SEDIMENTATION CONCERNS ASSOCIATED WITH THE PROPOSED RESTORATION OF HERRING RIVER MARSH, WELLFLEET, MASSACHUSETTS

Prepared for Cape Cod National Seashore, The Town of Wellfleet and The Association for Women Geoscientists, as part of a Geologist in-the-park project performed during the fall-winter of 2003-2004

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EXECUTIVE SUMMARY

INTRODUCTION

In 1909 construction of a dike was completed across the Herring River in Wellfleet, Massachusetts. Since that time the restriction of tidal flow has resulted in major water quality problems, fish kills, and the general degradation of a once productive 1100-acre salt marsh system. Multiple studies, conducted to determine ways of restoring habitat quality in and adjacent to the Herring River, have found that water quality can be improved and estuarine habitats restored by returning tidal flow to the area above the dike. However, the proposed opening of the dike, necessary to performing such a restoration, has raised concerns among local shellfishermen. The most recent question, and the impetus for this study, is whether increased tidal flow will change sedimentation below the dike. Town officials and resources managers are particularly interested in how changing the tidal regime in the river might affect sedimentation on shellfish beds. Therefore, the purpose of this study is to address sedimentation concerns related to the possible restoration of the Herring River and to assess the effect, if any, of altering the tidal system on oyster and hard clam culture in Wellfleet Harbor.

In order to address sedimentological concerns associated with increasing tidal flow to the Herring River, questions were solicited from local fishermen and Town officials concerning the proposed restoration, with special emphasis on the effects of dike opening on shellfish grants. Two major questions emerged:

1) Does opening the Herring River Dike affect the stability of The Gut?

2) Does opening the Herring River Dike affect sedimentation below (seaward of) the dike?

This report answers these two questions by synthesizing pertinent information from previous investigations augmented with new data and analyses specifically for the Herring River.

STABILITY OF THE GUT

The stability of The Gut has, for at least the past several hundred years, been controlled by forces along the Cape Cod Bay shoreline, and not by tidal flow in and out of Herring River. In order to truly understand the relationship between Herring River and The Gut, one must first comprehend The Gut's formation and geologic history. All of Cape Cod is made up of sediment deposited by glaciers about 18,000 years ago. As the glaciers retreated, sea-level began to rise as the ice melt returned water to the ocean basins. The rising sea inundated the Cape and waves began to erode the glacial sediments that compose it. The sediment removed from the cliffs of the Outer Cape was transported and redeposited by wind, waves and currents to form the Provincelands, Nauset Beach, Monomoy Island and The Gut. In such cases as Nauset Beach and The Gut to Jeremy, a strip of sand built a peninsula off of the mainland forming protected bays such as Pleasant Bay and Wellfleet Harbor, respectively.

Wellfleet Harbor occupies a part of a large depression that formed where glacial ice once existed and thus prevented the deposition of outwash sands. As the ice melted and sea-level rose the depression was flooded forming Cape Cod Bay. Islands such as Griffin Island, Great Island and Great Beach Hill formed from sands that filled holes or depressions in the melting ice sheet and became stranded and surrounded by water. On the ocean side, sea-level caused erosion along the glacial uplands. The removal of these sands, and subsequent movement northward, left behind the sea cliffs of Wellfleet and Truro. Once the sand reached the north end of the glacial outwash, at present Pilgrim Heights, it began to accumulate forming the Provincelands. The formation of the Provincelands prevented sand from the east from reaching the bay side beaches, leaving only the sediment eroding from the bay side uplands as a source. This sand, supplied from the north by long shore drift, formed the barrier beaches that today connect the bayside islands, Bound Brook I., Griffin I., Great I., and Great Beach Hill. Together these intermittent barrier beaches, spanning down to Jeremy Point, provide protection from waves and form the sheltered environment of Wellfleet Harbor.

Historically, the Herring River most likely emptied directly into the bay by flowing through the area that The Gut now occupies. However, as sand built south across this opening, forming The Gut, the Herring River was deflected to the south. This deflection indicates that river flow alone was not strong enough to maintain a tidal inlet. Bearing in mind that this change in flow direction occurred before the river was diked, it is a reasonable to conclude that small changes in tidal flow through the present dike would have no effect on The Gut. It also seems reasonable that even complete removal of the dike would not cause The Gut to breach; historical data demonstrate that the flow of an unaltered Herring River is simply too weak to maintain a tidal opening.

The existence of a broad tidal flat behind The Gut's fringing marsh is a testament to these low flow velocities. The accumulation of fine sand proves that there is not enough energy in the ebbing tide to transport it out to sea. Moreover, there is not even enough energy to scour the edge of this mudflat along the low tide channel. This lack of scour is documented by historic aerial photographs and topographic maps, which show the same channel configuration prior to the dike's construction as today. This continuity proves that even with the maximum ebbing flow, i.e. with no tide-restricting dike, there will be no scouring of the mudflat. Further evidence of the lack of any downstream effect of the dike is the fact that tidal conditions, such a tidal range, below the dike have not been affected by its installation. As intended, the construction of the dike has altered the river above it, with little change to the area below it.

The continued stability of The Gut, like its original formation, is primarily dependent on sand supplied from movement along Cape Cod Bay beaches and wind transport of finer grains to make and maintain the dune system. Erosion of The Gut is likely to occur as a result of storms. However, the wide salt marshes that back this beach and dune system provide a formidable resistance to erosion. It is highly unlikely that a channel would be cut through the thick cohesive marsh peats; therefore, there is little chance of a permanent inlet forming from a breach in The Gut.

It is more probable that in the case of a high-energy storm an overwash from the bay would occur through a low in the dunes. An overwash is a fan shaped deposit of sand that is washed from the beach through a break in the dunes and deposited on the adjacent salt marsh surface. An overwash occurred on Ballston Beach during both the Blizzard of 2003 and the Halloween Storm of 1991. If this were to occur along The Gut, which is less likely because storm waves are smaller and less frequent on the bay side than the open ocean, natural post-storm processes would heal the beach. As seen on Ballston, smaller waves, which occur under normal/non-storm conditions, move the sand back onshore and rebuild the beach and dunes filling in the topographic low. Furthermore, even if a temporary overwash were to occur along The Gut, it is unlikely that there would be significant changes in water characteristics in Wellfleet Harbor, which would still receive most of its tidal volume from the south.

Both sea-level rise and a deficit of sand supplied to this system are the main natural forces of erosion along The Gut; however, human impacts exacerbate this erosion. Foot paths over the dune crest remobilizes sand and causes downward erosion. The resulting low-lying area is ideal for a washover to occur during a storm. The Town of Wellfleet and Cape Cod National Seashore are working to lessen this human impact.

SEDIMENTATION IN THE LOWER HERRING RIVER

To address questions pertaining to sedimentation below the Herring River dike, previous studies were researched and augmented by conducting a new study. An exhaustive literature search yielded only one pertinent study, also for Herring River, entitled *"Hydrodynamic and Salinity, Modeling for Estuarine Habitat Restoration at Herring River, Wellfleet, Massachusetts"* by Malcolm L. Spaulding and Annette Grilli completed in 2001. This study showed that the dike has reduced the tidal range above the structure by greater than 4.5 times, resulting in an asymmetry between the flood and ebb flow velocities of the lower portion of the river. This asymmetry increases the naturally flood dominant transport of sediment, resulting in a large deposit of sand just upstream of the dike. This deposit is referred to as a flood-tidal delta. A small ebb-tidal delta formed below the dike during its construction, but unlike the flood-tidal delta, modern sedimentation here is nil, allowing shellfish to colonize.

Spaulding and Grilli's (2001) hydrodynamic study addressed whether any of these sediments accumulating upstream of the dike would be resuspended and carried downstream if the Herring River were to undergo restoration. They modeled peak velocities in the river with all three tidal gates open on the dike and found that the flow would be less than 10 cm/sec. This predicted flow is half the standard 20 cm/sec necessary to resuspend any sand within the river. In addition, the 2001 study reported that any downstream movement of the flood-tidal delta sediments, or the fine–grain deposit just upstream of it, would most likely be a result of a rainstorm. However, seaward transport of sediment through the dike with all gates open would be the same as today, because all three flapper gates allow water to move in a seaward direction. Therefore it is likely that the resulting sediment transport patterns with the dike open would be identical to those during past rainstorms with the gates in their current configuration. During these events the larger sand size particles will likely settle just below the dike, near the present ebb-tidal delta, while the smaller silt-and clay-sized grains will widely disperse and deposit in the fringing marshes of The Gut or offshore. In researching this study and talking to local shellfisherman, there no reports of siltation on shellfish beds after rainstorms.

To address this subject of sediment transport below the dike, Dr. Spaulding used existing field data to assess the potential for velocities to reach the necessary 20 cm/sec. Using the equation *velocity = volume of water per unit time / unit area*, Dr. Spaulding calculated peak flow with all gates open to be less than 6 cm/sec below the dike. Thus, this hydrodynamic study predicts no sediment will be resuspended in the event that all three gates of the Herring River dike are opened.

In order to test this prediction this study focused specifically on past changes in sedimentation in the lower portion of the Herring River. The theory behind this approach is that by measuring the changes in sedimentation after flow was constricted, it will be possible to predict the response of reverse conditions. Coastal topographic maps and aerial photographs, spanning the last century and a half, were used to map the intertidal region below the Herring River dike. Aerial photography revealed that a split s-shaped geometry, expressed in the low tide channel today, is the same as it was back when the first air photo was taken in 1938. This geomorphic consistency indicates that little to no sediment movement occurred over the past 65 years; this period includes any changes in flow from the breach and subsequent repair of the dike in 1968 and 1975, respectively. Since no real changes appear to have occurred since the installation of the dike, the 1974 USGS topographic map correctly represents the post-dike shape of the intertidal region in this area. In comparing this 1974 topographic map to one from 1848 prior to the dike construction, the only difference was the absence of the ebb-and flood-tidal deltas. Conversely, then it is logical to predict that any future adjustment to the dike's configuration, including complete removal, would affect sedimentation very little and only close to the dike itself.

The 2001 Spaulding and Grilli study showed that opening all the tide gates would not result in any movement of any sediment. In addition, the present study indicates that if the whole dike were to be removed, the only change in sediment patterns would be proximal to the dike. Therefore, with respect to the shellfish grants on Egg Island, they are simply too far away to be affected by any alteration of flow through the dike. Real-world evidence to support this fact was provided in 1968 with the rusting out of a sluice gate allowing tidal exchange for the next six years. There is no evidence that areas of high shellfish production such as Egg Island experienced increased sedimentation during this time. On the contrary, the consensus was that shellfish actually colonized in the area around the dike and subsequently died after the dike was repaired. An explanation of the brief colonization is that increased flood currents caused by the deterioration of the tide gates moved the fine sediment coming from Cape Cod Bay past the dike and up into the marsh. Salinity behind the dike also increased, favoring estuarine bivalves. In contrast, rebuilding the dike structure once again restricted flow. As the velocities slowed near the dike, fine sediment that would have otherwise been carried into the far reaches of Herring River, were once again deposited directly above and below the dike, thus covering the shellfish that had recently colonized.

Data from the restoration of Hatches Harbor show increased landward transport of sediment. Since March of 1999 portions of the Hatches Harbor flood plain diked in 1930 have been undergoing incremental restoration of tidal exchange. The amount of sedimentation within the system was studied from 1997 to present using Sediment Elevation Tables or SETs. Data from these SETs show that sediment in the marsh below and just above the dike are accumulating at about 3 mm/year, which is the norm to compensate for local sea-level rise. However, accumulation rates of over 10 mm/year are recorded at SETs located farthest upstream from the dike, exactly what would be expected from the restoration of tidal flow and dominant upstream sediment transport..

Three SETs are already located in the Herring River marsh: 1) The Gut salt marsh, 2) the Phragmites marsh below High Toss and 3) the drained marsh above High Toss. These locations have been measured once a year to determine sediment accretion and/or loss, since 2000. In addition to the continued monitoring of these SETs, new monitoring of sediment grain size and organic content is proposed specifically to address the concerns of sedimentation on shellfish beds.

CONCLUSIONS

The Stability of the Gut and Its Relationship to the Herring River

- The continued stability of The Gut is dependent on the same two factors that governed its formation: 1) sand supply and 2) sea-level rise.
- The Gut influences the Herring River rather than vice versa as evidenced by:
- The large meander or bend in the river that occurred as a result of The Gut's formation, that forced water to flow south through the harbor.
- The existence of a wide mudflat on either side of the main ebb channel even before the dike was constructed, indicative of low ebb-flow velocities from the river.
- It is unlikely that The Gut would breach and form a permanent inlet due to the extensive marsh backing this barrier beach. If a large storm were to cause erosion along The Gut, a temporary washover may occur; however, natural post-storm rebuilding processes would quickly close it.
- Foot traffic across the dune system has worsened erosion and increased the possibility of a blowout. The Town of Wellfleet, Cape Cod National Seashore and volunteers are taking action to repair and limit this damage.

Sedimentation in the Lower Herring River

- Hydrodynamic models by Spaulding and Grilli in 2001 indicate that velocities above the dike, with all gates open, would be half that required to resuspend sediment.
- Calculations show that maximum flow velocities below the dike, with all gates open, will be just over a quarter (6 cm/sec) of the 20 cm/sec necessary to resuspend sediment.
- Geomorphic analysis of the intertidal area below the Herring River Dike shows almost no change over the past 155 years, with the exception of the formation of a small ebb- and larger flood-tidal delta. Otherwise, channel morphology below the

present dike was the same before dike construction in 1909 as it is today; the dike has had little effect on downstream sedimentation.

- The predicted change in sedimentation, as a result of restoring tidal flow to the Herring River, would be minimal and proximal to the dike.
- Data from both the 1960s breach and from Hatches Harbor sedimentation not only support this prediction, but also indicate that the resulting changes around the dike will improve sedimentary conditions for shellfish repopulation.

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