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# MORPHOLOGIC RESPONSE TO A NEW INLET, PACKERY CHANNEL, CORPUS CHRISTI, TEXAS

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**Abstract**: In Jul 2005, Packery Channel was opened by Hurricane Emily during the second year of its construction. This inlet connects Corpus Christi Bay and Upper Laguna Madre to the Gulf of Mexico, and it is the first artificially cut inlet in Texas in 17 years. The inlet has remained open and navigable for shallow-draft recreational boats despite construction delays, and its parallel dual jetties were completed in Sep 2006. A physical process monitoring program was initiated prior to construction in 2003 to track the evolution of the channel, surrounding nearshore, and adjacent beaches. Maximum ebb current in the inlet often exceeds 1 m/s, and an ebb shoal has not yet formed. The shorelines adjacent to the jetties, as well as the seaward longshore bars, respond to seasonal changes in wind direction, hence direction of longshore sand transport. Shoreline change varies seasonally, but adjacent to the inlet the shoreline is nearly symmetrical.

## INTRODUCTION

Environmental interests as well as the commercial and recreational fishing and boating communities in Texas have long been proponents for opening small inlets to connect its bays and lagoons to the Gulf of Mexico (Lockwood and Andrews 1952; Carothers and Innis 1960). Such inlets modulate salinity in the bays and lagoons, and provide a path for migration of juvenile marine organisms. In the early 1970s, such a "Fish Pass" was cut across Mustang Island and into Corpus Christi Bay, but it gradually shoaled and closed

(Behrens1979). The Texas experience with new small inlets is varied, with examples of inlets expanding and deepening too rapidly (Rollover Pass – Bales and Holley 1989), inlets closing too quickly (Yarbrough Cut – Lockwood and Andrews 1952), and yet other inlets being relatively stable (Mitchells Cut – U.S. Army Corps of Engineers (USACE) 1992). There is a general need for improved inlet design for the Texas coast (see Kraus, this issue, for related discussion). Newly created inlets will alter the surrounding coastal morphology at several space and time scales (Kraus 2006).

Historically, Corpus Christi Bay, Texas, was served by two natural inlets (Price 1952) or “passes” in local terminology, Aransas Pass (shared with Aransas Bay to the north) on the north side and Corpus Christi Pass on the south side, in the SSE corner (Fig. 1 and Fig. 2). Dredging of Aransas Pass started in 1912, and its re-direction into Corpus Christi Bay in 1924 caused Corpus Christi Pass to slowly shoal and become a flat ephemeral pass that was overwashed during more severe tropical storms and hurricanes (Price 1952). For many years, local interests have wanted to reopen the old Corpus Christi Pass through an existing dead-end channel called Packery Channel for water exchange. An additional navigational amenity is that access to the Gulf of Mexico from the Upper Laguna Madre and Corpus Christi Bay system would be about 3 miles (5 km) rather than the 23-mile (37 km) transit to Aransas Pass.

The North Padre Island (Packery Channel), Nueces County, Texas, Storm Damage Reduction and Environmental Restoration Project was authorized in the Water Resources Development Act 1999 as a Federal project with Nueces County, Texas, as the original local sponsor. The City of Corpus Christi assumed local sponsorship in 2000. Construction began in Oct 2003, and the inlet officially opened in Oct 2006. It is stabilized by two parallel jetties oriented 12 deg north of shore normal. The jetties are spaced 300 ft (91 m) apart extending 1,430 ft (427 m) into the Gulf of Mexico. The channel is to be maintained to a depth of 14 ft (4.3 m) MLLW. The original design study estimated that, after equilibrium, a dredging cycle of 1-3 years would be required (Kraus and Heilman 1997). Sand dredged from the channel as new work and maintenance material will be placed on adjacent beaches as a shore-protection element.

In Jul 2005, Packery Channel was opened by Hurricane Emily during construction of the jetties. The inlet connects Corpus Christi Bay and Laguna Madre to the Gulf of Mexico, the first new artificially created inlet in Texas in 17 years (Figs. 1 and 2), and now effectively defines the boundary between Padre Island and Mustang Island to the north. Inlet construction was in its second year when the storm surge eliminated the approximately 350-ft (107 m) wide sand plug that separated the channel from the Gulf and served as a land bridge for construction. The inlet has remained open since then.

This paper presents selected results of the 3 years of physical process monitoring of the channel, shoreline, nearshore bathymetry, and current. In addition to its general benefit for improving knowledge of coastal inlets, monitoring supports adaptive management of Packery Channel and adjacent beaches as a sediment-sharing system.

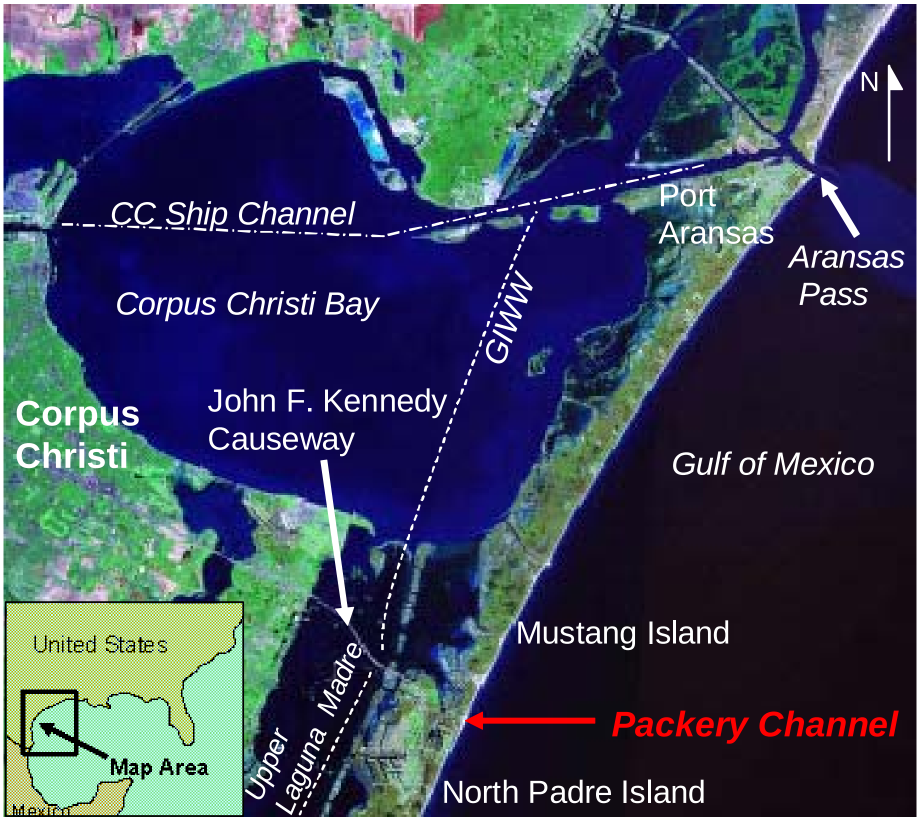


Fig. 1. Location map for region of Packery Channel, Texas.

## MONITORING PROGRAM

In anticipation of construction, in Aug 2003 the USACE Galveston District initiated baseline and construction monitoring of morphology change at Packery Channel and the adjacent beaches through a contract with Texas A&M University-Corpus Christi (TAMU-CC). The functional design of Packery Channel identified probable responses in morphology (Kraus and Heilman 1997) and hydrodynamics (Brown and Militello 1997). The monitoring program includes surveys of the beach profile, ebb shoal, and channel; sediment sampling; measurement of channel current; aerial photography; shoreline and upper beach surveys; and development of a combined wave, circulation, and morphology change numerical model. Survey data are recorded relative to NAVD88, and depths are referenced to MSL (MSL = NAVD88 + 0.48 ft). The monitoring area encompasses 2.4 miles (3.8 km) of the Packery Channel inland waterway from the Gulf Intracoastal Waterway (GIWW) intersection to State Highway (SH) 361, the 1 mile (1.6 km) entrance channel west of SH361, and 8 miles (13.2 km) of adjacent beach from south of Bob Hall Pier on Padre Island to north of Mustang Island State Park.

Access to data, aerial photography, and real-time current measurements is available at the Texas Inlets Online website (http://goliath.cbi.tamucc.edu/TexasInletsOnline/). The physical processes monitoring program was described by Williams et al. (2005). An independent environmental monitoring program is also being conducted (HDR/Shiner

Moseley 2006). Past monitoring was accomplished in part by coordination with construction milestones listed in Table 1.

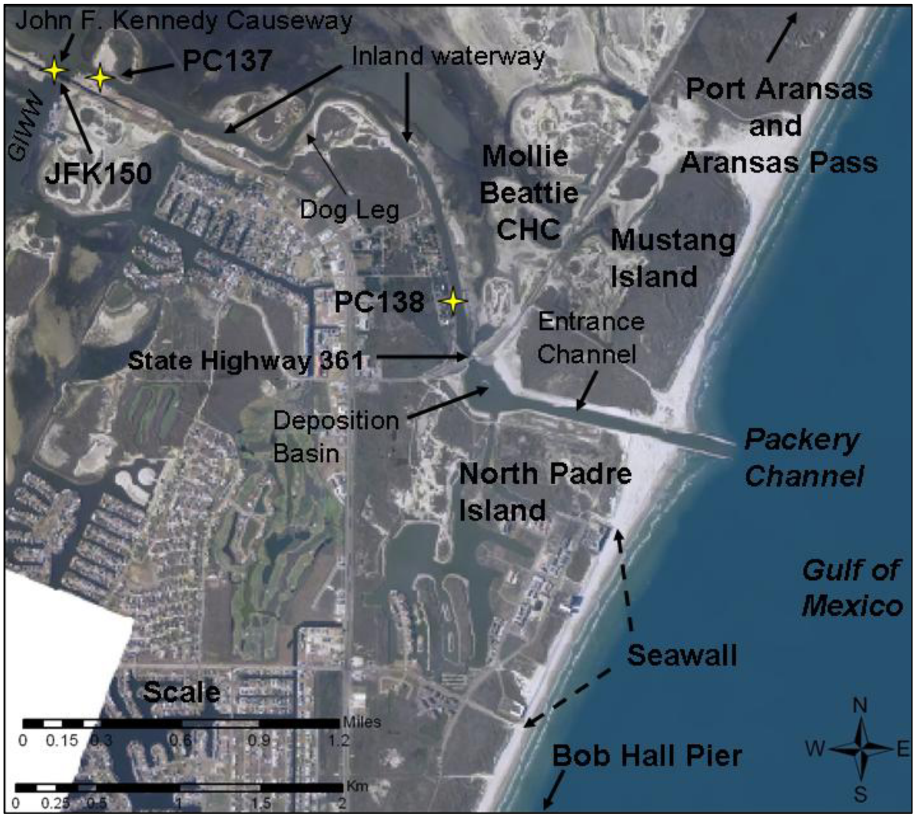


Fig. 2. Packery vicinity map, 16 Aug 2006 (Tobin Aerial Photography).

## RESULTS

### Water Level, Wind, and Channel Current

Packery Channel is located near two long-term tide gauges, a National Ocean Service (NOS) gauge in the Gulf of Mexico at Bob Hall Pier called "Corpus Christi," and the other on the bay side and along the original Packery Channel inland waterway (Fig. 2). Water level along the Texas coast is controlled by the astronomical tide, local wind, and seasonal change in Gulf water level. A seasonal or low-frequency fluctuation occurs with highs around May and October, and lows in August and December through January. The tide at the Corpus Christi gauge and Packery Channel is diurnal with diurnal range of 1.63 ft (0.50 m) and 0.38 ft (0.12 m) respectively.

The wind along the Texas Coast is strongly bimodal with persistent southeasterly wind from March or April to August or September. Northerly episodic winds accompany frontal passage from September or October to February or March. Southerly winds increase as fronts approach, with rapid reversal in direction as the systems move off the coast. With the opening of Packery Channel, the strong wind enhances water exchange between Corpus Christi Bay and the Gulf of Mexico. Persistent southeasterly and onshore directed easterly wind force water from the Gulf into the bay system, whereas northerly, particularly northwesterly wind, forces water toward the Gulf. Prior to opening of Packery Channel, northwesterly winds set up water in the SE corner of Corpus Christi Bay causing water to rise along the flats adjacent to SH361, now known as the Mollie Beattie Coastal Habitat Community (CHC). With a pathway to the Gulf through Packery Channel, water exits this portion of the bay during frontal passages, greatly enhancing the ebb current flow in the inlet.

**Table 1. Packery Channel Construction Timeline**

| Activity | Date | Comment |
|---|---|---|
| Construction begins | Oct 03 | --- |
| Dredge inner channel | Dec 03 - Apr 04 | --- |
| Land dredged to form channel; material placed on south beach | Apr – Jul 05 | 136,077 cy (104,038 $m^3$) bypassed |
| Channel opens (Hurricane Emily) | 19 Jul 05 | Removed sand plug |
| Narrow channel remains open | Jul - Dec 05 | --- |
| Channel dredged; material placed on beach south of inlet | Jan - Feb 06 | 679,089 cy (519,200 $m^3$) bypassed |
| S jetty completed to 1,430 ft (427 m) | Mar 06 | --- |
| N jetty completed to 1,430 ft (427 m) | Jun 06 | Landward end incomplete |
| Scour hole at S Jetty filled with rock and concrete slabs | Aug 06 | --- |
| Landward end of N jetty completed | Sep 06 | --- |
| Official opening. Transfer to local sponsor in progress | Oct 06 | --- |

Three current monitoring stations were deployed to measure the current in Packery Channel and in the GIWW near the Packery Channel intersection (Fig 2). The magnitude of the current is either enhanced or suppressed during periods of strong wind (Fig. 3). The primary Packery Channel current station, PC138, is located 0.25 mile (0.4 km) north of the SH361 Bridge (http://lighthouse.tamucc.edu/qc/138/). The current follows the phase of the tidal signal measured at the Corpus Christi gauge in the Gulf of Mexico. A second station, PC137, is located near the Packery water level station. The Packery stations were deployed during Sep 2005, each equipped with a side looking SonTek Argonaut mounted on existing structures at mid-depth. Data are collected remotely and posted in real time. The current speed at PC138 is an order of magnitude greater than at PC137. The difference in speed is related to distance from the inlet and change in channel orientation (dog leg). In the inland waterway of Packery Channel, the dog leg effectively separates the western section of the channel from the eastern channel. The entrance channel begins at the SH361 bridge and deposition basin.

Since deployment in Sep 2005, the average ebb and flood current speeds have been 0.44 and 0.38 m/s, respectively, and a maximum ebb current of 1.85 m/s and maximum flood current of 1.56 m/s have been measured during strong wind. Flood flow is enhanced by strong E-SE wind forcing water against the Gulf shoreline and into the bay/lagoon system through the channel (Fig. 4). Strong E-SE wind typically precedes frontal passage. Ebb flow is enhanced during frontal passage as water set-up along the northern shore of the bay/lagoon system by E-SE wind is released, in part, through Packery Channel. Northerly winds can initiate abrupt reversal in current direction. Ebb flow will often continue for several days as the bay system returns to equilibrium level.

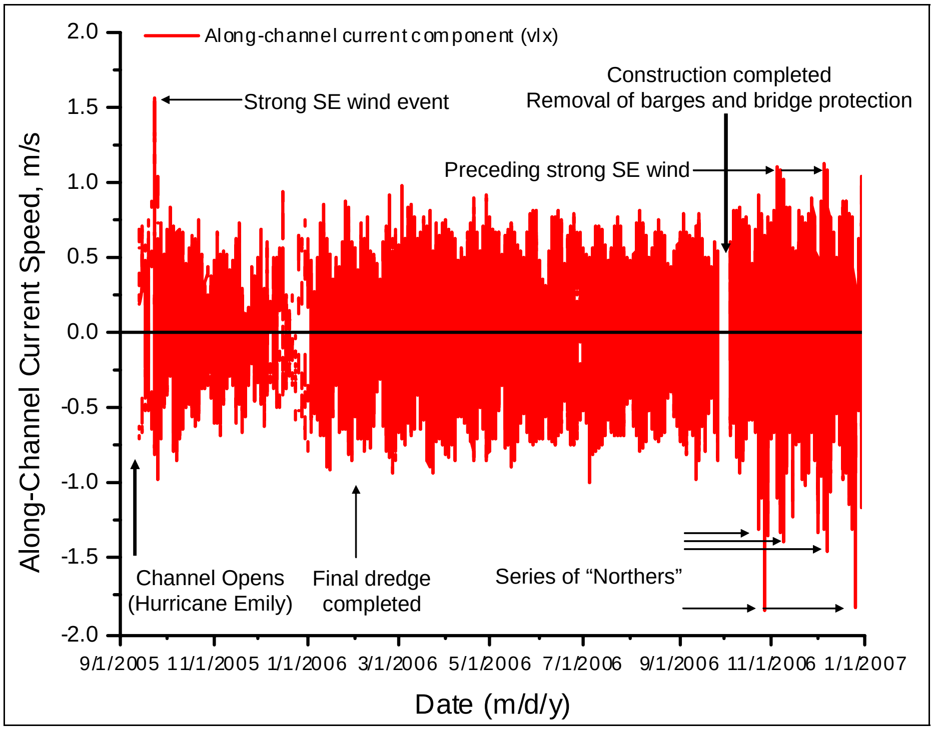


Fig. 3. Current record for PC138 showing key events.

The GIWW current meter (JFK150) is bottom mounted at a depth of 26 ft (8 m) in the center of the channel under the John F. Kennedy Causeway Bridge. Current in the GIWW is strongly influenced by the southeasterly wind that dominates the signal during the spring and summer (Fig 5). Although the signal follows the Gulf tide, flood flow pushing southward may be subdued or reversed during persistent SE wind. The current flows northward under solar diurnal SE forcing with reversals during frontal passage. The average current speed toward Corpus Christi Bay to the north is 0.23 m/s, and to the south it is 0.20 m/s. The maximum current speed toward the north recorded since Jun 2006 was 0.79 m/s and toward the south 0.78 m/s.

**Sediment**

Sediment in the study area is supplied by two sources. The bay and lagoon supply silt and shell hash introduced through erosion of flats and shoreline. North Padre and Mustang Island beaches supply fine sand. Finer grain size material with a component of shell hash is found in the inland waterway nearest to the GIWW where weaker currents allow deposition of sediment originating in the adjacent bay and lagoon. The deposition basin includes the influence sedimentation with fine material found around the periphery and deeper central sections. The entrance channel bottom is composed of fine sand with a median grain size of 0.15 mm. Sediment grain size increases moving toward the barrier islands where the median grain size of North Padre and Mustang Island sand is, on average, 0.16 mm.

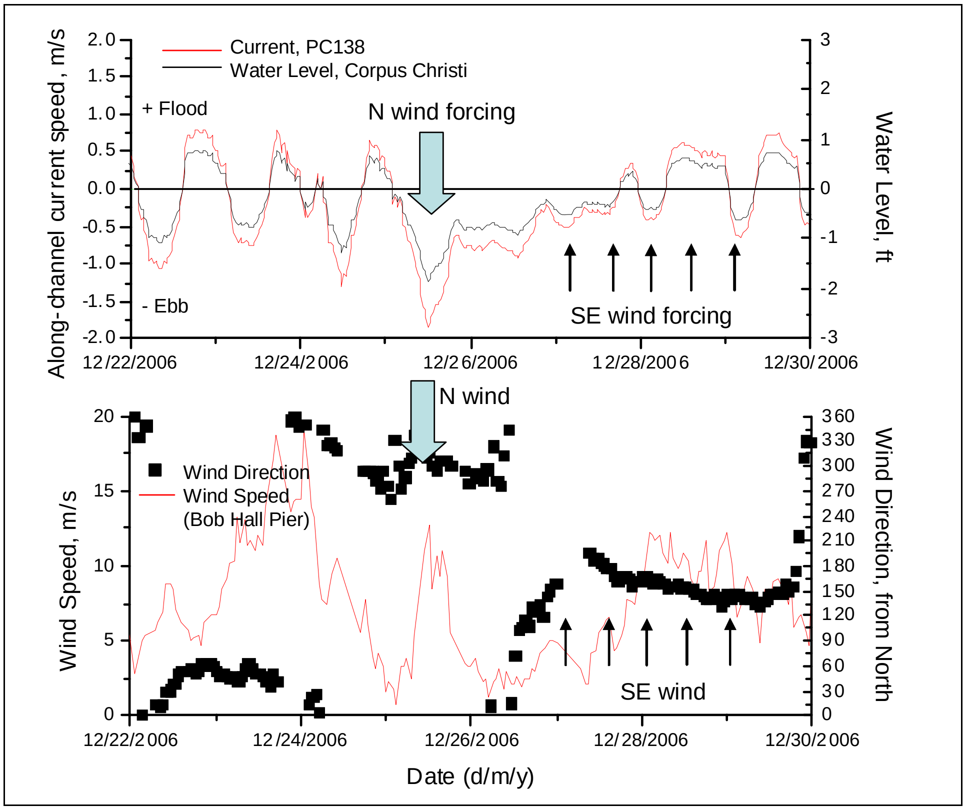


Fig. 4. Response of current to wind forcing at PC138.

## Long-Term Shoreline Change and Longshore Sand Transport Rate

Along this coast, long-term shoreline change is recession of about 5 ft/yr (1.5 m/yr) (Morton and Pieper 1977). The design study for the project (Kraus and Heilman 1997) indicated that Packery Channel is located near a divergent nodal point in longshore sand transport. They estimated that the net direction of transport is to the south, with a gross rate of 150,000 to 250,000 cu yd/yr and net rate of 45,000 to 70,000 cu yd/yr.

## Nearshore and Channel Morphology

In the early stages of jetty construction from Aug 2004 to Jul 2005, sand accreted between the short jetties. The sand plug that functioned as a land bridge for construction activities began to slowly advance seaward as did the adjacent shoreline to the north. Once the storm surge associated with Hurricane Emily removed this limiting feature, changes in morphology both within and adjacent to the inlet accelerated. In addition to Emily, Hurricanes Katrina and Rita increased flow in the new inlet during autumn of 2005. The narrow entrance channel remained open and navigable by small craft. In Jan 2006, with the channel still open, the entrance was dredged to facilitate barge operation associated with construction, as well as to replace sand eroded at the south end of the seawall during the active storm season. The incomplete north jetty limited the extent of dredging into the Gulf of Mexico.

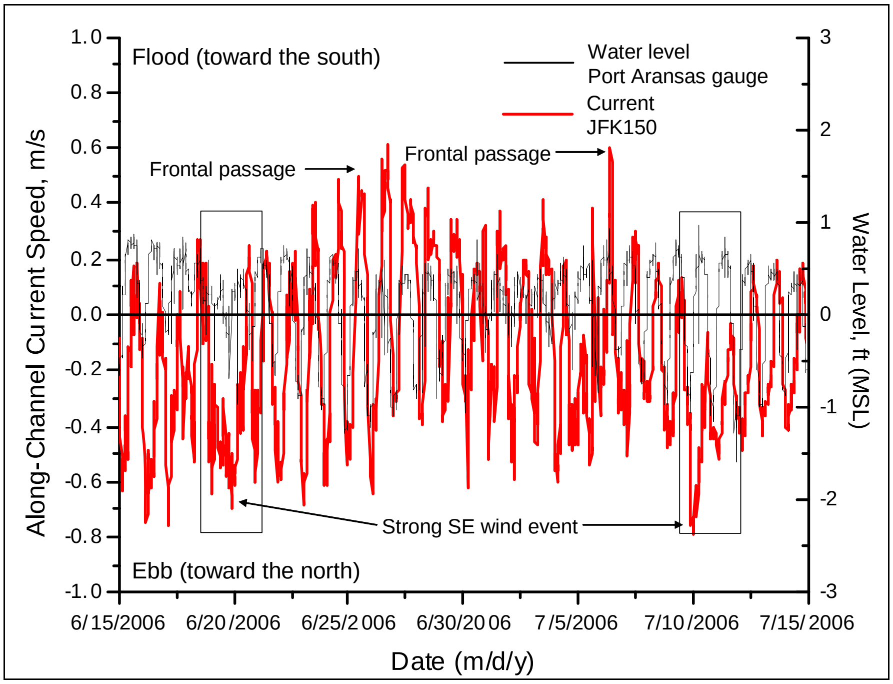


Fig. 5. Wind influence on GIWW current direction.

After the channel opened during Hurricane Emily, shoaling occurred at the existing mouth as observed on 29 Jul 2005 (Fig. 6). Depth in the channel where the sand plug had been was on the order of 2 to7.5 ft (0.6 to 2.3 m) with deepest areas in the center channel. The depth at the planned gulfward end of the jetties was 7 to 13 ft (2 to 4 m).

A survey was conducted on 6 Mar 2006 after completion of dredging in Feb 2006. The mouth of the channel had scoured, with shoaling evident adjacent to the jetties west of the mouth. Scour developed at the ends of the uncompleted north jetty and completed south jetty with depths of 20 to 22 ft (6 to 7 m) and 20 to 26 ft (6 to 8 m), respectively, where the pre-construction depths had been 10 to 13 ft (3 to 4 m) (Fig. 7). This broad region of scour extended beyond the jetties offshore of the mouth with depths of 17 to 20 ft (5 to 6 m). Seven months after Emily forced the channel open, no offshore bar or ebb shoal had formed.

The response of the channel to spring waves from the E-SE was captured in the 17 May 2006 survey (Fig. 8). A well-defined sand bar with crest at a depth of 7 ft (2 m) intersected the south jetty approximately 450 ft (137 m) from its seaward end. The south jetty was completed in Mar 2006, while construction of the northern jetty continued. No longshore bar adjacent to the north jetty appears in this survey. In the entrance channel, deposition occurred along the north jetty and erosion along the south jetty. A probable source for the sediment along the north jetty was a gap that existed between the channel revetment and the incomplete north jetty. This gap allowed transport of sand into the channel during storm surges prior to its closure in Aug 2006. Channel center depth varied from 9 to15 ft (3 to 5 m). Scour at the seaward ends of the north and south jetties decreased to 15 to 19 ft (4.5 to 5.8 m) and 18 to 20 ft (5.5 to 6 m), respectively.

Reduction in scour at the south jetty was related, in part, to placement of the final stone at the offshore extent. The two regions of jetty tip scour on the north and south merged and extended with depths of 15 to 20 ft (4.5 to 6 m) radiating offshore from the mouth and no ebb shoal was present.

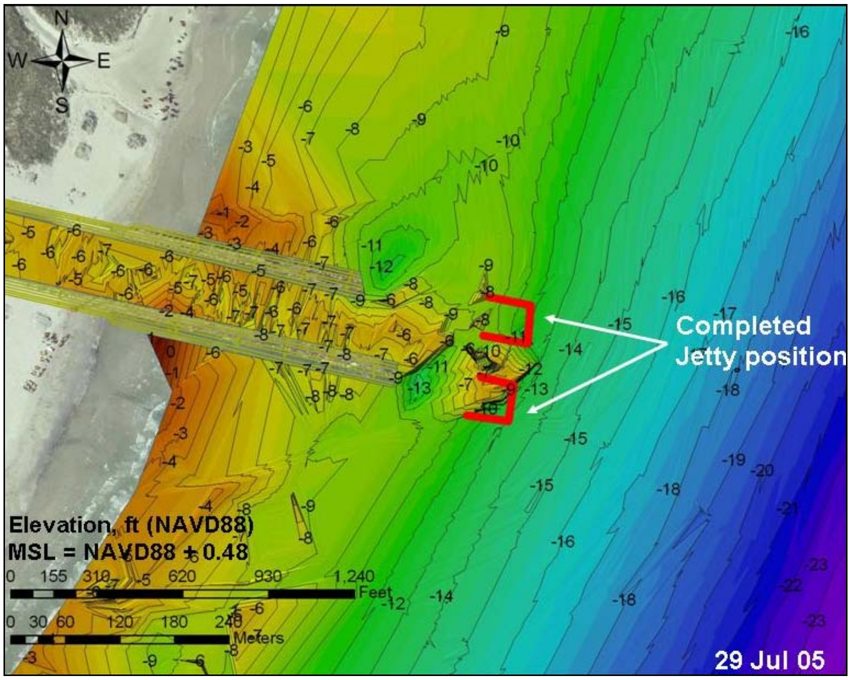


Fig. 6. Channel and nearshore morphology after Hurricane Emily (29 Jul 2005).

By Aug 2006, the offshore extents of both jetties were complete and onshore construction including the landward end of the north jetty was approaching completion. The south bar had become more defined under SE wind waves transporting sediment toward the north. This bar migrated 450 ft (137 m) offshore and was now in line with the end of the south jetty (Fig. 9). A possible jetty tip shoal developed to the north. In the channel, depth increased along the north jetty by 1 to 4 ft (0.3 to 1.2 m), while central channel depth remained variable with an average decrease of 1 to 2 ft (0.3 to 0.6 m). The offshore region of scour expanded, although a narrow, 40-ft (12-m) wide ridge developed between the jetty tip scour and offshore region of scour. Depth of the ridge was on the order of 16 ft (4.8 m). No ebb shoal or bypass bar was present.

The most recent (16 Dec 2006) survey was conducted after a transition period in weather patterns with numerous frontal systems moving off the coast. These abrupt, strong reversals in wind from SE to out of the NE-NW caused a reversal in sediment transport toward the south, changing the nearshore morphology adjacent to the inlet. In addition, prior to this time, the current had been astronomically dominated and only enhanced or subdued by SE wind forcing water from the Gulf into the bay-lagoon system. Two striking changes occurred as the nearshore responded to the reversal in the sediment transport system: 1) the south bar deflated and became less defined with a small shoal protruding offshore at northern end, and 2) a well defined bar developed north of the inlet (Fig. 10). Scour became more pronounced at the seaward end of the north jetty where depths offshore of the mouth ranged from 14 to 25 ft (4 to 7.6 m) with the deeper region directly adjacent to the jetty. The narrow ridge identified 3.5 months prior widened to 190 ft (58 m), effectively separating the offshore scour from the jetty scour. The depth along the ridge decreased approximately 2 ft (0.6 m) to an average of 14 ft (4.3 m). No ebb shoal was present 1.5 years after the channel opened.

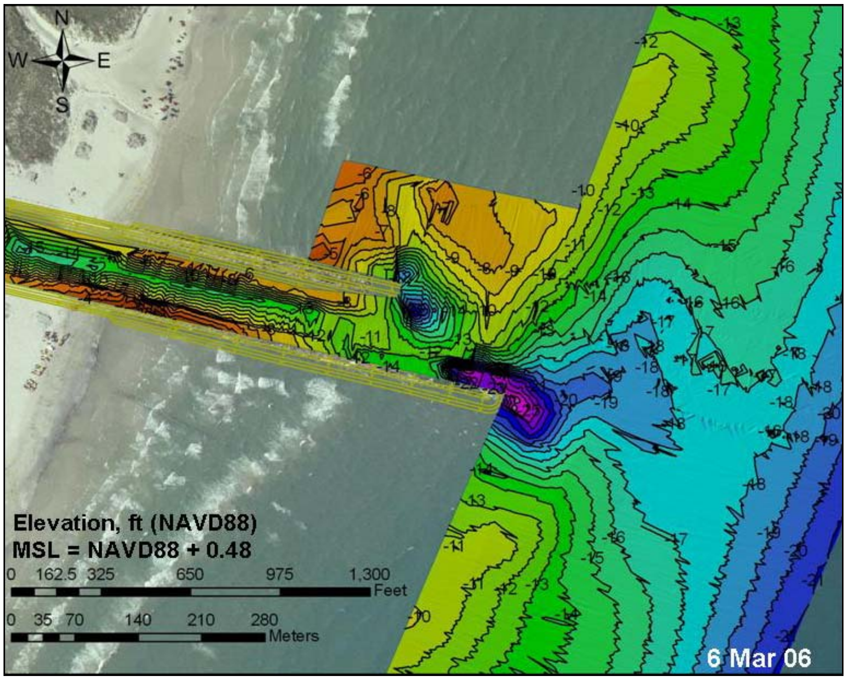


Fig. 7. Scour at channel mouth after final dredging (6 Mar 2006).

By 16 Dec 2006, the majority of the inner entrance channel had deepened, with transport of the scoured sediment toward the inlet mouth. Contours indicate forcing toward the Gulf (Fig. 10). No shoaling occurred at the channel mouth, with depths of 11 to 18 ft (3.4 to 5.5 m) across the entrance. The existence of this deep region at the mouth indicates that the source of the sand shoaling in the inner channel is from redistribution of existing channel sand. Scour along the jetties, particularly the northern jetty, is the likely source.

A strong ebb current exceeding 1.0 m/s with a maximum of 1.85 m/s was measured at PC138 from Oct 2006 through 16 Dec 2006. Over that period, ebb flow occurred more frequently and was sustained longer than flood flow due to strong forcing by N-NW wind during frontal passage. The persistent ebb flow is an effective forcing mechanism capable of redistributing channel sediment eastward toward the channel mouth and ultimately offshore into the Gulf of Mexico. The current in the entrance (between the jetties) will be stronger than that measured at PC138, because of the friction created by channel length and SH361 bridge piers between the entrance and PC138.

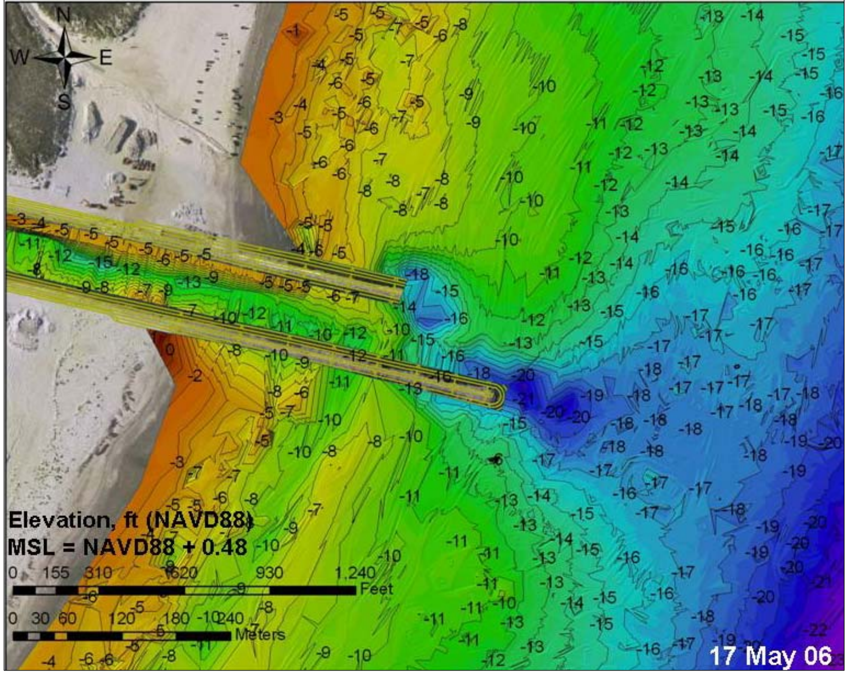


Fig. 8. Scour offshore of channel mouth (17 May 2006).

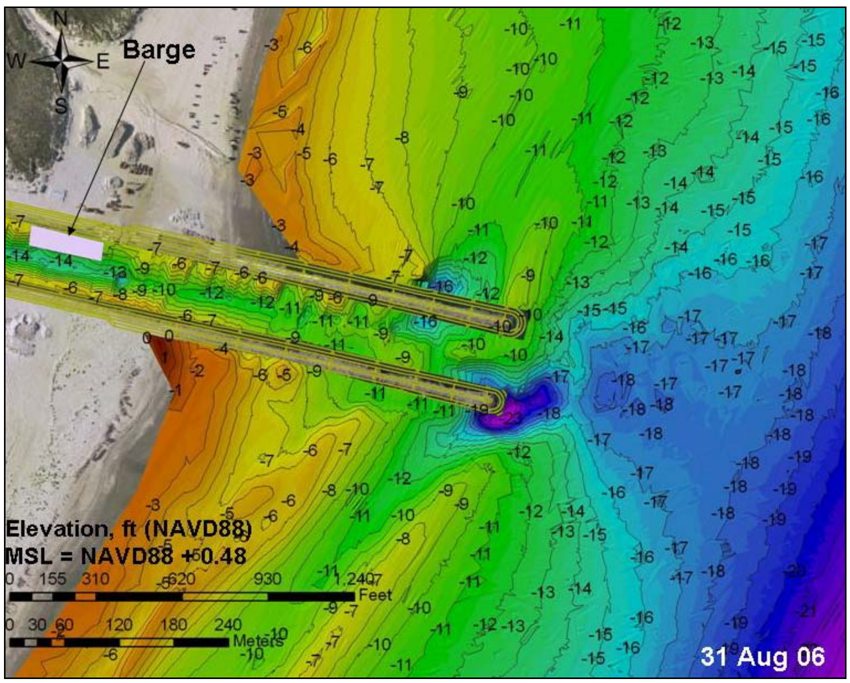


Fig. 9. Jetty tip scour and offshore scour at channel mouth (31 Aug 2006).

**Shoreline Change and Beach Profile Response**

Shoreline change beyond that attributable to seasonal and annual responses has so far been restricted to the region directly adjacent to the inlet and moderates within 1.5 miles (2.4 km) to the south and 1 mile (1.6 km) to the north. Surveys extended from south of Bob Hall Pier northward beyond Mustang Island State Park, a distance of 8.2 miles (13.2 km). The 1.5 to 2- ft (NAVD88) contour corresponds to the location of the berm crest and was selected for comparison to the Aug 2003 pre-construction baseline.

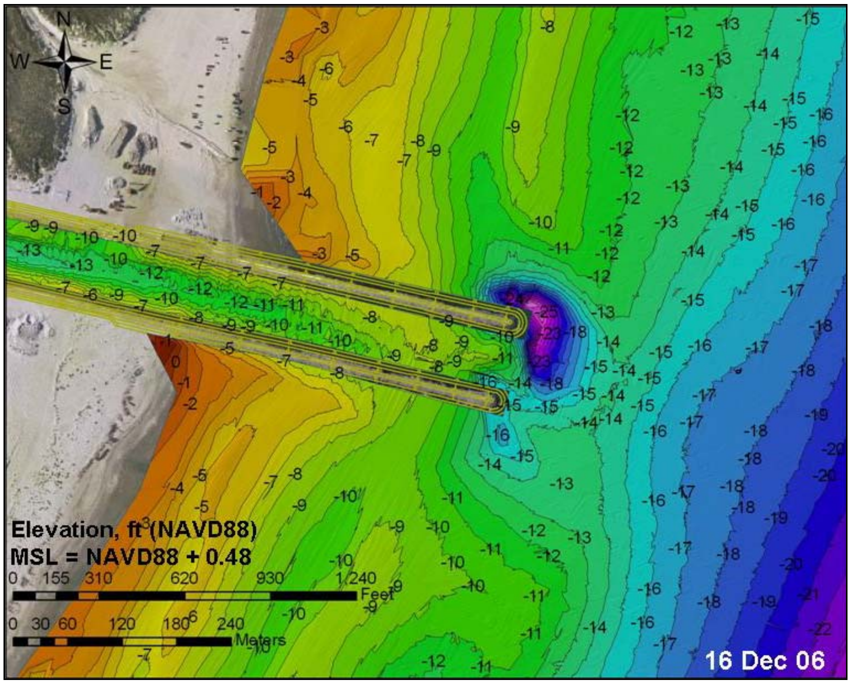


Fig. 10. Ridge between regions of scour offshore of channel mouth (16 Dec 2006).

The shoreline consistently advanced from the inlet to the south end of the seawall from Aug 2003 to Jul 2006. Near to the south jetty, the shoreline advanced a maximum of 400 ft (122 m). Advance in front of the seawall, ranging from a maximum of 200 ft (61 m) on the north end to a post-bypassing maximum of 155 ft (47 m) at the more variable south end, owes to mechanical bypassing (Fig. 11). After the active 2005 tropical storm season, the shoreline at the south end of the seawall receded some 100 ft (31 m), while the northern end remained stable. The shoreline maintained a net seaward position of on the order of 200 ft (61 m) nearest the north end of the seawall and a minimum of 80 ft (24 m) at the south end. Variability in shoreline position at the south end is likely related to distance from the sheltering by the jetties and may be exacerbated by the interaction of the terminus of the seawall and intersection of a paved access road that creates an unrestricted pathway for overwash during storm surge.

Shoreline change adjacent to the north jetty was more erratic, but moderated within 1 mile (1.6 km) of the inlet. During initial construction, shoreline advance near the north jetty was greater than that observed on the south side (Jul 2004 to Oct 2004). Shoreline recession to the 2003 baseline position from Oct 2004 to Jan 2006 was primarily due to sand lost around the incomplete landward end of the jetty during storm surge and may have been compounded by bypassing to the south around the incomplete seaward end of the northern jetty. Once the north jetty neared completion, the adjacent shoreline shifted to a maximum seaward position of 380 ft (116 m). As of Jul 2006, the northern shoreline advance was such that the north and south shoreline adjacent to the inlet were nearly symmetrical. The advance of the northern shoreline indicates at least intermittent transport to the south with impoundment at the jetty.

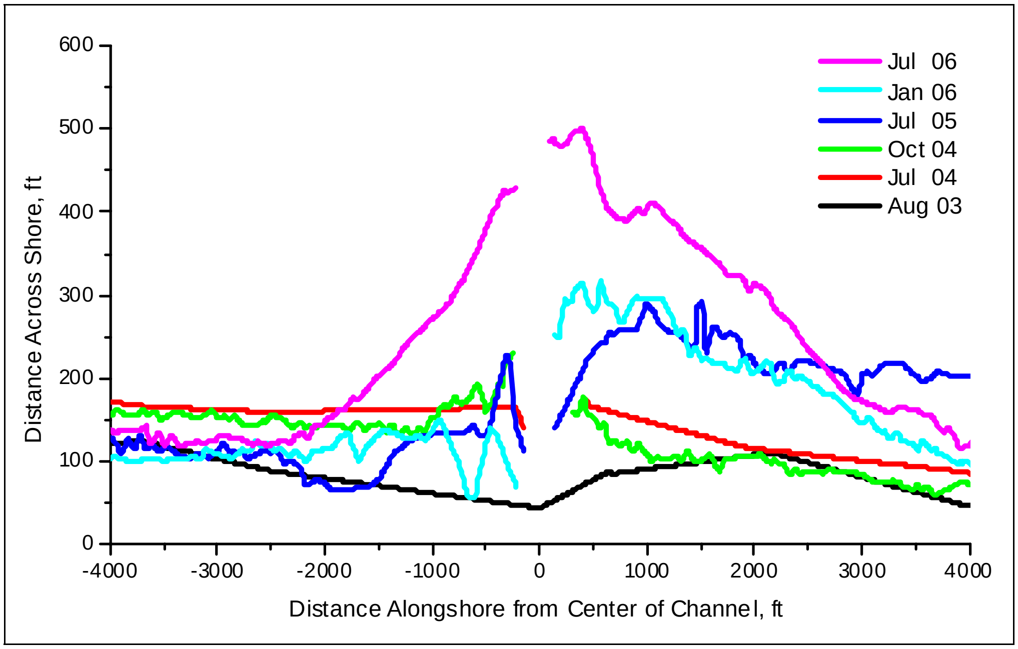


Fig. 11. Shoreline position change adjacent to the new inlet from Aug 2003 to Jul 2006.

## CONCLUDING DISCUSSION

Over the 1.5 years since Packery Channel opened in Jul 2005, the channel has remained open primarily by scour induced by consistent, astronomically forced currents enhanced by seasonal wind tide. East-southeasterly directed frontal systems force flow and sediment toward the Gulf of Mexico. Current speed at PC138 is close to that, but as much as 0.35 m/s greater during wind events, than that predicted for the SH361 Bridge in the original design study of hydrodynamics by Brown and Millitello (1997). Therefore, it follows that current speeds on the order in excess of 1-1.35 m/s occur in the entrance channel. The greater observed speed is likely related to shallower channel water and higher than average wind speeds during the monitoring period. As a result of such strong sustained currents in the entrance channel, depth in the entrance channel has mainly increased with redistributed sand transported toward the channel mouth, forming a shoal to the west. The strong ebb flow not only forced the progradation of the shoal toward the Gulf, but, also, in combination with the longshore current, has induced scour at the mouth and contributed to the large region of scour offshore of the mouth. The speed of the ebb current has increased since the channel opened. No ebb shoal formation has been yet been detected.

Southerly directed longshore sediment transport dominates during the spring and summer induced by E-SE winds. The northerly directed transport during the spring and summer of 2006 induced migration of the seaward bars offshore to intersect with the south jetty tip. Autumn is typified by frontal passage and reversal in direction of longshore transport. The southerly directed transport caused rapid development of an offshore bar perpendicular to the north jetty during autumn 2006.

The southern shoreline adjacent to the inlet steadily advanced since 2003, but the northern shoreline position was erratic due to sediment loss around the incomplete north jetty. Once the jetties were completed, the northern shoreline advanced significantly and by Jul 2006 the shoreline was symmetrical with respect to the inlet. Northerly directed sediment transport is generally considered to occur during the summer, but the data indicates an intermittent southerly directed component. Development and dissipation of sand bars supports a strong seasonal bias in sediment transport in the nearshore. The rapid advance of the northern shoreline indicates that southerly directed sediment transport does occur during summer months and is related to the location of the channel at a divergent nodal area in the local longshore sediment transport system.


## ACKNOWLEGEMENTS

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