Tidal Inlet Protection Strategies (TIPS)

Phase 1—Final Report

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Executive Summary

- Response operations in tidal inlets face numerous challenges: the most important of which are the constantly changing water depths and current patterns.
- Recognition of the typical morphological features of an inlet system enables planners and responders to understand how water depth and current pattern change through the tidal cycle.
- This understanding should form the basis for the selection of realistic and practical response strategies to minimize the transport of oil through an inlet on a flooding tide toward vulnerable back-bay environments.
- In reality, there are a number of positive strategies and tactics that can be implemented to control the potential movement of oil through an inlet and the purpose of this study is to identify those opportunities for planners and responders.

Tidal inlets are complex and dynamic systems that include ebb and flood tidal deltas on either side of an inlet throat between barrier islands. 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. The key challenges that planners and responders face include:

- 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;
- current reversals approximately every 6 or 12 hours, depending on the type of tide; and
- high current velocities in channels and wave-induced currents across ocean-side shoals.

This report addresses these challenges and provides guidance to understand the morphology and processes within tidal inlets so that locations can be identified where protective operations are feasible and strategic approaches can be developed.

The results of this study are intended for use by planners and responders and can form part of response plans, Area Contingency Plans, or Geographic Response Plans. The process of identifying practical strategic and tactical options can help ensure that expectations are realistic and that appropriate types of equipment are available for inlet protection at specific locations. During a response operation, the Guide can be used to ensure that available resources are put to best use and that decision makers select practical strategies based on the environmental conditions at the time. The Guide provides separate stepwise approaches for preplanning activities and for response decisions.

Development of potential response strategies is directly linked to the characteristics of the tidal inlet system. These characteristics can be used to indicate locations where general strategies (such as exclusion, deflection, diversion to shore, containment and recovery) may be feasible. Guidance is also provided to assess the practicality of candidate strategies in terms of limits and conditions associated with supporting tactics and equipment. Non-conventional tactics and equipment may be required in many situations.

Response operations at a tidal inlet become necessary if open-water strategies cannot prevent oil from approaching an inlet on a flooding tide (i.e. with inflow to the back-bay environment). The favorable opportunities (green boxes) and the least practical situations (red boxes) for response strategies during a flooding tide, when oil is most likely to be transported into a back bay through an inlet system, are illustrated in Figure E.1. For most inlet systems, response strategies during a flooding tide are limited to the marginal channels of both the ebb- and flood-tidal delta areas. Within these areas of opportunity, the preferred options are to divert oil towards on-water or shoreline recovery areas. Protective strategies are limited primarily to flood tide conditions as an ebbing tide typically holds oil offshore.

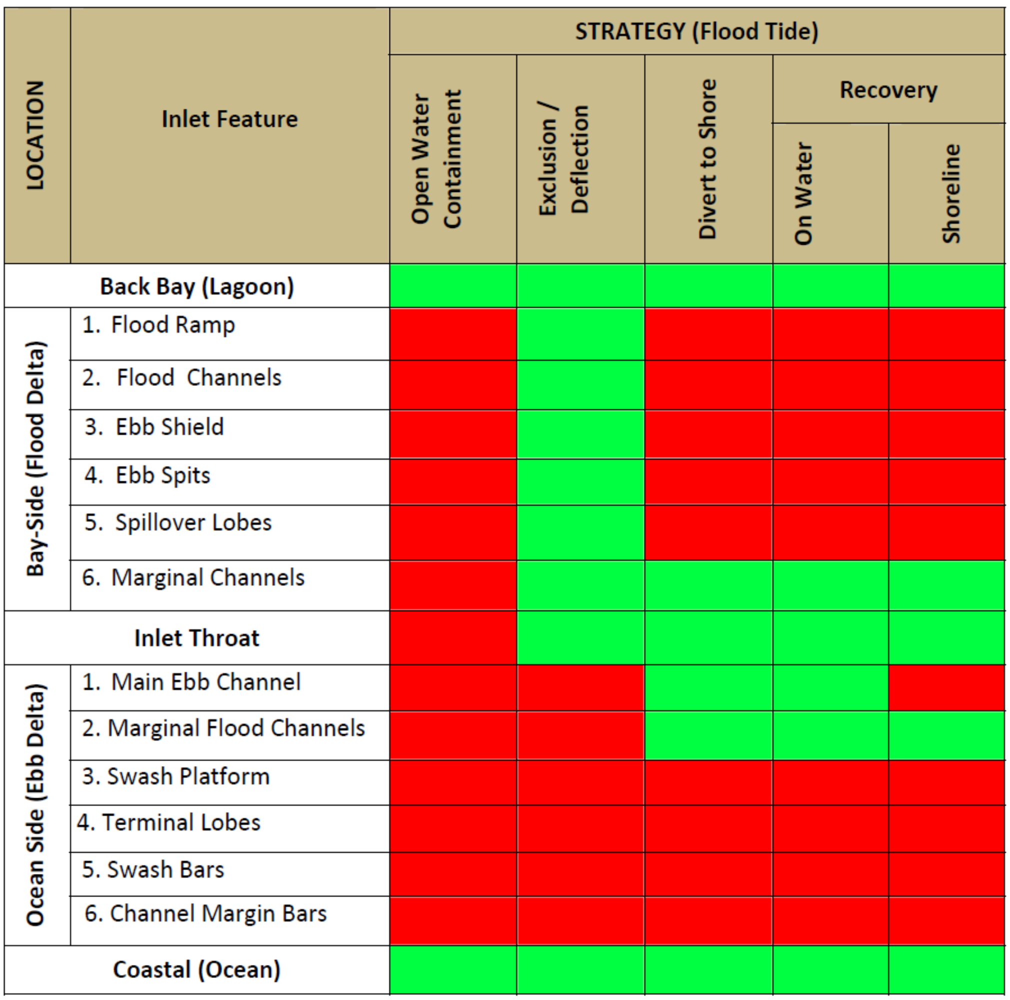


Figure E.1. Tidal Inlet Protection Strategies (TIPS) by Location During a Flooding Tide

Contents

Tidal Inlet Protection Strategies (TIPS)
Final Report

1 Introduction

Tidal inlets are found on barrier beaches worldwide and form a connection between the open-ocean and environmentally vulnerable sheltered bays, lagoons, marshes and tidal creeks. Inlets can be complex, variable, and challenging environments for oil spill control. The development of successful protective strategies requires:

a. basic understanding of the morphology and processes of the tidal system; and

b. knowledge of feasible and specialized tactics and equipment (including limitations and operating requirements) for operation in tidal environments.

1.1 Purpose of the Study

This report presents an approach for the development of Tidal Inlet Protective Strategies (TIPS) which are based on knowledge of the physical systems involved and feasibility of tactical options. Strategies and tactics identified using the results of this study are subject to real-time conditions and pre-spill planned strategies should be re-evaluated during a response. The report considers potential tactics at a level appropriate for strategic planning, but is not intended to provide instructions for the implementation of those tactics. The Guide is intended to be used by strategic planners and responders, and may be appropriate for inclusion in an Area Contingency Plan (ACP) or a Geographic Response Plan (GRP).

1.2 Scope

The Scope of the Report is divided into three major components:

- INLET CHARACTER AND DYNAMICS—Section 2 provides an understanding of the physical dynamics of tidal inlet systems, which include Ocean side and Bay-Lagoon side tidal deltas as well as the inlet or tidal throat itself.

- PLANNING—Section 3 focuses on planning considerations, such as oil transport and operational opportunities and constraints.

- RESPONSE—Section 4 describes generic response strategies, provides a guide for the selection of tactical options, and presents the special requirements and limitations of tactics and associated equipment, which may be feasible for operation in the unique tidal inlet environment.

Strategies to prevent oil from reaching sheltered bays and lagoon can involve a range of offshore and nearshore options that include mechanical recovery, controlled burning, and dispersants, although it is unlikely that burning or dispersant application would be used in the immediate proximity of a tidal inlet. The response options in and around inlets focus primarily on mechanical recovery and booming strategies for a variety of practical reasons and environmental concerns. Physical solid barriers, such as dams, have been used historically with mixed results and may cause environmental impacts by cutting off the water exchange between the ocean and back bays. In addition, the effort required for the construction of dams and other engineering options, such as pilings, in tidal channels can be time consuming and may preclude their use when immediate action is required.

As the focus of the report is on providing guidance for the selection of appropriate strategies within a tidal inlet system, minimal attention is given to more conventional interior containment and control actions in back bay or lagoon areas. A range of tactical implementation manuals provide detailed information on equipment types or specifications and how they can be deployed effectively (e.g. ExxonMobil 2008: Hansen and Coe 2001).

The report focuses on floating oil from offshore sources rather than oil that may sink, submerge or be neutrally buoyant and is intended for use at larger inlets. Protection strategies and response guidelines for small tidal channels or ephemeral inlets, that are typically less than 200 m (220 yards) wide and 1 m (3 feet) deep on sand beaches, are the subject of a separate report and field guide: API Technical Reports 1150-1 and 1150-2 respectively (API 2013 a and b)

1.3 Organization and Content

Section 2 describes and explains the key physical features of inlet systems:

- Section 2.2 provides a summary description of the MORPHOLOGY, or form, and character of inlets and the physical PROCESSES that operate in an inlet system.

- Section 2.3 presents a methodology to RECOGNIZE KEY COMPONENTS and PATTERNS for response planning and provides a TEMPLATE to summarize the physical character of an inlet.

- Section 2.4 describes the manner in which water depth and current patterns constantly change through the tidal cycle, so that the challenges associated with operations in an inlet system can be understood.

Section 3 considers strategic planning for practical response options in a tidal inlet system in the context of typical floating oil transport pathways (Section 3.1) and inlet dynamics (Section 3.2). Two key factors in the development of strategic decisions are understanding (a) where and when OPPORTUNITIES may exist for effective, diversion and/or containment and recovery (Section 3.3), and (b) typical operational, logistics and access CONSTRAINTS (Section 3.4).

Section 4 applies the knowledge of the dynamics of inlet systems and of the changing pattern of opportunities and constraints to enable the development of OBJECTIVES and STRATEGIES that may effectively control oil transport and protect sensitive back-bay environments.

- Section 4.1 describes the generic protection strategic options (Table 4.1) and discusses key information requirements for response planning.

- Section 4.2 provides a guide to the selection of Tidal Inlet Protections Strategies (TIPS). RESPONSE GUIDELINES are presented in the context of MORPHOLOGY and GEOGRAPHIC LOCATION and in terms of different STAGES of the TIDAL CYCLE (Figure 4.1).

- Section 4.3 provides brief discussions of limitations and requirements of individual RESPONSE TACTICS and associated equipment necessary to implement proposed protection strategies. This section includes a set of “RULES OF THUMB” (Section 4.3.2) related to practical considerations based on operational experience to assist in the strategy/tactics selection process. Tactical guidance for fourteen options is presented in Section 4.3.3.

Appendix A provides two USER GUIDES for pre-spill planning (Section A.1) and for guidance during a response operation for which there has been no pre-spill development of inlet protective strategies (Section A.2).

Appendix B provides a working example of the method presented in Section 2.3.1 to recognize inlet components from charts.

Appendix C provides an interpretation of the tidal delta components from a satellite image based on the methodology described in Section 2.3.3.

2 Key Physical Features of Tidal Inlets

2.1 Introduction

Tidal inlets are commonly created either through storm-generated scour channels or by spit growth across an open bay or estuary (Hayes 1991). 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.

Inlets are most frequent in coastal environments with a mesotidal range (2-4 m: 6-12 feet). Sediment transport and inlet morphology are dominated by wave processes in coastal environments with a low tidal range (<2 m: <6 feet). As tidal range increases, the role of waves diminishes whereby inlets are rarely found on coasts with ranges greater than 4 m (12 feet), because wave energy is insufficient to form a barrier coast.

The importance of selecting protective strategies to match the physical character of an inlet and the associated current patterns has been recognized for many years (e.g. Hayes and Montello 1995: NOAA 1994: Owens *et al*. 1985) and this report builds on these studies to provide a summary of the relevant factors that should be considered by regional and local planners. Inlets can be viewed as complex and dynamic physical features of a coast, but at the same time all inlets have common features that are relatively simple to understand and that are relatively straightforward in terms of oil spill response options.

This section of the report provides an understanding of the physical character of tidal inlet systems that can be used for pre-spill planning and during response operations.

2.2 Generic Model for Oil Spill Response

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. These factors combine in a dynamic setting to create site-specific and unique current patterns and morphologies that vary depending on short-term or seasonal changes in wind and wave processes and changes in water levels associated with wind-driven (meteorological) tides, predicted astronomical tides, and seasonal river run-off.

Despite the complexity and dynamic character of tidal inlets, a number of parameters are relatively constant in the short term (weeks to months). The parameters include:

- sheltered versus open coast wave environments;

- predicted tidal water level changes;
- tidal current patterns;
- the overall morphology or shape of the tidal deltas on either side of the inlet throat; and
- the location, character and function of the channels through which tidal currents flow.

As these parameters are relatively constant, a generic inlet model has been developed that can be the basis for understanding how oil might be transported through an inlet and the response constraints that result from water depths, water level changes, and current flow directions and velocities.

The dominant feature of an inlet is the INLET THROAT. This is a narrow and relatively deep channel that is formed between two sand barriers (Figure 2.1). Within the channel, current speeds are high as water flow is constricted and sediment is transported on or near the sea bed into a bay or lagoon by flood currents or seaward toward the open ocean by ebb currents.

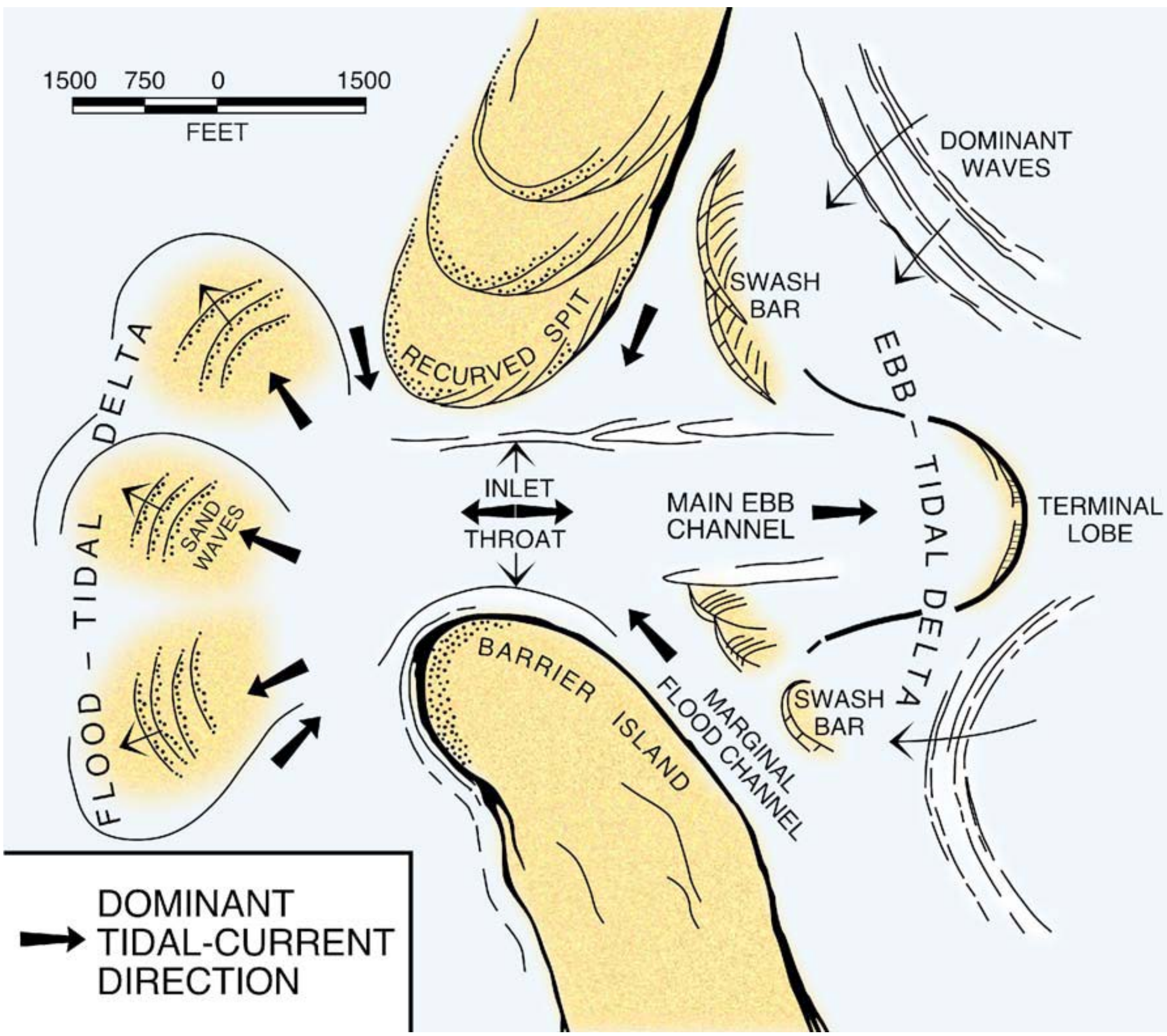


Figure 2.1. Key Features of a Tidal Inlet System (Hayes 1991)

The generic model is based on two primary environmental settings: the ocean side of the inlet system which is dominated by an EBB-TIDAL DELTA (Section 2.2.1), and the sheltered bay-side or lagoon environment which is dominated by a FLOOD-TIDAL DELTA (Section 2.2.2).

The symmetry of shoals and channels depicted in Figure 2.1 is rare, as inlet morphology is controlled by the relative magnitude of tidal and wave energy as well as the confines of bay geometry (Hayes 1975, 1991). Variations related to offset or overlapping inlets are discussed in Section 2.2.3 and to man-modified inlets in Section 2.2.4.

2.2.1 Ocean-Side Ebb Tidal Delta

The ebb tidal delta is a shoal built seaward by sand deposition as ebbing tidal waters slow and expand after passing through the constricted inlet throat (Figures 2.1, 2.2 and 2.3). The sediment at the terminus of the main ebb channel is reworked by wave action typically to create a rounded or arcuate form (#4 in Figure 2.2). Wave action moves sediment landward on the swash platform in the form of landward migrating swash bars (#5).

The ebb deltas can be intertidal or subtidal and breaking waves across shoals may limit boat or boom deployment operations. Adjacent to the inlet throat, the main ebb channel (#1) is flanked by marginal flood channels that are close to the shoreline (#2). These channels are significant in terms of oil transport as these are the first tidal waters to enter the inlet even as flow continues to ebb in the main channel, which may occur after low slack water in the bay.

The general shape of an ebb-tidal delta and the distribution of its sand bodies are determined by the relative magnitude of different sand transport processes operating at a tidal inlet. At tide-dominated inlets, the ebb-tidal deltas tend to be elongate having a main ebb channel and channel margin linear bars that extend far offshore (Figure 2.3). Wave-dominated inlet systems tend to be small relative to tide-dominated inlets. Their sediment shoals are driven onshore, close to the inlet mouth by the dominant wave processes. In many cases the ebb-tidal delta of these inlets is entirely subtidal. In other instances, sand bodies clog the entrance to the inlet leading to the formation of several major and minor tidal channels.

Mixed energy tidal 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. The example in Figure 2.4 is in a sheltered wave environment (Cape Cod Bay) with a 3 m (9 foot) tidal range.

Ebb-tidal deltas may also be highly asymmetric such that the main ebb channel and its associated sand bodies are positioned primarily along one of the inlet shorelines. This configuration normally occurs when the major back barrier channel approaches the inlet at an oblique angle or when a preferential accumulation of sand on the updrift side of the ebb delta causes a deflection of the main ebb channel along the down drift barrier shoreline. In the example shown in Figure 2.5 the construction of a spit platform (updrift sand accumulation) caused by a dominant wave approach direction has resulted in a deflected main ebb channel. Small marginal flood channels border the sides of the inlet.

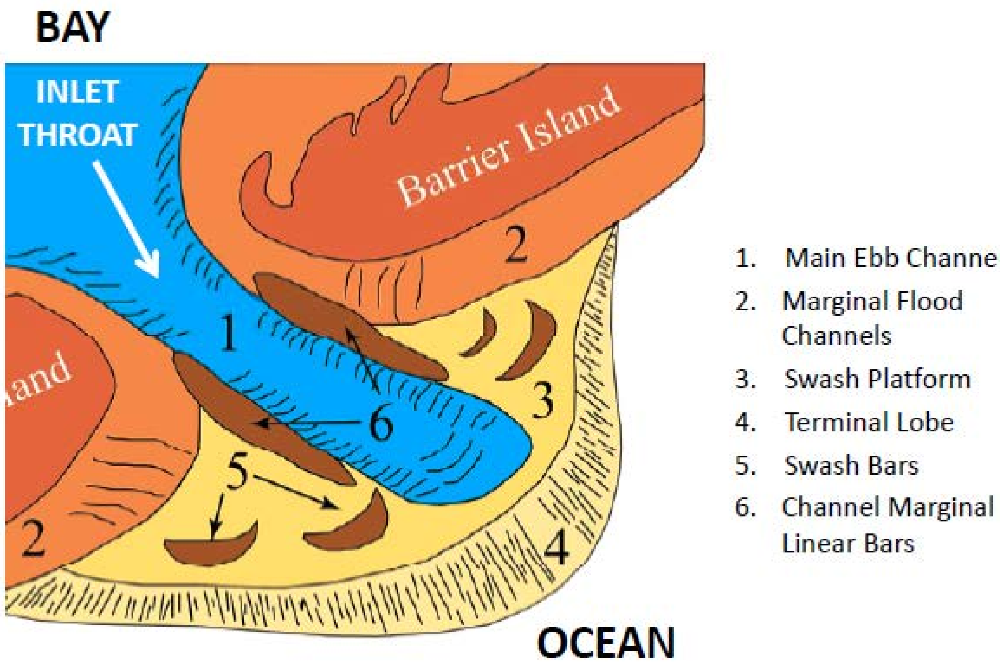


Figure 2.2. Morphological Components of a Generic Ebb-Tidal Delta

Figure 2.3. Satellite Image of Essex River Inlet (See Figure C.1)

Figure 2.4. Vertical Image of a Mixed-Energy Inlet, Sandy Neck, MA (See Appendix B)

Figure 2.5. Oblique Photograph of a Mixed-Energy Inlet

2.2.2 Bay-Side Flood Tidal Delta

The flood tidal delta forms in sheltered waters as sediment being carried into a bay or lagoon by the flooding tides is deposited (Figures 2.1, 2.3 and 2.6). This deposition results from the slowing of the current as the channel widens and flow expands once the water has passed through the narrow inlet throat.

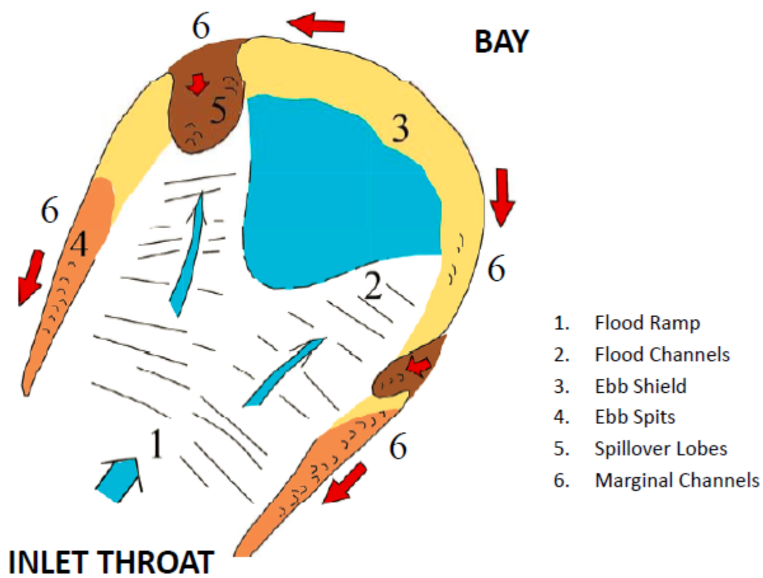


Figure 2.6. Morphological Components of Generic Flood-Tidal Delta

The flood delta contains exposed shoals at low tide so that water moves into the bay or lagoon through marginal channels (#6 in Figure 2.6) during the early and mid-flood stages. In the late-flood stage, the delta is largely or completely submerged as water then also flows through the flood channels (#2) across the flood ramp (#1) (Figure 2.7). The sand deposits are typically composed of sheet-like lobes of sand with landward-sloping ramps on their seaward sides covered by landward migrating waves of sand.

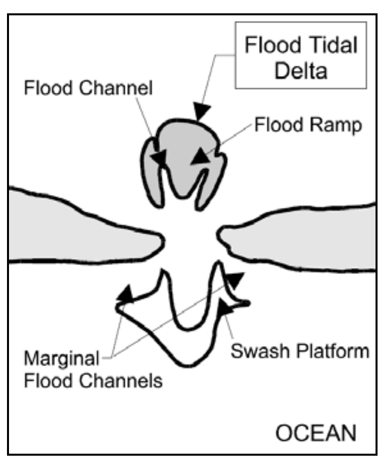


Figure 2.7. Key Depositional Features During a Flood Tide

After high tide, ebb flow is deflected by the ebb shield (#3) to marginal channels on both sides of the delta (#6) as the delta is slowly exposed by the falling water level. These currents carry sediment seaward, creating ebb spits (#4) on the flanks of the delta, which in turn help define the marginal channels (#6) that constrict both the late ebbing and the early flooding tidal waters.

Tidal inlets that are backed by a system of tidal channels, tidal flats, and salt marsh usually contain a single horseshoe-shaped flood-tidal delta (i.e., Figure 2.3). Contrastingly, inlets that are backed by large shallow bays may contain multiple flood-tidal deltas. Along some microtidal coasts, such as Rhode Island, flood deltas form at the end of narrow inlet channels cut through the barrier. Changes in the locus of deposition at these deltas produce a multi-lobate morphology (e.g. Figure 2.1) resembling a lobate river delta (Boothroyd 1978). Flood delta size commonly increases as the tidal prism increases and as the amount of open water area in the back barrier increases. In some regions, flood deltas have become colonized and altered by marsh growth, and are no longer recognizable as former flood-tidal deltas (Table 2.1). At other sites, portions of flood-tidal deltas are dredged to provide navigable waterways and thus, are highly modified.

Flood-tidal deltas are best developed in areas with moderate to large tidal ranges (1.5 to 3.0 m) because in these regions they are well exposed at low tide. As tidal range decreases, flood deltas become largely sub-tidal shoals.

Table 2.1. Summary of Inlet Morphology Variations (Modified From Hubbard *et al*. 1979 and Hayes 1991)

	INLET ENVIRONMENT		
VARIABLES	**WAVE DOMINATED**	**TRANSITIONAL**	**TIDE DOMINATED**
Primary Depositional Area	**Bay Side**: Small to large lobate or multi-lobate flood delta **Ocean Side**: Small ebb delta located close to shore	**Throat**: Wide with one or more tidal channels and sand shoals	**Ocean Side**: Well developed ebb delta that may be partly submerged. Contains small shoals and channel margin linear bars.
Secondary Depositional Area	**Ocean Side**: Small sand shoals located close to shore	Individual sand shoals or islands with one main channel	**Bay Side**: Flood delta well developed or colonized by marsh grass
Main Channel (Throat) Character	Small with one or more shallow channels and shifting sand shoals	Variable and changes during storms	Deep: narrow: stable: ebb dominated
Width/Depth Ratio	Variable: mostly high	Large but channels may be deep	Small
Channel Margin Bars	Absent	Variable	Large

2.2.3 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 (Figure 2.8).

The inlet illustrated in Figure 2.8 has a plentiful sediment supply and a dominant alongshore transport direction to the south. This is a microtidal coast with a tide-dominated inlet having a low tidal range (1.0-1.5 m) but the inlet system has a large bay area and large tidal prism.

Figure 2.8. Vertical Image of Overlapping Inlet: Eastern Sakhalin Island, Russia

2.2.4 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 buildup 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.
- Again, increases or decreases in the tidal prism result in long-term changes that can involve an enlargement or the closure of an inlet, respectively.

2.3 Recognizing the Components of a Tidal Inlet

The purpose of this Section is to enable planners and responders to recognize typical changes in depth and current patterns at an inlet through a tidal cycle. The method follows a step-wise process by which nautical charts provide depth data and oblique aerial photographs, videos, vertical photographs and satellite images (e.g. Google) assist in the identification and definition of the different components of the inlet system (Figures 2.1, 2.2 and 2.6).

A template (Table 2.2) is used to summarize the overall character of the inlet and the adjacent ebb- and flood-tidal deltas. Ideally a combination of information from a range of sources would be available for this component analysis.

This information then is used in Section 2.4 to link these physical components to the changes in water depth, shoal areas, and currents during the different stages of the tide. The results are summarized in Table 2.3 and Figure 2.9 (which uses a generic inlet system diagram) and can be used to identify appropriate locations within the inlet system where boom and recovery systems can be deployed most effectively.

2.3.1 Charts

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

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

    - the <u>High Water (HW) shoreline:</u> the area above the HW is light yellow on most charts: see Figures B.1, B3 and B.4;

    - the <u>Low Water (LW) shoreline:</u> this is the chart datum: the zone between HW and LW is colored green on most charts (Figure B.1): 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 <u>depth contours</u> 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 (Figure B.1), 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 <u>scale</u> 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 <u>six ebb and the six flood tidal delta components</u> shown in Figures 2.2 and 2.6.

5. Document the presence or absence of these components in the template provided below (Section 2.3.4, Table 2.2).

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: “average” 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

Appendix B provides a working example of steps 1 and 4 to define the HW and LW shorelines and the morphological components of an inlet system.

2.3.2 Oblique Aerial Photographs or Video Frames

1. Oblique aerial photographs are sometimes the least valuable images because light reflectance from the water surface can obscure underwater features (see cover photo).

2. Take or use photos during the low tide slack with the sun behind the observer. Figure 2.5 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 in Figures 2.2 and 2.6. Document the presence or absence of these components in the template provided below (Section 2.3.4, Table 2.2).

5. Breaking waves or lines of white caps are a good indicator of shoal patterns (see cover photo and Figures 2.5 and 2.8).

2.3.3 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 in Figures 2.2 and 2.6. See Figure C.1 for an example. Document the presence or absence of these components in the template provided below (Section 2.3.4, Table 2.2).

4. Breaking waves or lines of white caps are a good indicator of shoal patterns (see Figures 2.5 and 2.8).

2.3.4 Template to Define the Physical Character of a Tidal Inlet

Following the steps described above, Table 2.2 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. As noted above, not every inlet has the symmetry and character of the generic model shown in Figure 2.1, however, most inlets have most if not all of these components.

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 discussion in Sections 2.2.3 and 2.2.4 and would be entered as a straightforward YES / NO. Similarly the availability of current data would be entered with a reference to the source of that information. "Operational Difficulty" is discussed in Section 3.2 and can be referenced to Table 3.1.

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 in Figures 2.2 and 2.6, 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. These schematics 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 (see discussion in Sections 2.2.1 and 2.2.2).

Table 2.2. Template to Summarize the Physical Character of a Tidal Inlet

A. Inlet Name					
B. Tidal Range: *(from tidal predictions)*				Average Range	Spring Range
				m	m
Tidal Period: Diurnal Tide ______ Semidiurnal Tide ______ Mixed Diurnal/Semidiurnal Tide ______					
C. Location of Inlet Throat					
Latitude:			Longitude:		
D. Inlet Character *(circle as appropriate)*					
Straight beach	Offset	Overlap	Jetty(ies)	Rip Rap Armor	Bridges
Current Data	Available	Y / N	Source:		
Operational Difficulty (Table 3.1)					
E. Inlet Components					
INLET THROAT	Width m		Depth m		
EBB-TIDAL DELTA SYSTEM			**FLOOD-TIDAL DELTA SYSTEM**		
1. Main Ebb Channel			1. Flood Ramp		
2. Marginal Flood Channels			2. Flood Channel(s)		
3. Swash Platform			3. Ebb Shield		
4. Terminal Lobe			4. Ebb Spit(s)		
5. Swash Bars			5. Spillover Lobes		
6. Channel Margin Linear Bars			6. Marginal Channels		

2.4 Inlet Features, Water Depth and Currents

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. Table 2.3 links the morphological components of an inlet system illustrated in Figures 2.2 and 2.6 to typical water depths and current patterns during different stages of the tidal cycle.

The information in Table 2.3 is presented in Figure 2.9 as a set of color-coded schematics using the Legend below. This set of schematics provides critical guidelines for planners and responders in the selection of appropriate locations within the inlet system where boom and recovery systems can be effectively deployed (see Section 4). Operational practicality and feasibility depend to a large degree on water depths and current velocities. 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). In the four "Currents" schematics, the presence of breaking waves is considered an overriding factor and this is indicated by the red color code. In this context, the following terms apply for water depth and current patterns during the four primary tidal stages:

Legend for Color Codes in Figure 2.9

DEPTH—Typical Least Water Depth

Deep water: depths typically greater than 2 m (>6 feet)	(blue)
Moderate water: depths typically 1-2 m (3-6 feet)	(cyan)
Shallow water: depths typically less than 1 m (<3 feet)	(light cyan)
Exposed: above the water level (intertidal)	(red)

CURRENTS—Typical Maximum Current

Slack water: little or no current	(green)
Weak: tidal current typically less than 0.5 meter/second (<1 knot)	(green)
Moderate: tidal current typically 0.5 to 1 meter/second (1-2 knots)	(yellow)
Strong: tidal current typically greater than 1 meter/second (>2 knots)	(orange)

WAVES

Zone of breaking waves	(red)

The terms "low tide" and "high tide" refer to the slack-water periods that occur immediately before and after the tide reverses. 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. Water depth and current velocity are not the only variables to consider in planning and deployment of equipment, as flow directions also change with the tidal stages, as indicated in Table 2.3.

Table 2.3. Typical Water Depths and Current Patterns at Different Tide Stages

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

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.

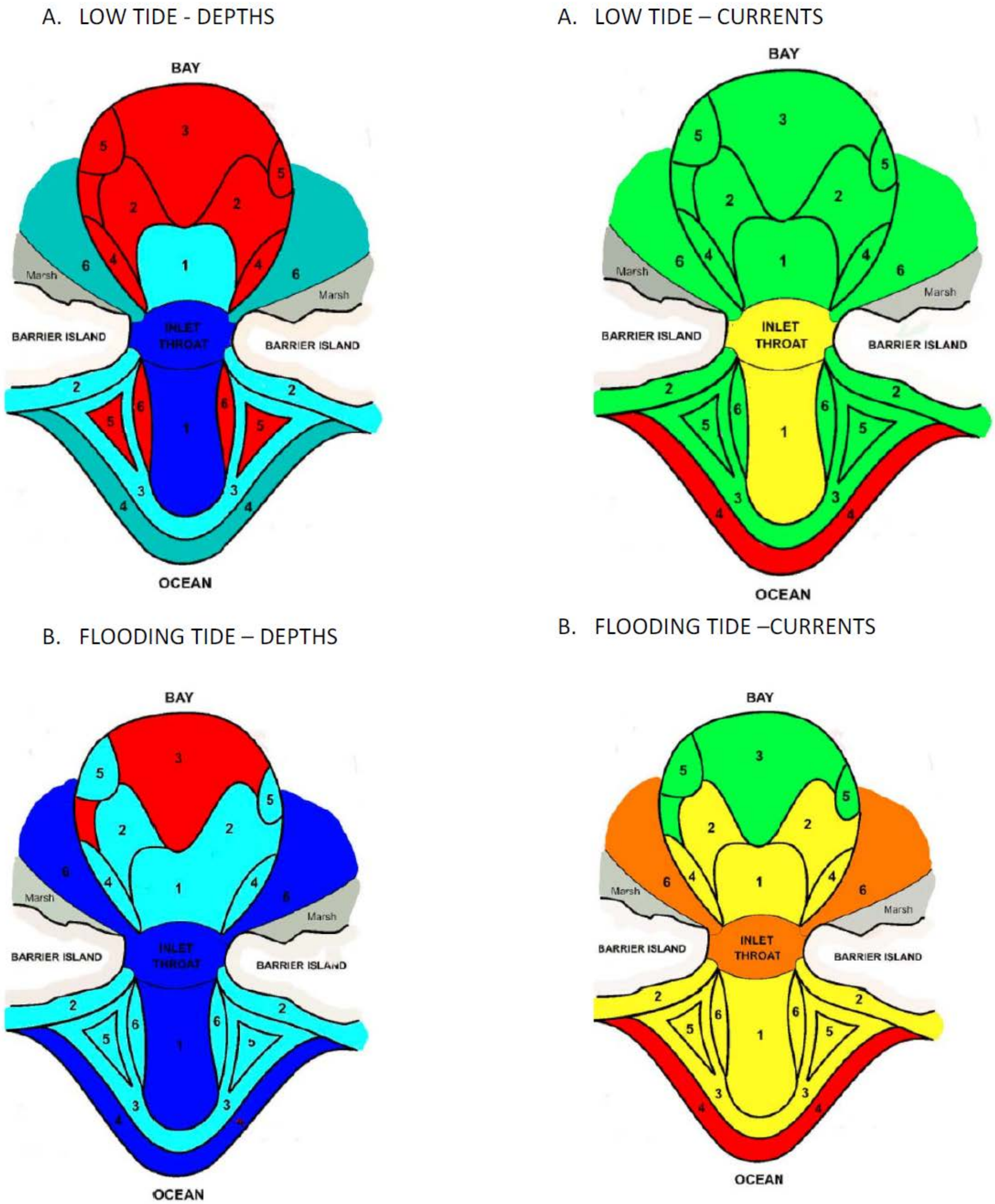


Figure 2.9. Set of Schematic Diagrams to Show Typical Water Depths and Current Patterns at Different Tide Stages (Based on Table 2.3)

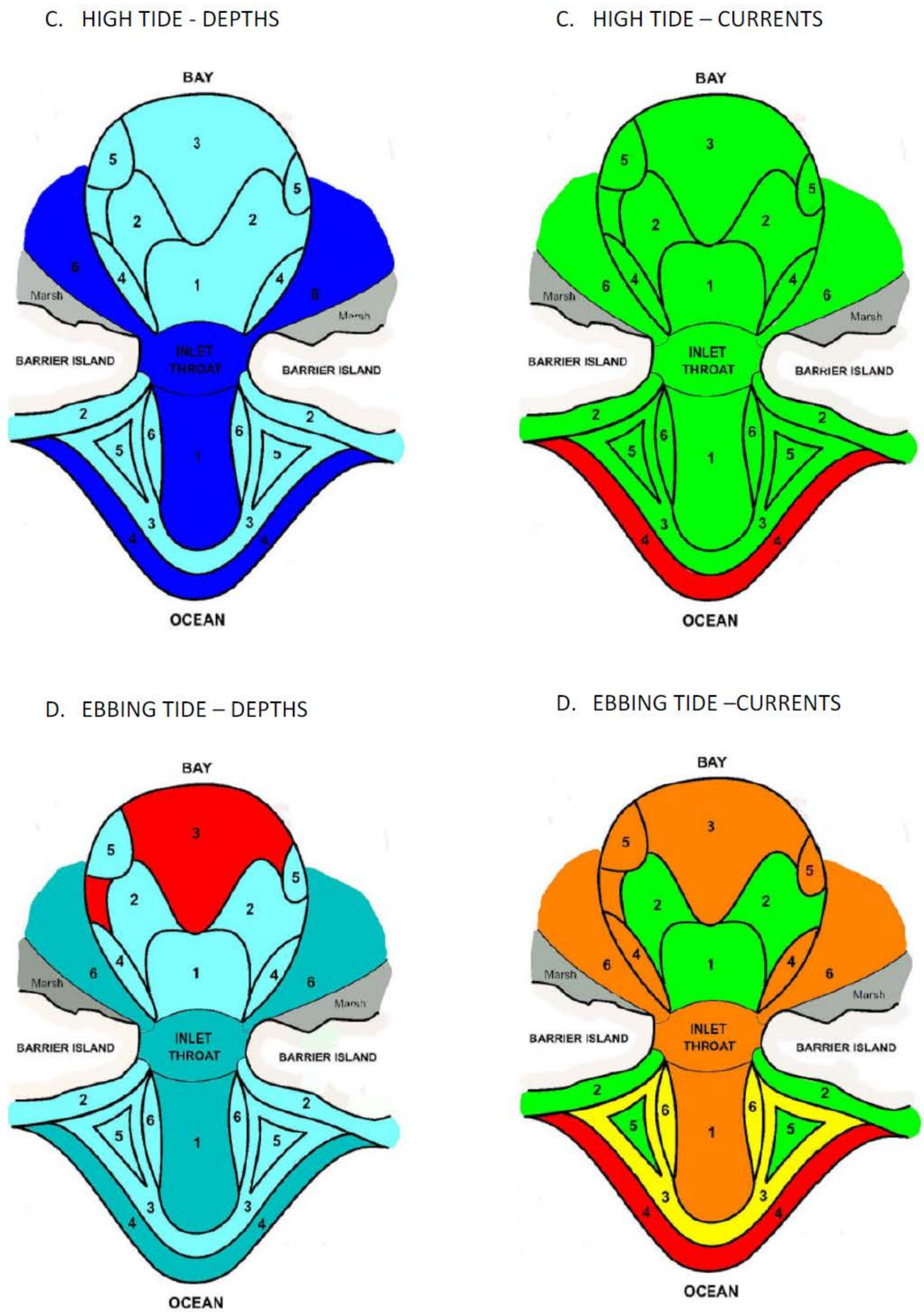


Figure 2.9. (continued)

3 Planning Considerations for Oil and Tidal Inlet Systems

Tidal inlets are critical pathways for oil to potentially enter coastal bays and lagoons and to impact tidal flats, wetlands, marshes and mangroves so they are key intercept points to protect these sensitive and vulnerable habitats. Typical oil transport pathways are summarized in Section 3.1. Two key factors in the development of strategic decisions include understanding (a) where and when OPPORTUNITIES may exist for effective, diversion and/or containment and recovery (Section 3.3), and (b) typical operational, logistics and access CONSTRAINTS (Section 3.4).

3.1 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 (Figure 3.1).

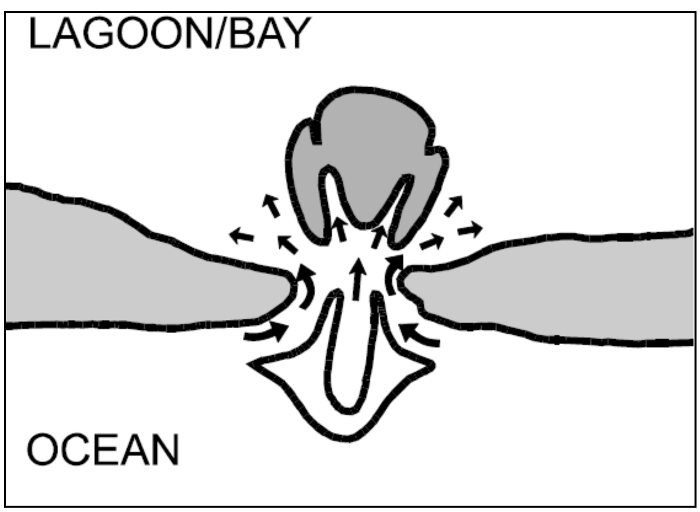


Figure 3.1. Tidal Currents During the Early and Mid-Flood Stage

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.

3.2 Inlet Dynamics and Oil Spill Planning

Tidal inlet dynamics present key planning challenges including:

- complex patterns of shoals and channels that are controlled by the balance between wave and tidal forces and bay geometry,
- constantly changing water levels and shoal exposures,
- intertidal areas that are often wide and are alternately exposed and submerged during each tidal cycle,
- potentially high current velocities in channels,
- a reversal of current direction approximately every 6 hours, or every 12 hours if the tides are diurnal, and
- wave-induced currents and breaking waves on ocean-side shoals.

Despite this complexity, most inlets have a similar pattern of shoals and channels that is reflected in the current patterns. Identification of the pattern of the shoals and channels is a key to understanding changes in water depths and flow pattern during different stages of the tide. This does not necessarily make planning or response any easier but provides for understanding when and where (a) opportunities may exist to intercept or control surface oil moving into a bay through an inlet (Section 3.3) and (b) depth and water flow present constraints to effective equipment deployment (Section 3.4).

In general terms, operational difficulty (effectiveness) increases with:

- inlet throat channel width,
- channel depth,
- tidal prism,
- tidal current velocity,
- wave exposure.

These features are listed in Table 3.1, which identifies some of the key overriding regional factors that influence operational difficulty for diversion, containment and recovery systems at inlets.

Table 3.1. Summary of Factors that Affect Operational Difficulty at Tidal Inlets

OPERATIONAL DIFFICULTY	INLET WIDTH	INLET DEPTH	TIDAL PRISM	TIDAL CURRENTS	BACK BAY CHARACTER	WAVE EXPOSURE	PREFERRED FLOOD TIDE TACTICS
Very Difficult: limited potential for success	Wide	Shallow	Large	Strong (>1 knot: 0.5 m/s)	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 knot: 0.25 m/s)	Sand beaches	Sheltered ocean shore	• Bay-side containment and deflection boom with on water and/or shoreside recovery in channel • Dams, solid barriers

Difficulty increases as:

- Width
- Depth
- Tidal current
- Tidal prism
- Wave exposure

In the development of a response strategy for oil that threatens an inlet the following are important considerations in the planning and decision process:

- NEARSHORE EXCLUSION STRATEGY.
  - o Exclusion strategies are probably impractical and rarely successful once oil reaches an inlet. Dams may be an option for small inlets, time permitting.
  - o If the objective is to prevent oil from entering a back bay are then the only likely successful strategy is to prevent oil from approaching and entering the inlet by on-water strategies, such as containment and recovery, diversion, dispersion or controlled burn.
  - o The only locations where an exclusion strategy may be effective would be for a narrow inlet with a small tidal prism (the tidal prism is defined “the open-water area of the bay, lagoon or marsh and tidal creek system times the tidal range”) (Table 3.1).
- TIMING.
  - o The key periods when response actions potentially can minimize the volume of oil that is transported into a back-bay environment are the Low Tide through High Tide window. In areas with semi-diurnal tides this window may vary from as little as a 6-hour to as much as a 9-hour period, depending on winds and on the size of the tidal prism that has to drain from the bay. With diurnal tides, the window may as much as 12 or 15 hours.
  - o The drainage of water from bays with large tidal prisms often continues through the low-tide slack period until the water levels on both sides of the inlet are the same and may delay the onset of the flooding tide for several hours.
  - o An ebbing tide will keep oil out of the inlet.

- PRACTICALITY.

  - Flow reversal and the effects that this condition has on anchoring systems is a critical factor in any inlet response. Current reversals typically require redeployment every tidal change, which makes cascading tactics problematic.

  - Two primary variables that affect practicality and effectiveness are water depth and current speed (Section 2.4).

  - Understanding these two latter variables in time and space, as summarized in Figure 2.9), enables planners and responders to avoid locations where depth and current would be constraining factors and to focus attempts to divert, contain or recover surface oil where condition might be more favorable.

3.3 Operational Opportunities: Morphology, Currents and Natural Collection Areas

In terms of OPPORTUNITES 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 (#1 in Figure 2.2) 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 (#6 in Figure 2.6) 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.

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. A good example in Figure B.4 (Appendix B) would be The Cove, located behind Beach Point and outlined by the green circle. This area would be a sheltered, slack-water environment with water depths up to 2 m (6 feet) at low tide and at least 1.5 m (5 feet) at all locations at high tide, as this is the mean tide range, with up to 3.5 m (11 feet) in other areas.

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.

3.4 Operational Constraints: Water Depths, Channels and Accessibility

Understanding changes in water depth, current velocity and flow direction as presented in Figure 2.9 identify "areas of opportunity" but also identify where specific tactics would be CONSTRAINED.

Typically areas to avoid for conventional floating booms and recovery system, 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 at a minimum. Breaking waves could limit practicality on the terminal lobe of the ebb delta.

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

3.5 Summary for Planning and Response

The important factor in planning is recognizing where and when opportunities and constraints exist so that decisions can be developed that are realistic and practical. Strategies, such as the diversion of oil from channels into natural collections areas for recovery, or tactics that employ equipment designed for fast-currents, can be developed in the context of understanding changes in water depths, current velocity and flow direction.

From a **tidal cycle perspective**, the main considerations are:

A. LOW TIDE.

   - Sufficient water depth for boom and /or skimmer deployment.
   - Even though water flow may be slack, many areas are shallow or, particularly in the flood tidal delta area, exposed.
   - Flow may continue out of the inlet throat and through the main ebb channel after the predicted low tide until the water levels on the bay and ocean sides are the same.

B. FLOODING TIDE.

- Depths remain shallow in many areas until mid-tide or late in the flood.
- Depth typically should be several times the draft of the equipment.
- Fast-water tactics and equipment should be used in fast currents.
- 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.

C. HIGH TIDE.

- Water depths may allow unrestricted access in most area, though some may remain shallow, such as the ebb shield.

D. EBBING TIDE.

- Oil on the water would be carried seawards out of the inlet system.

From a **<u>geographic perspective</u>**, there are three key physical environments of a tidal inlet in terms of OIL SPILL RESPONSE:

1. The WAVE-DOMINATED open ocean waters and shorelines.

   - Primary limitations on oil containment and recovery are related to a combination of breaking waves in shallow waters around the ebb tidal delta and tide currents in the channels.
   - During the initial stage of a flooding tide, oil on the ocean side of an inlet only would be transported into the inlet throat through one or both of the marginal flood channels until the bay has fully drained.
   - Strategic options include:
     - deflecting oil away from the inlet throat for on-water recover, and/or
     - diversion booming to direct oil to a beach for recovery (Figure 3.2).
   - 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.
   - During a flood tide, after the ebb flow ceases, *<u>control and recovery of oil is more likely to be successful on the bay side of an inlet</u>* where the waters are sheltered from wave action (see below).

2. The CURRENT-DOMINATED inlet throat.

   - As the water level in the ocean rises, flood waters enter the inlet along the marginal channels even as ebb currents continue to flow in the center of the channel.

- As soon as the outflow from the ebbing tide ceases, oil could be transported into the bay or lagoon by the relatively strong flood tide.

- Diversion to shore may be possible but *control and recovery of oil is more likely to be successful on the bay side of an inlet* where the current velocities are lower.

3. The WAVE-SHELTERED waters and shorelines of the bay or lagoon.

   - Primary limitations are strong flood tide currents in channels.

   - During the first stages of a flood tide, after the ebb drainage ceases in the inlet throat, the flood tide would carry oil in the channels around the flood tidal delta.

   - Flood currents are likely to be strongest during the 2-hour period after mid tide when flow is largely confined to the marginal channels.

   - During the late stages of a flooding tide the incoming waters would flow over most of the flood tidal delta.

   - Strategic options include:

     o Diversion booming to direct oil to a beach for recovery in the flood channels in the sheltered side of the inlet (Figure 3.2).

(a) (b)

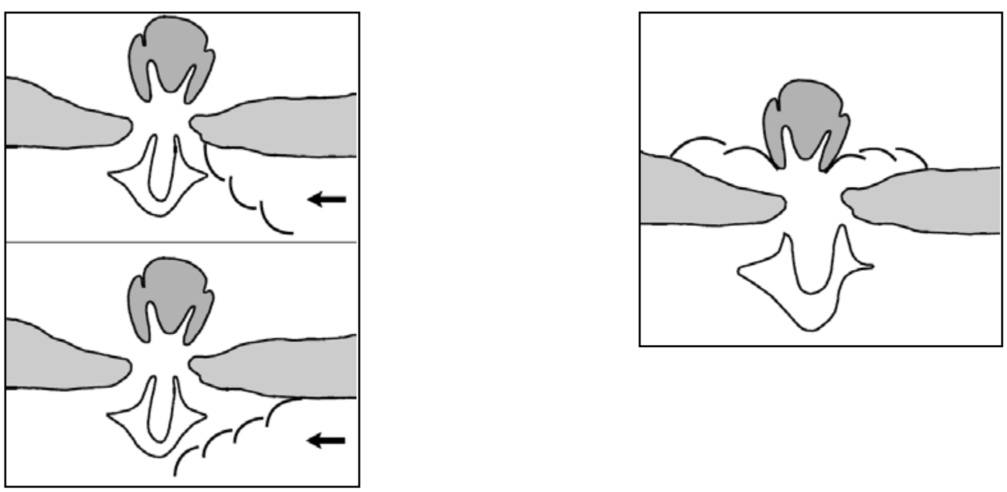


Figure 3.2. Booming Options During a Flooding Tide: (a) Diversion Towards Shore Updrift of the Inlet with Recovery on the Beach (top) or Deflection Away from the Inlet with On-Water Recovery (bottom); (b) Diversion Towards Shore in the Flood Channels and Recovery on the Beach

4 Tidal Inlet Protection Strategy ("TIPS") Selection Guide

4.1 Generic Strategies

Tidal Inlets present complex, dynamic and challenging environments for oil spill control. Challenges include high current velocities, changing tidal directions, shallow (or no water), swells, surges and breaking waves, and restricted shoreline access. As a result of these and other factors, attempts to protect tidal Inlets commonly have met with marginal success. This lack of success may have been influenced by a lack of understanding of inlet dynamics and lack of equipment suited to conditions prevalent in tidal inlets. HOWEVER, with an understanding of tidal inlet characteristics and processes AND an understanding of the applications and limitations of oil spill control technology, strategies CAN BE SUCCESSFULLY IMPLEMENTED within inlet systems in many cases to protect sensitive back-bay resources.

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 (Note: offshore mechanical recovery, dispersant application and burning strategies are outside the scope of this study.
    - 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 Table 4.1. Because of the complexity and variability of tidal inlets, the strategies presented may not include all possible options. Guidance provided herein should not preclude consideration of other options and should not replace the use of common sense.

Table 4.1. 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 and underway 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	Potential option for small inlets in relatively calm conditions. Would 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	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	Window of opportunity for installation	

Prespill field examination of specific tidal inlets is highly recommended for development of planning strategies. Field observations should include:

- Observations during low tide, and high flow conditions;
- Identification of (a) shoreline access points (preferably vehicular) to facilitate deployment, oil recovery and storage, and demobilization, (b) limitations to access, and (c) potential access improvements;
- Visual verification of current velocities and direction (at peak flood). Flow direction can be identified by tracking floating objects, such as oranges, and velocity by measuring the time required for a floating object to traverse a measured distance (these procedures have been used successfully for tidal inlet planning since at least the early 1970's);
- Locations of shoreline debris accumulations as these are representative of natural floating debris accumulation and are likely points of accumulation for spilled oil; and
- Types and locations of existing anchoring points. Shoreline anchor points include any large fixed objects to which booms can be attached. In water anchoring points include bridges, pilings and other rigid structures. Existing anchoring points can be critical in tidal inlets for fast deployment and positive anchoring.

These observations should be noted on charts, satellite photos, etc. and evaluated spatially in conjunction with tactical guidance (following discussion). Overlaps are usually indicative of preferred strategic and tactical action sites.

Drills, exercises and verification of Geographic Response Plans (GRPs) that test response strategies and tactics are useful to verify the feasibility and effectiveness of the selected option(s).

4.2 Candidate TIPS Selection Guide

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 in Figure 4.1. This Selection Guide is designed for the identification of those tidal inlet system components where various strategies may be feasible, based in part on the water depths and current characteristics as described in Table 2.3 and Figure 2.9. The Guide is organized by tidal system component features and 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 actions (on-water containment, exclusion/deflection booming, deflection to shorelines (for recovery), on water recovery, and shoreline recovery. Strategies are intended for the control and recovery of surface oil and do not address subsequent cleanup at the shoreline.

Multiple strategic options are identified for basic tidal inlet features. It is important to note that no strategic options are identified for a number of features which are located over most of the in the ebb delta (ocean side) as no functional tactics exist or are considered safe for these areas.

It is recommended that field observations accompany the use of this table in response planning. Testing of candidate strategies/tactics through drills and exercises is also recommended. Ultimately, however, successful implementation of each strategy/tactic is dependent on case-specific conditions.

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. Channel Margin Bars	Exposed	Moderate	Moderate	Moderate	Y					
Coastal (Ocean)		Deep	Deep	Weak	Weak	N	X	X	X	X	X

Figure 4.1. Tidal Inlet Protection Strategy (TIPS) Candidate Selection Guide for All Tide Stages

X — Strategy may be feasible, depending on site conditions

Strategy unlikely to be feasible

4.3 Strategies and Tactical Options

4.3.1 Strategies versus Tactics

The strategies identified in Figure 4.1 cannot be implemented without workable tactics and appropriate equipment. It is essential for planners to understand that, due to the complexity and variability of oil spill threatening tidal inlets, strategies and respective tactics may be difficult or impractical to implement in many cases. In addition, specialized equipment, such as “fast-water” booms and skimmers may be required. (Note: It is not the intention of this report to provide instructions on tactical deployment and equipment operation).

4.3.2 Tactical “Rules of Thumb”

Selection of practical TIPS should include an evaluation of whether tactics and equipment are appropriate and available for their implementation. Failure to consider to these rules is likely to contribute to an unsuccessful protection operation. The following Rules of Thumb are based on past field experience and should always be considered in evaluating the practicality of candidate TIPS:

a) **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;

b) **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;

c) **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;

d) **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;

e) **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;

f) **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;

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

h) **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. Drills and exercises for individual inlets are recommended.

4.3.3 Tactical Guidance Summaries

The following fourteen Tactical Guidance Summaries provide a variety of guidance information to assist in the planning and selection of strategic/tactical options. These guidelines are based in part on the water depths and currents presented in Figure 2.9.

Tactical Guidance Summaries (*with appropriate operating locations in italics*) include:

On-Water Containment

- Containment Booming (Figure 4.3.1): *Open Ocean, Back Bay, Lagoon*

Exclusion / Deflection

- Exclusion and Deflection Booming (Figure 4.3.2): *Ocean, Ebb Delta, Inlet Throat*
- Tidal System Exclusion (Dams, Tide Gates, and Weirs) (Figure 4.3.3): *Inlet Throat, Back Bay*

- Deflection Around Man-made Structures (Figure 4.3.4*): Inlet Throat, Flood Delta, Back Bay*
- Exclusion Booming (Figure 4.3.5): *Flood Delta, Back Bay*
- Deflection (Figure 4.3.6): *Flood Delta, Back Bay*

Divert To Shore

- Diversion Booming (Figure 4.3.7): *Flood and Ebb Deltas, Inlet Throat*
- Chevron Diversion Booming (Figure 4.3.8): *Ebb Delta. Inlet Throat*
- Cascading Diversion Booming (Figure 4.3.9): *Flood and Ebb Deltas, Inlet Throat*
- Boom Vanes and Rudders (Figure 4.3.10): *Flood and Ebb Deltas, Inlet Throat*
- Air Curtain Diversion (Figure 4.3.11): *Flood Delta, Inlet Throat, Back Bay*

Recovery

- On-Water Recovery (Figure 4.3.12): *Ocean, Flood and Ebb Deltas, Inlet Throat, Back Bay*
- Berms, Trenches, Pump/Vacuum (Figure 4.3.13): *Flood and Ebb Deltas, Back Bay*
- Sorbents (Figure 4.3.14): *Flood and Ebb Deltas, Inlet Throat, Back Bay*

The Tactical Guidance Summaries include the following information:

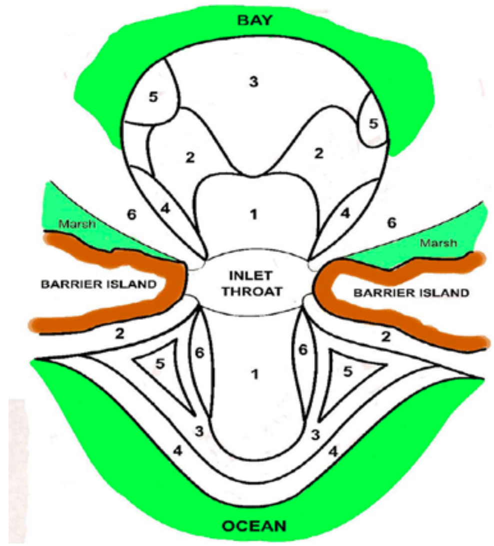
- A Generic Tidal Inlet System schematic showing locations where tactical operations for specific inlet components are typically feasible (**green shading**) and where tactics may be feasible under special circumstances (**yellow shading**). The morphological components follow those defined in Figures 2.2 and 2.6 and Table 2.3. Appendix A provides instructions on how to locate inlet-specific morphologic features.
- Objective of the Tactic.
- Representative photographs for typical deployments.
- Specialized equipment requirements as appropriate.
- Limitations on the implementation of the tactic.
- General operating requirements.

4.3.1	ON WATER CONTAINMENT
	CONTAINMENT BOOMING: *OCEAN, BACK BAY, LAGOON*

Open Ocean

Back Bay

Location



Equipment:

- High freeboard boom (Offshore).
- Smaller boom (Inshore).
- Boom handling vessels.
- Oil recovery capability.

Objective

- Deploy (1) open water boom on the seaward side of the Ocean-Side Ebb Delta to contain oil and prevent it from entering the Tidal Inlet System; (2) inshore boom for back bay / lagoon containment.

Limitations:

- High winds, swell, and breaking waves may preclude use of this tactic from safety as well as operational aspects.
- Complete containment unlikely in either case.

Operating Requirements

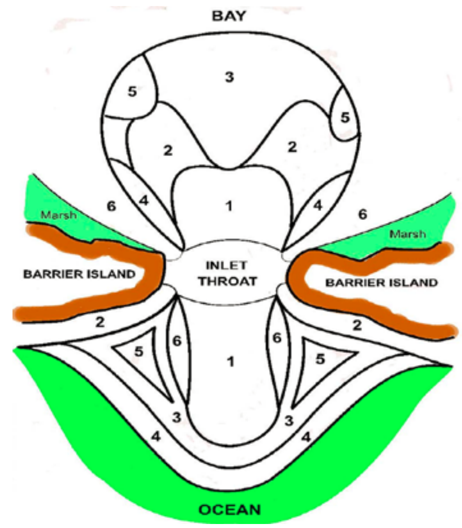
- Manned deployment—extensive marine resources may be required offshore.
- Oil impounded must be recovered immediately—skimming and offloading resources required.

4.3.2	EXCLUSION and DEFLECTION
	EXCLUSION and DEFLECTION BOOMING: *OCEAN, EBB DELTA, INLET THROAT*

Exclusion Boom

Deflection Boom

Location



Equipment

- Offshore skirt boom.
- Tidal seal boom.
- Offshore anchoring systems.
- Deployment vessels.
- Warning markers/lights.

Objectives

- Exclusion: Completely boom off tidal Inlet (seaward of ebb delta). Shore termination required on both sides of boom.
- Diversion (For oil moving inshore and along coastline); Deflect oil moving along the shoreline seaward allowing it to pass inlet flood tide zone.

Limitations

- Inclement weather and sea conditions; operational and safety issues.
- Booming is likely to be ineffective with breaking waves.
- Contained oil must be removed immediately to prevent loss.
- May interfere with inlet navigation.

Operating Requirements

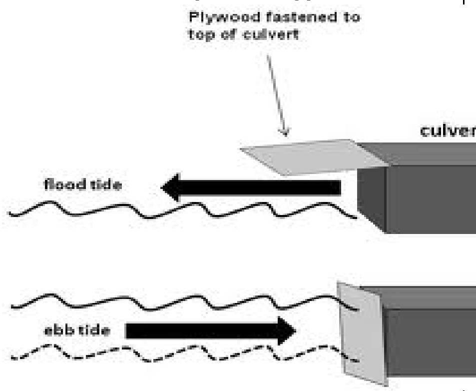
- Full time monitoring / boom adjustment team required.
- Oil recovery and storage resources required (on water and onshore).
- Booms and anchors may require removal during inclement weather.

4.3.3 EXCLUSION and DEFLECTION

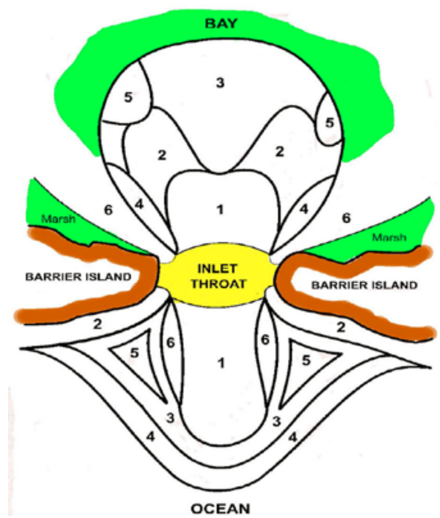
TIDAL SYSTEM EXCLUSION (Dams, Tide Gates, Weirs): *INLET THROAT, BACK BAY*

Exclusion Dam (Tidal Inlet)

Exclusion Barrier with Weir or Tidal Gate (Back Bay)



Location



Equipment:

- Tracked earthmoving equipment.
- Tidal Gates / materials.
- Warning buoys / lights.

Objectives

- Construct physical barrier to prevent oil from entering (1) inlet or (2) back bay or lagoon channels.

Limitations

- May be difficult to construct in inlets having large tidal prism.
- Permitting/Construction may require extended (and unacceptable) periods of time.
- May result in unacceptable interference with tidal flushing or other environmental problems.
- May interfere with navigation.

Operating Requirements

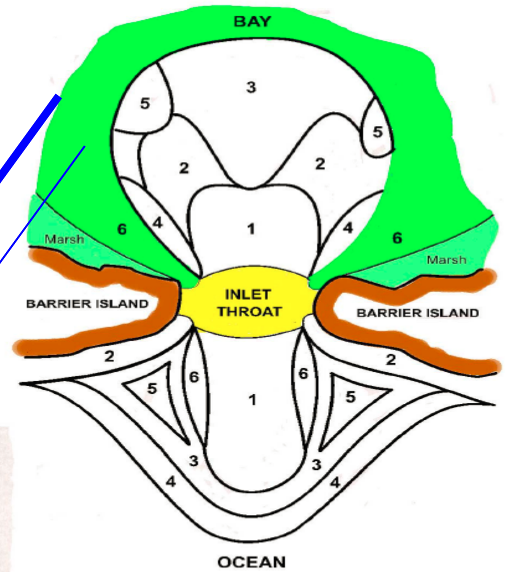
- Minimal once constructed; Weirs / tide gates may require operation if so equipped.
- Construct will require removal and restoration on completion of use.

4.3.4	EXCLUSION and DEFLECTION
	DEFLECTION BOOMING AROUND MANMADE STRUCTURES: *INLET THROAT, FLOOD DELTA, BACK BAY*

(a) Boom along armored tidal inlet

(b) Inlet deflection

Location



Equipment

- Most boom types can be used.
- Fenders to hold boom off shore.
- Flow reversing anchor systems or driven piles.

Objectives

- Install boom along rip rap or bulkhead face to bypass oil to quieter area for control and recovery (oil in rip rap or behind bulkheads is difficult to remove and can result in long term discharge.

Limitations

- Boom should be installed to stay seaward and as parallel to current flow/shoreline as possible.
- Sufficient minimum water depth to float boom.

Operating Requirements

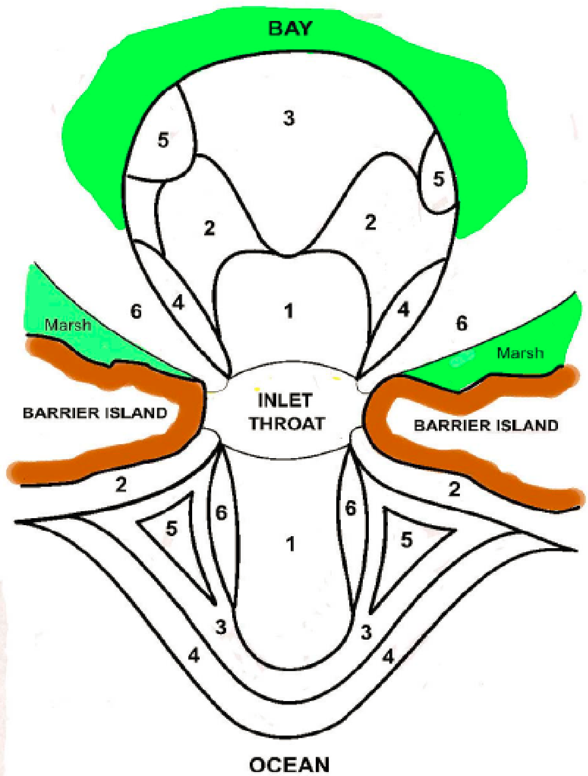
- Periodic monitoring and maintenance required.
- Sorbent (boom or snare sweep) can be placed between boom and feature.

4.3.5	EXCLUSION and DEFLECTION
	EXCLUSION BOOMING: *FLOOD DELTA, BACK BAY*

(a) Creek mouth exclusion

(b) Back bay wetland exclusion

Location



Equipment:

- Most inshore boom suitable.
- Reversing flow anchoring system or driven piles may be required.

Objectives

- Prevent oil from entering bay and lagoon side channels.

Limitations

- Minimum water depth should be several times the draft of the boom used.

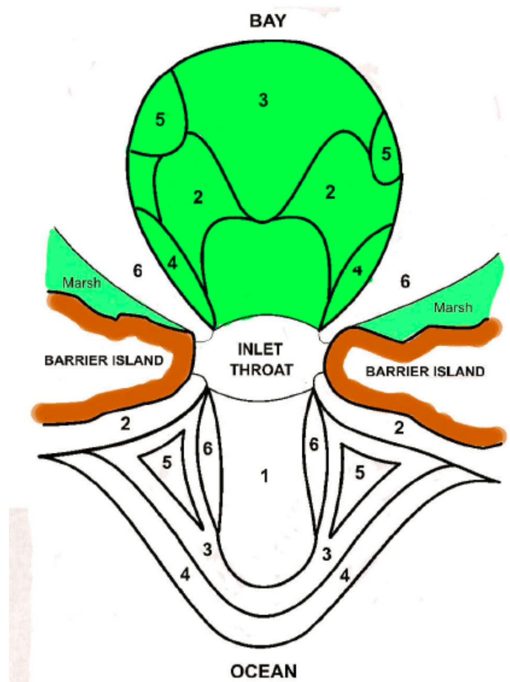
Operating Requirements

- Periodic monitoring and maintenance required.
- Periodic removal of any impounded oil and debris required.
- Boom will require demobilization in the event of deteriorating weather and sea conditions.

4.3.6	EXCLUSION and DEFLECTION
	DEFLECTION BOOMING: *FLOOD DELTA, BACK BAY*

Tidal Boom flood shield deflection

Location



Equipment

- Tidal seal boom.
- Multi-directional anchors, driven piles or screw anchors.

Objectives

- Deflect oil reaching ebb delta ramp and shield away from bay back and lagoon and toward marginal side channels for control and recovery.

Limitations

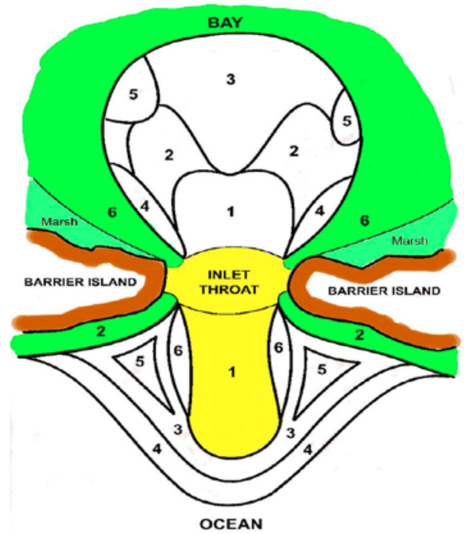
- Booms are difficult to move once deployed.

Operating Requirements

- Booms should be placed to direct floating oil away from back bay / lagoon and toward marginal channels.
- Maintenance of boom position may be difficult. Monitoring and redeployment may be required in response to any changes in local conditions.
- Boom may require demobilization in the event of deteriorating weather and sea conditions.

4.3.7	DIVERT TO SHORE
	DIVERSION BOOMING: ***FLOOD and EBB DELTAS, INLET THROAT***

Location



Equipment

- Interior Shorelines: Fast Water class boom preferred (shallow weighted skirt, bottom tensioned).
- Fast water multidirectional anchor systems or driven piles.
- Deployment boats.

Objectives

- Deploy fast water class boom in single catenary to divert oil to shoreline for recovery.

Limitations

- Minimum water depth should be deeper than draft of boom (suggest at least 3x).
- Anchors may drag on sand bottoms in high flow areas or when tides reverse, requiring redeployment.
- Provisions must be included to remove any oil impounded as it is collected. Vehicle access to boom apex recommended.

Operating Requirements

- Fast water and tidal anchoring tactics required (high maintenance and manpower requirement) High deployment angles are typically necessary and installation must be tight enough to direct oil all the way to the shoreline (Oil caught in bows in boom will be subject loss by entrainment under boom).
- Multiple (redundant) deployments generally recommended.
- Can be deployed using boom vanes (Fig. 4.3.10). Boom will require demobilization in the event of deteriorating weather and sea conditions.

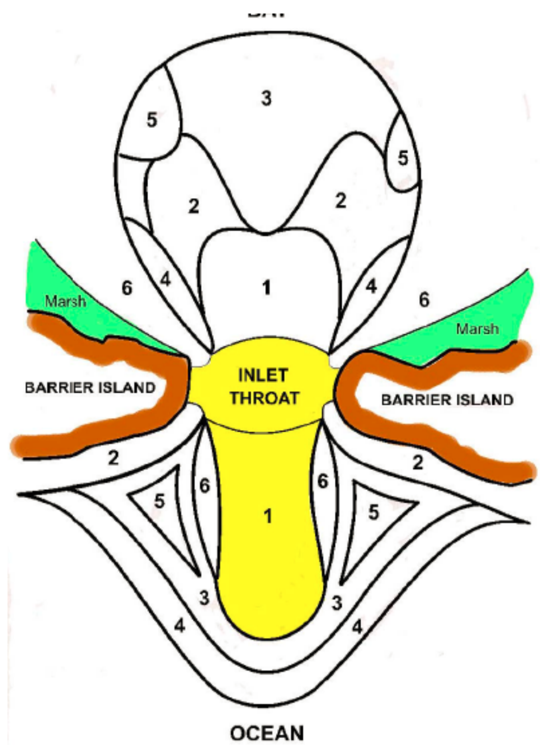
4.3.8

DIVERT TO SHORE

CHEVRON DIVERSION BOOMING: *EBB DELTA, INLET THROAT*

Closed chevron

Location



Equipment

- Fast water boom.
- Fast water multidirectional anchor systems or driven piles.
- Deployment Vessels.
- Warning/Navigation Lights.

Objectives

- Deploy boom in the inlet throat to direct floating oil toward Barrier Islands or fast water skimmers for recovery.

Limitations

- Minimum water depth should be deeper than draft of boom (suggest at least 3x).
- Anchors may drag on sand bottoms in high flow areas or when tides reverse, requiring redeployment.
- Boom may fail in presence of breaking waves.
- Deployment may interfere with navigation.

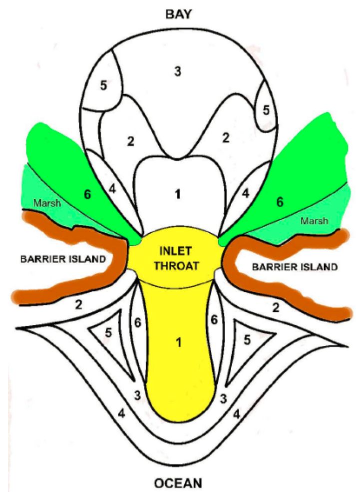
Operating Requirements

- Monitoring and redeployment may be required.
- Deployment is for deflection. Boom should not be allowed to impound oil.
- Boom will require demobilization in the event of deteriorating weather and sea conditions.

4.3.9 DIVERT TO SHORE

CASCADING DIVERSION BOOMS: *FLOOD and EBB DELTAS, INLET THROAT*

Location



Equipment

- Fast water class boom.
- Fast water multidirectional anchor systems or driven piles.
- Oil recovery and storage capability.
- Deployment and tending vessels.

Objectives

- Direct floating oil to shoreline in high current areas for recovery.

Limitations

- Minimum water depth should be deeper than draft of boom (suggest at least 3x).
- Anchors may drag on sand bottoms in high flow areas or when tides reverse, requiring redeployment.
- Rapid deployment and maintenance of boom position may be difficult, particularly in tidal situations.
- Longer deployment time requirements than other diversion systems.
- Boom may fail in presence of breaking waves.

Operating Requirements

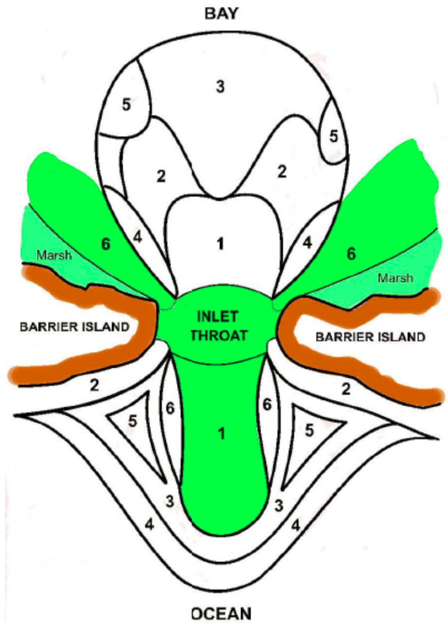
- Significant monitoring and redeployment may be required in response to any changes in local currents or wave approach direction. Not designed to contain oil.
- Boom will require demobilization in the event of deteriorating weather and sea conditions.

4.3.10	DIVERT TO SHORE
	BOOM VANES AND RUDDERS: *FLOOD and EBB DELTAS, INLET THROAT*

(a) Boom Vanes

(b) Boom Rudders

Location



Equipment

- Fast water class boom.
- Large and small boom vanes.
- Boom rudders.

Objectives

- Attach to fast water boom to rapidly deploy boom and maintain shape without anchors or vessels.

Limitations

- Minimum current of 1.5 knots required for deployment—not useable at lower velocity.
- Vane must float above bottom. (Suggest minimum depth of 3 feet (1 m) for small vane and 12 inch (0.3 m) skirt boom.
- Can deploy to only limited distances from shoreline.
- Vanes must be redeployed at every tidal reversal.

Operating Requirements

- Constant monitoring and redeployment crew required.
- Must have shoreline connection (Tidal seal boom, buried boom skirt, etc.).
- Contained oil must be recovered continually or boom drainage will occur.

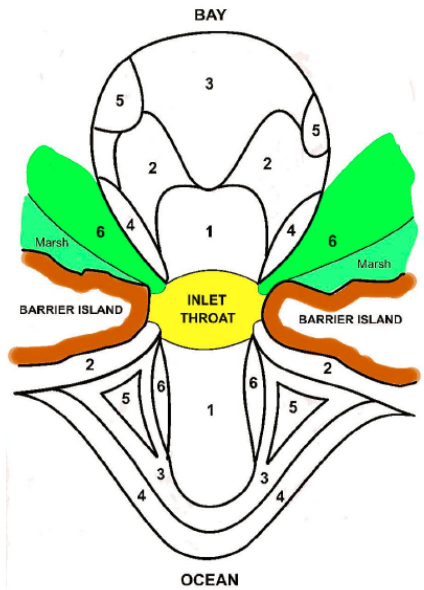
4.3.11 **DIVERT TO SHORE**

AIR CURTAIN DIVERSION: *FLOOD DELTA, INLET THROAT, BACK BAY*

(a) Prototype floating air curtain

(b) Air barrier

Location



Equipment

- Large portable compressors.
- Perforated pipe, hose, valves and anchors.
- Oil recovery sand storage equipment.

Objectives

- Flow of air from sunken pipe is used to create a diverging surface flow which presents a barrier to floating oil. Use to divert floating oil to shoreline for recovery.

Limitations

- Effectiveness diminishes at velocities above 1.5 knots.
- Requires minimum water depth > several meters.
- Require large compressors and shoreline access.
- Perforated pipe may be difficult to anchor or reposition in high currents.

Operating Requirements

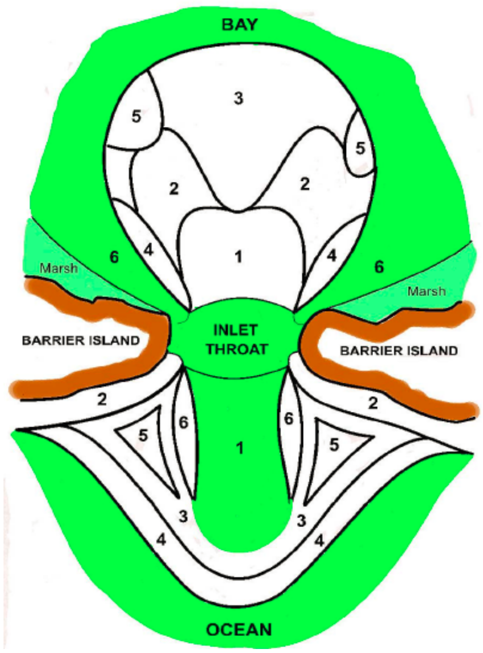
- Requires full-time operating personnel and monitoring.
- Submerged pipe and anchors require removal after use.

4.3.12	RECOVERY TACTICS
	ON-WATER RECOVERY: ***OCEAN, FLOOD and EBB DELTAS, INLET THROAT, BACK BAY***

a) Fast Water (NOFI)

b) Vacuums—Vacuum Truck

Location



Equipment

- Advancing/ offshore class skimmers.
- Fast Water Skimmers (high flow areas).
- Conventional skimmers (onshore).
- Support Vessels.
- Onsite storage capability.

Objectives

- Use vessel operated advancing or stationary skimming systems to recover oil contained offshore.
- Use anchored advancing or fast water skimmers to recovery oil in high current areas.
- Use fast water or conventional skimmers and vacuum trucks to recover oil contained along shorelines.

Limitations

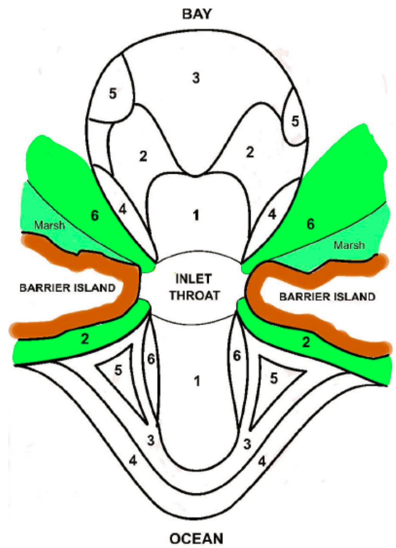
- Sufficient depth to float skimming device.
- Skimming effectiveness is likely to be ineffective with breaking waves.

Operating Requirements

- Requires full time operating personnel.
- Adequate storage capacity must be provided to maintain skimming.

4.3.13	RECOVERY
	BERMS, TRENCHES and PUMP/VACUUM: ***FLOOD and EBB DELTAS, BACK BAY SHORELINES***

Location



Equipment

- Manual or mechanized excavating equipment.
- Oil recovery / storage capability.

Objectives

- Construct pie across mid/upper intertidal zone to collect incoming oil. Pit may be connected to sand berm extending into water, or to diversion boom. Most useful where oil is moving along shoreline or diverted to shore.

Limitations

- May be difficult to keep pit open (caving of sides or infilling).
- Oil may be buried as pits fill in.
- Mechanized access to shoreline preferred.

Operating Requirements

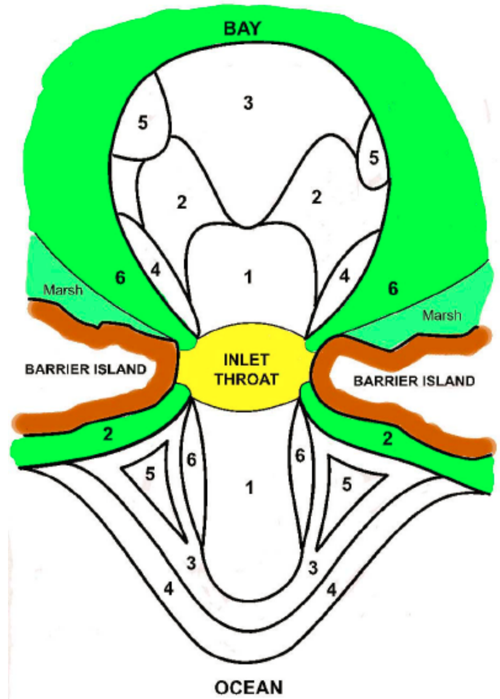
- Locations of all excavations must be accurately located and/or marked.
- Monitoring and recovery of collected material must be conducted periodically.
- Removal of all oil in pit sediments will be required during demobilization / restoration.

4.3.14	RECOVERY
	SORBENTS: ***FLOOD and EBB DELTAS, INLET THROAT, BACK BAY***

Anchored sweeps—shallow, intertidal

Boom gaps

Location



Equipment

- Stock of sorbents.
- Spent sorbent bags / bins.
- Screw sand anchors.

Objectives

- Sorbent sweeps can be attached to shallow and exposed sand bars to collect lighter amounts of floating oil.
- Sorbents can be used to back booms and plug boom gaps at shorelines.

Limitations

- Relatively calm conditions required.
- Anchoring sweeps may be difficult in exposed locations.

Operating Requirements

- Monitoring, repositioning and change out of sorbents required.
- Spent sorbents should be bagged and removed regularly.

5 References

API 2013a. Shoreline Protection on Sand Beaches: Phase 1—Final Report. API Technical Report 1150-1, Washington DC, 35 pp.

API 2013b. Shoreline Protection on Sand Beaches: Phase 2—Field Guide. API Technical Report 1150-2, Washington DC, 18 pp.

Boothroyd, J.C., 1987. Tidal Inlets and Tidal Deltas, In *Coastal Sedimentary Environments*, R.A. Davis, Jr. (ed.), Springer-Verlag, New York.

Carter, R.W.G., 1989. Coastal Environments. Academic Press, London, 617 pp.

Davis, R.A. Jr. and Fitzgerald, D.M., 2004. Beaches and Coasts, Blackwell, 419 pp.

Hayes, M.O., 1975. Morphology of Sand Accumulations in Estuaries. *In* Cronin, L.E. (ed.) Estuarine Research, Vol. 2, Geology and Engineering. Academic Press, NY, pages 3-22.

Hayes, M.O., 1991, Geomorphology and Sedimentation Patterns of Tidal Inlets: A Review. *Proceeding Coastal Sediments '91*, American Society of Civil Engineers, NY NY, 1343-1355.

Hayes, M.O. and Montello, T., 1995. The Development of Potential Protection Strategies for Tidal Inlets. *Proceedings International Oil Spill Conference*, American Petroleum Institute, Washington, D.C., Pub. No. 4620, pages 1012-1013.

Hubbard, D.K, Oertel, G. and Nummedal, D., 1979. The Role of Waves and Tidal Currents in the Development of Tidal-Inlet Sedimentary Structures and Sand Body Geometry; Examples from North Carolina, South Carolina, and Georgia. Journal. Sedimentary Petrology, 49 (4), 1071-1092.

NOAA, 2001. Mechanical Protection Guidelines. National Oceanic and Atmospheric Administration, Seattle WA, 87 pp.

Owens, E.H., Roberts, H.H., Murray, S.P. and Foget, C.R., 1985. Containment Strategies for Marine Oil Spills in Nearshore Waters. *Proceedings Oil Spill Conference,* American Petroleum Institute, Washington, D.C., Pub. No. 4385, pages 113-120.

USACOE, 1984. Shore Protection Manual. Department of the Army, US Army Corp of Engineers. Coastal Engineering Research Center, Vicksburg MS, 2 Volumes.

Appendix A

User Guide Checklists

A.1 User Guide for Prespill Planning Appendix

1. RECOGNIZE INLET FEATURES.

   a. Use the generic model of an inlet system (Figures 2.1, 2.2 and 2.6) and the steps listed in Section 2.3.4 to identify the component features of the inlet.

   b. Complete the template presented in Table 2.2.

   c. Bear in mind that not every inlet has the symmetry and character of the generic model shown in Figure 2.1.

2. UNDERSTAND THE DYNAMICS OF AN INLET SYSTEM.

   a. After the components have been identified, read Section 2.2 that describes some of the key processes that operate in the different parts of the inlet system.

   b. Consult Table 2.3 and Figure 2.9 which present the same information in tabular and graphic forms respectively, to understand how water depth and current patterns change for each of the component features as the tidal waters ebb and flood.

   c. Consult Sections 3.1 and 3.2 for descriptions of how oil moves through an inlet system on a flood tide.

   d. Read Sections 3.3 and 3.4 to identify some of the operational opportunities and constraints that are typical of inlet systems.

3. SELECT RESPONSE STRATEGIES AND TACTICS.

   a. Consult Section 4.1 to develop a regional response strategy that includes containment and recovery or elimination of the oil before it reaches the inlet area.

   b. Refer to Figure 4.1 to select which strategy(ies) would be appropriate in time and space for the specific inlet system.

   c. Refer to Table 4.2 for a summary of the tactical options for the selected strategy(ies).

   d. Consider operational constraints that may apply to the specific inlet system.

   e. Select strategies and tactical options.

4. VERIFICATION.

   a. Conduct site visits and field deployment exercises.

   b. Modify planned strategies and tactics as appropriate.

A.2 User Guide for Selection of Options During a Response Operation Appendix

1. GATHER INFORMATION.

    a. Obtain chart(s), vertical or oblique aerial photographs, and satellite imagery of the inlet system.

    b. Obtain predicted tide tables for the location.

    c. Determine the estimated arrival time of oil at the inlet system.

    d. Identify what types and amounts of response equipment are available.

    e. Identify deployment times, that is, when can the equipment be in place to contain, recover or redirect oil.

    f. Consult an inlet-specific plan, as might be presented in a Geographic Response Plan, then go to Step 4.

    g. In the absence of an inlet-specific plan, follow Steps 2, 3 and 4 below.

2. RECOGNIZE INLET FEATURES.

    a. Use the generic model of an inlet system (Figures 2.1, 2.2 and 2.6) and the steps listed in Section 2.3.4 to identify the component features of the inlet.

    b. Complete the template (Table 2.2).

    c. Bear in mind that not every inlet has the symmetry and character of the generic model shown in Figure 2.1.

3. UNDERSTAND THE DYNAMICS OF AN INLET SYSTEM.

    a. After the components have been identified, read Section 2.2 that describes some of the key processes that operate in the different parts of the inlet system.

    b. Consult Table 2.3 and Figure 2.9 which present the same information in tabular and graphic forms respectively, to understand how water depth and current patterns change for each of the component features as the tidal waters ebb and flood.

    c. Consult Sections 3.1 and 3.2 for oil movement through an inlet system on a flood tide.

    d. Read Sections 3.3 and 3.4 to identify some of the operational opportunities and constraints that are typical of inlet systems.

4. SELECT RESPONSE STRATEGIES AND TACTICS.

    a. Consult Section 4.1 to develop a regional response strategy that includes containment and recovery or elimination of the oil before it reaches the inlet area.

b. Refer to Figure 4.1 to select which strategy(ies) would be appropriate in time and space for the specific inlet system.

c. Refer to Table 4.2 for a summary of the tactical options for the selected strategy(ies).

d. Consider operational constraints that may apply to the specific inlet system.

e. Select strategies and tactical options and determine applicability for different tide stages.

Appendix B

Barnstable Harbor

Working Example of Using a Chart to Recognize the Physical Components of a Tidal Inlet

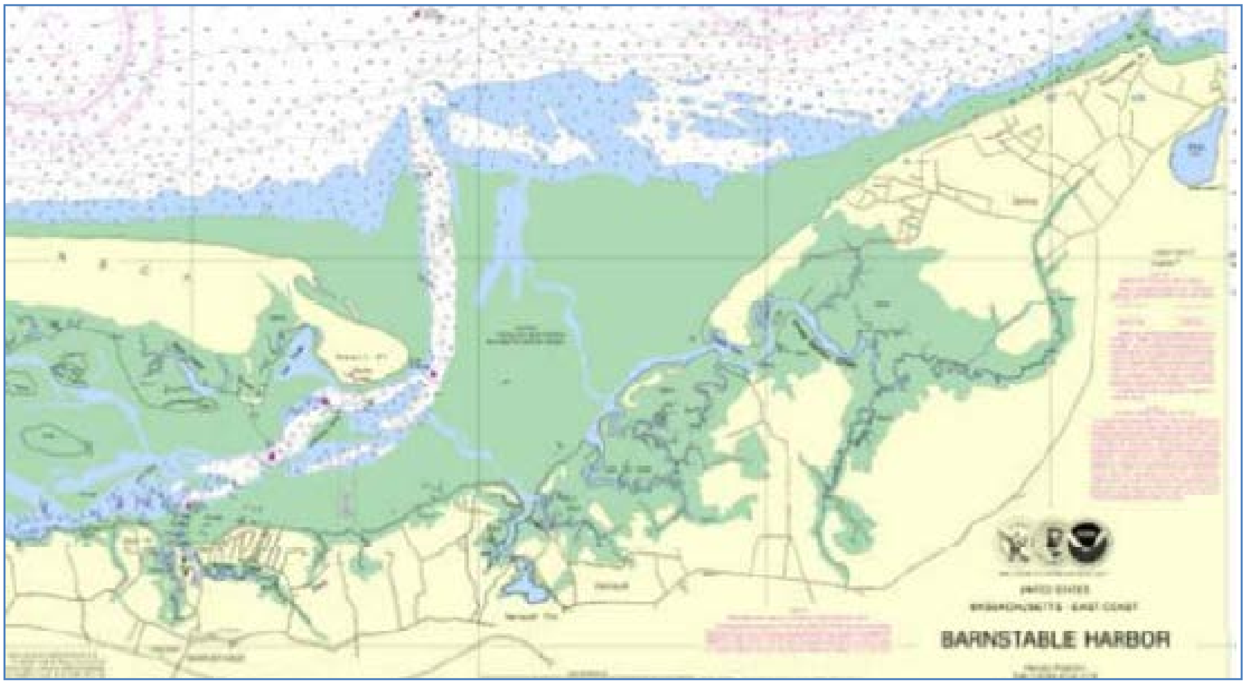


Figure B.1. NOAA Nautical Chart # 13251

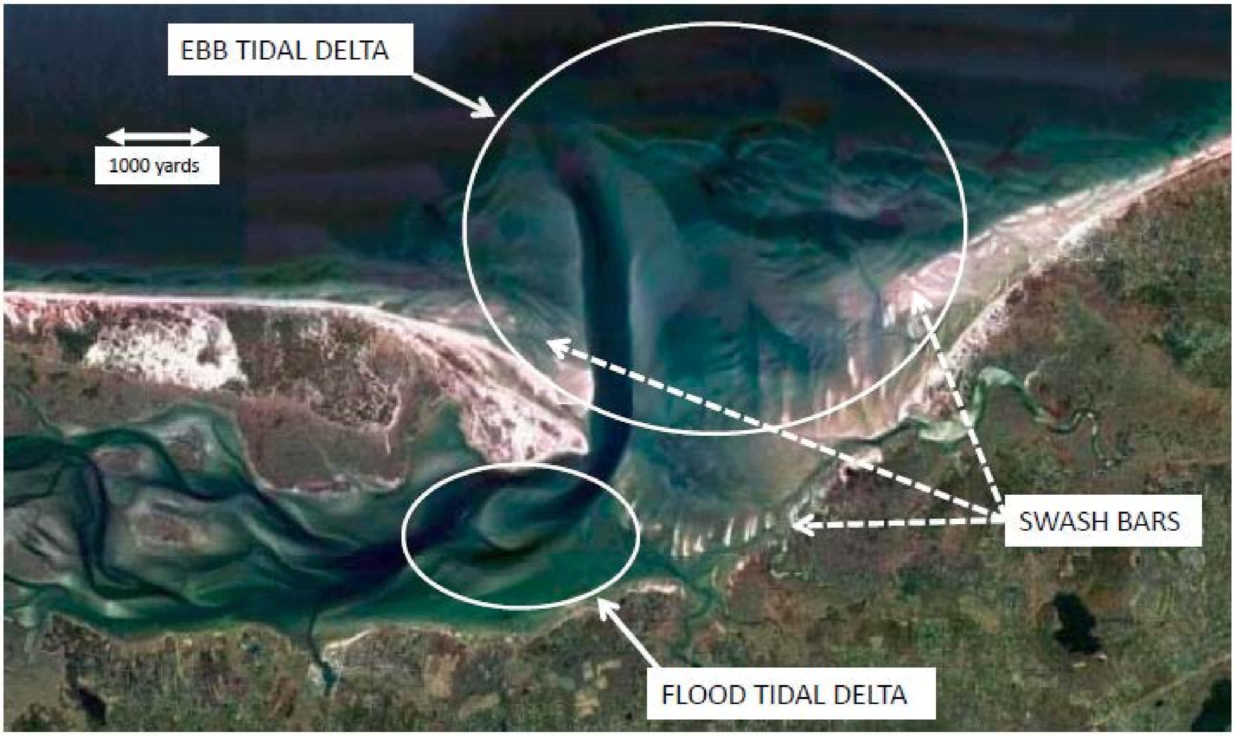


Figure B.2. Satellite Image: Time of Image with Respect to Tidal Water Level is Not Known

- LW and HW lines and depth contours are highlighted on enlarged sections of the nautical chart.
- Morphological components are identified from an interpretation of both the chart and the satellite image.
- These are labeled as indicated in Figures B.3 and B.4.
- In these examples, the primary channels are labeled in red.
- Spillover lobes on the flood delta ebb shield often are relatively small features at these scales. There are not evident from the chart but one (indicated by the green dot on the Figure B.4) is evident from the satellite image.

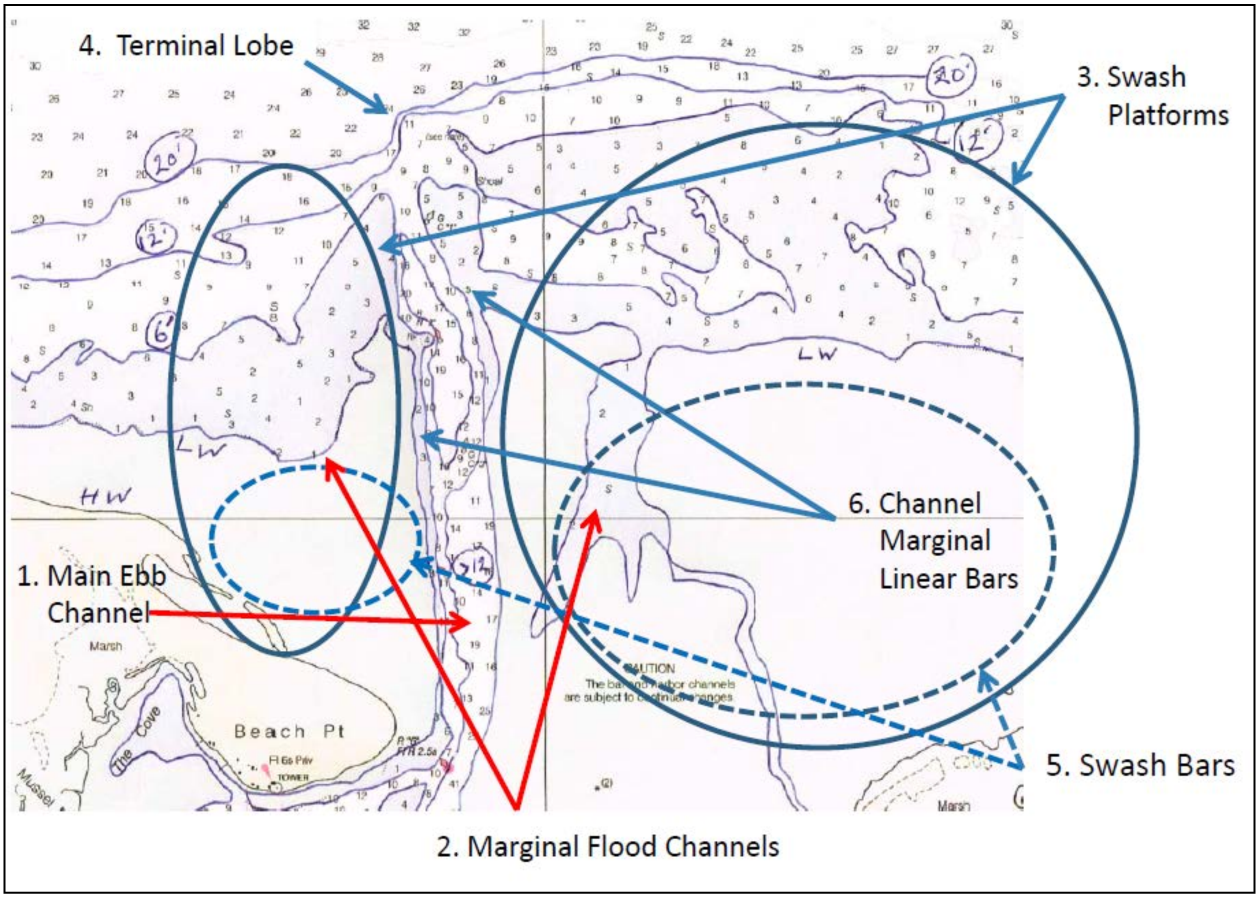


Figure B.3. Ebb Tidal Delta Components

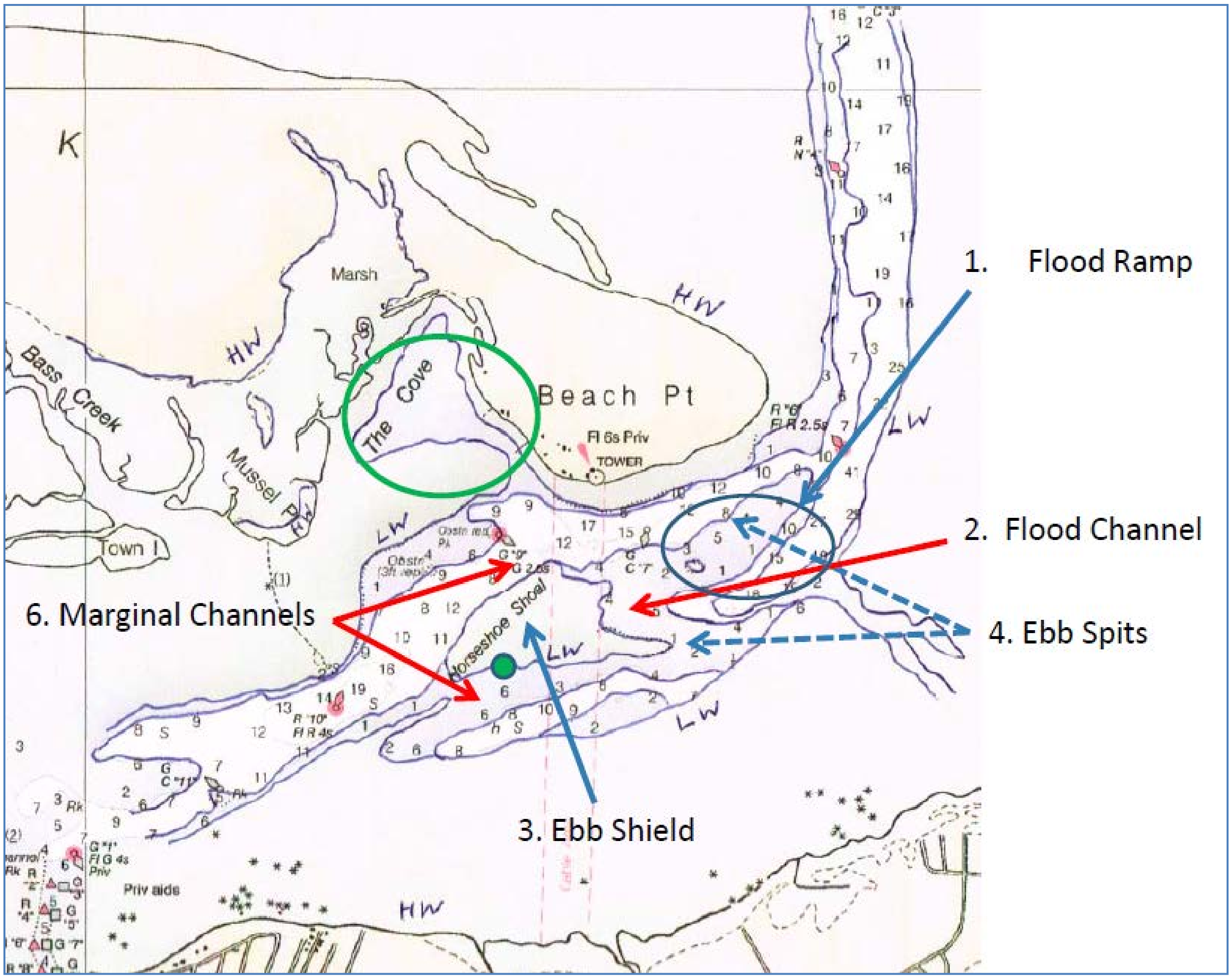
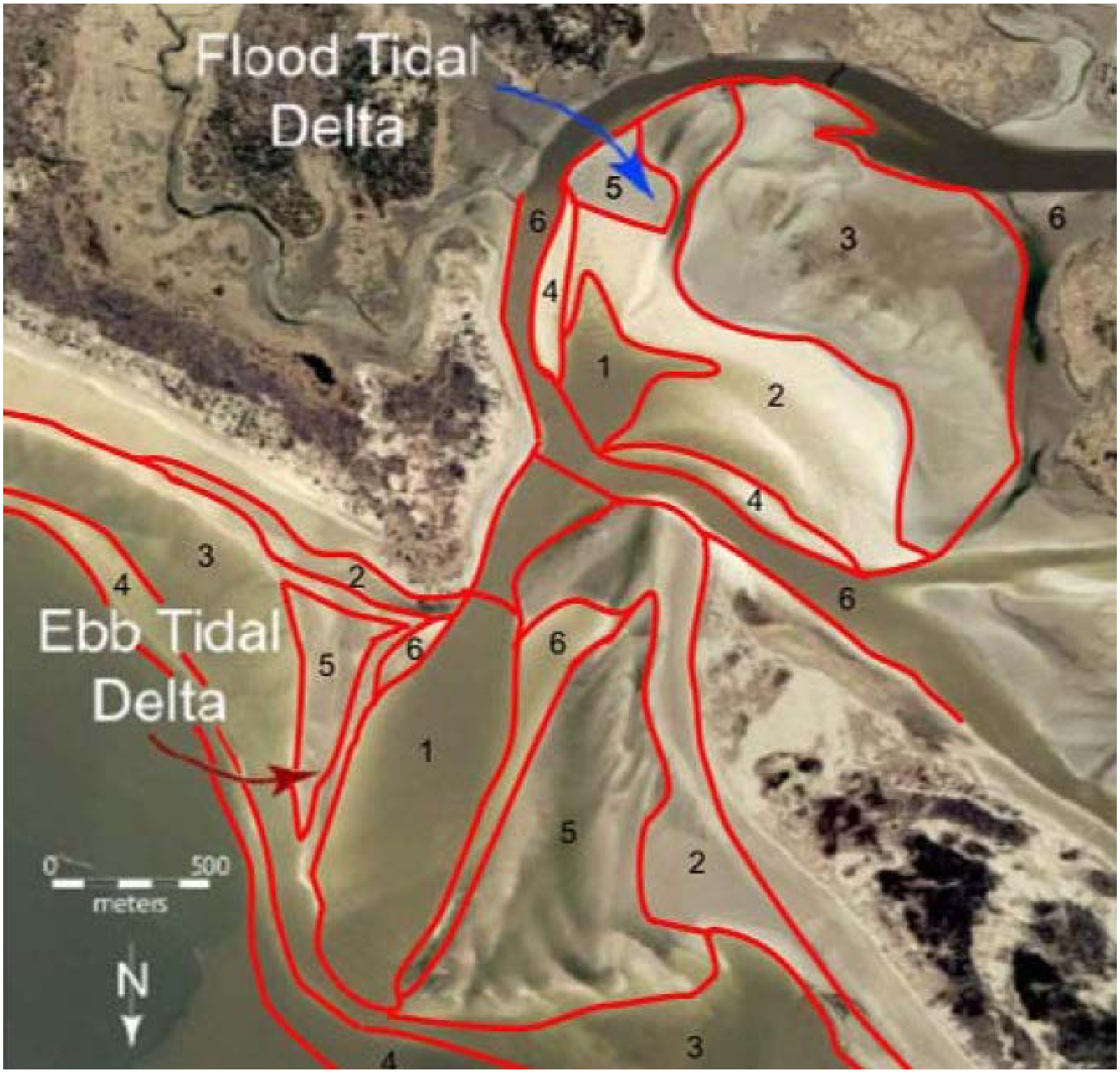


Figure B.4. Flood Tidal Delta Components

Appendix C

Essex River Inlet

This example shows an interpretation of the ebb and flood tidal delta components at the Essex River inlet, MA, from satellite imagery. The numbered components are listed in Figures 2.2 and 2.6.



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