Chapter 12: Tidal Inlets

Basic Morphology

Distribution
Formation
Sand Transport
Influence on Barrier Island
Inlet Relationships

Tidal Inlets

Inlet: conduit through which there is a direct exchange between ocean and bay water

Tidal Inlet: the depth of the main channel is controlled/maintained by the oscillation of the tide through the conduit (tidal currents)

Incident Wave Field

Unstructured Inlet

Structured Inlet

Jetty

Basic Morphology

Flood Tidal Delta
Ebb Tidal Delta

Barrier Island

Basic Flood Delta/Shoal Morphology

1 Flood ramp: dominated by strong flooding currents, sand waves
2 Flood channel: two shallow channels around the flood delta, sand waves
3 Ebb shield: highest landward portion of the delta
4 Ebb spit: sand scoured from shield by ebbing currents
5 Spillover lobe: ebbing currents breach the spit
**Basic Ebb Delta/Shoal Morphology**

1. **Main Channel**: dominated by ebb currents
2. **Terminal Lobe**: sand deposited as currents exit channel, reworked by waves
3. **Swash Platform**: broad interior plateau
4. **Marginal Bars**: confine the ebb-jet/current
5. **Swash Bars**: wave generated bars on the swash platform
6. **Flood Channels**: shallow channels upon which flood tide enters

**Influence of Waves on Ebb-Shoal Morphology**

**Additional Inlet Parameters**

- **Tidal Prism (P)**: volume of water flowing through the inlet during half of a tidal cycle
- **Tidal Range (\(a_0\))**: height of the tidal wave, measured from the high tide crest to the low tide trough
- **Cross-sectional Area (\(a_c\))**: surface area of a plane that bisects the throat (perpendicular to the inlet axis or channel)

**Inlet Distribution**

- Geology is conducive to inlet formation
- Depositional coasts
- Abundant sediment supply
- Broad flat shelf
- Greater tidal forcing
- Lower wave energy
Tidal Inlet Formation
Barrier Island Breaching

Shinnecock Inlet, 1938

Pikes Inlet, 1992

Nauset Spit, Cape Cod
(January, 1987)

Historical Development of Nauset Spit, Cape Cod
**Inlet Classification**

**Tide Dominated**
- Developed flood & ebb shoals
- Multiple ebb channels

**Wave Dominated**
- Large flood shoal
- Small ebb shoal

**Mixed Energy**
- Arcuate ebb shoal
- Possible flood shoal
- One main ebb channel

**Longshore Transport of Sand**

The evolution of the ebb and flood shoals in part depend on the volume of material delivered to the inlet by wave driven currents.

In addition the rate at which material is bypassed across an inlet controls the evolution of the beaches and downdrift barriers.
Natural Sediment Bypassing

**Bypassing:** process in which sand is transported across the inlet from the up-drift barrier to the down-drift beaches.

**Bruun & Gerritsen, 1959**

1. Wave driven transport around the periphery of the ebb-shoal complex
2. Tidal flushing through the throat of the inlet
3. Bypassing through migration of bar complexes and shifting of main channel

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**FitzGerald & Kraus Bypassing Models**

- Inlet migrates in dominant transport direction
- Channel becomes hydraulically inefficient and unstable
- Spit breaches providing a more direct exchange of water between ocean and bay
- Barrier Island downdrift of breach is bypassed

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**Stable Inlet Processes**

Price Inlet, SC

Illustrations indicate approximately 1 cycle for the four year period, however larger complexes have been observed to take up to 10 years to complete the bypassing process

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**FitzGerald & Kraus Bypassing Models**

- Low wave energy environments
- Wave bores enhance flood-currents, retard ebb-currents
- Result in a net landward movement of bar features

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**FitzGerald & Kraus Bypassing Models**

- As swash bars move up shoreface (beach face), they gain greater intertidal exposure
- This results in a decrease in the rate of shoreward migration because there is less time for the combined influence of wave and flood-tide currents to force their onshore movement
- The swash bars begin to stack up and coalesce into a much larger bar feature
Bar complex formation and landward migration over an eighteen month period

Resulting bar complexes can be quite large, and the overall bypassing process can take several months to even years before the sediment is welded to the downdrift shoreline.

- Throat position is fixed, however main channel is deflected due to wave driven transport and currents
- Spill-over channels bisect the bank of the main channel
- Eventually deflected channel becomes unstable and flow is forced through spill-over channel
- Bars downdrift of the new channel coalesce in inter-tidal zone
- Larger bar system welds to downdrift shorelines

Process similar to ebb delta breaching model except deflection occurs on the outer (distal) reaches of the channel, over a shorter time period, and resulting bar complexes are smaller.

Similar to Channel Migration and Spit Breaching model except the spit breaches through the spit platform (which is the area of active deposition and welding of ridges and bars).
- Wave generated currents drive the majority of sediment transport around the perimeter of the ebb-shoal complex.
- Wave dominated inlets tend to have flattened ebb-shoal complexes.
- Often inlet is unstable, requiring dredging and engineering structures to maintain the opening.

**Natural Sediment Bypassing (Brun & Gerritsen, 1959)**

\[ r = \frac{P}{M_{tot}} \]

- \( r \) = bypassing ratio
- \( P \) = spring tidal prism
- \( M_{tot} \) = gross littoral transport to the inlet

- \( r < 20 \) = unstable inlet; inlet may be closed occasionally during a storm event because the tidal prism is relatively small
- \( r = 20-50 \) = inlet with many bars (typical wave-dominated bar-bypassing system) and highly changeable channels; inlets are relatively unstable and dredging/structures are often required
- \( r = 50-150 \) = inlet with well-developed ebb delta and one or more channels (bar and flow-bypassing system, mixed energy)
- \( r > 150 \) = inlet is typical flow-bypassing system (tide-dominated); stable

**Barrier Island Types, Relation to Bypassing**

- Overlapping Barrier
- Updrift Offset Barrier
- Downdrift Offset Barrier
- Negligible Offset Barrier
**Sub-Classification of Barriers**

- Drumstick Barrier = Downdrift Offset Barrier

**Formation of Drumstick Barrier**

Complex wave refraction pattern around ebb-shoal leads to transport reversal at the attachment point.

*Note: Not as frequent for engineered or structured inlets*

**Equilibrium, Tidal Inlet Relationships**

- Inlets are evolving toward a dynamic state of equilibrium.
- Initial rate of growth of ebb and flood shoals complexes is rapid.
- The growth rate decreases as inlets develop more permanent morphologic features and establish bypassing pathways.
- The time it takes the inlet to reach equilibrium depends on the tidal prism, wave climate, and anthropogenic influences on the system (mainly dredging).
- As sea level rises can dynamic equilibrium be obtained?
Cross-Sectional Area and Tidal Prism Relationship, Jarrett, 1976

\[ Ac = C*P^n \]

- \( Ac \) = minimum cross-sectional area (m²)
- \( P \) = tidal prism (m³)
- \( C \) and \( n \) = correlation coefficients (jetties)

<table>
<thead>
<tr>
<th>Location</th>
<th>( C )</th>
<th>( n )</th>
<th>( Ac )</th>
<th>( Prismatic )</th>
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<tbody>
<tr>
<td>All Inlets</td>
<td>1.57 x 10⁻⁴</td>
<td>2.94</td>
<td>1.09</td>
<td>7.44 x 10⁻³</td>
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<tr>
<td>Hummock Inlet</td>
<td>3.03 x 10⁻⁴</td>
<td>2.30</td>
<td>1.97</td>
<td>1.54 x 10⁻³</td>
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<tr>
<td>Gulf Coast</td>
<td>9.21 x 10⁻⁴</td>
<td>0.84</td>
<td>0.86</td>
<td>1.0 x 10⁻⁴</td>
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<tr>
<td>Point Reyes</td>
<td>2.93 x 10⁻⁴</td>
<td>0.91</td>
<td>1.19</td>
<td>1.01 x 10⁻⁴</td>
</tr>
</tbody>
</table>

Walton and Adams, Ebb-Shoal Volume

Determined a relationship between tidal prism (P) and the volume of sand contained within the ebb-shoal complex for inlets in equilibrium.

\[ V_{ebb} = C*P^n \]

- \( V_{ebb} \) = volume of equilibrium ebb shoal yd³
- \( P \) = tidal prism (ft³)
- \( C \) and \( n \) = correlation coefficients based on energy regime

\[ H_s^2T^2 \]

- \( H_s \) = significant wave height
- \( T \) = significant wave period

For mildly exposed coast:
- \( H_s^2T^2 \leq 30 \)
- \( C = 45.7 \)
- \( n = 1.28 \)

For moderately exposed coast:
- \( 30 < H_s^2T^2 \leq 300 \)
- \( C = 40.7 \)
- \( n = 1.28 \)

For highly exposed coast:
- \( H_s^2T^2 > 300 \)
- \( C = 33.1 \)
- \( n = 1.28 \)

Prism = 3.29 x 10⁷ m³
Wave Climate; \( H = 1 \) m, \( T = 7 \) s, SE

Walton and Adams, Ebb-Shoal Volume

\[ C, n = \text{correlation coefficients based on energy regime} \]

\[ H_s^2T^2 \]

- \( H_s^2T^2 \leq 30 \) = mildly exposed coast
- \( 30 < H_s^2T^2 \leq 300 \) = moderately exposed coast
- \( H_s^2T^2 > 300 \) = highly exposed coast

- \( n = 1.23 \)
- \( C = 13.8 \times 10^{-5} \) for mildly exposed coast
- \( C = 10.5 \times 10^{-5} \) for moderately exposed coast
- \( C = 8.7 \times 10^{-5} \) for highly exposed coast

Shinnecock Inlet approximately 60 % of equilibrium volume. Attain equilibrium in ~ 75 years (Kraus, 2001). Dredging of the ebb-shoal will setback the evolution of the inlet.

Prism = 3.29 x 10⁷ m³
Wave Climate; \( H = 1 \) m, \( T = 7 \) s, SE

moderately exposed inlet

\[ C = 10.5 \times 10^{-6} \] and \( n = 1.23 \)
equilibrium ebb-delta volume = 11,200,000 m³.
1998 (6,463,000 m³) (Morgan, 1999).

Dredging of the ebb-shoal will setback the evolution of the inlet.