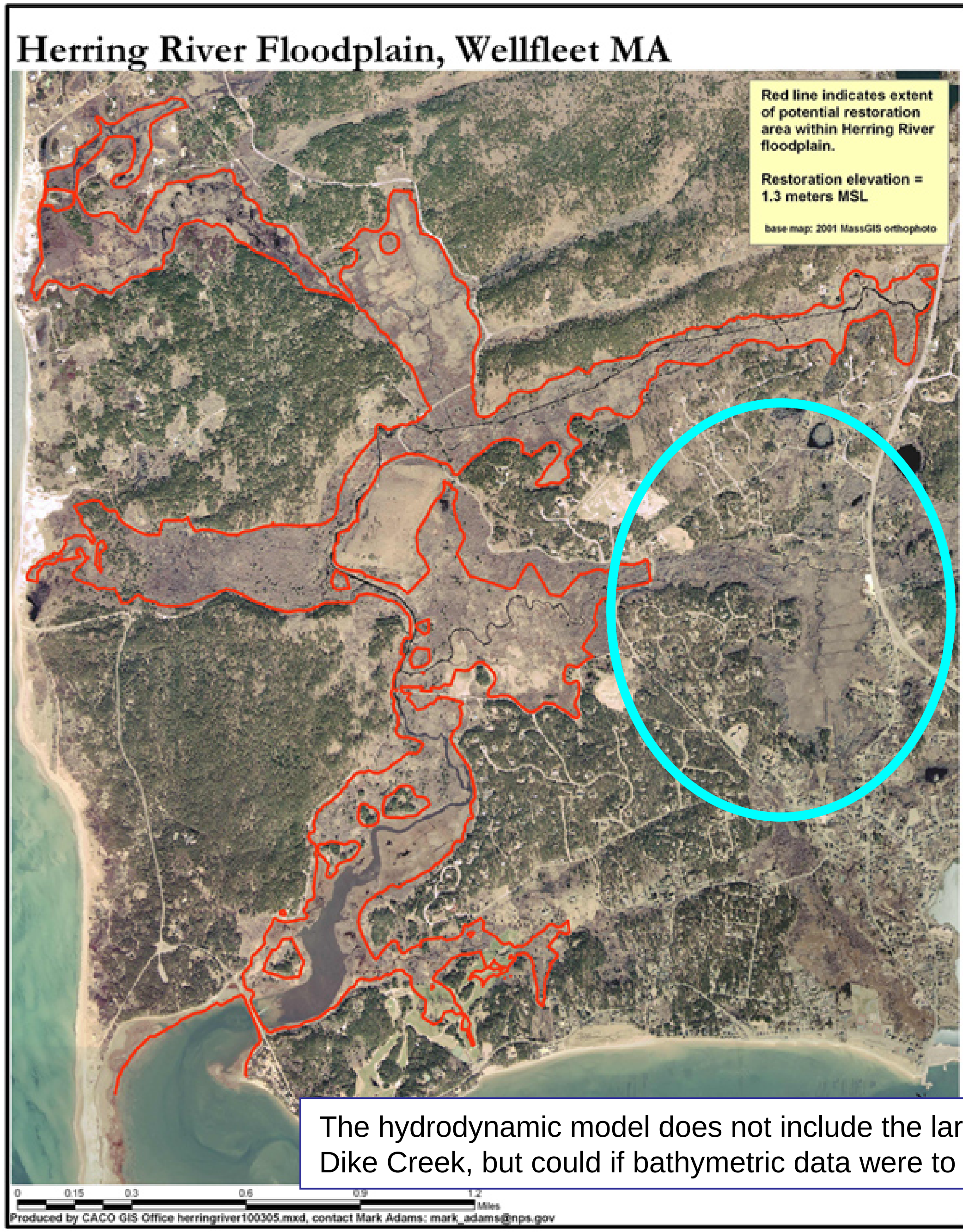


Performance of existing and proposed Herring River culverts relative to marsh elevation. Even when fully open, the existing culverts in the dike provide insufficient tidal volume to flood the marsh upstream, even though this wetland has seriously subsided since diking in 1909: note the difference in the vertical extent of marsh above ("diked marsh") and seaward ("open marsh") of the dike. In contrast, the model predicts that the proposed 30 meter wide culverts produce tides that closely approach those of the natural marsh, and both flood and drain the diked marsh during each tidal cycle.

High Toss culvert width



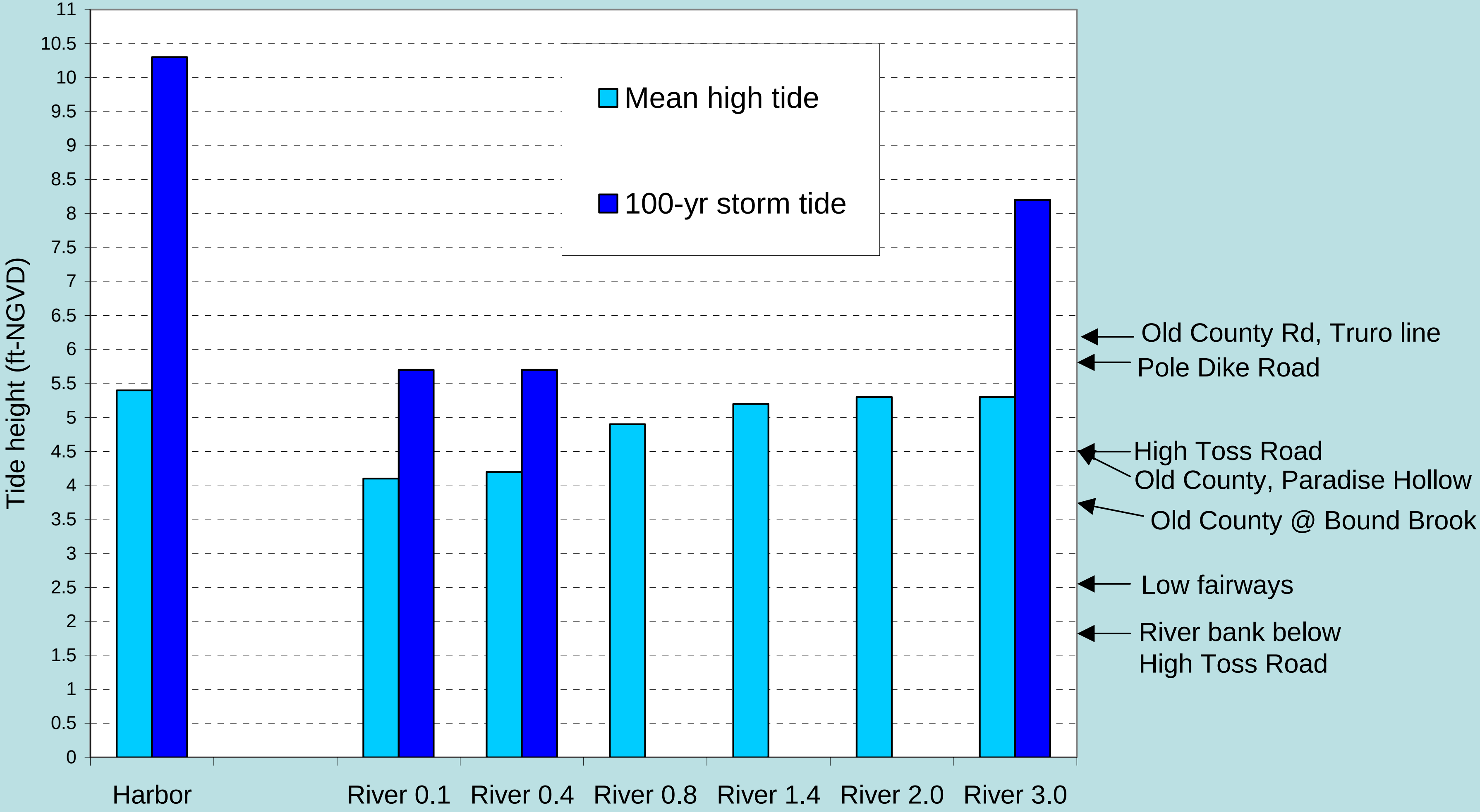
Understanding that High Toss Road represents an effective second dike, which would restrict tidal exchange with the wetlands upstream, the hydrodynamic model was used to find an opening width that minimized tidal restriction. The tidal "forcing" (dark blue line") assumes no tidal restriction at the Chequesset Neck dike. It appears that the opening at High Toss Road should be at least 10 meters (about 30 feet) wide to minimize this restriction.



Upper Pole Dike marsh?

The hydrodynamic model does not include the large (172-acre) wetland above Pole Dike Creek, but could if bathymetric data were to become available.

Mean high and 100-yr storm tides with 30-m wide culvert



Measured high tide heights for Wellfleet Harbor and model-predicted mean and 100-year storm tide heights for Herring River with the present culverts replaced with a 30-m wide, vertically adjustable opening at various settings. Numbers after "River" indicate culvert opening height in meters. For reference, the elevations of a few critical structures are indicated.

Tide Height Conclusions

- The Chequesset dike reduces tide range from 7.5 to 1.6 feet.
- Seawater reaches only to about 3000 ft north of the structure.
- Opening the existing structure increases tide heights but decreases tidal range and flushing.
- A dike opening must be at least 30 meters (100 ft) wide to remove tidal restriction at Chequesset Neck.
- Replacement of existing culverts with wide culverts:
    - Greatly improves tidal range and flushing;
    - Allows for incremental opening to full restoration;
    - Extends salinity to Old County Road, if desired;
    - Restores intertidal habitat, etc.
- Minimal opening of High Toss Road to remove restriction = 30 feet.