SAFE HARBOR
ENVIRONMENTAL MANAGEMENT
HABITAT RESTORATION

Bayside Coastal Bank Erosion Response Alternatives

This publication provides educational background material for exploring alternative responses to coastal erosion on the Outer Cape. Models, observations and techniques described are locally representative and not intended to be completely comprehensive. Thank you, Gordon Peabody, 2015

Image above by G. Peabody: Drift fencing may not change overall erosion rates.

I. Background: Bayside coastal banks can be from 6 to over 60 feet high. Banks are mixed, glacially compacted sediments. We study adjacent resource areas such as bluff area on top of bank; sloped face (or scarp) of bank itself: toe of bank (possibly with dune) at the bottom of bank; beaches; and near shore sandbars, as ***Linked Resource Systems,*** because they respond to storm energy as systems. Each site has unique ***Coastal Profile.*** Interactions of storm energy with coastal profiles creates the ***Coastal Process.*** This publication focuses on ***Bayside Resource Systems.***

II. Coastal Process: Understanding the ***Coastal Process*** is critical to understanding coastal erosion. The energy linking ***Coastal Resource Systems*** physically reshapes these systems by removing sand from one area (up drift erosion) and placing it elsewhere (down drift deposition).

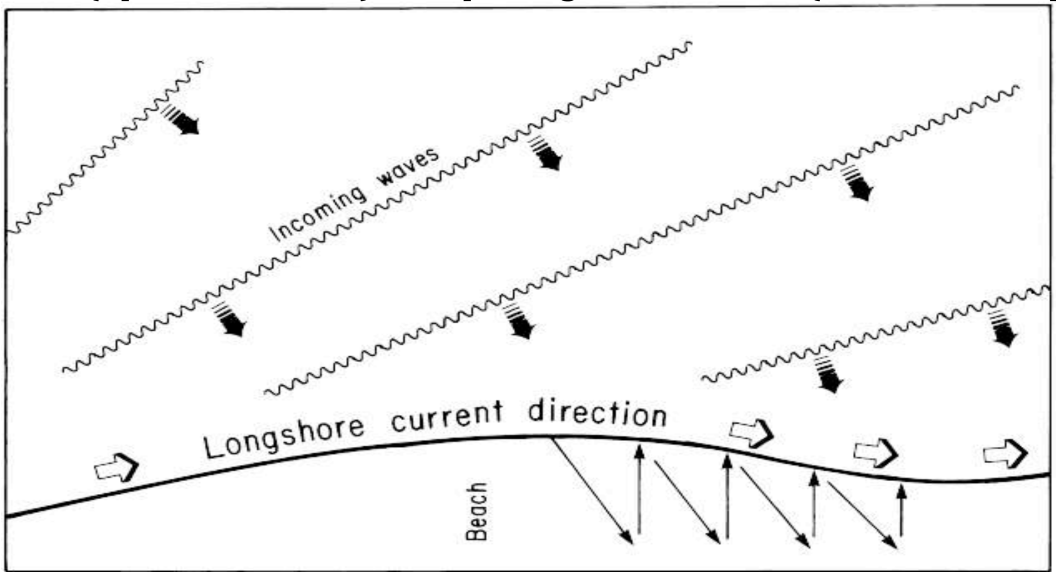

Image above: Wind and tide energy move sand from beach to near shore bars.

The near shore ***Transit Corridor*** (path) of this moving sand creates benthic (underwater) profiles (sand bars). Sand bars contribute to storm wave protection by creating benthic friction, reducing wave height.

Image above: Satellite view of Bayside beach, showing near shore sand bars.

Long term patterns of erosion and deposition may be categorized as: *balanced* ("dynamic equilibrium"); *overall net loss;* or *overall net gain*. Except for Provincetown, the Bayside coast of the Outer Cape is characterized by annual, variable net loss. This could be expressed as decadal zero net loss, followed by single year of cumulative, net loss. The ***Coastal Process is driven by a combined uncertainty of interactions***: coastal profile; synergy of storm waves and tide cycles; weather anomalies; climate change; seasonal wind and wave patterns; varied tide currents.

In coastal systems, ***sloping beaches absorb and diminish storm wave energy***. Wave energy will remove sand, transforming the beach to a more horizontal profile. Horizontal beach profiles allow undiminished storm waves direct access the toe of the coastal bank. When the toe absorbs wave energy, erosion moves toe materials seaward, replacing eroded beach material, transitioning the toe profile to horizontal. The lower bank is now exposed to wave energy. When the lower bank absorbs wave energy, erosion moves bank materials to the upper beach and a section of unsupported upper bank will collapse, creating a new toe, restoring the coastal profile. Sand removed from beaches usually creates near shore bars, reducing wave energy & providing protection for beaches.

Only a sloped beach and toe can protect a coastal bank from erosion. Deposition activity within the coastal system requires ***available sand***. On the Bayside, sand availability for deposition is in short supply. This is due to several controlling factors: seasonal, net loss erosion patterns; perpendicular coastal erosion control structures (groins, jetties) to the south (***up drift***), interrupting the north (***down drift***) flow of sand; pre-existing, up drift coastal bank structures (sea walls, revetments) lacking nourishment requirements. The resulting lack of available sand in transit corridors may contribute to lower profile sand bars, reducing storm wave protection. These cumulative, synergistic factors create a chronic, net loss along the western Bayside banks of Outer Cape Cod. Activities, structures and policies diminishing available sand, up drift supply or changes to transit corridors, could contribute to higher rates of Bayside bank collapse.

III. Review Let's review some of the relevant principles of the Outer Cape, ***Bayside Coastal Process*****:** ***Coastal Profiles*** respond to storm energy as ***Linked Resource Systems,*** integrating process with profile; Coastal profiles erode at ***differential rates over time***, based on synergy of variables and constants; Single storm events may create linear, *uniform erosion rates along specific sections of coastline*; Over time all ***sand on this section of coast will move north*** "down drift"; new sand will enter and transit the system from erosion and the partial collapse of "up drift" sections of coastal banks; Coastal Systems exhibit ***"Linkage to Scale",*** with connections to each other, a critical factor in evaluating effective erosion control strategies***.*** Refer to image below for overall sand transport patterns

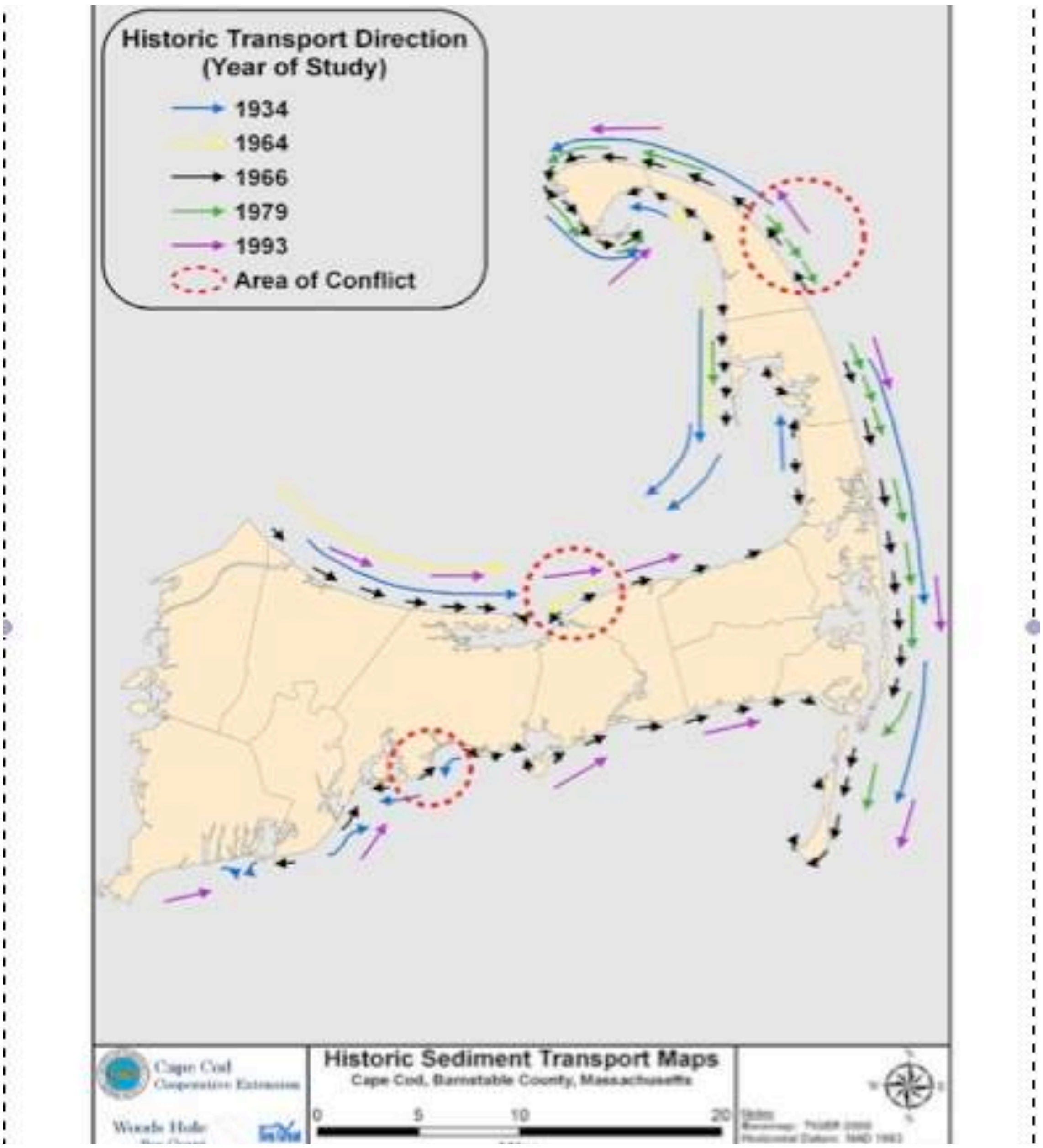

Image above by S. Berman 2012: Overall Cape Cod sand transport patterns

IV. Alternatives Analysis for Erosion Responses:

Alternative 1: No action

Image by G. Peabody: Increases in SLR or storm energy increase erosion.

a). Costs: (None)
b). Consequences: Continuing pattern of coastal erosion along adjacent coastline will determine timeline for property risk.

Alternative 2: Stone Revetments

Image by G. Peabody: Revetments may interrupt bank to beach sediment flow.

Alternative 2: Stone Revetment (continued)
a). Costs: Exponentially highest cost per foot of any alternative; permitting usually unavailable. Renourishment annually in addition to initial costs.

Image by Google Earth: Stone revetments create "end scour" on adjacent property.

b). Consequences: ongoing nourishment; liabilities when neighboring properties begin showing classical signs of scouring erosion from waves offset from structure. Potential interruption of long shore sand transport.

Alternative 3: Coir Rolls-Coconut husks wrapped in heavy fiber

a). Costs: (Significant) Permitting; Coir materials; Helical anchors; Renourishment sand; Native vegetation; Conservation Commission bylaw escrow may be required in some coastal communities to assure continued renourishment: $5000).

b). Consequences: see above image. Coir is not recommended for velocity zones (waves) or coastal use without nourishment. Ongoing renourishment and replanting are necessary. Erosion events are defined by uncertainty. Storm events create uniform erosion rates

Alternative 4: Drift Fence (Semi-Soft Solution)

a). Costs: (Intermediate) Fence materials; sand; vegetation. Permitting may be changing, based on performance questions.

b). Consequences: Fence slats resistance may result in accelerated erosion from out wash during over wash events; Replacement of fences due to impacts of erosion, waves and debris.

c.) Comment: This alternative was originally intended to provide a degree of protection and performance which have not been fully realized. The popularity has resulted in permitting protocols intended to facilitate implementation of a semi-soft response to Bayside erosion. Drift Fencing evaluation continues.

Image above: Large, treated posts require excavation to support typical Bayside sand drift fence. This alternative is now being re-evaluated in some communities.

Image above: Drift fences also require sand nourishment and beach grass planting. Nourishment and vegetation often require annual replacement.

Image above: Drift Fence may restrict overwash outflow, contributing to outwash of sand.

Image above by G. Peabody: sand accumulations seem unaffected by drift fencing

Alternative 5: Nourishment

"Nourishment", refers to placement of sacrificial sand in eroding coastal areas. Cape Cod's landform is composed of glacially consolidated sediments. Erosion along our coastline forms coastal banks. Consolidated sediments and coastal banks can never be restored because the conditions of their creation cannot be recreated. Erosion causes sections of coastal banks to collapse, forming a pile of sediment at the foot of the bank. This is called the "toe" of the bank. We refer to the toe as "the ATM" of coastal erosion. Storm energy in the form of wind, waves and currents remove material and sand from the toe. Placing new nourishment at the toe re-deposits sand in the ATM. Sand is currency in the coastal process. Future erosion events erode the sand but the coastal bank will remain intact.

5-1. Over Bank Nourishment

a). Costs: Permitting often minimal; Renourishment sand; vegetation; Sand from adjacent foundation excavations would meet compatibility requirements. Eroding, unvegetated banks are suitable.

b). Consequences: Mitigations need to address native revegetation on bluff as well as on bank and bank plantings using secured ladders.

Image by G. Peabody: Over bank renourishment can be spot directed using small equipment. This project utilizes sand from on site excavation materials

Safe Harbor Image above shows "full bank" nourishment. Sand is delivered to dump box from sand storage area. Equipment transfers nourishment along the full height of the bank, providing longer term, more sustainable, bank protection

Image above shows more sustainable, full bank nourishment.

5-2. Toe of Bank Nourishment

Image above: Conveyor being used to deliver sand to toe of bank.

Image above: Sand renourishment at toe of bank requires beach access.

a). Costs: Permitting variable; Renourishment sand; vegetation;
b). Consequences: Seasonal renourishment and replanting may be necessary, following coastal erosion. Coastal Bank is protected.

Using ladders to plant protects new nourishment by avoiding destabilization

5-3. NOURISHMENT SUPPORT SYSTEMS: Consolidated, Coastal Bank sediments can never be replaced. Unconsolidated sand nourishment from any source, placed at the toe will protect the bank. Native Beach Grass and ***Biomimicry*** collect and stabilize wind blown sand. We recommend using both systems. Existing beach grass can be removed prior to renourishment and replanted afterwards. Biomimicry can be lifted up to collect more sand.

Biomimicry sand collection system at toe of nourishment area.

Biomimicry collection systems can be raised to collect more sand.

Alternative 6: Relocation (Retreat)

Image above by G. Peabody: Relocating a residence away from a coastal bank.
Costs: Significantly less than rebuilding; Permitting often facilitated by Municipalities; Stabilize removal site. Consequences: 100'= 30-40 years.

IV. Cost Benefit Analysis with Recommendations

Conclusively, when we look 30 years into the future*, moving the structure provides the greatest security for the investment**. Keeping in mind that assessment and erosion response plans are site specific, they must also represent ***"Linkage to Scale". Response plans that ignore adjacent response plans (or the lack thereof) may unintentional create coastal anomalies which could become the focus of wave energy.

Installing any type of coastal bank erosion control system also *requires nourishment*. This **working definition of erosion control "*protects" the coastal bank by not allowing it to erode***, because regulatory authorities require placement of nourishment, available for use by the *Coastal System* during erosion events. All coastal bank erosion control systems (hard or semi-soft solution) are now required to provide sand nourishment for use by the coastal system during erosion conditions.

In considering the costs and consequences of alternatives (2: Revetment, 3: Coir Rolls and 4: Zig-Zag Fence): renourishment would still be necessary and required following any erosion event; The overall effectiveness of alternative 2, 3 or 4 would ultimately be determined by actions on abutting properties on this section of coastline; Without "*Linkage to Scale*" participation from abutting properties using similar structures, your property could create an anomalous coastal profile; Anomalous profiles tend to attract more wave energy, creating ongoing maintenance issues and subsequent erosion (scour) on abutting properties. ***Alternative 6: Retreat (Relocation) is most sustainable for long term interests. If relocation is not practical, we recommend Alternative 5: Renourishment as more sustainable for medium-term interests.*** Nourishment on adjacent properties would be recommended.

SUGGESTED, (DIRECTIONAL) CO-FACTORS OF COASTAL EROSION