SAFE HARBOR
ENVIRONMENTAL MANAGEMENT
HABITAT RESTORATION

COASTAL PROCESS ON OUTER CAPE COD

Our ***Coastal Process*** results from the interaction of energy and land mass. Tide, wind and wave energy transform sand bars, intertidal beaches, upper beaches, coastal banks and dunes. Sand is removed from one area (erosion) and placed it elsewhere (deposition). Safe Harbor considers resource areas and the energy flowing through them as "***Resource Systems***". Storm Energy, linking these systems together creates "***Linked Resource Systems"***. *Models, processes and observations described are locally representative and may not be inclusive.*

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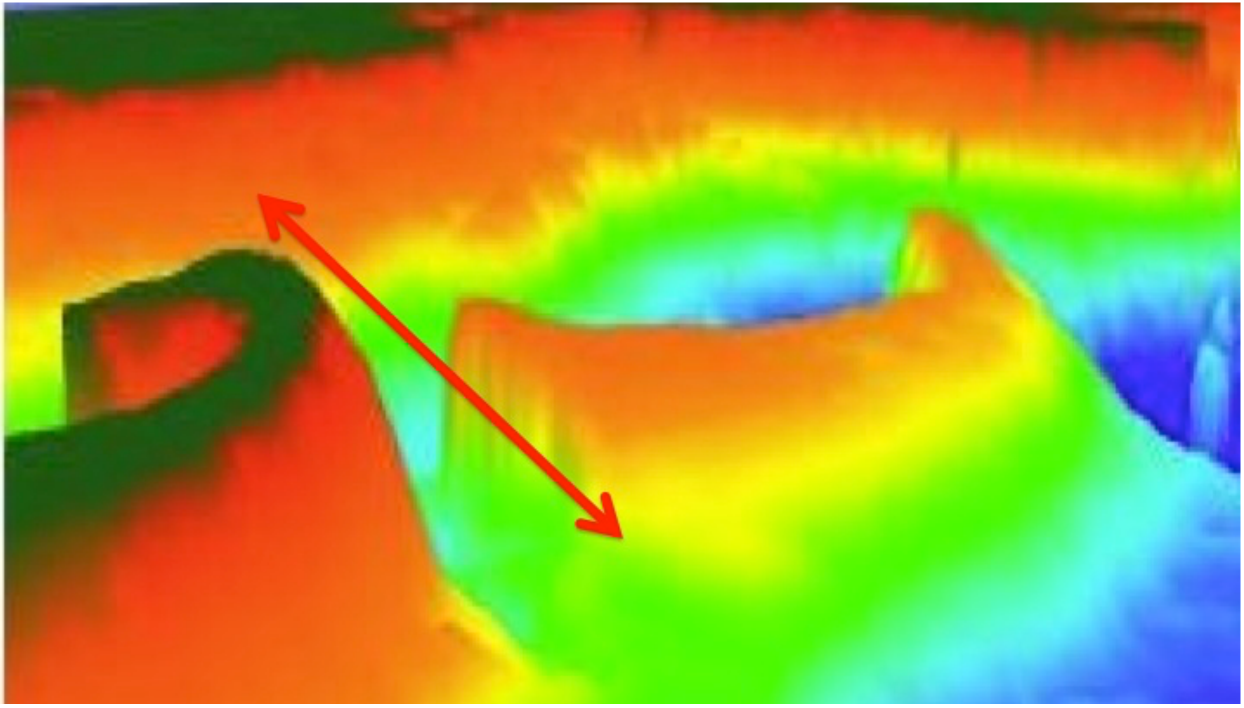
The Coastal Process cannot be attributed to a single cause or explained in a linear, cause-and-effect manner. Sand is in motion along Bicoastal Outer Cape Cod. Between northern Wellfleet ***updrift***, and Provincetown ***downdrift,*** sand is moving north. New sand enters the system from eroding beaches and coastal banks ***updrift***. Wave and tide energy create ***Transit Corridors*** for sand transport of sand bars parallel to the shoreline, linking sources and destinations. Sand moves from these eroding sources and is deposited as beaches and dunes ***downdrift***.. Coastal banks, beaches, sandbars and dunes respond to wind, tide and wave energy as systems, creating the overall dynamic of the coastal process. ***Linkage to Scale***. *Understanding "linkage to scale is a critical factor in erosion control strategies, helping* your solution fit into the coastal process. gordonpeabody@gmail.com www.SafeHarborEnv.com

I. TIDAL FLOW IS THE "SLEEPING GIANT"

We often forget to evaluate tidal power in Coastal Resource Systems. We can quantify some aspects of tidal energy using a basic model: *Cape Cod Bay (CCB) can be viewed as a 20-mile diameter bowl with a representative tidal depth of 10 feet. Every six hours, the entire bay fills up.*



The weight and velocity of water moving in and out of Cape Cod Bay contribute to the Coastal Process. Storm energy and the bathymetric restrictions (shown in above image), of Stellwagon Bank and the Cape Cod landform, create changing velocities and sand transport patterns.

1. *Area of CCB surface = (3.14 x 10-mile radius)^2 ≈ 300 mi^2*
2. *We then convert sq miles to sq feet: 300 mi^2 = 1,584,000 ft^2*
3. *Tidal volume = 1,584,000 ft^2 x 10 ft tidal depth = 15,840,000 ft^3*
4. *15,840,000 cubic feet of water enter CCB on this 10-foot tide.*
5. *This translates to 118,800,000 gallons of water*
6. *Weighing approximately 986,040,000 pounds.*
7. *Nearly half a million tons of water move in and out of Cape Cod Bay within the six hour time period we are measuring.*
8. ***Over a 24-hour time period**, we begin with the approximate volume of 118,800,000 gallons that entered CCB over a 6 hr period, which represents only 25 % of the daily volume of 2 incoming and 2 outgoing tides.*
9. ***Total daily volume of tidal water moving into and out of CCB is approximately 475 million gallons, or nearly two million tons of exchange.***

II. COASTAL PROCESS CO-FACTORS

1.Tide

Tidal currents interrupted by coastal landforms accelerate and move parallel (lateral) to the shoreline. Lateral currents are referred to as “alongshore” and are bidirectional, depending on state of the tide. A synchronous low tide may limit storm damage. A synchronous high tide may amplify storm damage. Low tide exposes miles of open area to absorb wave energy. High tide provides a platform for wave propagation to reach the upper beach.

2.Wind

Wind energy, variable in direction, intensity and duration, generates direct material transport through erosion and deposition. Materials are transported from higher velocity areas to low velocity areas. Material deposition zones can be the upper beach, dune or toe of the bank. Transport also occurs laterally, parallel to the beach and face of the bank. Under intense, onshore wind conditions, accelerating wind blows beach materials against the bank, removing material from the bank face. Wind drives this mix up and over the top of the bluff, velocity is reduced and the sand deposited. Safe Harbor has documented the collection of a half million pounds of sand on a 10,000 sq ft (50 lbs per sq ft) area at the top of an ocean front bluff. Wind energy can transport sand horizontally, laterally or vertically.

3. Waves

Wave energy is redirected by coastal bathymetry. The cross section of a wave is only partially seen at the surface. Most of a wave form is moving under water. As waves cross the nearshore coastal profile, energy is reduced through bathymetric friction.

4. Bathymetry

Sand bars exhibit significant, time- and tide-sensitive linkages in their ability to protect beaches and Coastal Banks.

5. Topography

Landforms interrupt and reduce the cross sectional wind flow, increasing velocity. Along the beach, face, and bluff of the bank, it is possible to have significant differences in wind velocity within Coastal Systems.

Topography may alter tidal energy. Tidal currents encountering landforms move parallel to land and accelerate. More water has to move faster through a narrower transit corridor. Significant differences in tidal velocities may occur within the same Coastal Resource System.

7. Topography may alter wind energy. Wind energy has characteristic, seasonal patterns. Summer patterns are predominantly low velocity south winds; winter patterns are predominantly high velocity, north winds. After crossing open water, surface level, onshore winds experience significant restrictions from Coastal Banks..

8. Bathymetry may alter tide and wave energy. Bathymetry reshapes waves and in some cases, such as sand bars, waves reshape bathymetry. Sandbars absorb wave energy, reducing wave size. This provides a degree of protection for beaches and Coastal Banks. Frictional energy contributes to shoreward movement of sand across sandbars. Sand is also moved across bars to beaches. Sand bars also create barriers trapping incoming tide waves against the beach. When the tide reverses, this water creates huge “rip channels” to drain. During long duration storm pulse events, these openings allow storm waves on subsequent tides to significantly erode beaches. Inshore waves transfer energy directly through impact. Energy is also transferred less directly, by sand erosion, transport and deposition. The degree of wave intensity (frequency) contributes to deposition or removal of beach sand. Low frequency waves contribute to deposition of sand, increasing beach elevation. High frequency waves contribute to removal of sand, decreasing beach elevations.

III. LINKING SYNERGISTIC CO-FACTORS

1. Wind and Wave:

Wind energy blows against the fluid surface of the sea. Friction creates uneven ripples known as capillaries or "cat's paws". Continued wind pressure against capillaries generates increasingly larger waves, which move with the wind direction. Wave size is determined by three primary variables: wind speed, wind duration, and wind direction. Speed describes the potential energy available for creating waves. Duration describes the amount of time available for energy exchange. Direction is defined as open water distance (or "fetch"). Greater fetch will create larger waves.

> **Onshore wind**, generating high frequency wave energy, erodes beach sand, which is transported laterally, in the direction of the tide current.
>
> **Side shore (angled) wind,** generating high frequency wave energy, erodes beach sand.
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> **When side shore wind and waves are synchronous** with lateral tidal current, there is an exponential potential for erosion and transport.
>
> **When side shore wind and waves are not synchronous** with lateral tidal currents, there may be minimal, net lateral transport.

2. Sand Bars, Beaches and Coastal Banks:

Beaches and sandbar profiles are linked by the transfer of storm energy and sand mass transfer during pulse events and tide cycles. Sand removed by wave erosion is transported through backwash currents away from the beach. Beyond the surf-zone, reduced turbulence reduces transport and sand is deposited as sand bars. Changes in rates of deposition create changes in bathymetric friction. Variable rates of bathymetric friction contribute to variable rates of sand transport from bars to beaches and during Ocean Storms, from beaches to bars. During onshore winds, waves will push incoming tidewater inshore, over sandbars. Once the tide reverses, this trapped water drains by creating deep, perpendicular "Rip Channels" in the sandbar. Storm waves are reduced by sand bars, except where temporary or chronic "Rip Channels" exist. Rip Channels are linked to erosion anomalies.

Beaches with angled (perched) profiles are best able to absorb wave energy. When the magnitude or duration of wave energy erodes excessive sand, the beach profile transitions reshaping the beach from angled (perched) to horizontal. Horizontal profile beaches allow waves access to the upper beach, transitioning that profile from angled to horizontal, to renourish the beach, protecting the Coastal Bank.

Coastal Banks are linked to the coastal process through the above links and their own structure (bluff, face, toe). When erosion events transition lower and upper beach profiles, waves have access to the toe of the Coastal Bank.

The toe now absorbs wave energy and erodes. Materials from the toe move seaward to replace upper beach materials. Once the toe profile has transitioned to horizontal, the bank will absorb wave energy and a section will collapse, creating a new toe to restore the profile.

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