Tidal Inlet Protection Strategies (TIPS) Field Guide

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Contents

Field Guide for Tidal Inlet Protection Strategies (TIPS)

Introduction

Tidal inlets occur along most barrier coasts and therefore these dynamic systems must be considered separately when designing an overall strategy for oil coming towards the coast. Inlets are the gateways that can allow oil to enter extensive, sensitive marsh, mangrove and sheltered tidal flats environments that dominate backbarrier lagoons, bays, and estuaries. Reversing tidal flow, wave-current interaction, and periodic exposure of tidal sand bodies make advance planning a necessity if oil is to be contained. Important attributes of tidal inlets and how these relate to the development of response strategies are provided below.

- Tidal currents dominate areas adjacent to the inlet throat and inside the inlet, whereas the shoals seaward of the inlet are dominated by waves and wave-generated currents.
- Currents at tidal inlets can reach high speeds where the entire tidal prism must flow through the narrow channel.
- Flooding tides can transport oil into bays and lagoons and surrounding sensitive tidal flat, marsh, and mangrove habitats.
- Response operations at tidal inlets face numerous challenges, the most important of which are the constantly changing water depths and reversing current directions. At large inlets, wind-generated currents also can affect oil transport.
- Recognition of the morphological features of an inlet system enables planners and responders to understand how water depth and current pattern change through the tidal cycle.
- Determination of morphological features and current patterns provide the basis for selecting realistic and practical response strategies for minimizing oil transport through an inlet during flooding tides.
- With a basic understanding of the hydrology and morphology of a tidal inlet and dedication of resources, it is possible to implement a number of protective actions which can mitigate risk and reduce oil spill impacts.

How to Use This Guide

This field guide is intended to be used by strategic planners and responders with the <u>purposes</u> of:

- explaining the physical dynamics and characterization of a tidal inlet,
- identifying oil transport and operational constraints and opportunities for tidal inlet protection,
- identifying potential strategies for protection,
- providing considerations and checklists for tidal inlet protection.

This Field Guide is divided into the following four parts.

PART 1: Physical Character of Tidal Deltas

PART 2: Planning

PART 3: Strategy and Tactics Selection

PART 4: Checklists

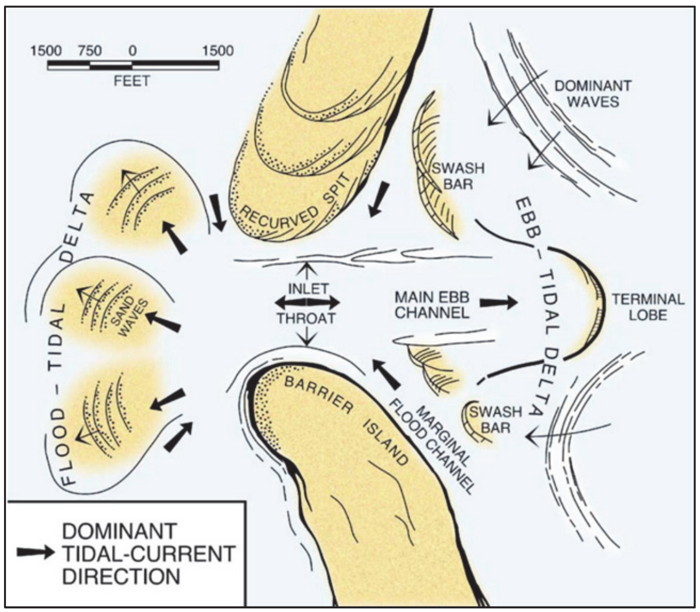
<u>First-time users should turn to the checklists on pages 25 and 26 which run through the steps required to select options for a response operation with reference to the relevant sections of this Field Guide.</u>

PART 1: Physical Character of Tidal Deltas

Tidal Deltas and Their Importance and Challenges for Protection

Tidal inlets are found on shorelines worldwide and form a connection between the open ocean and environmentally sensitive sheltered bays, lagoons, marshes and tidal creeks. Tidal inlets are complex and dynamic systems that include ebb and flood tidal deltas on either side of an inlet throat. These systems provide pathways for oil to enter sheltered back-bay tidal flats, marshes and mangroves (bay-lagoon complex) and are critical control points for protection of these sensitive and vulnerable environments. Currents generated by the tidal exchange between the ocean and bay or lagoon maintain the main channel of a tidal inlet. The currents slow as the main channel (the “inlet throat”) widens on either side of the inlet and deposit sediment to form shoals or underwater deltas.

The character of a tidal inlet results from a combination of geologic and oceanographic factors that include wave action, tidal range, the tidal prism in the bay or lagoon, freshwater input to the bay or lagoon, sediment availability, and alongshore sediment transport. The tidal prism is defined as the open-water area of the bay, lagoon or marsh and tidal creek system multiplied by the tidal range.



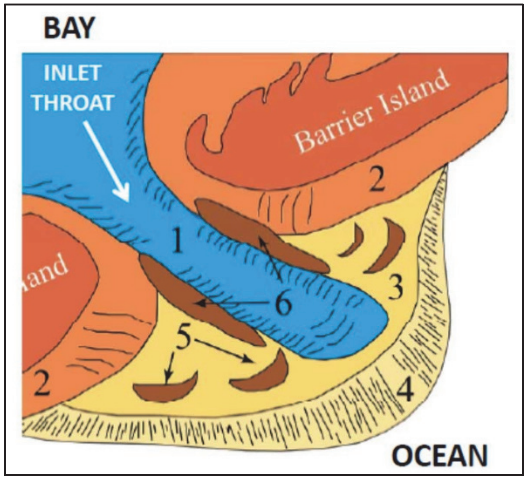
The key challenges that planners and responders face include:

- high current velocities in channels and wave-induced currents across ocean-side shoals;
- constantly changing patterns of shoals and channels that are controlled by the balance between wave and tidal forces and bay geometry;
- intertidal areas that are often wide and alternately exposed and submerged during each tidal cycle; and
- current reversals approximately every 6 or 12 hours, depending on the type of tide.

How to Recognize the Components of a Tidal Inlet: Ebb Delta

The Ebb Delta

- Is a shoal built seaward by sand deposition as ebbing tidal waters slow and expand after passing through the constricted inlet throat.
- Can be intertidal or subtidal.
- May limit boat or boom deployment operations due to waves breaking across shoals.
- At tide-dominated inlets, tends to be elongated with a main ebb channel and channel margin linear bars that extend far offshore.
- At wave-dominated inlets (such as that shown in the adjacent photograph), tends to be comparatively small with sediment shoals driven onshore, close to the inlet mouth, by the dominant wave processes. Often subtidal or have several major and minor tidal channels.
- At mixed-energy inlets, typically have a well-formed main ebb channel boarded by a broad swash platform and sand bodies that widely overlap the adjacent inlet shoreline.



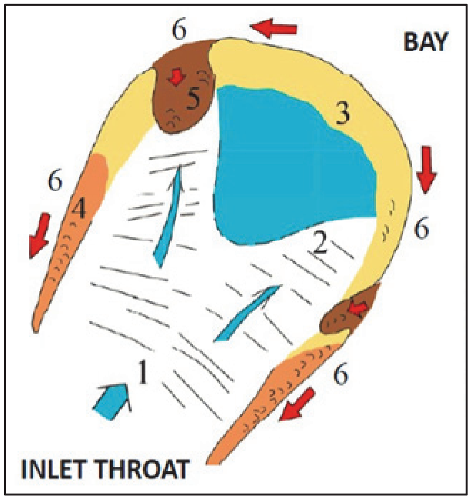
Ebb Delta Components

1. **Main Ebb Channel** is a narrow and relatively deep channel formed between two sand barriers adjacent to the inlet throat.
2. **Marginal Flood Channels** flank the main ebb channel close to the shoreline, and are the first tidal waters to enter the inlet even as flow continues to ebb in the main channel.
3. **Swash Platform** is a broad, shallow platform located on both sides of the main ebb channel.
4. **Terminal Lobe** is formed by reworked sediment deposited at the terminus of the main ebb channel.
5. **Swash Bars** are formed by sediment migrating landward by wave action.
6. **Channel Marginal Linear Bars** border the main ebb channel and sit above the swash platform.

How to Recognize the Components of a Tidal Inlet: Flood Delta

The Flood Delta

- Forms in sheltered waters as sediment is deposited by the flooding tides due to slowing of the current as the channel widens and flow expands after passing through the narrow inlet throat.
- Contains exposed shoals at low tide, but is largely or completely submerged in the late-flood stage.
- When backed by a system of tidal channels, tidal flats, and salt marsh, is usually a single horseshoe-shaped delta.
- When backed by large shallow bays, may contain multiple flood-tidal deltas.
- Commonly increases in size as the tidal prism increases and as the amount of open water area in the back barrier increases.
- Have, in some regions, become colonized and altered by marsh growth and are no longer recognizable as former flood-tidal deltas.

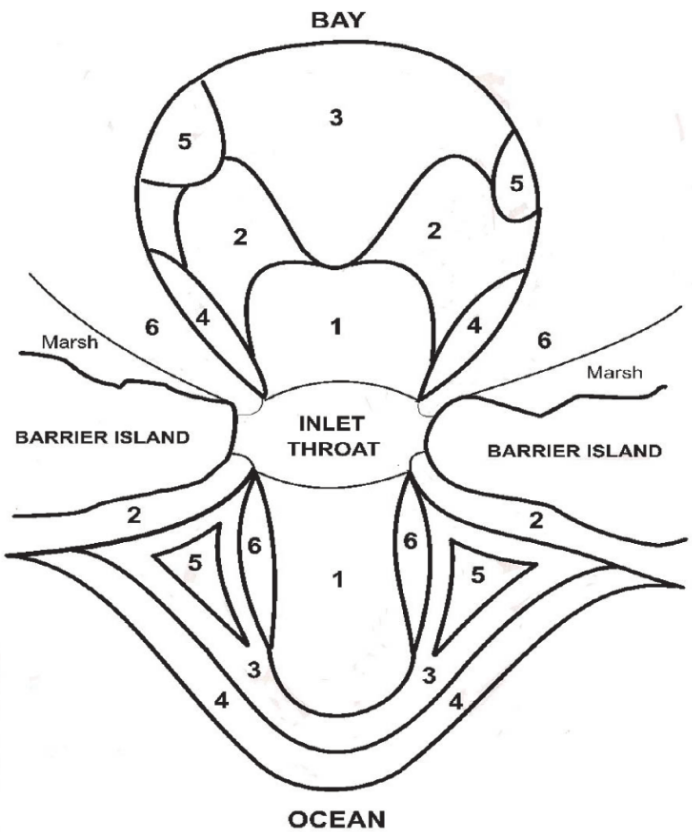


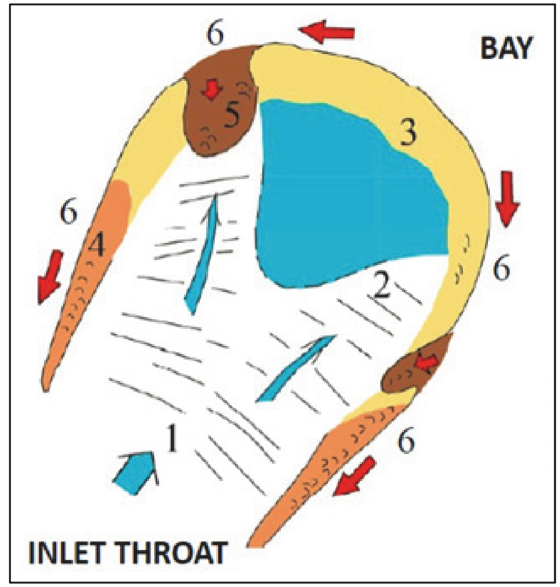
Flood Delta Components

1. **Flood Ramp** is formed by sheet-like lobes of deposited sand with landward sloping ramps on their seaward sides covered by landward migrating waves of sand
2. **Flood Channels** allow water flow only during the late-flood stage (blue arrows) and at high tide
3. **Ebb Shield** deflects ebb flow to marginal channels after high tide (red arrows)
4. **Ebb Spits** are created by sediments being carried seaward by ebb currents
5. **Spillover Lobes** are formed by deposited sand where ebb currents have breached the ebb shield or ebb spits
6. **Marginal Channels** allow water to enter the bay or lagoon between late ebbing and early to flooding stages

The Thirteen Physical Components of a Tidal Delta (Including the Inlet Throat)

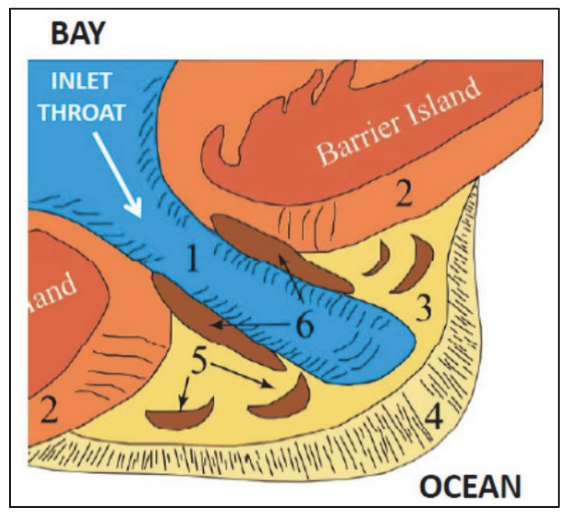
This tidal inlet schematic is used as a template for interpreting tidal inlet morphology. See page 8 for further details.





Flood Tidal Delta

1. Flood Ramp
2. Flood Channels
3. Ebb Shield
4. Ebb Spits
5. Spillover Lobes
6. Marginal Channels



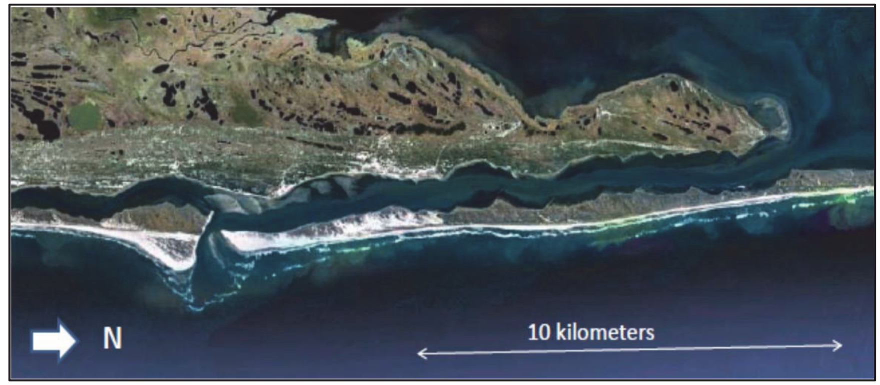
Ebb Tidal Delta

1. Main Ebb Channel
2. Marginal Flood Channels
3. Swash Platform
4. Terminal Lobe
5. Swash Bars
6. Channel Marginal Linear Bars

Other Features of a Tidal Delta

Overlapping and Offset Inlets

- Overlaps can develop where there is a sufficient sand supply and a strongly dominant direction of wave approach and longshore transport.
- At stable inlets, the tidal prism maintains a permanent main channel, forcing sand to bypass the inlet along the ebb-tidal delta shoals.
- Although overlapping inlets are stable in the short term (months to years), the up-drift barrier spit may be breached during storms to create a new inlet; the original inlet may close as the tidal prism is reduced by this new exchange pattern; the new inlet may migrate along shore as part of a long-term (decades) cycle of breaching and inlet migration.
- A prevailing or dominant wave approach direction frequently creates an offset as waves refract around the delta: this results in a down-drift offset as the beach progrades seaward (see adjacent image).

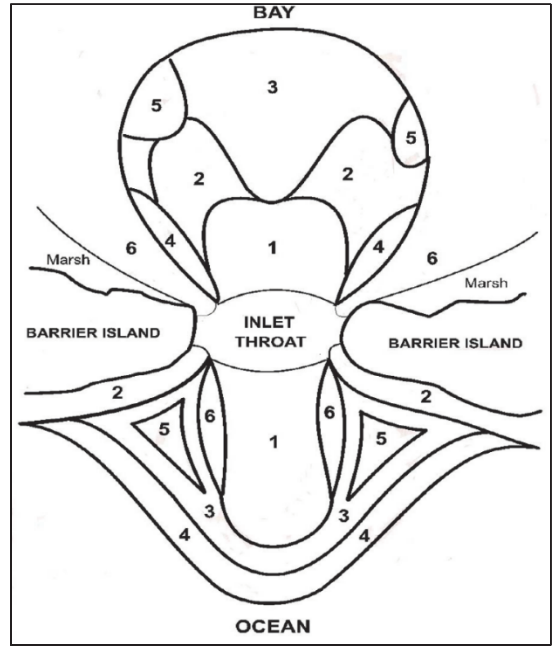


Man-Modified Tidal Inlets

- On the ocean coasts the primary human impact is associated with jetty construction, or dredging, or a combination of both.
- This type of coastal engineering work is intended to enhance navigation by stabilizing the inlet shoals or maintaining a specific channel depth.
- Most of these changes are long-term (years) and can result in alteration of both the ebb and flood-tidal delta components.
- Typically a jetty interrupts the alongshore transport of sand to the inlet channel – the result is a build-up of sand on the up-drift beach and coincident erosion on the down- drift beach where the sand supply is reduced or cut off.
- Typically the construction of jetties results in more concentrated tidal flow that moves the ebb-tidal delta seaward.
- In some instances the interruption of natural sand bypassing has been offset by pumping sand from the prograding up-drift to the eroding down-drift beach.
- In back-bay environments the construction of barriers, such as causeways, and filling or dredging can significantly alter the tidal prism and natural sand transport system by changing prism volumes and tidal channel configurations.

Template to Summarize the Physical Character of a Tidal Inlet (1)

Effective response strategies require that planners and responders recognize typical changes in depth and current patterns at an inlet through a tidal cycle. The following form may be used as a template to identify which of the physical components are present at an individual inlet. This template is designed as a checklist to provide the basic information to define and describe the physical character of an inlet system. Although not every inlet has the symmetry and character of the generic models shown in this Field Guide such as the diagram on this page (numbered components are explained on pages 4 to 6), most inlets have most if not all of these components. The following are key steps for completing the template.



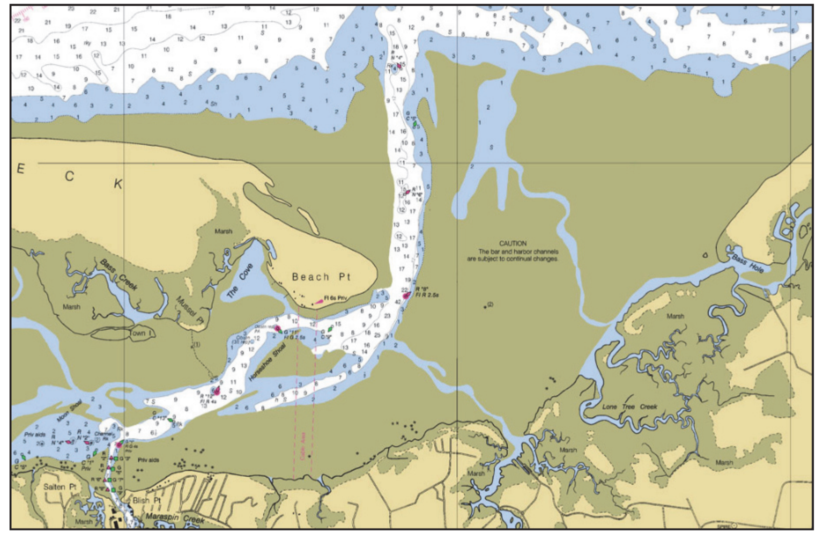
- The first boxes in the template (A, B and C) are completed based on readily available information on location and tides.
- The inlet character (Box D) is based on the points on page 7, and would be entered as a straightforward YES / NO.
- The availability of current data would be entered with a reference to the source of that information.
- "Operational Difficulty" can be referenced to page 18.
- Inlet throat width and depth data (Box E) typically can be measured from nautical charts or estimated from oblique/vertical images.
- The individual ebb- and flood-tidal delta features listed in Box E are based upon the morphological components defined on pages 4 and 5, respectively, and a YES / NO would indicate that component is present/absent and has been identified for the inlet.

This identification process is important as changes in water depth and current patterns during the different stages of the tide are closely linked to the morphological features. The schematics used in this Field Guide indicate the relative location and size of each of the ebb- and flood- tidal delta features, although the actual locations and sizes of these components may vary considerably from one inlet to another, in particular between wave- and tide-dominated environments. This information can be used to identify appropriate locations within the inlet system where boom and recovery systems can be deployed most effectively.

Template to Summarize the Physical Character of a Tidal Inlet (2)

<table>
<tr><td colspan="6">A. Inlet Name</td></tr>
<tr><td colspan="4" rowspan="2">B. Tidal Range: (from tidal predictions)</td><td>Average Range</td><td>Spring Range</td></tr>
<tr><td>m</td><td>m</td></tr>
<tr><td colspan="6">Tidal Period: Diurnal Tide ____________ Semidiurnal Tide _________ Mixed Diurnal/Semidiurnal Tide ___________</td></tr>
<tr><td colspan="6">C. Location of Inlet Throat</td></tr>
<tr><td colspan="3">Latitude:</td><td colspan="3">Longitude:</td></tr>
<tr><td colspan="6">D. Inlet Character (circle as appropriate)</td></tr>
<tr><td>Straight beach</td><td>Offset</td><td>Overlap</td><td>Jetty/ies</td><td>Rip Rap Armor</td><td>Bridges</td></tr>
<tr><td colspan="2">Current Data Available?</td><td>Y / N</td><td colspan="3">Source:</td></tr>
<tr><td colspan="6">Operational Difficulty</td></tr>
<tr><td colspan="6">E. Inlet Components</td></tr>
<tr><td>INLET THROAT</td><td colspan="2">Width m</td><td colspan="3">Depth m</td></tr>
<tr><td colspan="3">EBB-TIDAL DELTA SYSTEM</td><td colspan="3">FLOOD-TIDAL DELTA SYSTEM</td></tr>
<tr><td colspan="2">1. Main Ebb Channel</td><td></td><td colspan="2">1. Flood Ramp</td><td></td></tr>
<tr><td colspan="2">2. Marginal Flood Channels</td><td></td><td colspan="2">2. Flood Channel(s)</td><td></td></tr>
<tr><td colspan="2">3. Swash Platform</td><td></td><td colspan="2">3. Ebb Shield</td><td></td></tr>
<tr><td colspan="2">4. Terminal Lobe</td><td></td><td colspan="2">4. Ebb Spit(s)</td><td></td></tr>
<tr><td colspan="2">5. Swash Bars</td><td></td><td colspan="2">5. Spillover Lobes</td><td></td></tr>
<tr><td colspan="2">6. Channel Margin Linear Bars</td><td></td><td colspan="2">6. Marginal Channels</td><td></td></tr>
</table>

How to Use a Chart to Map the Components of a Tidal Inlet



1. Use the most recent and detailed nautical chart that is available to analyze water depth data.

2. To define the morphology of the shoreline and sea bed, draw in red or black on the chart:

   - the High Water (HW) shoreline: the area above the HW is tan on most charts;

   - the Low Water (LW) shoreline: this is the chart datum: the zone between HW and LW is colored green on most charts. Chart datum in the US is defined as the "mean lower low water" which is typically the Spring Low Tide water level that occurs during the full and new moons; and

   - any depth contours marked below LW: the contours typically are given in feet, fathoms (1 fathom = 6 feet) or meters, but the unit of depth measurement is in itself not important: on many charts the area between LW and the first depth contour is colored light blue, but this can vary and there can be more than one shade of blue depending on the scale of the chart.

3. If a graphic scale is not provided on the chart, use the latitude scale on the right or left chart margin.

   - One (1) minute of latitude = 1 nautical mile = 6,076 feet = 1.15 miles = 1852 meters = 1.852 kilometers

   - 10 seconds of latitude = 308 meters or 1013 feet

4. Locate and mark on the chart the six ebb and the six flood tidal delta components shown on pages 4 to 6, as demonstrated on the charts on page 12.

5. Document the presence or absence of these components in the template provided on page 9.

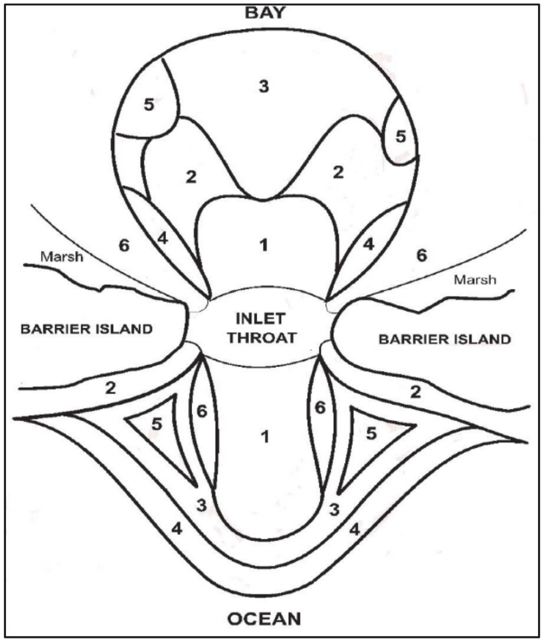
6. Locate and highlight on the chart access or staging areas (e.g. roads, tracks or parking lots).

7. Look up the average and spring tidal range for the location from published tidal predictions ("large" or "spring" tides occur at time of a full and new moon: "neap" tides occur 7 days after the full and new moon).

8. If you need to look up the meaning of symbols or abbreviations on a chart, refer to: http://www.nauticalcharts.noaa.gov/mcd/chart1/ChartNo1.pdf

9. Review information in the Coastal Pilots: http://www.nauticalcharts.noaa.gov/nsd/cpdownload.htm

How to Use an Image to Map the Components of a Tidal Inlet



Oblique Aerial Photographs or Video Frames

1. Oblique aerial photographs are sometimes the least valuable images because light reflection from the water surface can obscure underwater features (see photograph on page 1).

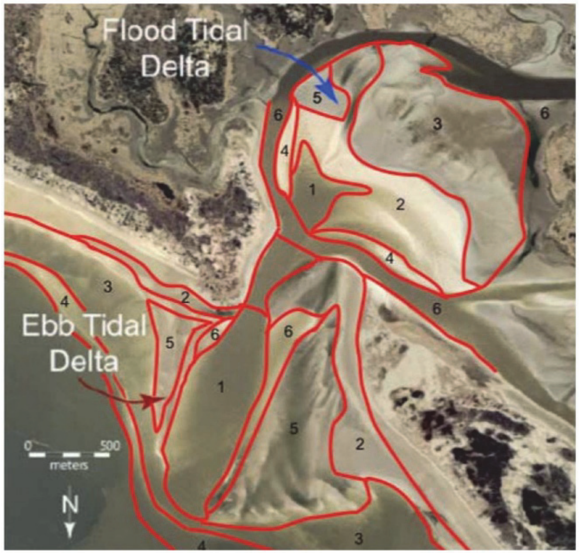
2. Take or use photos obtained during the low tide slack with the sun behind the observer. The photograph on page 4 is an oblique photograph taken at low tide so that shoals and channels are easily identified.

3. Try to identify the time the photo or video was taken and compare to the nearest predicted tidal elevation at that time.

4. Locate and mark on the chart the six ebb and the six flood tidal delta features shown on pages 4 and 5. Document the presence or absence of these components in the template on page 9.

5. Breaking waves or lines of white caps are a good indicator of shoal patterns (see photo on page 1).

Vertical Photographs or Satellite Images



1. View at the best resolution possible.

2. Try to identify the time the photo or image was taken and compare to the nearest predicted tidal elevation at that time.

3. Locate and mark on the chart the six ebb and the six flood tidal delta features shown on pages 4 and 5, as demonstrated in the adjacent annotated image. Document the presence or absence of these components in the template provided on page 9.

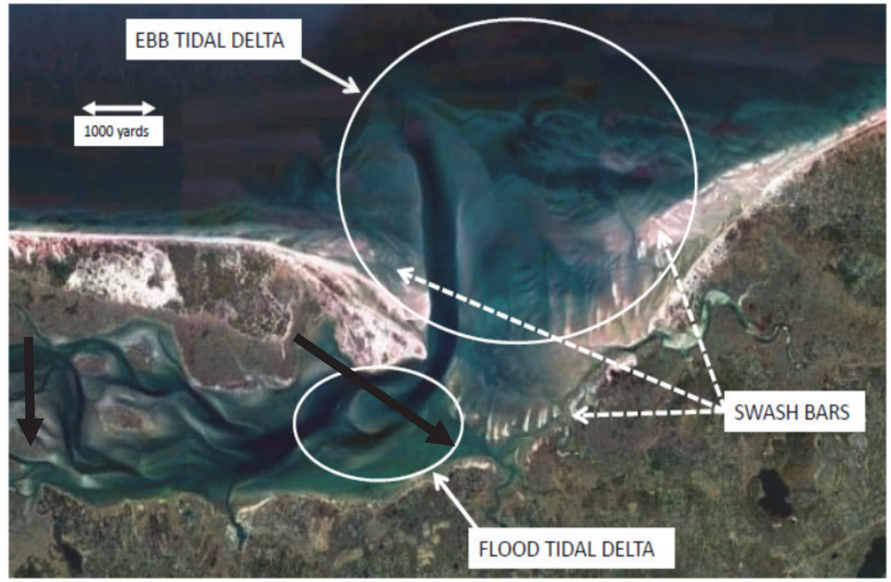
4. Breaking waves or lines of white caps are a good indicator of shoal patterns (see photo on page 1).

The example on this page shows an interpretation of the ebb and flood tidal delta components at the Essex River inlet, MA from satellite imagery. The physical components can be easily compared with the model above (numbered components are explained on pages 4 to 6).

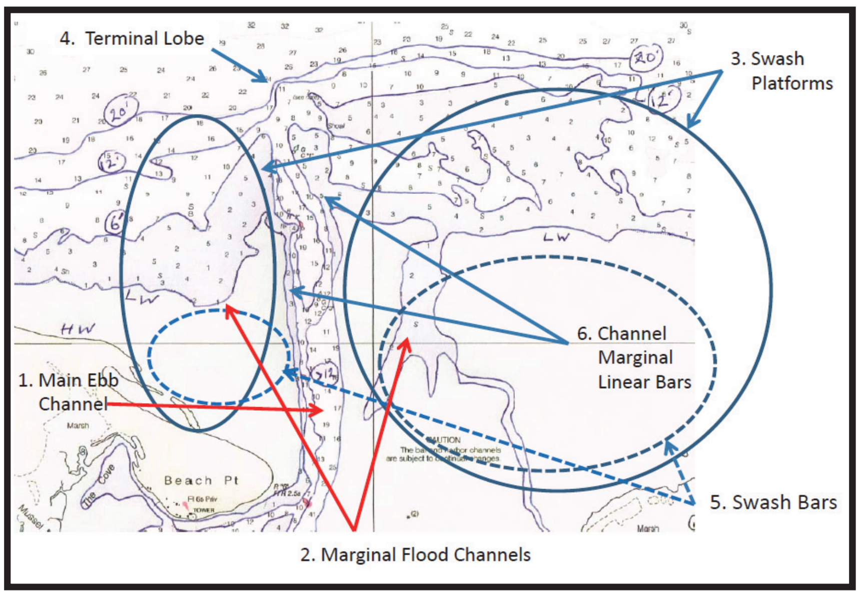
How to Map the Components of a Tidal Inlet

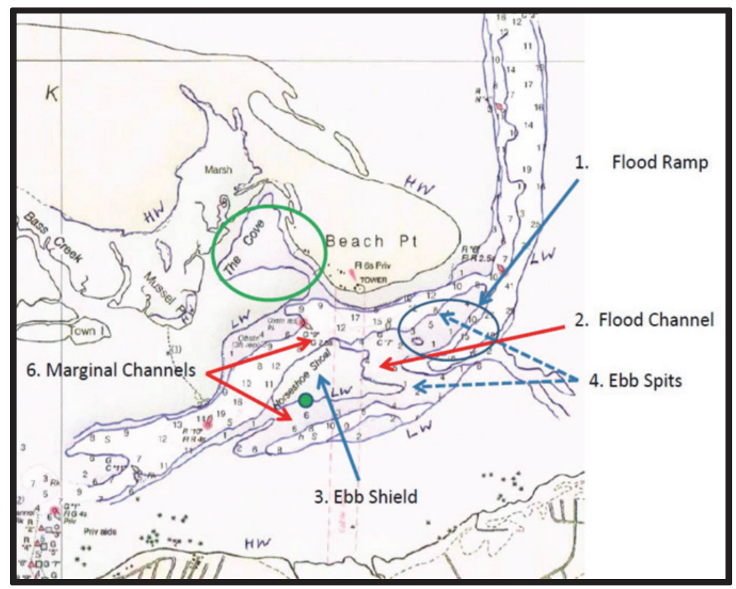
Note – this is the same location as the chart on page 11

First:
Define the major features of the inlet (right)



Then:
Identify the individual physical geographic components (below)





PART 2: Planning

Operational Controls

- One of the most challenging operational aspects of spill response activities at a tidal inlet is to plan for the constant changes in water depth and current flow intensity and direction. See pages 14, 15 and 16 for typical water depths and current patterns during different stages of the tidal cycle.

- Operational practicality and feasibility depend to a large degree on water depths and current velocities and the operating requirements of the response equipment. Ideally, the water depth would be Moderate or Deep (>1 m or 3 feet) and currents would be Weak or Slack (<0.5 m/s: <1 knot). See the table on page 18 for additional factors for operational difficulty.

- Exclusion strategies such as exclusion booming are probably impractical and rarely successful once oil reaches an inlet. The only circumstances where such actions may be feasible involve construction of dams and possibly booming at narrow inlets with small tidal prisms.

- Flow (current) reversals typically require redeployment every tidal change i.e. every 6 (semi-diurnal) or 12 hours (diurnal).

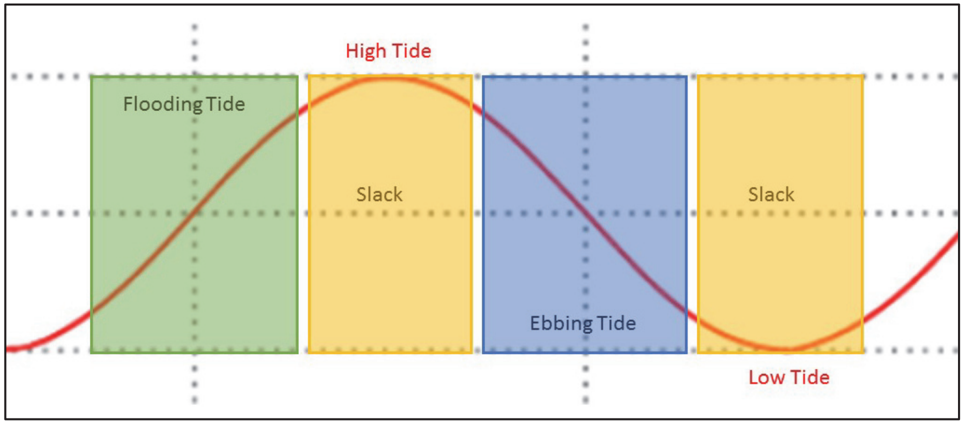
- Ebbing tides keep oil out of the inlet, but oil is transported into the inlet on a flooding tide. See page 17 for oil transportation considerations.

- The key period for potentially successful response is the Low Tide through High Tide window, which may last 6 to 9 hours where tides are semi-diurnal, or 12 to 15 hours where tides are diurnal.

- The terms "low tide" and "high tide" refer to the slack-water periods that occur immediately before and after the tide reverses (see diagram at right of tidal water levels).

- Each "low" and "high" tide slack-water period lasts for approximately 2 hours.

- Typical semi-diurnal tides have ebb and flood tide periods on the order of 3 hours, though diurnal tides will run for a 9-hour period.

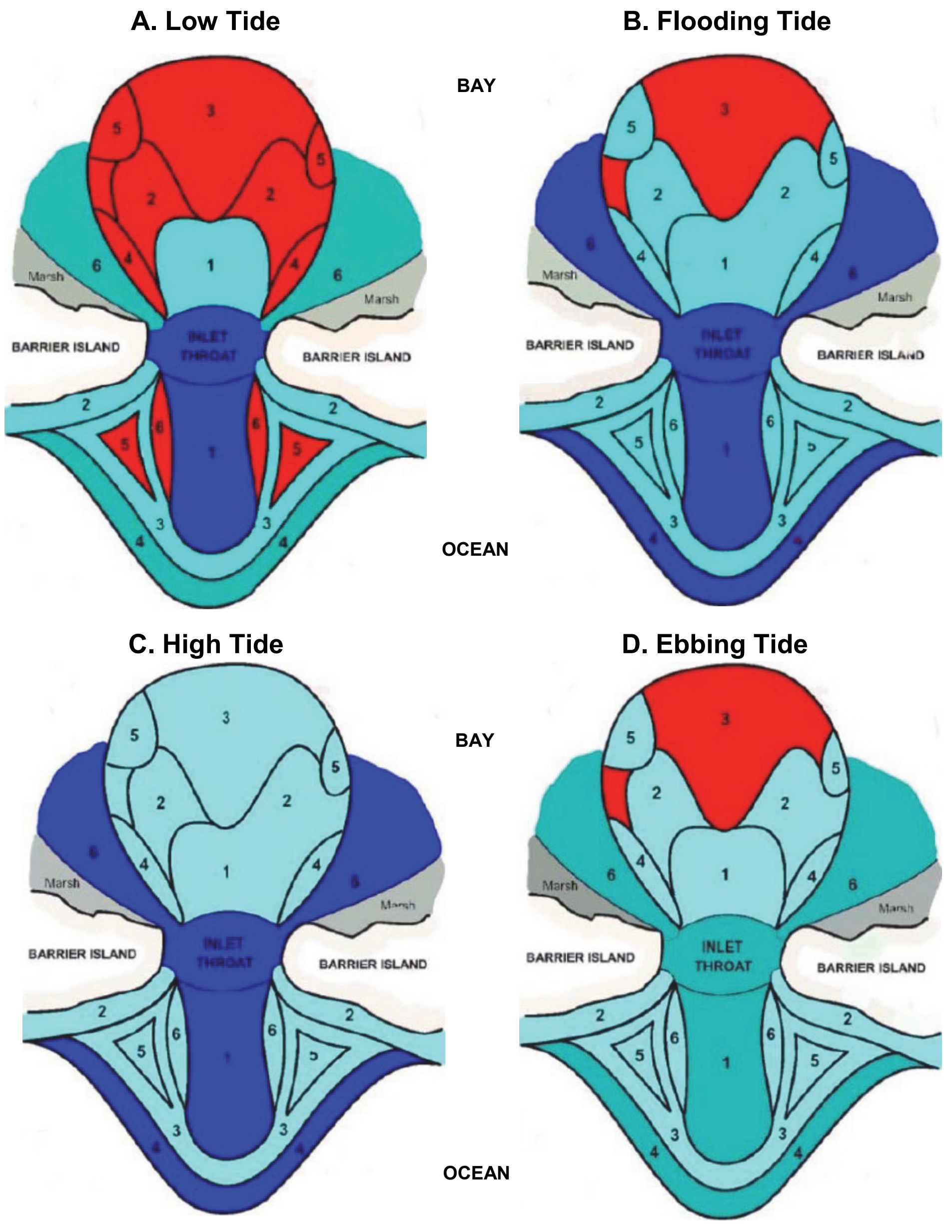


Typical Water Depths and Current Patterns at Different Tide Stages

NOTE During the ebbing tide, flow in the ebb delta marginal flood channels (*) may be towards the inlet if there is a strong outflow through the main channel.

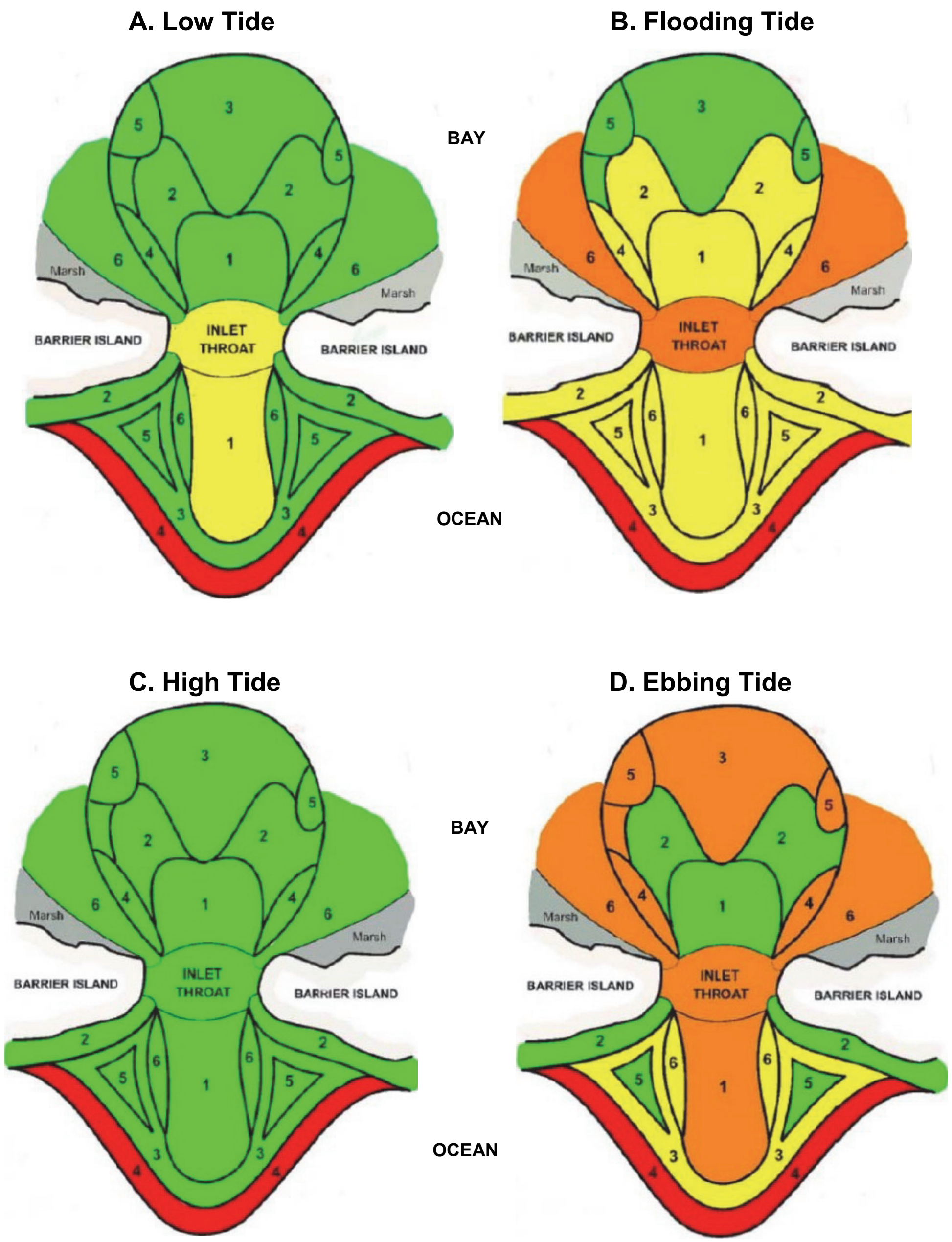
Inlet Feature	Low Tide	Flooding	High Tide	Ebbing
Bay Side: Flood Delta Area				
1 Flood Ramp	— Shallow to deep water — Slack or weak ebb	— Shallow to deep water — Moderate flood	— Moderate to deep water — Slack or weak flood	— Shallow to deep water — Slack or weak ebb
2 Flood Channels	— Exposed to shallow water — Slack	— Shallow water — Moderate flood	— Moderate water — Slack or weak flood	— Shallow water — Slack or weak ebb
3 Ebb Shield	— Exposed — Slack or weak ebb	— Exposed to shallow water — Slack or weak flood	— Moderate water — Slack or weak flood	— Exposed to shallow water — Strong ebb
4 Ebb Spits	— Exposed to shallow water — Slack or weak ebb	— Shallow water — Moderate or weak flood	— Moderate water — Slack or weak flood	— Shallow water — Strong ebb
5 Spillover Lobes	— Exposed to shallow water — Slack	— Shallow water — Weak flood	— Moderate water — Slack or weak wind-driven flow	— Shallow water — Strong or moderate ebb
6 Marginal Channels	— Moderate to deep water — Slack or weak ebb	— Deep water — Strong or moderate flood	— Deep water — Slack or weak wind-driven flow	— Deep water — Strong ebb
Inlet Throat Area				
Main Channel	— Deep water — Slack or weak ebb	— Deep water — Strong or moderate flood	— Deep water — Slack or weak flood	— Deep water — Strong ebb
Ocean Side: Ebb Delta Area				
1 Main Ebb Channel	— Deep water — Moderate ebb or slack	— Deep water — Moderate flood	— Deep water — Slack or weak flood	— Deep water — Strong ebb
2 Marginal Flood Channels	— Shallow water — Slack or weak ebb	— Shallow water — Moderate flood or weak wave-driven flow	— Moderate water — Slack or weak wind-driven flow	— Shallow water — Weak ebb or flood current*
3 Swash Platform	— Shallow water — Slack or weak ebb	— Shallow water — Moderate flood	— Moderate water — Slack or weak wave-driven flood	— Shallow water — Moderate or weak ebb
4 Terminal Lobe	— Moderate to deep water — Slack or weak ebb — Zone of breaking wave action	— Deep water — Moderate flood — Zone of breaking wave action	— Deep water — Slack — Zone of breaking wave action	— Deep water — Moderate ebb — Zone of breaking wave action
5 Swash Bars	— Exposed to shallow water — Slack or weak wave-driven flow	— Shallow water — Moderate or weak flood	— Moderate water — Slack or weak wave-driven flow	— Shallow water — Weak ebb
6 Channel Margin Bars	— Exposed to shallow water — Slack or weak ebb	— Shallow water — Moderate flood	— Moderate water — Slack or weak wave-driven flow	— Shallow water — Moderate ebb

Set of Schematic Diagrams to Show Typical Water Depths at Different Tide Stages



Legend: Water Depths
Deep water: depths typically greater than 2 m (>6 feet)
Moderate water: depths typically 1-2 m (3 to 6 feet)
Shallow water: depths typically less than 1 m (<3 feet)
Exposed: above the water level (intertidal)

Set of Schematic Diagrams to Show Typical Current Patterns at Different Tide Stages



Legend: Currents and Waves
Slack water: little or no current
Weak: tidal current typically less than 0.5 meter/second (<1 knot)
Moderate: tidal current typically 0.5 to 1 meter/second (1 to 2 knots)
Strong: tidal current typically greater than 1 meter/second (>2 knots)
Zone of breaking waves

Oil Transport Considerations

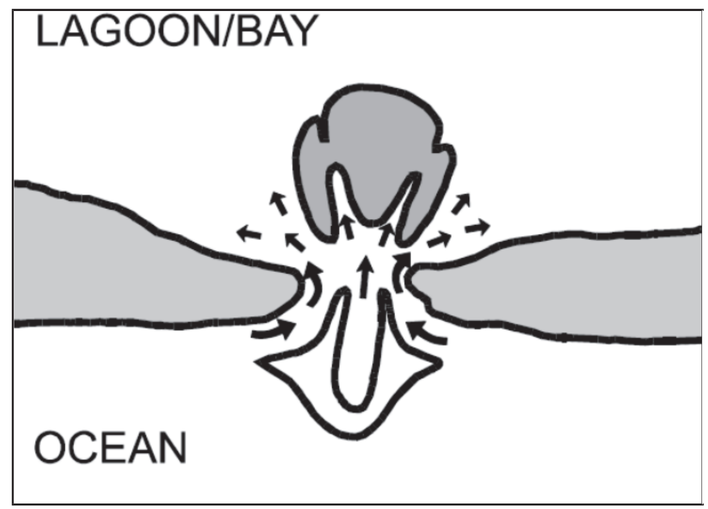
Three stages of the tide are important for considering **oil transport** from a slick approaching an inlet:

A. Ebb Tide and Low Tide Slack.

- During the ebb tide stage, water flows out of the inlet throat until the water levels on the ocean and the lagoon or bay sides are the same.
- This outflow may continue after the low-tide is reached in the ocean, a period lasting for 1 to 2 hours into the early stages of the rising flood tide, and delaying the movement of water into the bay or lagoon.

B. Early and Mid Flooding Tide.

- During the first half of the flood tide stage, flow into the bay or lagoon is confined to marginal flood channels on both sides of the ebb-tidal delta.
- Water entering the bay flows around the flood delta shoal (see adjacent figure showing tidal currents during the early and mid-flood stage).



C. Late Flooding Tide.

- During the second half of the flood tide stage, water levels rise and water flows through the channels and across the ebb-tidal shoal into the inlet. Water entering the bay flows around and over the flood-tidal delta.
- Flood currents are likely to be strongest during the 2-hour period around mid-tide when water levels are still relatively low and flow is largely confined to the marginal channels.

Factors Affecting Operational Difficulty at Tidal Inlets

Operational Difficulty	Inlet Width	Inlet Depth	Tidal Prism	Tidal Currents	Back Bay Character	Wave Exposure	Preferred Flood Tide Tactics[1]
Very Difficult: limited potential for success	Wide	Shallow	Large	Strong (>1 knot)	Wetlands	Exposed ocean shore	• Open-water deflection with ocean boom • Bay-side containment or deflection and recovery
Difficult: some potential for success							• Open-water deflection with ocean boom • Bay-side containment or deflection and recovery
Little Difficulty: good potential for success							• Bay-side containment and deflection boom with on water and/or shoreside recovery in channel
Not Difficult: very good potential for success	Narrow	Deep	Small	Weak (<0.5 kt)	Sand beaches	Sheltered ocean shore	• Bay-side containment and deflection boom with on water and/or shoreside recovery in channel • Dams, solid barriers

1 See API 2014, Tidal Inlet Protection Strategies: Phase 1 – Final Report. API Technical Report 1153-1 for Tactical Guidance Summaries for different response tactics at tidal inlets

Operational Opportunities and Constraints (1)

Operational Opportunities: Morphology, Currents and Natural Collection Areas

In terms of **opportunities** for equipment deployment, the locations where exists a combination of depths >1 m (3 feet) and weak or slack currents (<0.5 m/s: <1 knot) typically would be:

- Low Tide

  The main channel in the ebb tidal delta and the inlet throat have moderate to deep water and the currents are slack (after the outflow from the bay is completed).

- Flooding Tide

  The inlet throat and the marginal channels in the flood tidal delta have moderate or deep waters, although the currents may be moderate; elsewhere the waters typically are shallow until mid-tide or late in the flood cycle.

- High Tide

  Many areas have moderate to deep waters with slack currents, though the bay side usually would be more sheltered from wave action than the ocean side.

- Ebbing Tide

  Operations are typically not conducted during ebbing tides because the water flow prevents oil from entering the inlet. It might be possible, however, to contain and recover oil that may be flowing back out of the inlet during the ebb.

Planning for suitable diversion or collection locations involves considering the different spatial features described above within the inlet system as well as looking for quiet or slack water areas along the bay shores.

Natural collection areas can be identified in the field by debris accumulations. Assuming that floating oil would follow a path similar to floating debris, these zones typically are good indicators of where oil might accumulate naturally and may be useful as collection and recovery sites for oil diverted out of the adjacent channels.

Operational Opportunities and Constraints (2)

Operational Constraints: Water Depths, Channels and Accessibility

Understanding changes in water depth, current velocity and flow direction as presented on pages 13 and 14 identifies "areas of opportunity" but also identifies where specific tactics would be **constrained**.

Typically areas to avoid for conventional floating booms and recovery systems, in terms of water depth, and therefore access and deployment practicality, and of high current strength, and therefore boom or skimmer effectiveness, would be:

- Low Tide

  Access could be limited and boom deployment, other than shore-seal booms, constrained on the shallow or exposed swash bars and the shallow swash platform on the ebb delta and most of the flood channel, ebb shield and ebb spits on the flood-tidal delta. Breaking waves could limit practicality on the terminal lobe of the ebb delta.

- Flooding Tide

  Shallow areas on the flood channels, ebb shield and ebb spits on the flood-tidal delta could limit access during the first half of the flood. Currents typically are strongest in the inlet throat and the marginal channels of the flood-tidal delta, particularly around mid-tide.

- High Tide

  This is the period when access or deployment constraints would be at a minimum. Breaking waves could limit practicality on the terminal lobe of the ebb delta.

- Ebbing Tide

  Operations are typically not conducted during ebbing tides because the water flow prevents oil from entering the inlet.

Notwithstanding these constraints, tactics designed for use in fast currents (see Hansen and Coe, 2001) and equipment such as shore-seal boom can overcome some of these limitations.

PART 3: Strategy and Tactics Selection

Conventional strategies for protection and control of oil spills threatening tidal inlets include:

- Prevention of Oil from Entering the Inlet
    - Physical treatment or containment/recovery of floating oil offshore before it reaches the tidal inlet.
    - Physical exclusion of oil from the inlet by exclusion booming.
    - Redirection of oil moving alongshore by deflection booming around the inlet.
    - Closure of the inlet by construction of temporary dams or other physical barriers.
- Control Actions Within the Tidal Inlet System (Inlet Throat, Ebb and Flood Deltas)
    - Exclusion and deflection away from sensitive features or toward locations where control and recovery is feasible.
    - Diversion of oil to shorelines where control and recovery is feasible.
    - On water oil recovery.
- Control Actions Within the Interior Back Bay and Lagoon
    - Exclusion of floating oil from sensitive areas by booming.
    - Containment and recovery of oil in quiet water.

The selection and implementation of response strategies must recognize that the characteristics of tidal Inlets are highly variable and that the generic strategies are subject to inclement weather and oceanographic conditions, availability of appropriate equipment and trained response personnel, and other often unknown factors, and may not always be effective, practical, or safe. The strategic options, including advantages and limitations, are summarized in the table on page 22.

A Guide for the selection of candidate strategies based on the components of a generic tidal inlet during a flooding tide, when oil would be moving through the system towards a back-bay or lagoon environment, is presented on page 23. This Selection Guide is designed for the identification of those tidal inlet system components where various strategies may be feasible. The Guide provides summary information on minimum water depths, maximum current velocities, and probable presence of breaking waves. The Guide also identifies potential strategic options where appropriate for generic types of response actions. Strategies are intended for the control and recovery of surface oil and do not address subsequent cleanup at the shoreline.

Summary of Strategic Options

Strategy	Advantages	Limitations	Comments
Offshore on-water mechanical recovery, controlled burning, and dispersant application	Prevents oil reaching an inlet	Typically cannot recover or eliminate 100% of the oil	Guidance regarding offshore mechanical recovery, controlled burning and dispersant application are outside the scope of this study
Ocean-side exclusion booming	Prevents oil reaching an inlet	Feasibility and practicality decrease as inlet size, wave height and current velocity increase	Potential option for small inlets in relatively calm conditions
Ocean-side booms redirect oil toward the shore and/or away from the inlet for recovery	Prevents oil entering the main channel	Strong currents and/or breaking waves	Would likely require cascading booms in a difficult operating environment
Inshore mechanical recovery	Removes oil from further penetration into tidal inlet	Strong currents, tidally varying depths, and breaking waves	Fast water advancing skimmer required
Bay-side booms redirect oil toward the shore and/or away from the inlet for recovery	Sheltered wave environments	Strong current in inlet throat could entrain oil so some portion may enter bay subsurface	Potential effectiveness decreases with rising tide as oil can flow over central shoal
Dams to close surface flow through an inlet	Effective barrier	Window of opportunity before oil reaches inlet. Would require a nearby sediment source for dam construction	Potential option for small inlets in relatively calm conditions. May require underflow pipes to maintain circulation.
Protection and containment booms and barriers	Prevents oil from reaching sensitive areas	Limited to low current velocity areas, water depth requirements	Anchoring may be critical. Consider use of driven piles for anchoring.
Pile driven boom anchoring system	Provides stable anchoring in high current flow	Limited window of opportunity. Would require sliding bridles to adjust to changing water levels and maintenance for reversing currents	Little flexibility
Air bubble barriers	Effective for surface and submerged oil. Unaffected by changes in flow direction of water level changes	Limited window of opportunity for installation. Only effective in low currents	Not commonly used in dynamic environments.

Tidal Inlet Protection Strategy (TIPS) Candidate Selection Guide for All Tide Stages

Location/Inlet Feature		Water Depth Minimum (m)		Current Velocity Maximum (knot)		Breaking Waves	Strategy (Flood Tide)				
							Open Water Containment	Exclusion/ Deflection	Divert to Shore	Recovery	
		Ebb Tide	Flood Tide	Ebb Tide	Flood Tide					On Water	Shoreline
Back Bay (Lagoon)		Shallow	Moderate	Weak	Weak	N	x	x	x	x	x
Bay-Side (Flood Delta)	1. Flood Ramp	Shallow	Moderate	Weak	Moderate	**Y**		x			
	2. Flood Channels	Exposed	Moderate	Weak	Moderate	**Y**		x			
	3. Ebb Shield	Exposed	Moderate	Strong	Weak	N		x			
	4. Ebb Spits	Exposed	Moderate	Strong	Moderate	N		x			
	5. Spillover Lobes	Exposed	Moderate	Strong	Moderate	N		x			
	6. Marginal Channels	Moderate	Deep	Strong	Strong	N		x	x	x	x
Inlet Throat		Deep	Deep	Strong	Strong	N		x	x	x	x
Ocean Side (Ebb Delta)	1. Main Ebb Channel	Deep	Deep	Strong	Moderate	N			x	x	
	2. Marginal Flood Channels	Shallow	Moderate	Weak	Moderate	**Y**			x	x	x
	3. Swash Platform	Shallow	Moderate	Weak	Moderate	**Y**					
	4. Terminal Lobes	Deep	Deep	Moderate	Moderate	**Y**					
	5. Swash Bars	Shallow	Moderate	Moderate	Moderate	**Y**					
	6. ChannelMargin Bars	Exposed	Moderate	Moderate	Moderate	**Y**					
Coastal (Ocean)		Deep	Deep	Weak	Weak	N	x	x	x	x	x

X – Strategy may be feasible, depending on site conditions
Strategy unlikely to be feasible

Tactical "Rules of Thumb"

- **Not all conventional response equipment may perform adequately in the open coastline/tidal inlet environments**. The implementation of TIPS strategies and tactics may require specialized equipment (i.e. fast-current equipment) and highly trained or experienced responders.

- **Tactics which rely on equipment which must float require a minimum water depth greater than the draft of the equipment**. Some equipment, particularly booms, require additional depth to relieve the excess pressure built up by the presence in the water of the device itself.

- **Tactics and equipment must be suitable for reversing flow (tidal) environments**. Typically, setting anchors and maintaining their position is difficult in reversing flow situations, and in many situations complete redeployment and/or continual readjustment every tidal cycle is necessary. The use of existing fixed anchoring points is recommended, where practical, such as may be available on bridge supports or other man-made structures.

- **Strategies involving on-water containment or diversion to a containment area MUST include provisions to recover the impounded oil**. Oil not collected immediately is subject to re-mobilization associated with high flow entrainment or other forms of containment failure, or by tidal reversals.

- **Diversion strategies require precise boom configurations**. If configurations are allowed to bow, they become containments which are likely to fail in high flow situations. Diversion strategies typically require continual monitoring and adjustment.

- **Recovery operations require on-water or shoreline storage capable of accommodating the combined output from all concurrent skimming operations**. Skimmers cannot continue to operate if there is insufficient storage capacity for the recovered fluids, that is, both oil AND entrained water.

- **Implementation of most TIPS may be constrained by time and manpower requirements**. The ability to deploy/redeploy equipment must match the tidal windows. Sufficient (sometimes dedicated) manpower must be available.

- **Responders should be familiar with each inlet.** Tactics are best conducted by responders familiar with the area and trained specifically in the implementation of the planned strategies. Strategies and tactics can be used to develop Geographic Response Plans for individual inlets and then these can be the basis for drills and field exercises.

PART 4: Checklists

The following checklists can be used to assist in the identification of strategic and tactical options for the protection of tidal inlets during a) planning, exercises, or training, and b) a response operation.

A. Checklist for Pre-spill Planning

1. Recognize Inlet Features	
	Use the generic model of an inlet system (see pages **4**, **5** and **6**) and the instructions on page **8** to identify the component features of the inlet.
	Complete the template presented on pages **8** and **9**.
	Consult pages **10, 11** and **12** to use the information available (charts, photographs or videos) to map the components of a tidal system.
	Bear in mind that not every inlet has the symmetry and character of the generic models shown on pages **4**, **5** and **6**.
2. Understand the Dynamics of an Inlet System	
	After the components have been identified, read pages **4** through **7**, which describe some of the key processes that operate in the different parts of the inlet system.
	Consult pages **14**, **15** and **16** to understand how water depth and current patterns change for each of the component features as the tidal waters ebb and flood.
	Consult pages **17** and **18** for oil movement and factors affecting operational difficulty at tidal inlets.
	Read pages **19** and **20** to identify some of the operational opportunities and constraints that are typical of inlet systems.
3. Select Response Strategies and Tactics	
	Develop a regional response strategy that includes containment and recovery or elimination of the oil before it reaches the inlet area.
	Refer to pages **21** to **23** to select which strategy (ies) would be appropriate in time and space for the specific inlet system.
	Refer to page **24** for a summary of the tactical "rules of thumb" for the selected strategy (ies).
	Consider operational constraints that may apply to the specific inlet system.
	Select strategies and tactical options.
4. Verification	
	Conduct site visits and field deployment exercises.
	Modify planned strategies and tactics as appropriate.

B. Checklist for Selection of Options During a Response Operation

1.	Gather Information
	Obtain chart(s), vertical or oblique aerial photographs, and satellite imagery of the inlet system.
	Obtain predicted tide tables for the location.
	Determine the estimated arrival time of oil at the inlet system.
	Identify what types and amounts of response equipment are available.
	Identify deployment times, that is, when can the equipment be in place to contain, recover or redirect oil.
	Consult an inlet-specific plan, as might be presented in a Geographic Response Plan, then go to Step 4.
	In the absence of an inlet-specific plan, follow Steps 2, 3 and 4 below.
2.	Recognize Inlet Features
	Use the generic model of an inlet system (see pages **4**, **5** and **6**) and the instructions on page **8** to identify the component features of the inlet.
	Complete the template presented on pages **8** and **9**.
	Consult pages **10, 11** and **12** to use the information available (charts, photographs or videos) to map the components of a tidal system.
	Bear in mind that not every inlet has the symmetry and character of the generic models shown on pages **4**, **5** and **6**.
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4.	Select Response Strategies and Tactics
	Develop a regional response strategy that includes containment and recovery or elimination of the oil before it reaches the inlet area.
	Refer to pages **21** to **23** to select which strategy (ies) would be appropriate in time and space for the specific inlet system.
	Refer to page **24** for a summary of the tactical “rules of thumb” for the selected strategy (ies).
	Consider operational constraints that may apply to the specific inlet system.
	Select strategies and tactical options and determine applicability for different tide stages.

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