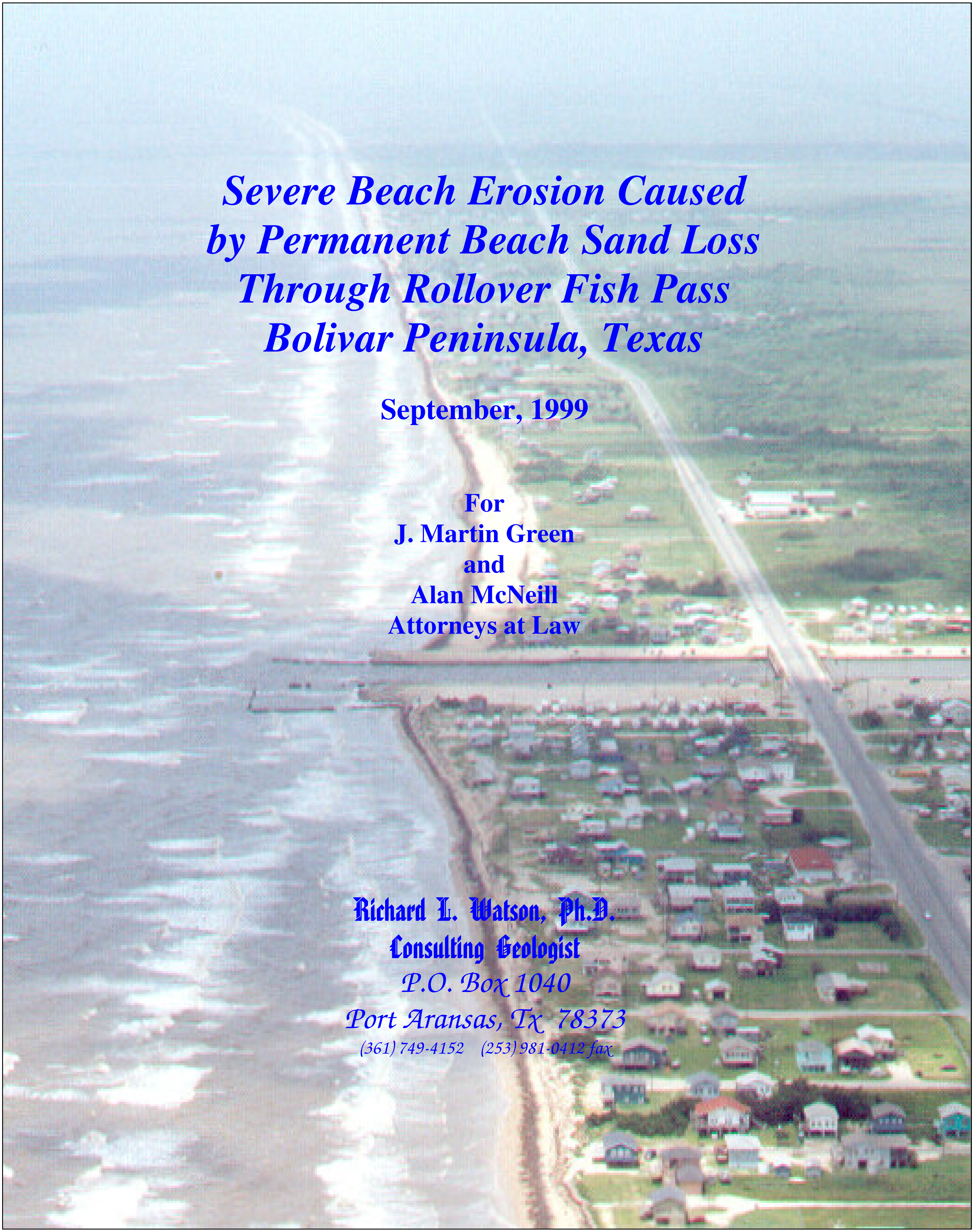

Severe Beach Erosion Caused by Permanent Beach Sand Loss Through Rollover Fish Pass Bolivar Peninsula, Texas

September, 1999

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EXECUTIVE SUMMARY

The wealth of nearly 50 years of scientific and engineering studies of Rollover Pass and erosion of beaches in the vicinity of the pass demonstrate that loss of beach sand through Rollover Pass into the GIWW and Rollover Bay is causing accelerated beach erosion of the beaches west of Rollover Pass. There are indications the sand loss is also causing erosion of the beaches east of Rollover Pass, but to a lesser extent.

Dredging data from the U.S. Army Corps of Engineers (Bales and Holley, 1985, 1989) indicates that 240,000-290,000 cubic yard of beach materials are transported through Rollover Pass and deposited in the Gulf Intracoastal Waterway annually. This means that almost 10 million cubic yards of sand has been lost from the beaches through Rollover Pass since it was built in 1956.

All of Bolivar Peninsula has been eroding for many years, with the exception of the 7 miles of beaches east of the Galveston north jetty. The long-term erosion rate has been about 5 feet per year. Since Rollover Pass opened in 1956, beaches west of Rollover Pass have been eroding much faster than the general long-term rate for the area. Since 1995, and the occurrence of tropical storms Dean, Josephine, and Frances, the beach erosion within about 5 miles west of Rollover Pass and a short distance to the east of Rollover Pass has accelerated with losses as great as 60 feet in a single storm. Losses this great have never occurred near Rollover Pass in the past.

This massive new erosion is not just due to these three tropical storms. Bolivar Peninsula has been subjected to attack by tropical storms and hurricanes throughout its history. Rather, this extreme erosion is because there were 40 years of sand loss greater than 200,000 cu yd/yr from the beaches through Rollover Pass. This has resulted in the total removal of the normal sand reservoir in the offshore bars, on the beach and backbeach and in the dunes for over three miles west of the pass. This is clearly shown by the clay beach exposed by tropical storm Dean in 1995. There is no sand left. It all went into the GIWW and Rollover Bay. The beaches continue to erode as longshore sediment transport carries the remaining sand westward where it accumulates north of the Galveston jetty.

The 40 years of sand lost through Rollover Pass have removed the natural sand storage in the offshore bars, beach and dunes. As a result, the beach cannot rebuild between storms by moving sand onshore from the bars back onto the beach, as would normally be the case. This is going to result in ever increasing acceleration of erosion with each succeeding storm because the profile inland from the present vegetation line contains even more clay and less sand.

The Parks and Wildlife Department has known of the sand loss through Rollover Pass and the need for beach nourishment of 20,000 to 200,000 cu yd/yr since at least 1959. This estimate was raised to 240,000 to 290,000 cu yd/yr in 1985.

The sand flowing into the Gulf Intracoastal Waterway requires that that the channel be dredged about every two years at a cost of over $720,000 to the Corps of Engineers.

If Rollover Pass is not closed, and if the material lost from the beaches into Rollover Bay and disposal sites 35 and 36 is not replaced on the beaches, rapid scarp erosion of the beaches near Rollover Pass will continue with each new storm, since the bluff that is now eroding has little sand to nourish the beaches. This will result in the loss of even more land and structures and may eventually result in a permanent breach turning Bolivar Peninsula west of Rollover Pass into Bolivar Island.

We recommend, as has been recommended for 40 years, that a beach nourishment program be initiated. Most of the sand lost through Rollover Pass into the GIWW has been stored in dredge material disposal sites 35 and 36. This material should be placed back onto the beaches west of Rollover Pass. (Additional material can also be taken from Rollover Bay). At least 1 million cubic yards of sand should be placed on the five miles beaches west of Rollover Pass before the next hurricane season.

We recommend that Rollover Pass be permanently closed, to stop the annual loss of tremendous amounts of sand from the critically eroding beaches of Bolivar Peninsula. There is no other way to effectively stop beach sand loss through Rollover Pass. This is the same recommendation made by Parks and Wildlife Department Officials in 1979 and by General Land Office Commissioner Mauro in 1996 (Mauro 1996 and Mauro 1996b).. This will also reduce the dredge maintenance costs for the adjacent Gulf Intracoastal Waterway by over 3/4 million dollars annually.

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INTRODUCTION

Beaches in the vicinity of Rollover Fish Pass located at Gilchrist, Texas, on the Bolivar Peninsula, have suffered accelerated erosion since Rollover Fish Pass was artificially created in 1954-55. For about 100 years, the beaches on Bolivar Peninsula have been eroding at an average rate of about five feet per year. Beyond this baseline erosion, there is an abundance of scientific and engineering literature, dating from the late 1950's to the present, thoroughly documenting that erosion of the beaches southwest of Rollover Fish Pass has accelerated since the pass was opened. The studies further document this erosion is due to large volumes of beach sand being swept inland through the Pass and permanently deposited in Rollover Bay and the Gulf Intracoastal Waterway (GIWW), in the vicinity of Rollover Pass.

Figure 1 Location Map

Most of the scientists and engineers who have studied Rollover Pass and the beach erosion southwest of the Pass, have recommended there be ongoing beach nourishment programs using dredges to pump the sand lost from the bay back on to the beaches annually. There have been only a few individual instances when this advice has been followed and beach nourishment was accomplished. Beach nourishment has never been regularly accomplished. There has never been adequate replacement of the sand lost from the beaches through the Pass. The result of over 40 years of large volumes of beach sand loss through Rollover Pass is severe and accelerating erosion of beaches southwest of the Pass, with resulting loss of land and privately owned homes and other structures.

Most artificially created small passes (inlets through the barrier islands and peninsulas) on the Texas coast have tended to close naturally because the movement of beach sand along the coast in the littoral drift system exceeded the capability of the tidal flows through the passes to keep them flushed free of sand. Rollover Pass is an exception to this trend. Figure 2 shows Rollover Pass in July, 1999. The original steel sheet pile bulkheads lining the pass have been replaced with new concrete bulkheads. Wide concrete armored ends now extend beyond the beach, into the Gulf.

Figure 2 Rollover Pass

When Rollover Pass was designed in 1953 by Lockwood and Andrews, they certainly did not expect runaway erosion. "The plan would provide a fish pass at a minimum initial construction cost, which would be expected to operate similar to a natural inlet, except that it would be necessary to provide continuing periodic dredging of the cut to keep it open" (Lockwood and Andrews, 1953).

> The pass was constructed between October 1954 and February 1955. It had an 80-foot bottom width and an 8-foot depth. Sloping earthen sides were constructed except for the southwest side which was protected by a steel sheet pile bulkhead.
>
> Unusually high tides during 1955 resulted in extensive erosion of the pass. The Gulf entrance widened to about 500 feet and the depth of water under Highway 87 bridge increased to 30 feet.
>
> In November, 1955, in an effort to stop erosion, a steel sheet pile wall (sill) was constructed across the pass 40 feet south of the Highway bridge. Alternate sheet piles of this sill were driven 2 feet below mean sea level to permit some water flow through the pass. A short steel pile groin was constructed about 350 feet northeast of the inlet centerline on the Gulf side to stop further erosion of beach front and to protect nearby summer homes.
>
> The Pass remained partially closed until July 1958 while the Corps of Engineers was preparing recommendations for its stabilization. Their report was published in April 1958. The report proposed constructing steel sheet pile bulkheads along both sides of the pass, north and south of the highway bridge, installation of a second sill across the Gulf entrance, and periodic deposition of sand on the Gulf beach area southwest of the pass to replace material lost through littoral drift processes. These recommendations were implemented between July 1958 and May 1959, with the exception of beach nourishment (Lockwood, Andrews & Newnam, 1974, p.4).

The fact that the Rollover Fish Pass had to be closed shortly after it opened, because it eroded from 80 feet to 500 feet demonstrates its tremendous sand transport capability. It was necessary to line both sides of the Pass with steel sheet pile bulkheads and a steel sill of sheet pile bulkheads driven to five feet below mean low water to stop uncontrolled widening and deepening of the Pass.

COASTAL PROCESSES

The wind in the nearshore Gulf of Mexico generates waves which move toward the shore in the direction toward which the wind is blowing. As the waves approach shallow water, they become steeper and eventually break, forming surf. Once the waves have broken, they become a moving mass of water approaching the shoreline at a slight angle. This generates a current moving parallel with the shoreline within the surf. Whenever a wave breaks, it suspends sand from the bottom into the water. This sand is then carried a short distance along the shoreline until it settles out, only to be re-suspended and carried along by the next breaking wave. This process creates a virtual conveyor belt of sand along the shoreline in the surf zone. It has been called a river of sand and frequently amounts to hundreds of thousands of cubic yards of sand. The diagram from Lockwood Andrews and Newnam (1974) shows a wind rose of the duration of winds for each direction throughout the year. Winds from the southeast and east dominate and produce average wave directions from the east through the south. These waves approach the shore at an angle and result in a net movement of beach material from northeast to southwest (Fig. 3).

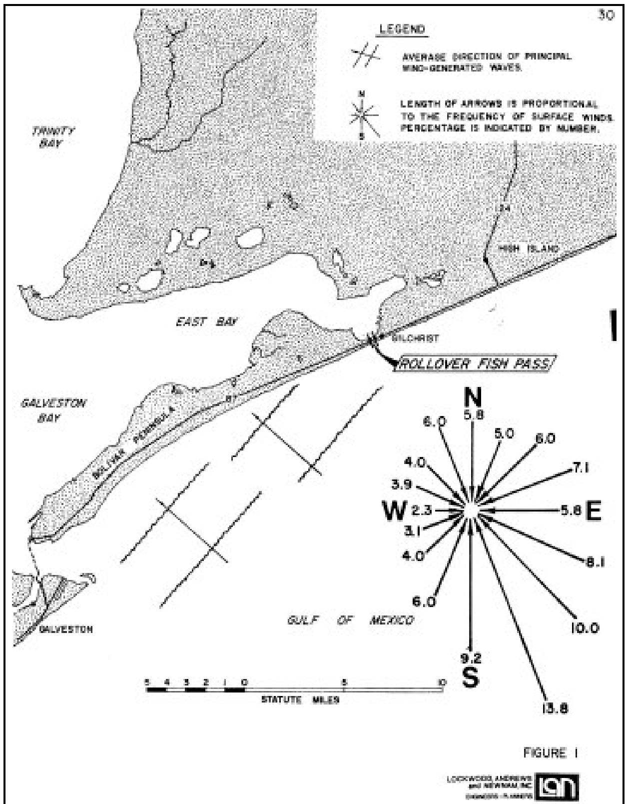

Figure 3. Winds and Waves (From Lockwood, Andrews and Newnam, 1974)

The amount of sediment transported along the shoreline as littoral drift at any location is dependent on the size of the breaking waves, and the angle they meet the shore. If there is sand present on the beach, it will be transported in a downdrift direction. In order for there to be equilibrium and not have a net loss of sand and beach erosion due to the littoral drift sand transport system, it is critical that each section of beach have the same amount of sand supplied to it from the updrift direction as is removed in the downdrift direction. If less is supplied than is removed, then beach erosion will occur. If more is supplied than removed, then beach growth or accretion will occur. This causes a large fillet of sand to build up on the updrift side of a jetty or groin. Sand is being brought in from the updrift side, but none can get past the jetty. At the same time, the downdrift side of the jetty or groin usually has a highly eroded beach. Sand is still leaving on the littoral drift conveyor belt, but no sand is coming from the updrift side. It is trapped by the jetty.

Inlets also produce beach erosion by starving the downdrift beaches of sand. Sand flows in through the inlet and is deposited in the bay. The beaches, downdrift of the inlet, are starved by the amount of sand that flows in through the inlet. This is what has been happening to the beaches in the vicinity of Rollover Pass for over 40 years (Fig. 4).

> As the water surface in the Gulf of Mexico rises daily, a differential in water elevation is established between this higher water surface and that in protected bays and estuaries. The differential gradually diminishes as water enters the bays through natural or artificial (man-made) openings in the barrier chain. This is the flood cycle. Eventually the water surface in the Gulf drops to a level below that in the bays and the cycle reverses itself (ebb condition) with water flowing out of the bays toward the Gulf.
>
> As water flows through an inlet, it carries with it suspended matter. This material eventually settles in the bay because of the decrease in water velocity. At Rollover Pass during the flood cycle, sediment already in suspension as a result of wave action and littoral transport occurring at the Gulf entrance is readily swept through the inlet into Rollover Bay where it is deposited. If tidal differential and, therefore, water velocity were the same during flood and ebb cycles and if wave action in both the Bay and Gulf was the same, then an ideal situation would exist where material in the same quantity would shift from one end of the inlet to the other and back again, thus maintaining a perfectly balanced system. This, however, is not the case at Rollover Pass or in most other inlets in the United States. A recording of tidal levels in the Gulf and Rollover Bay shows that high tide levels in the Gulf are more often higher than levels in the Bay (56 percent vs 44 percent). This diurnal inequality produces flood currents which are predominant and cause littoral drift materials from the Gulf to accumulate inside the Bay. Another factor contributing to imbalance is the higher current velocity required to scour bay bottom deposits to bring them to a state of suspension compared to the lower velocity needed to merely sustain movement of already suspended littoral drift material.
>
> As a consequence of this imbalance, some littoral material that would normally be deposited immediately downdrift of the inlet (southwest) to replace material picked up from there and moving further downdrift is not available having been swept through the inlet. This area of beach front therefore has suffered a greater net loss of material (Lockwood, Andrews and Newnam, 1974, p12).

Figure 4. Beach Erosion Southwest of Rollover

This July 1999 photograph shows the severe beach erosion southwest of Rollover Pass described by Lockwood Andrews and Newnam in 1974. Since 1974, the erosion has progressed dramatically. The present shoreline would be at the location of the red line or further to the east (left in the photograph) in the absence of beach erosion caused by sand loss from the beaches through Rollover Pass (Fig. 4).

> Since the opening of Rollover Fish Pass in 1955, the beach area immediately southwest of the Gulf entrance extending approximately 4,000 feet toward Galveston has been eroding at a more rapid rate than the rest of the Bolivar shoreline. This erosion shows in aerial photographs as a concave interruption inland in the relatively straight beach line.
>
> Simply stated, sand is scoured from this area and moved downdrift by wave currents. Sand which would normally come from updrift to replace this material is not available in an equal volume because part of it is swept through the inlet towards Rollover Bay during the flood cycle. This material is never returned to the Gulf littoral process in the ebb cycle for the reasons previously explained. The latest Corps of Engineers erosion study for the years 1956 to 1974 revealed that, in the first 4,000 to 5,000 feet southwest of Rollover Pass, the average erosion rate has been 13.5 feet per year.......... A historical review of the effects of natural processes taking place along the Gulf of Mexico shoreline in general and specifically along Bolivar Peninsula for as far back as records are available reveals that the shores have always been eroding. For the years 1850 through 1956 the rate at Gilchrist was estimated at 5 feet per year. This amount of beach front loss was occurring before Rollover Fish Pass was opened in 1955 and would continue to occur whether the inlet was present or not. However, for a distance of about 4,000 feet immediately southwest of the inlet, the rate of erosion is double that in adjacent areas since the inlet was cut, based on cross-section surveys in 1956 and 1974. The increase can be attributed to the presence of the inlet, as explained in this report (Lockwood, Andrews and Newnam, 1974, p19).

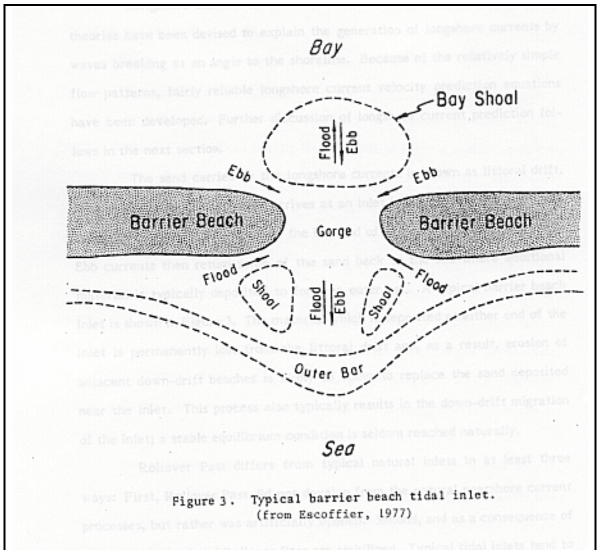

Figure 5. Ebb and Flood deltas (From Bales and Holley, 1984)

In addition to washing sand into the bays and forming a flood tidal delta in the bay, the ebb jet washes material offshore and forms an ebb tidal delta as well (Fig. 5). The sand in the ebb and flood tidal deltas is no longer available for transport down the beaches.

Tropical storms and hurricanes cause both permanent and temporary loss of beach sand. During a storm, the upper beach and dunes are eroded and much of that sand is carried offshore into a nearshore bar system. With the return of calm waves after the storm that material is carried back up onto the beach over a period of many months and sometimes years. Once the sand is deposited on the beach by waves, the wind will blow it inland to the first vegetation and a dune ridge will form. This is important, because the sand in that dune ridge will be carried Gulfward to the bar system in the next large storm. This cycle repeats with every storm. In some cases, if there is no dune ridge and the barrier island or peninsula is very low, a considerable amount of sand is carried inland and deposited as flats on the bay side of the barrier.

If there is no dune ridge storing sand between storms, and sand is carried inland, or further offshore out of reach of the gentle waves which can carry it back onshore, there is permanent beach erosion. The sand body in the vicinity of Rollover Pass is very thin and is underlain by clay (Goldston Engineering, 1985.) Much of the dune ridge southwest of the Pass that was present before the construction of Rollover Pass has been lost to erosion. The result has been rapidly accelerating beach erosion. When storms attack a clay shore, all of the clay is carried permanently away in suspension. It is not deposited just offshore in the bar system to be carried back onshore with the return of gentle waves.

BEACH EROSION ON BOLIVAR PENINSULA
Studies in the 1950's

One of the earliest descriptions of erosion on Bolivar Peninsula and the significance of Rollover Pass in causing some of that erosion was included in the 1959 study by the U.S. Army Corps of Engineers (COE).

> It is found that there is extensive active erosion along the Gulf shore between High Island and a point seven miles east of Galveston entrance that results in a deficiency of beach materials of about 200,000 cubic yards of material annually, and further, that construction of the fish pass has resulted in an increase in the deficiency of about 18,000 cubic yards annually. The most satisfactory method of controlling the shore erosion would be by

> replenishment of the beach materials. This could be done by placing 18,000 cubic yards annually, obtained from the pass, or to place 200,000 cubic yards obtained from Rollover Bay to alleviate all erosion southwest of the pass (COE, 1959, p.5).

The COE made a study of beach erosion by comparing surveys made by the United States Coast and Geodetic survey in 1850-51 to 1937 and by the COE in 1956.

> The comparison indicates a general gulfward advance of the shore line of Bolivar Peninsula for about 7 miles northeast of the Galveston north jetty with a marked increase in the rate after construction of that jetty. Gulfward movement of contours to the 18-foot depth in this section was even more rapid. East of the foregoing section the comparison indicates a landward recession of the shore. The historic rate of shore line and depth contour recession increased gradually eastward, the maximum recession of the shore line at Gilchrist being about 5 feet per year between 1851 and 1956, the total period of record........
>
> In October, 1956, approximately one year after flow through the fish pass channel had been restricted, erosion processes were continuing at a noticeable rate along the Gulf shore for about one-half mile west of the pass and were threatening to undermine some of the houses adjacent to the eroding shore. ....
>
> In February, 1957, the Game and Fish Commission placed approximately 6000 cubic yards of fill along the Gulf shore west of the fish pass. ......The sand fill eroded rapidly during the first month after placement, however, the rate of erosion decreased thereafter until the bank line approached its original position on May 20, 1957, about 120 days after placing.
>
> ......a comparison of the shoreline and offshore depth changes prior to opening of Rollover Fish Pass indicates an annual rate of shore recession of about 5 feet at Gilchrist tapering to zero at a point about 7 miles east of the Galveston north jetty. Since opening of the pass the rate of loss has increased along the shore for about one mile west of the pass (COE, 1959, pp. 13-14).

The COE arrived at a rate of 18,000 cu yd/yr of sand lost due to the pass, because the 6,000 cubic yards placed on the beach eroded in 4 months. As we will see, this early estimate of sand loss through the pass is probably less than 1/10 of the actual amount of sand lost through the pass each year. They concluded, based on shoreline recession of 5 feet per year tapering from the pass to zero at a point 7 miles northeast of the Galveston jetty, that the annual deficiency of littoral materials between Rollover Pass and the north jetty at the Galveston entrance was about 200,000 cu yd/yr. Morton, *et al.* 1983 noted that: "The most recent shoreline accretion on the Peninsula's western tip can be attributed to sediment supplied by beach erosion and trapped by the north jetty at Bolivar Roads. Over 28 million cubic yards of sand have been added to the beach and along the jetties by coastal processes since jetty construction in 1876."

Figure 6. Accumulation of sand north of Galveston jetty

This huge accumulation of beach materials was carried west along the shore of Bolivar Peninsula and accumulated north of the jetty at the Galveston Entrance Channel is shown in Figure 6. All of the material enclosed in red was deposited since the jetty was built 123 years ago in 1876. This amounts to about 260,000 cu yd/yr. This is fairly close to the 200,000 cubic yards estimated to be lost to the beaches in the updrift source are between Rollover Pass and the point 7 miles east of the jetty. This may be a good estimate of the net longshore sediment transport to the southwest along the Rollover Pass area.

> Continuation of shore recession at a rate up to 5 feet per year as indicated by historical surveys may be expected if no remedial measures are undertaken. In addition an increased rate of recession for about a mile west of the pass may be expected to continue as long as the pass retards normal passage of littoral drift westward alongshore and no remedial measures are undertaken........... Continuation of the erosion caused by opening of Rollover Pass could be prevented by closing the pass or by periodically supplying suitable sand to the shore west of the pass to offset the deficiency in supply caused by accumulation of littoral materials in the pass or in its inner and outer bars (COE, 1959, p. 16).

The recommendation to periodically supply sand to the beaches west of Rollover Pass has not been followed. Elsewhere the report recommended that the beach nourishment be carried out on a frequency of between one and five years depending on the amount of material placed. Suitable material for beach nourishment was found in Rollover Bay.

BEACH EROSION ON BOLIVAR PENINSULA
Studies in the 1960's

In 1966, Terrance R. Leary of the Texas Parks and Wildlife Department applied to the Galveston District COE to dredge 42,500 cubic yards of material from Rollover Bay and deposit along the east side of the Pass from the bridge to the Gulf and along 2000 feet of the Gulf beach southwest of the pass. This placement along the beach southwest of the pass may be the first beach nourishment since the recommendation by COE in 1959 to nourish the beaches west of the pass. Other documents indicate the work was done by August, 1969. Even if the entire 42,500 cubic yards were placed on the beach southwest of the Pass, that amounts to only 4250 cu yd/yr, and is far below the 18,000 cu yd/yr recommended by COE, (1959.)

BEACH EROSION ON BOLIVAR PENINSULA
Studies in the 1970's

In their 1972 study, Prather and Sorenson took beach profiles at 200 feet, 400 feet and 600 feet west of the Pass and 400 feet and 600 feet east of the Pass in 1971, and compared them with profiles taken at these locations in 1963, 1965, and 1968.

> The profiles show a general recession of the west beach has occurred when compared to the east beach. This is evident in all data west of the inlet with the exception of station 200, but the depositional patterns at that position are probably not indicative of the behavior of the rest of the downdrift beach. The southwest sheet pile bulkhead extends into the Gulf for approximately 100 feet and affects the wave patterns in that area. This in turn affects the erosion rates near the entrance. ....
>
> The beach east of the pass is somewhat more stable than it is on the downdrift side of the inlet. ....it was possible to obtain only two profiles on the updrift side of the beach. Those obtained do indicate a general stability of the shoreline, and are probably representative of the entire beach east of the inlet.
>
> Figure 7 is an overhead photograph of Rollover Fish Pass taken in February, 1972. The stability of the updrift beach is full evident, and the recession of the west beach is shown in comparison (Prather and Sorenson, 1972, p34).

In 1974, Brown *et al.*, reports that although prior beach erosion rates in the vicinity of Rollover Fish Pass were on the order of 5 feet per year, recent rates are greater than 10 feet per year.

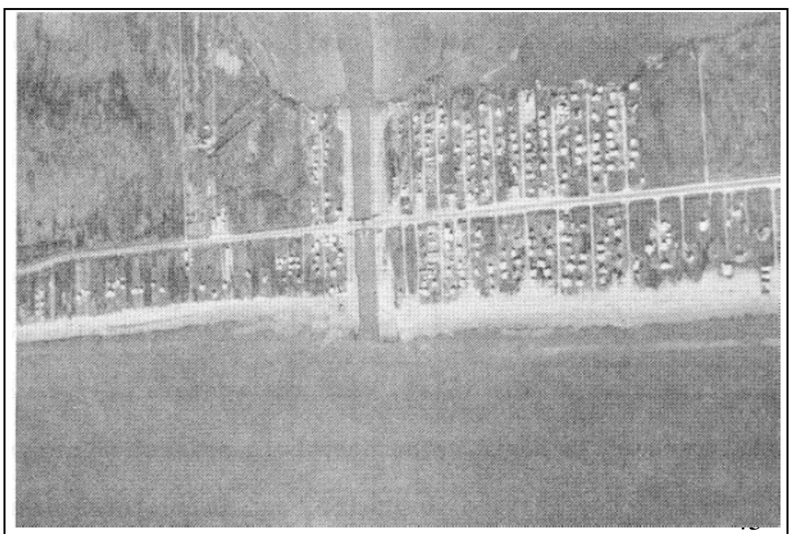

Figure 7, Photo February 1972 by Prather and Sorenson

According to Morton (1975): "The opening of Rollover Pass contributed to local erosion in that area." Morton indicated the long term erosion rate for the Bolivar Peninsula in the vicinity of Rollover Pass was 5 to 10 feet per year for the time interval from 1882-83 to 1970-74.

BEACH EROSION ON BOLIVAR PENINSULA

Studies in the 1980's

Mason (1981) used beach profiles measured by COE and by Lockwood, Andrews and Newnam (1973) along with aerial photo analysis to show the rate of erosion caused along the beaches west of Rollover Pass as a function of distance from the pass (Figure 8).

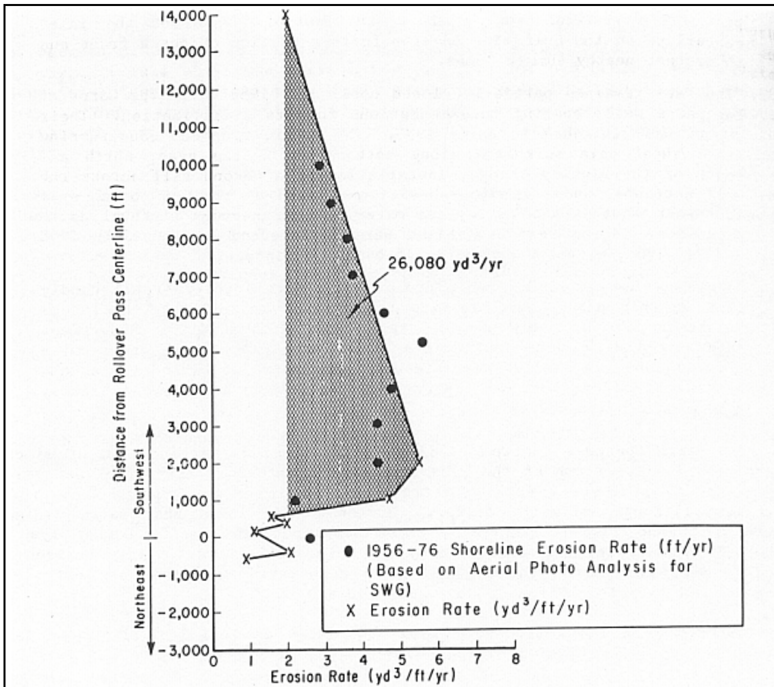

Figure 60. Comparison of beach profile and aerial photo erosion rates.

Figure 8 (From Mason, 1981)

Note that Mason assumed the effect of Rollover Pass in causing erosion decreased to zero at the station located 14,000 feet west of the pass. Mason concludes: "Thus, the shaded area in Figure 60 represents the annual volume loss from the longshore transport system due to inlet processes, i.e., about 26,000 cubic yards. It is likely that there is accelerated erosion further to the west due to sand loss from the littoral drift system through the pass into the bay.

"One aspect to consider, however, is that sand flows through the inlet and is deposited in Rollover Bay. This sand would normally have gone to the beach westward along Bolivar Peninsula where it would have reduced erosion or contributed to accretion near the Bolivar Roads jetties" (Morton, Pilkey, Pilkey and Neal, 1983).

Table 2.8

Rate of Change of Mean Shoreline Position near Rollover Pass, 1941-1976

(after U.S. Army Corps of Engineers, 1984a)

Year	Rate of Change (ft/yr.) East of Pass	Rate of Change (ft/yr.) West of Pass	Rate of Change (ft/yr.) Entire Reach	Change in Shoreline Position (ft.)	Net Change in Shoreline Since 1941 (ft.)	No. of Hurricanes
1941-52	-10.9	-11.1	-10.9	-119.9	-119.9	7*
1952-53	8.1	1.6	6.7	6.7	-113.2	0
1953-56	40.6	6.3	31.7	95.1	-18.1	0
1956-67	-20.9	-13.4	-19.3	-212.3	-230.4	6
1967-70	10.9	-4.8	8.1	24.3	-206.1	0
1970-76	1.7	-5.6	-2.5	-15.0	-221.1	5

Notes:

Negative values indicate erosion

* The COE reported 10 hurricanes for this period. Carr (1967b), however, reported 7 hurricanes for the period 1941-1952, inclusive. The COE figure may include some tropical storms.

Table 1. (From Bales and Holley, 1985, Table 2.8)

As part of an exhaustive study of Rollover Pass, Bales and Holley (1985) presented data collected by other researchers. Table 1 is their compilation of beach erosion data from COE for the vicinity of Rollover Pass. Note that for the period prior to opening of the pass in 1956, there were some periods of accretion both east and west of Rollover Pass. However, after the pass was opened, there was only erosion west of the pass, even though there were periods of accretion east of the pass. This is due to loss of littoral drift materials through the pass, leaving the downdrift beaches starved for sand.

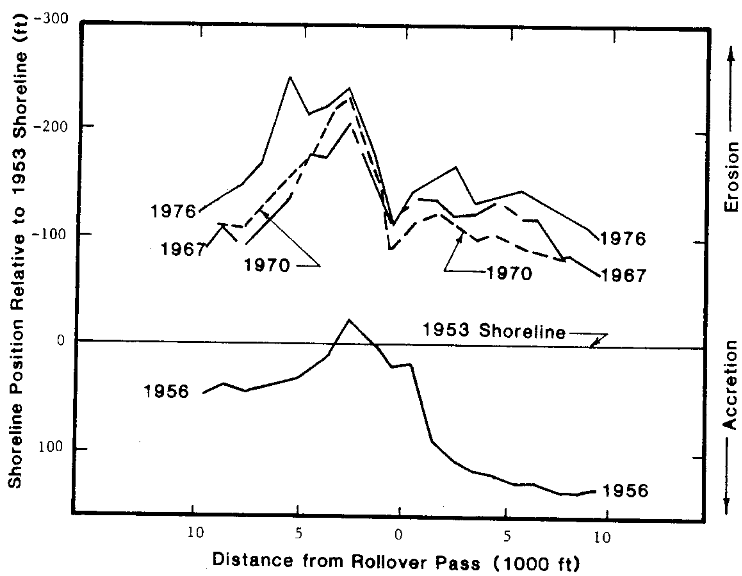

Figure 2.30. Shoreline Positions near Rollover Pass Relative to the 1953 Shoreline (from U.S. Army, Corps of Engineers, 1984a)

Figure 9. Shoreline Positions Relative to 1953 shoreline From Bales and Holley, 1985

Bales and Holley (1985) presented shoreline locations determined by the Corps of Engineers (Fig. 9). The shoreline as of 1953 is taken as a baseline. Note that there was accretion to the shoreline between 1953 and 1956. After 1956, there was severe erosion of the shoreline, with the erosion of the shoreline west of Rollover Pass nearly twice the amount of erosion of the shoreline east of Rollover Pass. By 1976, the excessive erosion west of the pass extended at least 6 miles west of Rollover Pass.

A plot of the shoreline positions for the years 1930, 1956, 1965, 1974 and 1982 shows greater erosion west of the pass than in a similar area east of the pass for the 1965, 1974 and 1982 shorelines (Figure 10.). This demonstrates the effect of the pass in accelerating beach erosion in the downdrift area to the west of the pass. East of the pass, the shoreline showed accretion between 1965 and 1974 and also between 1974 and 1982. On the west side of the pass, where the shoreline was starved for sand by sand loss through the pass, both of these time periods are represented by erosion. Part of the accretion east of the pass is probably due to accumulation of littoral drift materials against the groin on the east side of the pass. This accumulation on the east side of the pass against the groin also serves to starve the beaches west of the pass of sand.

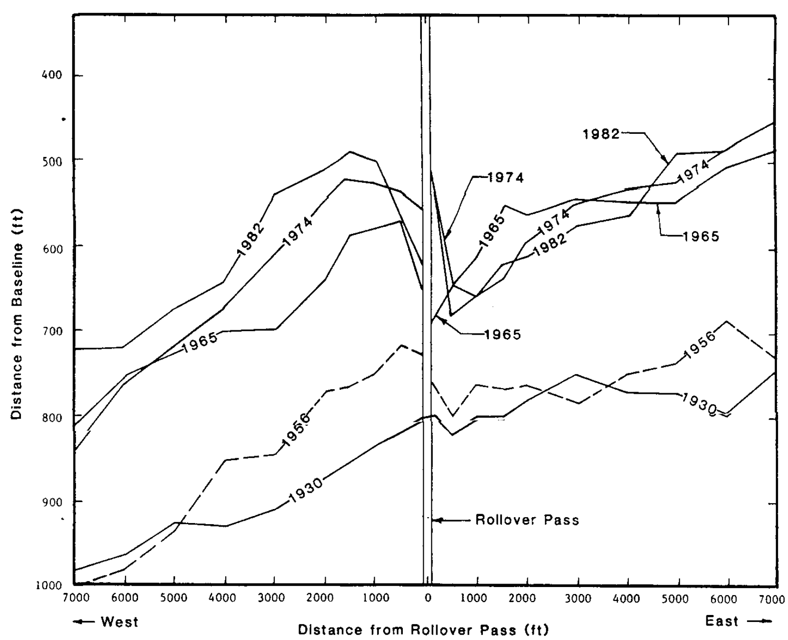

Figure 2.31. Shoreline Position near Rollover Pass: 1930, 1956, 1965, 1974, and 1982.

Figure 10. Shoreline Positions (From Bales & Holley, 1985)

> Rollover Pass probably affects littoral processes and beach erosion in three ways. These include (1) a temporary trapping of sand moving in the littoral zone behind the sheet piling walls which extend into the Gulf, (2) trapping of sand north of the Pass in Rollover Bay, the Intracoastal Waterway and East Bay, and (3) the transport of sand out of the littoral zone by the ebb flow jet from the Pass....... From 1965 to 1982, the shoreline within about 4,000 ft. east of the Pass is seen to be generally in an accretional state. (Figure 2.31){See Figure 8 above} This is probably due to the temporary storage of sand behind the sheet piling and is further evidence that the net longshore transport is in the southwesterly direction. (Bales & Holley, 1985, p. 88).

Bales and Holley state that the ebb jet is probably not strong enough to move much sand offshore beyond the littoral zone. “Except for the period 1956-65 (and the period 1956-74), which is a consequence of the 1956-65 rates), the shoreline erosion rates west of the Pass exceeded those east of the Pass. The erosion rates east and west of the Pass were very nearly the same prior to construction of the Pass, i.e., 1930-56” (Bales and Holley, 1985, p. 93).

Dredging of the Gulf Intracoastal Waterway

Until 1985, all estimates of the volume of sand lost from the beaches of Bolivar Peninsula by transport through Rollover Pass were based on estimates derived from shoreline retreat and measurement of the rate of erosion of sand placed on the beach during beach nourishment projects. Bales and Holley (1985 and 1989) compared dredging records for the Gulf Intracoastal Waterway (GIWW) adjacent to Rollover Bay prior to opening of Rollover Pass with the dredging records for the same reach of the GIWW after Rollover Pass was opened.

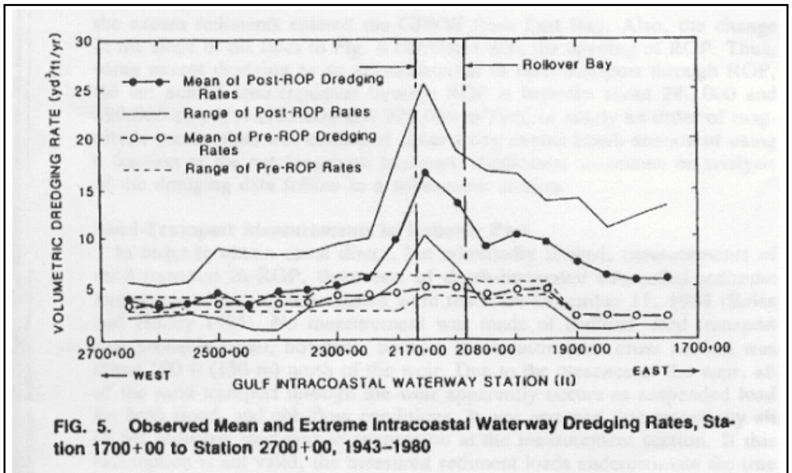

Figure 11. Dredging Rates (From Bales & Holley, 1989)

The vertical lines to the right of center of Figure 11 show the location of Rollover Bay. Rollover Pass is located to the left side of Rollover Bay in the illustration. Note the average pre-Rollover Pass dredging rates shown by the light line with the open circles are much lower than the average post Rollover Pass dredging rates shown by the heavy line with the solid circles. Note also, there was no "peak" in dredging rates in the vicinity of Rollover Bay until Rollover Pass was opened. In addition, this diagram shows that the lowest range of post Rollover Pass dredging rates in the Rollover Bay area was greater than the highest range of pre Rollover Pass dredging rates. Clearly, the opening of Rollover Pass greatly increased the rate of dredging of the GIWW in the vicinity of Rollover Pass due to the large amount of sand moving in through Rollover Pass.

Refer to Appendix I for similar plots of volume of material dredged from the GIWW in the vicinity of Rollover Bay from 1985 through 1995 (Data provided by the Galveston District COE 1999). Note dredging was required nearly every two years and the greatest volume of material removed was always in the vicinity of Rollover Bay. There can be no doubt that the huge excess of sand accumulating in the GIWW near Rollover Bay is beach sand carried in through Rollover Pass.

> .....the presence of ROP resulted in an average increase of about 290,000 cu yd/yr of material dredged from the GIWW between stations 1900+00 and 2450+00.
>
> There are fewer data for the period prior to construction compared to the period following the opening of ROP, and the source of the excess dredged sediments has not been positively identified. However, it appears that the amount of sediments dredged from the GIWW near ROP at least doubled following the opening of ROP. There is no apparent basis for assuming that the excess sediments entered the GIWW from East Bay. ......Thus, using excess dredging as an approximation to sand transport through ROP, the net annual sand transport through ROP is between 240,000 and 290,000 cu yd/yr, or nearly an order

of magnitude greater than was estimated using excess beach erosion or using a fraction of the net longshore transport (Bales and Holley, 1989, p. 437).

This is a major step in explaining how sand moving through Rollover Pass on flood tides can cause major beach erosion on the southwest side of the pass. The increase in dredging of the GIWW since Rollover Pass was opened clearly indicates 240,000 to 290,000 cubic yards of sand which would have moved to the southwest to nourish the beaches between Rollover Pass and the Galveston entrance jetties has been permanently lost through the pass into the GIWW. It is interesting to note that a loss of 290,000 cubic yards of beach sand would have a value of at least $870,000/yr considering a cost of $3.00 per cubic yard to artificially nourish the beaches using dredged material from Rollover Bay. Over the 40 year life of Rollover Pass, that represents a total loss of nearly 35 million dollars worth of beach sand.

Bales and Holley (1985 and 1989) measured the actual load of sand suspended in the current in Rollover Pass channel. They did not measure sand moving along the bottom (bed load), so their measurements may actually underestimate the actual sediment transport. Their data was also taken on a day with relatively calm waves. The actual sediment transport will be higher when the surf is higher, since there is more sand in suspension on high surf days (Table 2).

TABLE 1. Summary of Rollover Pass Suspended-Sediment Measurements

Measurement number (1)	Time (2)	Flow (cfs) (3)	Tidal differential* (ft) (4)	Average velocity (ft/sec) (5)	Average sediment concentration (mg/L) (6)	Measured transport rate (yd/yr) (7)
1	0945–1050	2420–ebb	−0.8	2.0	50	53,000
2	1210–1255	1610–ebb	+0.3	1.4	47	33,000
3	1545–1620	3060–flood	+0.6	2.4	161	219,000

*Positive differential indicates that the water level in the Gulf was higher than the Bay water level.

Table 2. Suspended Sediment (From Bales & Holley, 1989)

Note that even though these data were collected when the wave suspended load was smaller than normal due to small waves in the Gulf, the flood transport of 219,000 cu yd/yr was vastly greater than the ebb transport of only 33,000 and 53,000 cu yd/yr. This shows a major percentage of the flood tidal transport which carries beach sand into Rollover Bay will remain in Rollover Bay. Also the flood transport of 219,000 cu yd/yr (measured during relatively calm wave conditions) supports the concept that the increase in dredging of the GIWW by 240,000 to 290,000 cu yd/yr is due to beach sand flowing in through Rollover Pass.

Finally, Bales and Holley (1989) graphed the cumulative volume of material dredged from the GIWW near Rollover Pass (Figure 12).

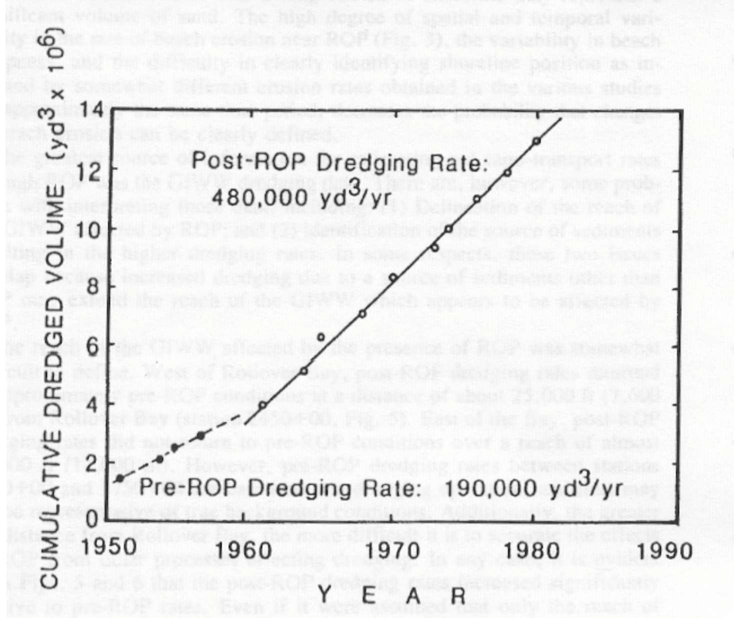

FIG. 6. Cumulative Volume Dredged from Gulf Intracoastal Waterway, Station 1900+00 to Station 2450+00

Figure 12. Cumulative Dredged (From Bales & Holley, 1989)

"All of the evidence seems to indicate that a single shift, as compared to a gradual change, occurred to the dredging rates between about 1958 and 1964 (Fig 6 {Figure 12 this report}), i.e, during the period when ROP was opened. The spatial distribution of dredging rates shown in Fig. 5 {Fig 11 this report}, in which increases were greatest in Rollover Bay and decreased with distance from the Bay, indicates the changes were a relatively local phenomenon and not the result of a systematic change in the dredging operations" (Bales and Holley, 1989, p. 441).

It is logical to conclude that the excess dredging of up to 290,000 cu yd/yr in the GIWW is sediment carried through the pass which would otherwise have been available to nourish the beaches west of Rollover Pass. Figure 12, demonstrates this was a sudden change brought about by the opening of Rollover Pass.

> Based on analysis of excess beach erosion within two miles west of the Pass , it appears that Rollover Pass results in an identifiable excess beach erosion rate of between 8,000 and 26,000 cuyd/yr. If, however, net sediment transport northward through the Pass is on the order of 200,000 cuyd/yr, then the total effect of Rollover Pass on the littoral budget is more on the order of 200,000 cuyd/yr rather than 26,000 cuyd/yr. Only the excess beach erosion within about two miles of the Pass can be distinguished (or identified) from the natural erosion because of the variability of the erosion rates and because the effects of the Pass at distances greater than two miles from the Pass probably represent a small change spread over a long distance of shoreline (Bales and Holley, 1985, p. 175).

> A value of about 5 ft./yr seems to be a representative average long-term, natural erosion rate for beaches within five miles of the Pass. Shoreline erosion adjacent to the Pass exceeds the long-term natural erosion rate. For two miles southwest of the Pass, the excess erosion rate seems to be between 2 and 7 ft/yr, representing a volume between 8,000 and 26,000 cuyd/yr over the two mile reach of shoreline (Bales and Holley, 1985, p. 188.)

> Sediment budgets of the coastal zone between Sabine Pass and the Galveston north jetty have resulted in estimates of sand loss due to the presence of Rollover Pass of between 118,000 and 147,000 cuyd/yr. Most of that loss was assumed to be due to the ebb-flow jet from the Pass transporting sand offshore (Bales and Holley, 1985, p. 188.)

This is substantiated by a map of surface sediments which shows a bulge of sand just offshore from Rollover Pass (Figure 13).

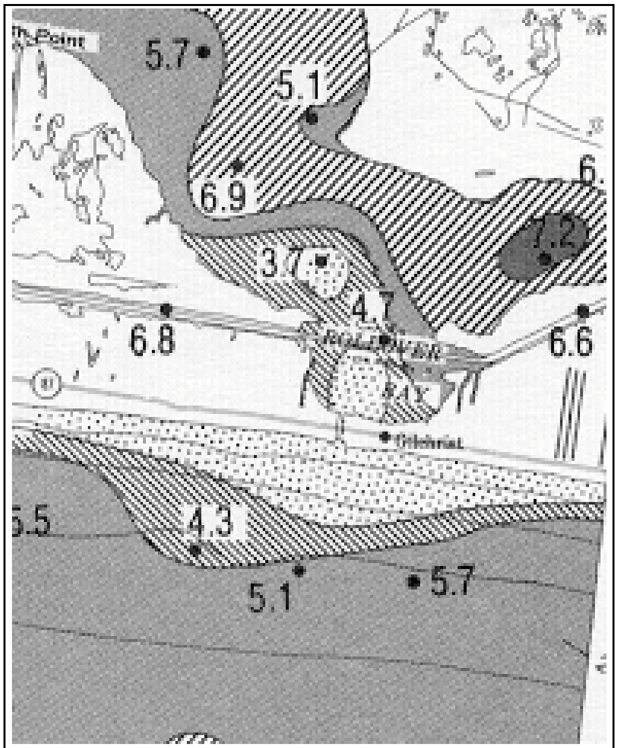

Figure 13 (From White *et al.*, 1985)

It is likely that some of the estimates of sand loss due to strong ebb tides jetting sands offshore beyond the reach of waves contributes to accelerated beach erosion west of the pass. This map produced by the Bureau of Economic Geology of the University of Texas certainly demonstrates that some sands have been jetted offshore by Rollover Pass and are present as an ebb tidal delta as shown by the sand bulge offshore from Rollover Bay and Gilchrist. Note that the bulge is offset to the west, the direction of sediment transport along the coast.

Paine and Morton (1989) found: "Shoreline near Rollover Pass (stations 43 to 46) was relatively stable between 1974 and 1982. Shoreline 1.5 mi in either direction of the pass was also stable to slightly accretionary between 1930 and 1956-57 but retreated rapidly between 1956-57 and 1974, after completion of the pass.

Professor Y.K. Wang and his Ocean Engineering students studied Rollover Pass and beach erosion due to the presence of the pass.

> The erosion is attributed to the tidal flow through Rollover Pass. The general understanding is that a predominantly flood tide through Rollover Pass carries sediments from the littoral drift into Rollover Bay. The sand deposited there constitutes a deficiency of suspended sand in the littoral current running along the downdrift beach. The deficiency causes the water to lift sediment from the nearshore area and the beach in order to replenish its suspended load. The loss of that sand is the essence of the beach erosion problem (Wang, 1989, p 2.1.1).
>
> The sediment still in the littoral transport system after the effect of the Galveston and Sabine jetties, approaches Rollover Pass where much of the littoral flow is sucked into the bay where more sand is lost. Very little of the sand entering the inlet ever gets back out; the study of suspended sediment samples shows that sand transport into the bay on a flood tide can be as much as 310% of the transport out on the ebb tide (Wang, 1989, p. 2.2.7).
>
> After Rollover Pass has taken its toll, the water approaching the beaches downdrift of the Pass carries little to no suspended sediment. The energy of the water, however, is the same and therefore it picks up sediment off the downdrift beaches to refill its sediment

> budget. This is the mechanism of erosion affecting the shoreline near Rollover Pass (Wang, 1989 2.2.7).

Wang and his students recommended nourishing the beaches and rebuilding the dunes with 830,000 cubic yards of sand to be removed from Rollover Bay. They further recommended installing jetties to keep sand from entering Rollover Pass and a sand bypass dredging system to transfer sand from the northeast side of the pass to the southwest side of the pass so that the flow of littoral drift materials would no longer be interrupted. They felt that these improvements taken together would reduce the shoaling of Rollover Bay and the GIWW, repair the beach erosion southwest of Rollover Pass and alleviate future beach erosion that would otherwise be caused by sand loss through the pass.

BEACH EROSION ON BOLIVAR PENINSULA
Studies in the 1990's

Dannenbaum Engineering Corporation and Texas A&M University Galveston prepared the Galveston County Shore Line Flood Protection, Restoration and Implementation Plan in 1992?. They state: "Erosion near Rollover Pass is due primarily to the tidal changes in and out of this man-made inlet. Numerous studies have been performed on the Pass. All have indicated that the Pass is extremely erosive active, and Rollover Bay has continued to silt since the Pass was cut in the 1950's. The silting of Rollover Bay also creates increased maintenance costs for dredging the intercoastal (sic) waterway which crosses Rollover Bay (Dannenbaum *et al.*, 1992 p. 29)."

They identified the erosion rates at Gilchrist and in the Rollover Pass area as critical. The zone between High Island and Rollover Pass was rated the most critical because of the danger of losing the road which would cut the developments on Bolivar Peninsula off from the mainland.

Rating the shoreline from Rollover Pass to Caplen, they conclude: "This section of the Gulf shore ranks as the second highest problem area within Zone 1. Six acres have been lost to erosion from 1953 to 1990 in this 14,000-foot section of beach. Erosion is approximately 6 feet/year. This section of the Bolivar Peninsula has one of the highest erosion rates due to Rollover Pass. Houses have been lost in the past and today homes are threatened. Storm damage would destroy several homes" (Dannenbaum *et al.*, 1992, p. 37).

"Rollover Pass has been studied by numerous entities. Each has concluded the Pass is unstable. The movement of tidal waters in and out of Rollover Bay has accelerated erosion. The intide movement carries sediment into Rollover Bay. A system is needed to reduce Gulf shore erosion and block sediment flow into the bay" (Dannenbaum *et al.*, 1992, p. 39).

Dannenbaum, *et al.* recommend nourishing the beaches between High Island and Rollover Pass and the beaches between Rollover Pass and Caplen with 32.22 cubic yards of sand per linear foot of beach. Their 1992 estimated dredging costs were $3.50 per cu yd.

The estimated cost was $11,125,000 for the beach between High Island and Rollover Pass and $2,800,000 for the 14,000 feet of beach between Rollover and Caplen. For this section of shoreline, they recommended dredging the bay near the GIWW and placing the material on the beaches at Rollover Pass.

In 1995 the Corps of Engineers again studied the erosion problem of the beaches in the vicinity of Rollover Pass.

> The General Land Office, acting on behalf of the State of Texas, requested that the U.S. Army Corps of Engineers, investigate the feasibility of utilizing materials dredged from the Gulf Intracoastal Waterway (GIWW) across Rollover Bay for the beneficial purpose of providing nourishment to the Gulf of Mexico beach in the vicinity of Rollover Pass near Gilchrist, Texas.
>
> The plan that the General Land Office asked to be studied involves the transport of materials which are removed from the GIWW across Rollover Bay to the beach on the west side of Rollover Pass for the purpose of restoring the erosional shoreline and retarding future erosion. This conceptual plan would make use of the heavier, sand-sized sediments which are known to accumulate in the GIWW by using a discharge pipeline from the hydraulic dredges which maintain the waterway to transfer the materials through Rollover Pass, and to create a berm or beach ridge 4000 feet long, 50 to 100 feet wide and 5 feet high on the upper shoreface to the southwest of the pass. The berm thus created would provide a large source of beach sediments to replenish the littoral sediment supplies in the area, and may be expected to provide the additional benefit of forming beach dune habitat if it becomes vegetated. The beach berm may also give increased protection from storm surges in the Gulf of Mexico, thus reducing flood damages to the developed areas.
>
> The proposed project is similar in many respects to those which have been recommended in the past (U.S. Army 1959, 1971, 1985;Williams, *et al.* 1979)(King, 1995, p. 7).
>
> At least three previous studies of the beach erosion problem have been conducted in this area (U.S. Army 1959, 1971, 1985). These studies concluded that the Gulf Shoreline in the study area was seriously erosional, and recommended beach nourishment. ....
>
> The Gulf Shoreline on either side of Rollover Pass was relatively stable during the period from 1930 to the mid-1950's (Morton, 1975), but erosion rates accelerated after the pass was constructed in 1955 (U.S. Army 1959, 1971; Morton, 1975). The erosion of beach and loss of properties on either side of Rollover Pass has prompted interest in stabilizing or reversing the recent trend by putting to beneficial use the heavier materials which are routinely dredged from the Gulf Intracoastal Waterway near the pass (King, 1995, p.1).

King reviewed earlier studies and noted that previous estimates of the amount of sand trapped by Rollover Pass range only up to 29,000 cubic yard per year. He emphasized, however, that Bales and Holley (1985, 1989) found that the shoaling rate in the GIWW adjacent to Rollover Bay increased from 240,000 to 290,000 cu yd/yr after Rollover Pass was opened (Figure 9). King further states:

> The test samples showed that much of the sediment in the channel was suitable for beach nourishment and that, in addition, useable quantities of sand were available from disposal areas 35 and 36 to the east and west of Rollover Bay respectively. Test findings also showed that the channel areas having the highest percentage of sands were those immediately opposite the main tidal channel from the pass - a fortunate circumstance which minimizes the distance over which the materials would have to be transported for beach maintenance (King, 1995, p. 15).

This is a significant finding. Most of the material collecting in the GIWW that is represented by the excess dredging required since the pass was opened and the material which has been removed from the GIWW to dredge material disposal areas is sand of a suitable size to use for beach nourishment. It is obvious this material is beach sand which would have moved westward on the longshore transport system to nourish the beaches west of Rollover Pass, if it had not been swept in through Rollover Pass to be deposited in the GIWW and later stored in the disposal areas.

It is evident the annual beach sand loss due to Rollover Pass is not 29,000 cubic yards or less, but a major percentage of the 240,000 to 290,000 cubic yards of excess material dredged from the GIWW in the vicinity of Rollover Bay. In addition, if sand is washed offshore by ebb-tidal jets as several authors have suggested and is supported by the sand bulge shown in Figure 12, then perhaps the total sand loss due to Rollover Pass is even greater than 240,000 to 290,000 cu yd/yr.

King concludes the proposed beach nourishment project should be implemented as quickly as possible. He further recommends that the previously dredged materials stored in disposal areas near Rollover Bay should be used as well. A final recommendation is that the beach berm created from the dredge materials be planted with native dune and coastal prairie vegetation in order to stabilize it.

James Kieslich of the Galveston district of the U.S. Army Corps of Engineers completed the section 933 study of Rollover Pass at the request of the General Land Office. Note that this study post dates the 1994-95 modifications to the pass by the Texas Parks and Wildlife Department.

> The Gulf of Mexico shoreline in the immediate vicinity of the Pass is experiencing erosion rates of 5 to 10 feet per year and this has resulted in the loss of property and damage to several residences. The GIWW skirts the bay side of Bolivar Peninsula and the current dredging practice is the placement of dredged material from the GIWW into contained disposal sites. This study focuses on identifying Federal interest in placing the dredged material on the beach in lieu of existing disposal sites. Federal interest will be based on storm damage reduction benefits attributable to the placement of the dredge material (U.S. Army, 1995, p.1).

> The main objective of plan formulation was to decide whether to place the material on the west, east, or both sides of Rollover Pass. After initial assessment of the shoreline within

> the Rollover Pass area, a decision was made to limit the placement alternative to the west side of the Pass (see enclosed study area map) because this area was found to have the greatest potential for storm damage reduction benefits. Other criteria used to formulate the placement site location consisted of shoreline change data and beach profile shape. In addition, the west side placement was found to be more stable than placement to the east in that there was less of a chance that the material would quickly move back into the Pass (U.S. Army, 1995, p.2).

TABLE 1
SHORELINE CHANGES FOR ROLLOVER PASS VICINITY

Side	Point	1930-1956 GC*75-6	1956-1974 GC 75-6	1974-1982 GC 89-1	1982-1990 GC 93-1	1930-1990 GC 93-1	
		Distance (ft)	Distance (ft)	Distance (ft)	Distance (ft)	Distance (ft)	Rate (ft/yr)
East	43	0	-175	0	-32	-207	-3.5
East	44	0	-275	21	120	-134	-2.2
West	45	100	-250	9	-174	-315	-5.3
West	46	0	-300	0	63	-237	-4.0

*GC - refers to the Geological Circulars published by the Bureau of Economic Geology at the University of Texas at Austin.

Table 3 Shoreline Changes (From U.S. Army, 1995)

Table 3 is a compilation of shoreline erosion rates compiled form Geological Circulars of the Bureau of Economic Geology of the University of Texas. Note that the shoreline was stable or accreting prior to construction of the Pass in 1956.

> The rates demonstrate that substantial losses have occurred since construction of the Pass in 1956. The shoreline on each side of the Pass, however, did undergo slight accretion during the 1974-1982 time frame which represents a relatively storm-free period. Meanwhile, the present trend has been slight accretion for the area east of the Pass and severe erosion immediately to the west of the Pass. *This is mainly caused from the predominant east to west sediment transport and configuration changes of the Pass due to recent structural improvements by the Texas Parks and Wildlife Department* (emphasis mine). A remarkable difference in the beach profile also exists between the two locations. The west side has virtually no sandy beach with improved property being threatened within the tidal zone. The east side possesses a gentle sloping beach with structures and improved properties set further inland. It was concluded from this information that placement on the west side of Rollover Pass would be most appropriate (U.S. Army, 1995, p. 3).

The report concludes that regulations do not permit federal cost sharing in this beach nourishment project.

The General Land Office prepared the Texas Coastwide Erosion Response Plan in 1996 (Mauro, 1996b). “Although relative sea level rise and background sediment deficit are known to exist on the peninsula, the locally accelerated erosion rate is a direct consequence of the presence of Rollover Pass and other sediment-trapping structures (Morton, 1975). The presence of Rollover Pass on the updrift side of Caplen results in a more acute sediment deficit there than along neighboring beaches” (Mauro, 1996b, p. 44).

The General Land Office recommends temporary bluff stabilization, a long term beach nourishment program using sand from Rollover bay and the GIWW. They also recognized the need to stop sand moving through Rollover Pass and the resultant loss to the downdrift beaches. “A sand bypassing system to transport material across Rollover Pass from east to west should be considered. This would reduce the loss of beach sand into Rollover Bay or into deeper offshore waters (Wang, 1989). *Closure of Rollover Pass to normal tidal flow would achieve the same result.*” (emphasis mine)(Mauro, 1996b., p. 45).

In 1997 Robert Morton studied shoreline movement between Sabine Pass and the Brazos River, Texas from 1974 to 1996 (Fig. 14).

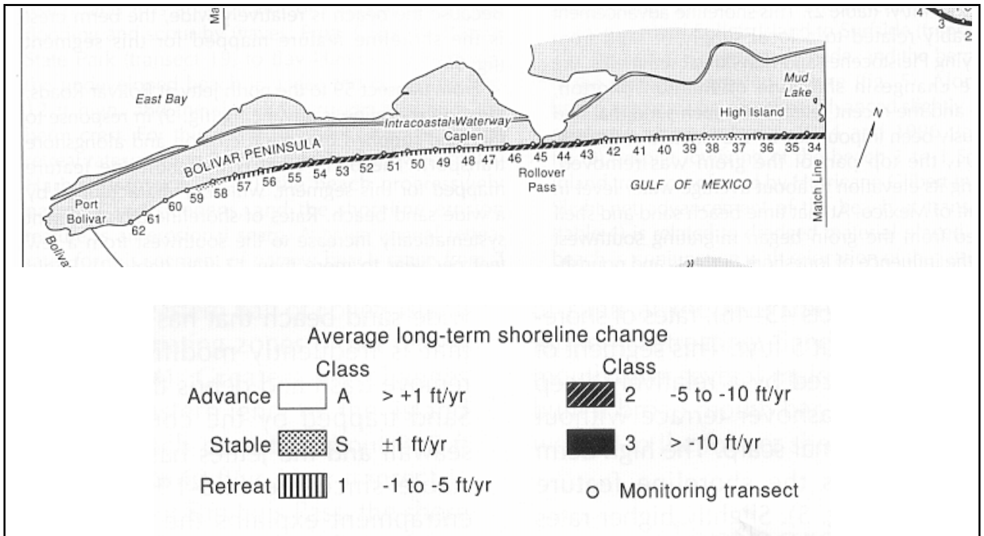

Figure 14 Shoreline Retreat (From Morton, 1997)

> Near Rollover Pass (transects 43-46), rates of shoreline recession averaged about 5 ft/yr. This segment of the Gulf shore is characterized by a relatively steep narrow sand beach and washover terrace without dunes, or a low (<5ft) erosional scarp. The high berm crest or erosional scarp is the shoreline feature mapped for this segment (Fig. 5). Slightly higher rates of erosion for this beach segment compared with those to the northeast are partly attributable to sand losses from the littoral system. Some sand migrating along the beach is transported through Rollover Pass into East Bay, where it is deposited as a flood-tidal delta. This deposit has increased the shoaling rates in the Gulf Intracoastal Waterway. Local additional losses of sediment from the littoral system are attributed to riprap and concrete revetments that trapped sand and shell on the updrift (northeast) side and deprived the beaches to the southwest of that sediment.
>
> Recession rates are moderately low (4 to 6 ft/yr) along Bolivar Peninsula southwest of Caplen...... There the beach is sandy and relatively wide, and low vegetated dunes have formed. ......
>
> From transect 59 to the north jetty at Bolivar Roads, the Gulf shoreline is advancing (Fig. 9 {Figure 13 this report}in response to the sand supplied by updrift erosion and alongshore transport. The berm crest is the shoreline feature mapped for this segment, which is characterized by a wide sandy beach. Rates of shoreline advancement systematically increase to the southwest from a few feet per year to more than 17 ft/yr (Morton, 1997, p. 20).

The sand building up the beach within 7 miles of the north jetty at Galveston is eroded from the beaches between Rollover Pass and Crystal Beach. The sand eroded from the beaches between Rollover Pass and Crystal beach 7 miles east of the Galveston jetty was replaced by longshore transport from the east until Rollover Pass was opened. Since Rollover Pass was opened in 1955-56, most of the sand which moves westward in the longshore transport system is flushed into Rollover Bay and the GIWW where it is deposited. It is no longer moving west to nourish the beaches west of Rollover Pass. Figure 6 shows the result of 123 years of sand which has eroded from beaches between Rollover Pass and Crystal Beach accumulating east of the north jetty at Galveston. One third of that huge accumulation is the amount eroded from beaches west of Rollover Pass in the 40 years that Rollover Pass has been open and diverting the westerly longshore sand flow into the bay and away from the beaches west of Rollover Pass.

Figures 15, 16, 17, and 18 from Morton (1997) show shoreline positions from the 1880's to 1996. Each profile can be located on the map (Fig. 14) by the numbers along the shoreline. The four profiles nearest to the Galveston north jetty, 62, 61, 60, and 59 have shown beach accretion since the 1880's. Until about 1985 or 1990, the beaches from station 58 to station 51 a few miles west of Caplen have been stable. They have only shown erosion past the 1880 position since 1990. All of the stations from 50 to 43 just west of Rollover Pass were relatively stable from 1880's until 1956 when Rollover Pass opened. At that time rapid beach retreat began. Station 50 is five miles west of Rollover Pass. These profiles clearly show that Rollover Pass initiated and continued beach erosion for at least five miles west of Rollover Pass. It also appears that the opening of Rollover Pass also caused beach retreat to at least 2 miles to the east of Rollover Pass (see profile SP-BP 43, Figure 15).

Morton continues:

> Rollover Pass ...is another man-made feature that has substantially altered the response of the Gulf Shoreline to waves and currents. After this artificial channel was constructed in 1955, rates of beach retreat increased near the inlet, especially on the downdrift (southwest) beach toward Caplen. Slightly higher rates of retreat for this beach segment compared with those to the northeast are partly attributable to the groin effect of the channel-stabilizing structures and attendant sand losses from the littoral system through the pass. Some sand migrating along the beach is transported through Rollover Pass into East Bay, where it is deposited as a flood-tidal delta. The fish pass at Rollover has been open long enough that the shoreline has adjusted to the decreased sand supply. Rapid beach retreat southwest of Rollover is partly related to impoundment of beach sediment by riprap structures that have recently been removed (Morton, 1997, p.25).

Appendix A (cont.)

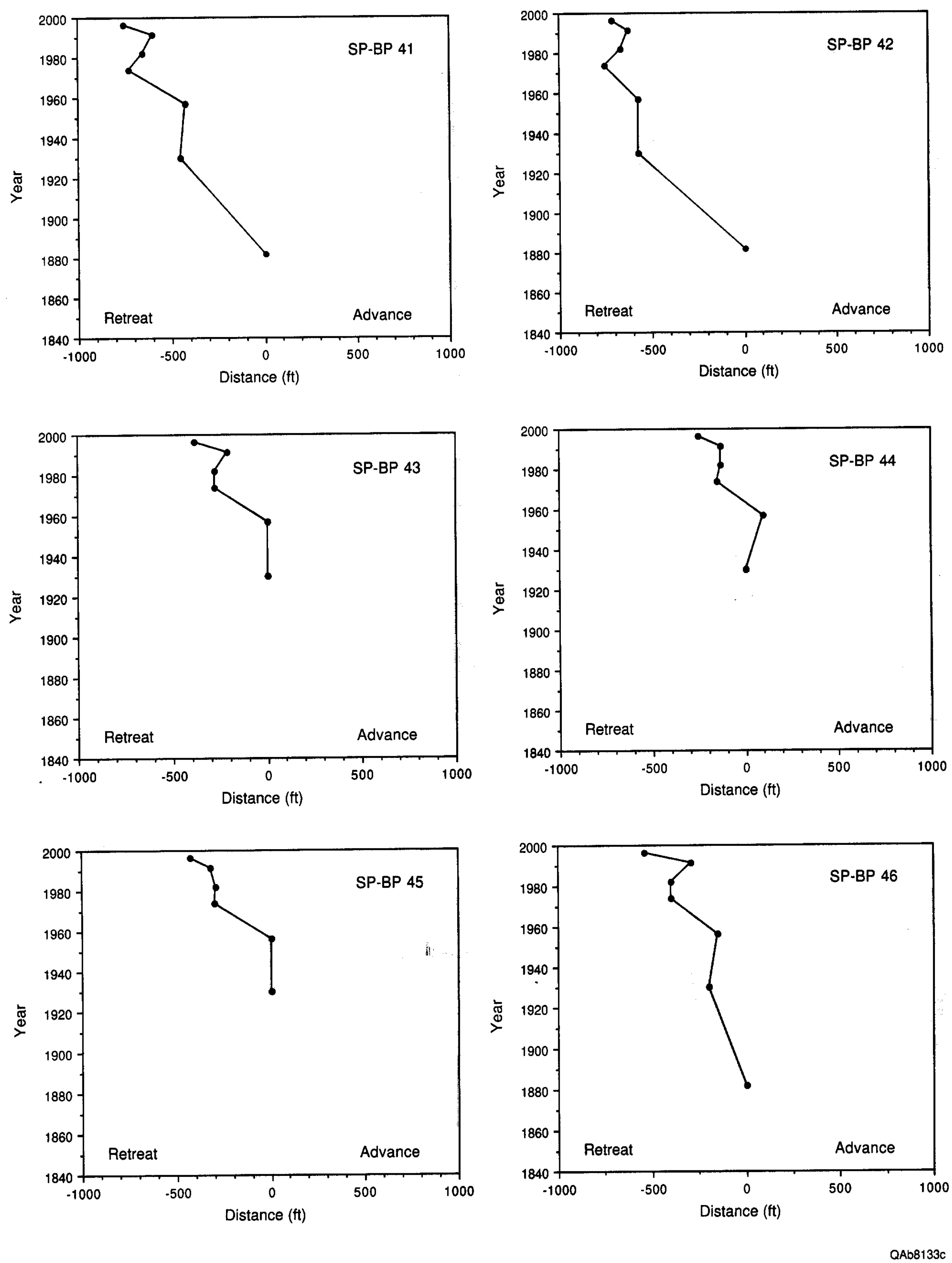

Figure 15. Shoreline Movement Bolivar Peninsula (From Morton, 1997)

Appendix A (cont.)

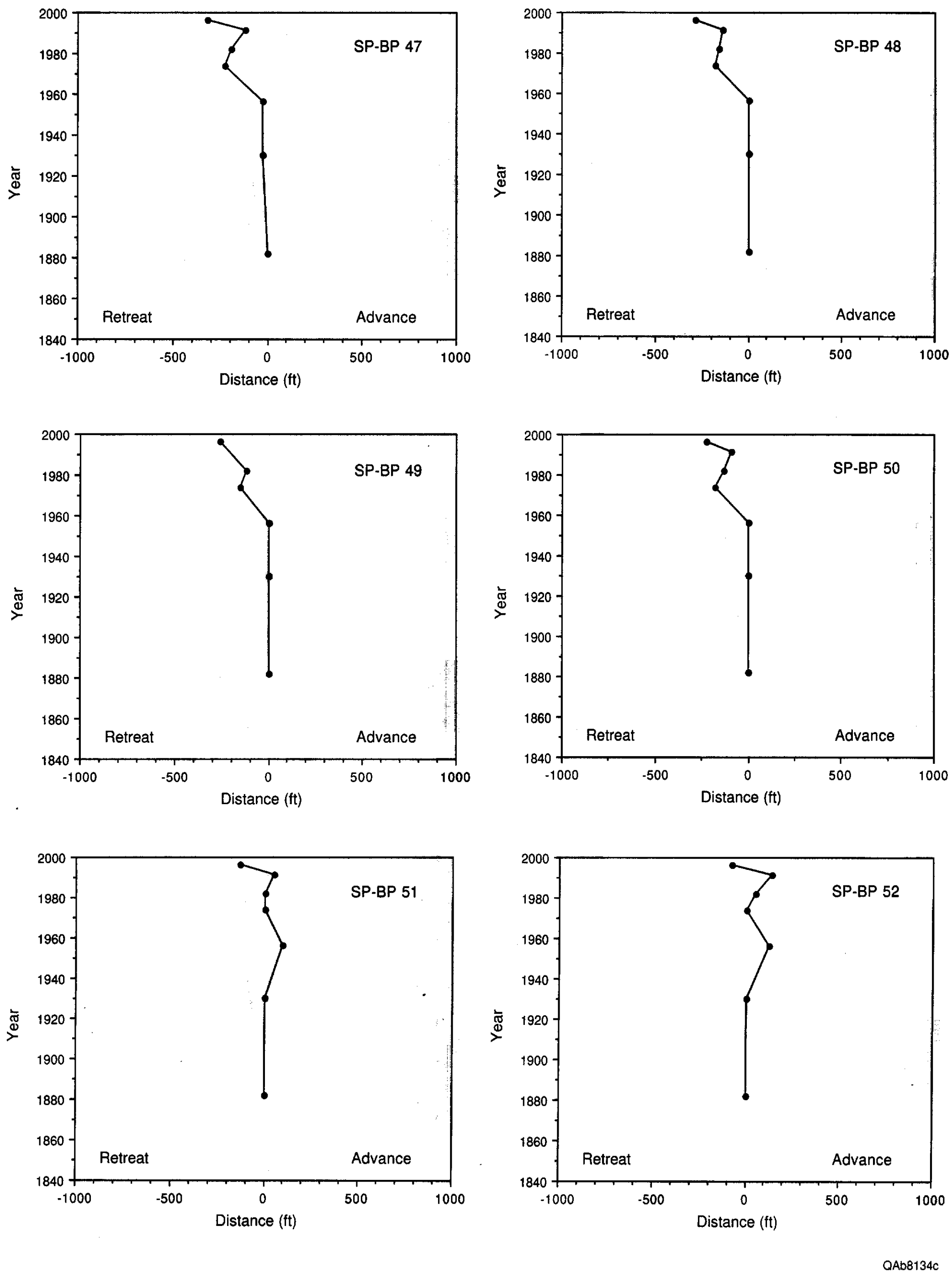

Figure 16. Shoreline Movement Bolivar Peninsula (From Morton, 1997)

Appendix A (cont.)

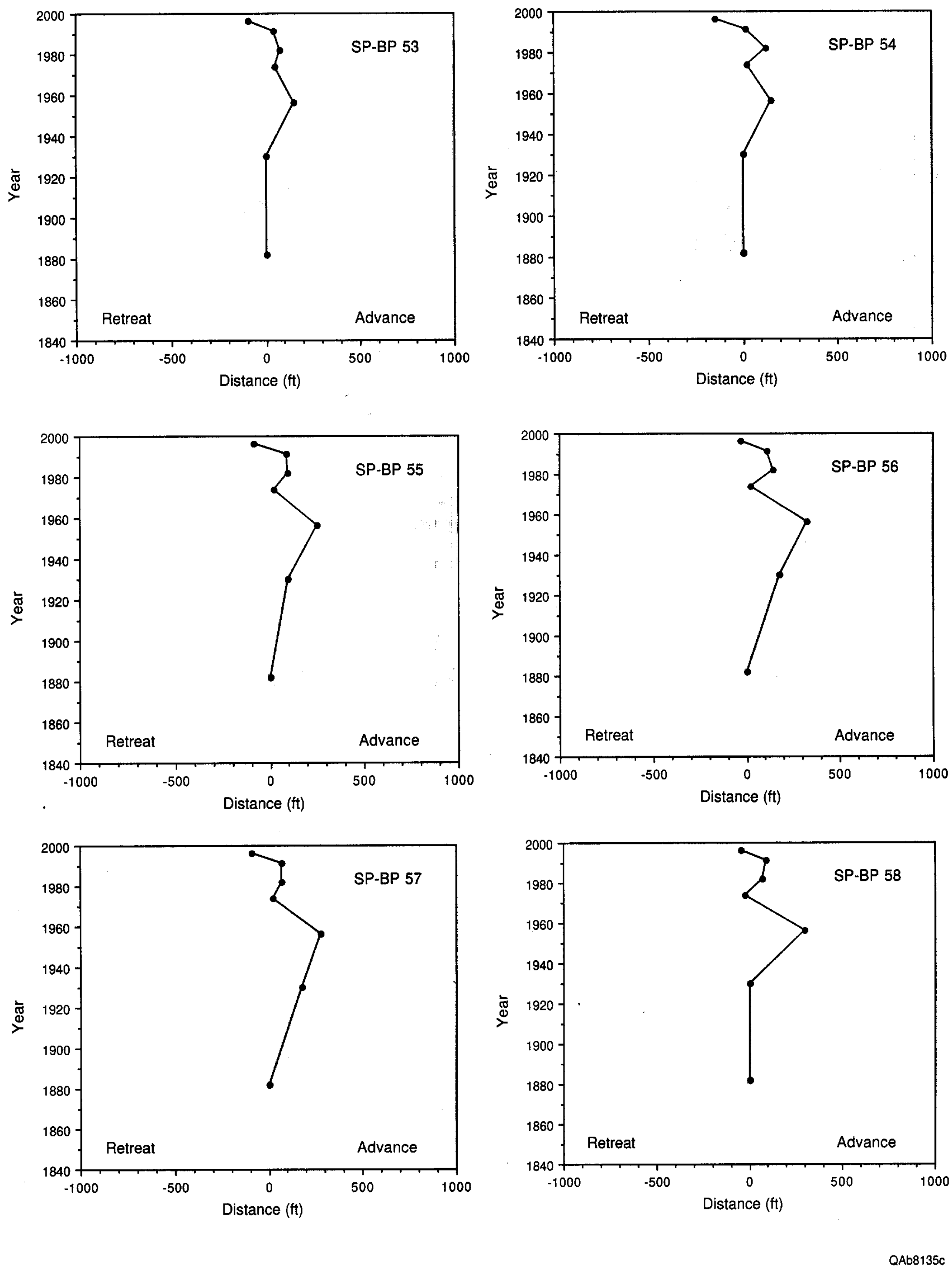

Figure 17. Shoreline Movement Bolivar Peninsula (From Morton, 1997)

Appendix A (cont.)

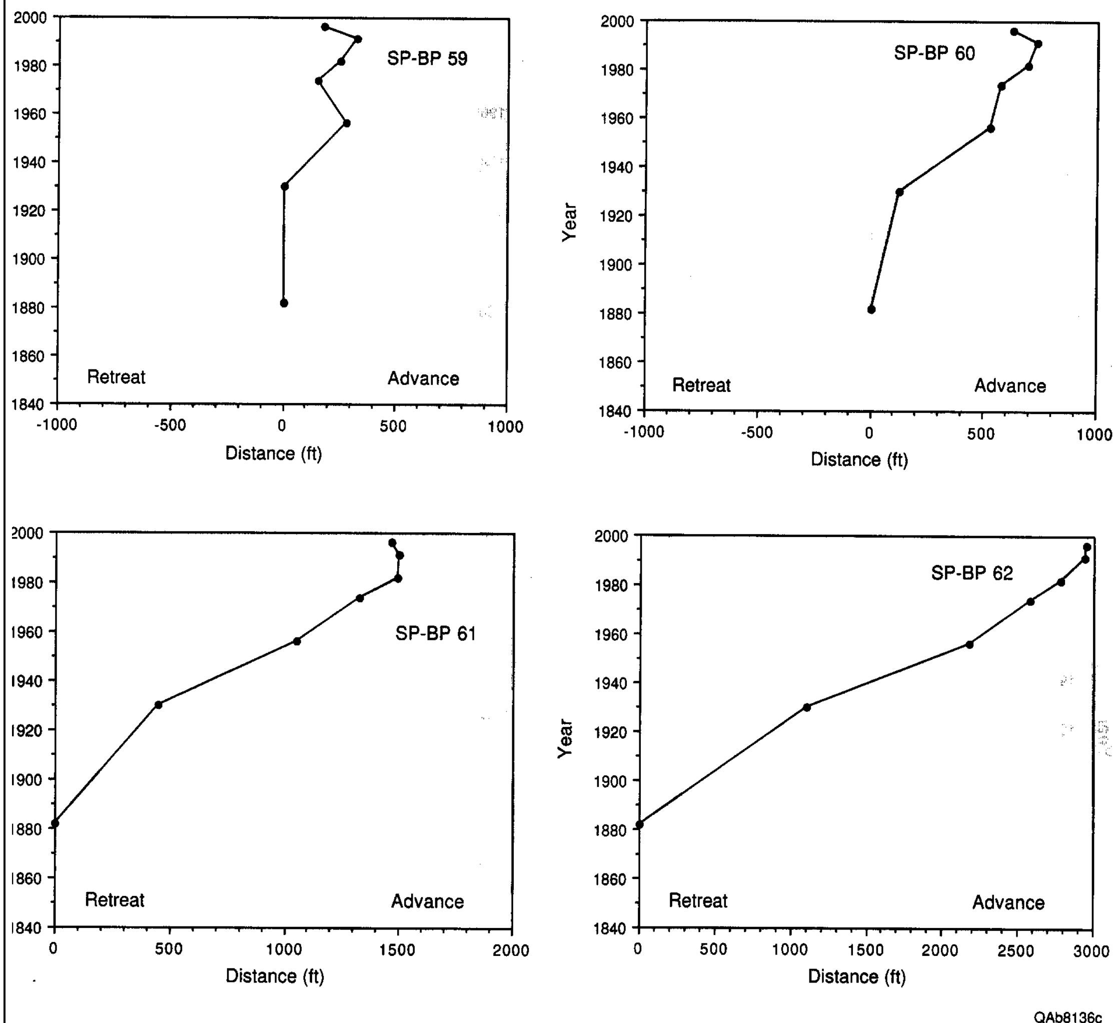

Figure 18. Shoreline Movement Bolivar Peninsula (From Morton, 1997)

In June 1999, Gibeaut and Gutierrez of the Bureau of Economic Geology of the University of Texas at Austin published a study of beach erosion and shoreline changes in Galveston County from 1994 to 1998 with emphasis on the changes caused by tropical storms Josephine and Frances (Gibeaut and Gutierrez, 1999). They plotted the retreat of the vegetation line, the retreat of the shoreline and the volume of sand lost between April 1995 and September 1998 (Fig. 21).

Note that on Bolivar Peninsula (on the right side of the plots) nearly all of the vegetation line retreat, and shoreline occurred in the vicinity of Rollover Pass.

From 1995 to 1997, the vegetation line retreated 7 to 10 meters within several kilometers of Rollover Pass. The shoreline remained stable along western Bolivar Peninsula, but retreated 18 meters within 1 to 2 miles southwest of Rollover Pass.

On most of Bolivar Peninsula there was an increase in the total volume of sand on the profiles. However, in the vicinity of Rollover Pass, and especially for 5 kilometers west of Rollover Pass there was significant loss of sand in the profile. For about three miles southwest of Rollover Pass, the amount of sand loss reached 27 cubic yards per yard of beach. That is over three dump trucks of sand for each yard of beach front.

Figure 19 (Beach at Gordon House late summer 1995)

"From BEG-09 to Rollover Pass and just east of Rollover Pass at GLO-22, the beaches lost sand in the form of scarp retreat. In 1997, back-beach scarps 1 to 1.5 m high were present" (Gibeaut and Gutierrez, 1999). Figure 19 shows a scarp of this type in front of the Gordon house about 2 miles west of Rollover Pass. The picture was taken late in the summer of 1995 after tropical storm Dean. Note the ledges of clay forming the beach instead of sand. This is very significant because it shows the shoreline eroded back so far inland, that there is no longer a thick sand body in the location of the beach.

Figure 20 Late Summer 1995 at Gordon house

This second late-summer 1995 photograph clearly shows the Gordon House in the background well back from the bluff and the two palm trees still a distance back from the bluff. Notice the location of the deck. It is moved inland in later photographs. The beach is composed of clay ledges, and other clay beds are visible in lower part of the bluff. There is no longer sand available to promote natural healing of the beach between major storms (Fig. 20).

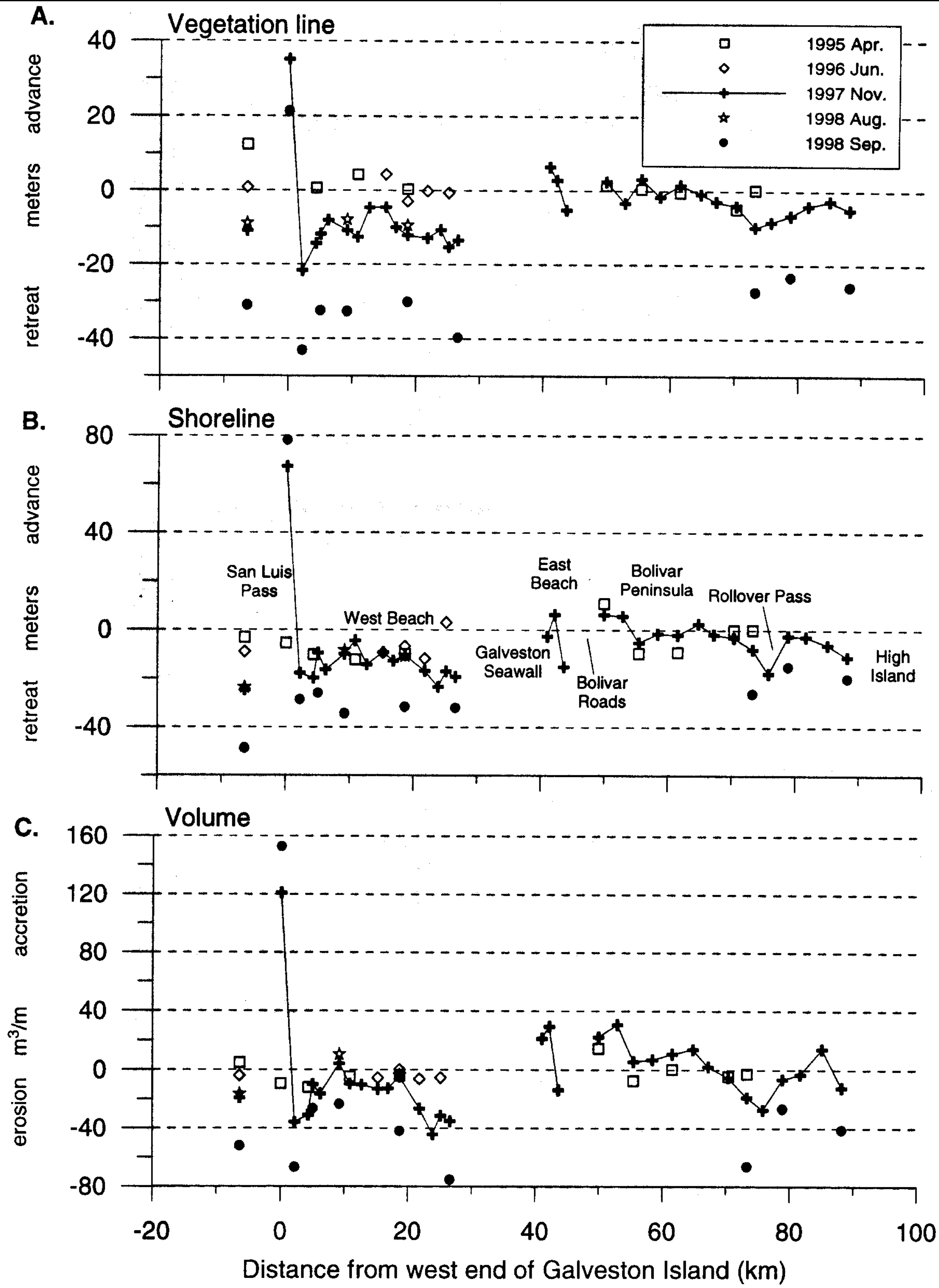

Figure 4. Cumulative change in beach profiles since September 1994: (A) vegetation line movement; (B) shoreline movement; and (C) profile volume change.

Figure 21 Vegetation and shoreline retreat (From Gibeaut & Gutierrez, 1999)

It is apparent that there was major erosion in the time period between November 1997 and September 1998 (Fig. 21). This is probably mostly due to tropical storm Frances in 1998. Note that in the vicinity of Rollover Pass the vegetation line retreated about 18 m (60 ft). The shoreline retreated 5 m (18 ft). The beach lost about 50 cubic yards of sand per yard of beach front. That amount is an additional six or seven dump trucks of sand per yard of beach in one year. The total loss from 1994 to 1998 is about 77 cubic yards of sand per yard of beach front (10 dump trucks per yard of beachfront).

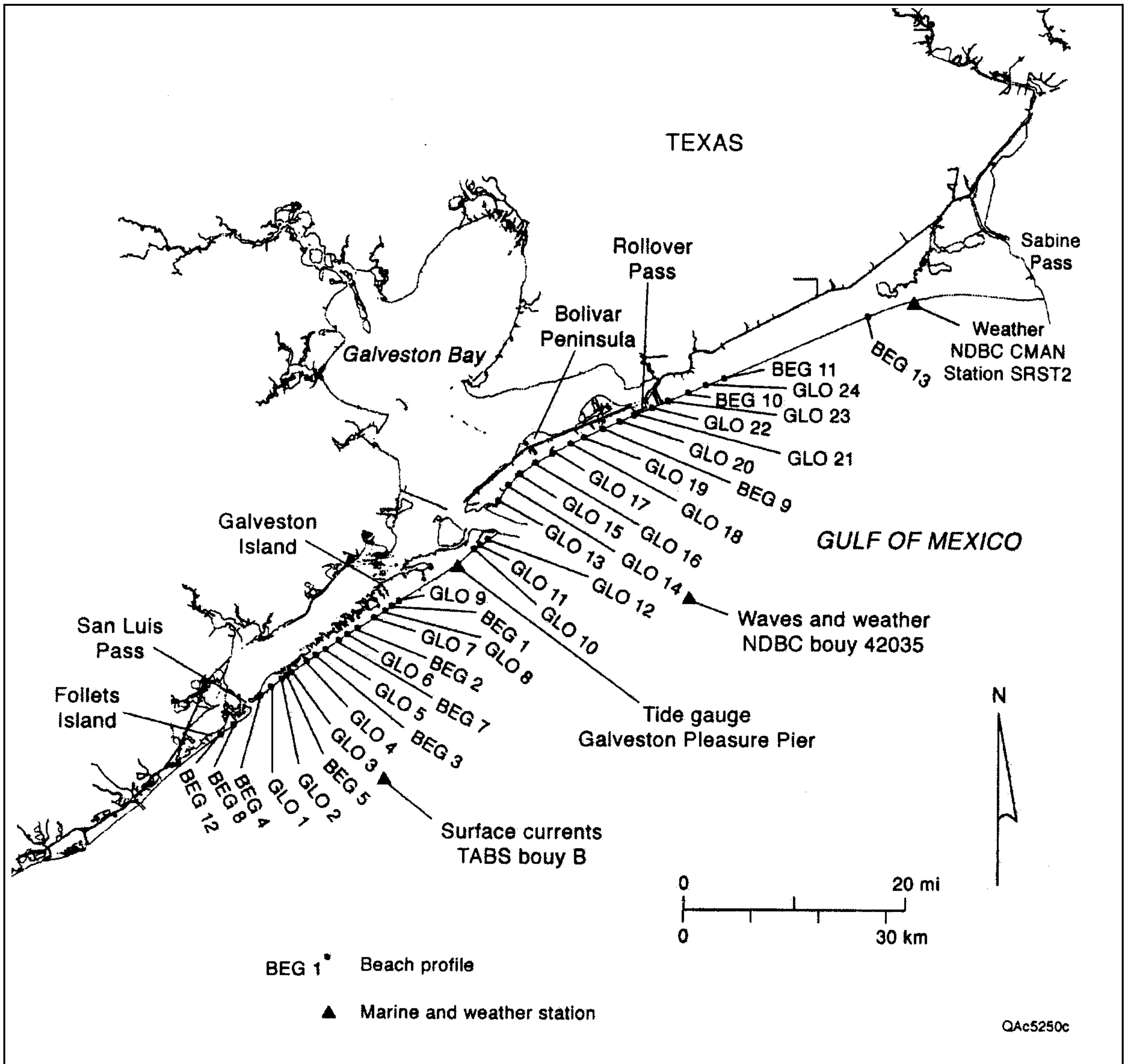

Figure 22 Location of beach profiles (From Gibeaut and Gutierrez, 1999)

Refer to Figure 22 for a map showing the location of beach profile locations used by Gibeaut and Gutierrez, 1999. Note that BEG-09, about 4.5 miles west of Rollover Pass, shows almost no erosion from 1994 to 1997. GLO-20 (3 miles west of Rollover Pass), and GLO-21 1 mile west of Rollover Pass show major erosion from 1994 to 1997 and 1998. As we move east of Rollover Pass, only profile GLO-22 (1 mile east of Rollover Pass) shows significant erosion in this time period. GLO-23 (only 2.5 miles east of

Rollover Pass) shows little effect of Josephine from 1994 to 1997. In other words, the only significant erosion caused by these tropical storms was within 5 miles to the west of Rollover Pass and less than 2.5 miles to the east of Rollover Pass. It is apparent that the long term sand loss through Rollover Pass, perhaps in conjunction to the improvements to Rollover Pass made in 1995 caused the accelerated erosion that happened only in the immediate vicinity of the pass (Figs. 23, 24, 25).

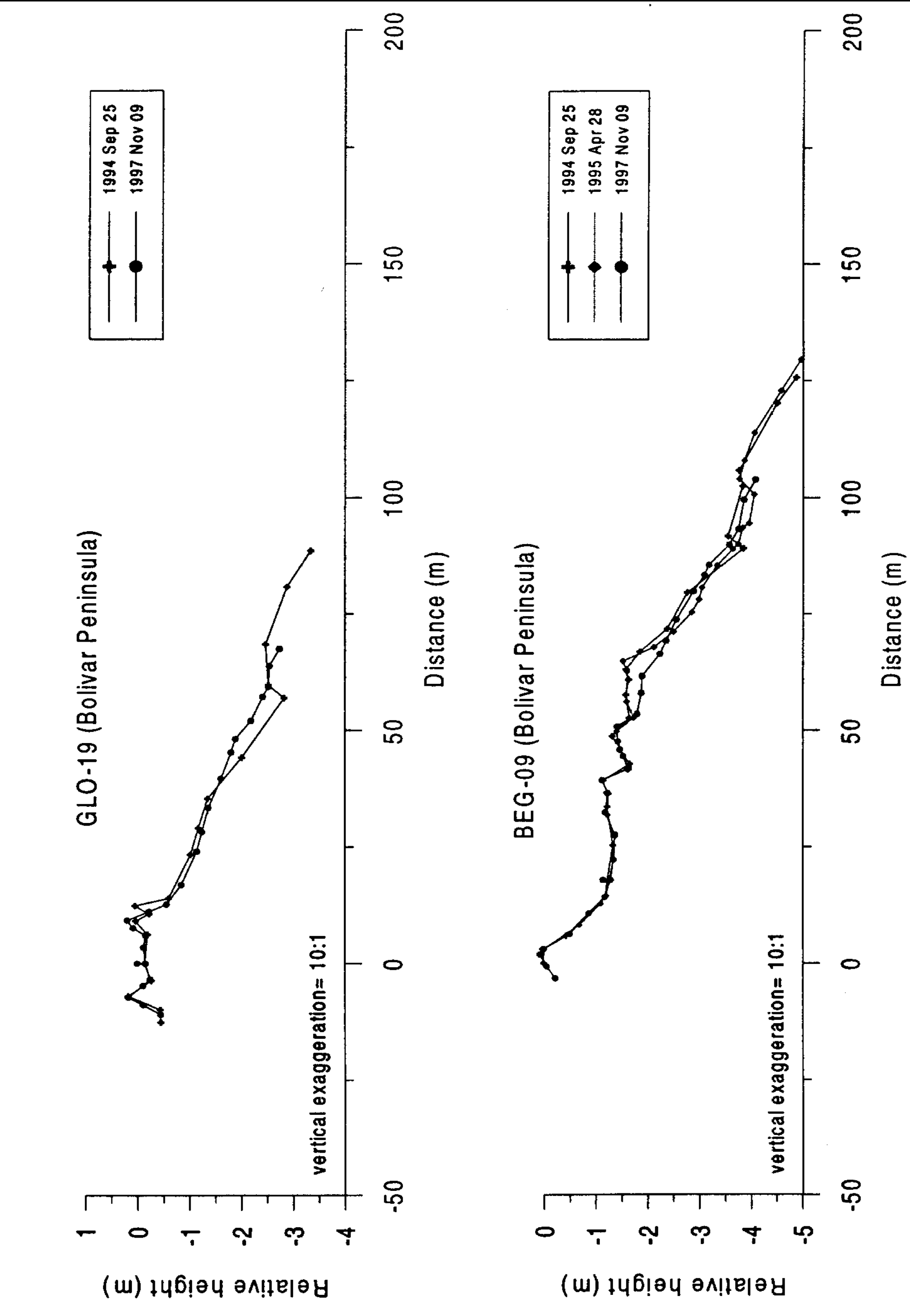

Figure 23 Profiles GLO-19 and BEG-09 (From Gibeaut and Gutierrez, 1999)
GLO-19 is 6 mi west of ROP; BEG-09 is 4.5 mi west of ROP

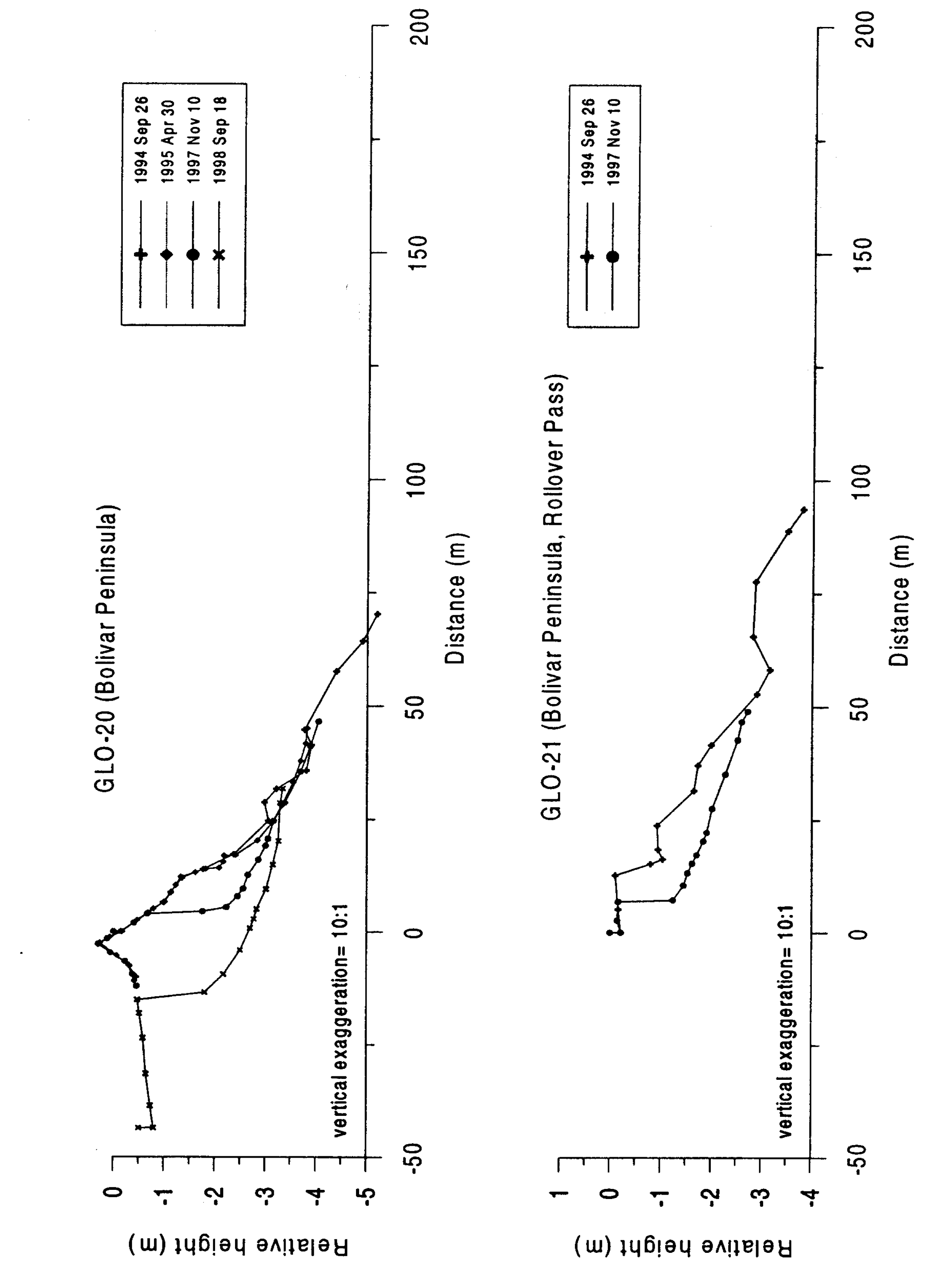

Figure 24 Profiles GLO-20 and GLO-21 (From Gibeaut and Gutierrez, 1999)
GLO-20 is 3 mi west of ROP; GLO-21 is 1 mi west of ROP

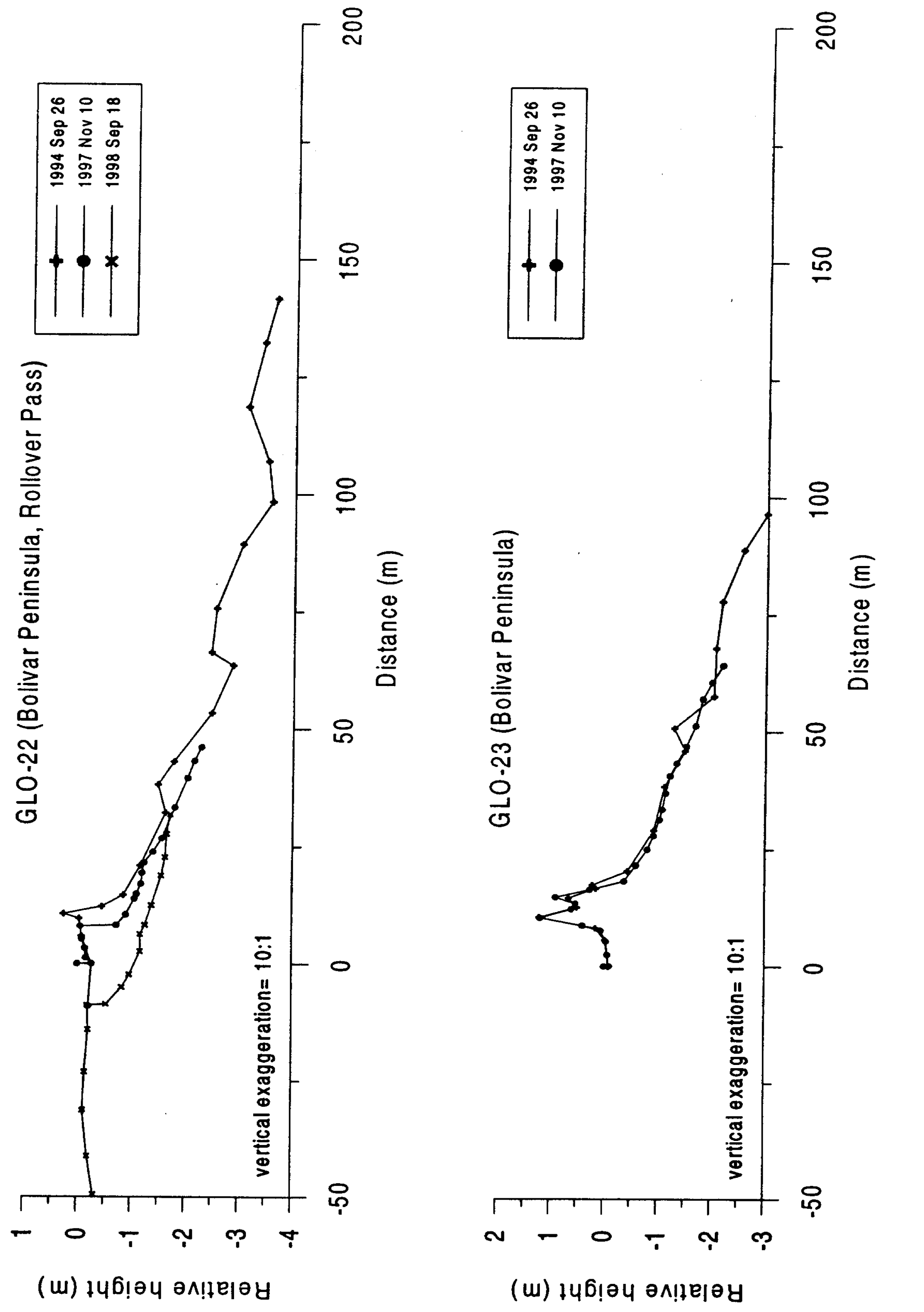

Figure 25 Profiles GLO-22 and GLO-23 (From Gibeaut and Gutierrez, 1999)
GLO-22 is 1 mi east of ROP; GLO-23 is 2.5 mi east of ROP

> The water level and wave conditions that occurred during TS Josephine appear to be the threshold when significant dune and beach changes occur along the upper Texas coast. The mean higher high water level (MHHW) approximates the elevation of the top of the beach berm. Adding half of the height of the waves to the water level heights relative to MHHW indicates the reach of the storm waves above the pre-storm beach. For Josephine this elevation peaked at 2.27 m and heights above 2.0 m lasted for about 11 hours. This allowed cutting back or complete erosion of incipient foredunes and vegetated, artificial and piles formed by beach scraping. The tops of these incipient foredunes and sand piles were generally 1.5 to 2.0 m above the berm. In areas of relatively high rates of long-term shoreline retreat, such as northeast of San Luis Pass at GLO-01, southwest of the Galveston seawall at GLO-08, BEG-01, AND GLO-09, and adjacent to Rollover Pass at GLO-20,21, AND 22 scarps were reactivated by Josephine. At all other locations only the incipient dunes were cut back and the landward primary dunes that were 2.5 to 3.5 m above the berm top were not affected.
>
> TS Frances had a much greater impact on the beaches and dunes than TS Josephine did. The upper reach of the storm waves, computed as above, was 3.0 m above the berm tops and heights greater than 2.0 m lasted 53 hours. This caused extensive scarp retreat in the same areas as Josephine did (Gibeaut and Gutierrez, 1999, p. 20).
>
> The variable heights and widths of the foredunes along this coast made a significant difference in the type of erosion and effects on landward property caused by TS Frances. Where foredunes were less than 3-m above the berm tops and narrower than 30 m, they were completely eroded and overwash occurred. Foredunes higher than 3 m and wider than 30 m protected the landward environment.
>
> Overall, TS Josephine {I think the authors mean TS Frances, RLW} caused the greatest change during the storm and for at least one year after the storm where the shoreline is experiencing relatively high rates of long-term retreat (Fig. 12). {Fig. 21 this paper} This correlation is explained by low dunes, no dunes, or the presence of scarps when the storm struck and by a lack of sand for recovery during the year after the storm in areas of high long-term shoreline retreat (Gibeaut and Gutierrez, p.23).

Figure 26 shows the extreme increase in long term shoreline erosion rates just to the west of the pass by a sharp dip in the solid line on this graph. Note also that along the Bolivar Peninsula the greatest sand volume loss from 1994 to 1997 was in the vicinity of Rollover Pass. The erosional losses from 1997 to post TS Frances in 1998 shown by the solid line with triangles was also very severe in the Rollover Pass vicinity, and especially west of Rollover Pass.

It is likely the extreme shoreline and vegetation line retreat in the Rollover Pass and resulting property losses were caused by loss of the sand reservoir that would have been on the beaches, back beaches and dunes, if that sand had not been lost through Rollover Pass over many years.

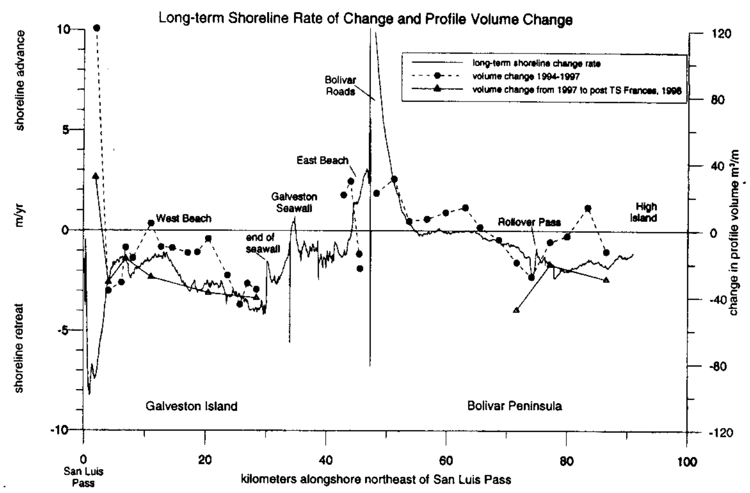

Figure 26 Long term shoreline change and profile volume change caused by Tropical Storms Josephine Frances (From Gibeaut and Gutierrez, 1999)

Gibeaut and Gutierrez have shown that where there was an adequate sand storage in the foredunes and backshore, serious shoreline erosion was not caused by TS Josephine or TS Frances. On the other hand, at locations where the shoreline did not have this protection or was backed by erosional scarps, the shoreline retreat due to the tropical storms was severe.

Figures 19 and 20 show that even relatively mild TS Dean caused bluff retreat up to several miles west of Rollover Pass. Before 40 years of sand loss through Rollover Pass, the beaches in the vicinity of Rollover Pass were relatively wide and backed by a low dune ridge and wide, vegetated yards seaward of the houses.

Figure 27 West from the Green and Gordon Houses in 1983.

Figure 27 shows the beach about 2 miles west of Rollover Pass in 1983. Note the backbeach is covered with vegetation and low dunes and represents a considerable sand supply. It is a very different beach from that shown in the same vicinity in Figures 19 and 20 in 1995, just 12 years later.

When there is good sand storage in the beach profile, including the back beach and foredunes, there is good protection from long-term beach erosion and permanent loss during storms. With an adequate sand storage, storms move sand offshore during the storm. It then moves back onshore with the gentle waves in the months and years after the storm and goes back into storage on the upper backshore and foredunes. However, it a shoreline is subjected to a long term annual loss of as much as 200,000 to 300,000 cubic yards such as is lost inward through Rollover Pass annually, the beach is unable to maintain its long term sand storage which provides natural beach erosion protection during storms.

The problem is especially acute on the Bolivar Peninsula where the sand body is limited and clays are encountered at a shallow depth. These have been exposed by erosion (Figs. 19 and 20). Once the shoreline erodes to this extent, there is no sand on either the backshore or foredunes to move offshore and slow wave attack during storms. Instead, rapid retreat of the scarp occurs. Since little sand was carried offshore and temporarily deposited, there is no sand to move back onshore in the calm period between storms. The clays are carried off in suspension to never return. The result is that each storm causes permanent shoreline erosion and retreat.

If Rollover Pass had never been opened, over 200,000 cubic yards of beach materials would never have been swept through it annually and deposited in Rollover Bay and the GIWW. Over a period of 40 years, Rollover Pass has removed as much as 9 million cubic yards of sand from the beaches. The beaches of Bolivar Peninsula, and especially those west of Rollover Pass, would not have eroded to where they lost their entire sand storage and began scarp and bluff erosion facilitating the rapid retreat during TS Frances and TS Josephine.

The sudden rapid acceleration of erosion west of Rollover Pass during Frances and Josephine is not because they were particularly bad storms. It was caused because there was no longer any sand storage on the beach, backbeach and foredunes. Refer to Appendix II for a series of photographs of private properties showing the acceleration of beach erosion after 1995.

This problem probably would have occurred eventually due to the long term erosion of Bolivar Peninsula in this vicinity at about 5 feet per year. However, if Rollover Pass had not been starving the beaches of sand for 40 years, the severe and rapid bluff erosion would not be occurring now.

TEXAS PARKS AND WILDLIFE OFFICIALS HAVE KNOWN FOR 40 YEARS THAT THE BEACHES WEST OF ROLLOVER PASS NEEDED REGULAR NOURISHMENT AND THEY VOTED TO CLOSE THE PASS OVER 20 YEARS AGO

In 1953, Lockwood and Andrews prepared a preliminary design plan for Rollover Pass for the Fish and Game Commission. They expected to have difficulty keeping the pass open and expected regular maintenance dredging of the channel would be required. This was their experience with other small man made passes on the Texas coast. When the pass immediately eroded to a depth of 30 feet from 8 feet and widened from 80 feet to 500 feet, the State first became aware of the tremendous erosive capability of Rollover Pass and immediately closed it with steel sheet pile bulkheads.

In 1959 the Galveston District Corps of Engineers completed a study and recommended stabilization of the channel, with steel bulkheads along its sides and a steel sill to limit flow through the channel. They also recommended an on-going beach nourishment program to regularly place sand on the beaches southwest of the pass to replace the beach sand lost through the pass. They estimated 18,000 cubic yards of material were lost through the pass annually, and that there was a total deficit of about 200,000 cubic yards of sand on the beaches between Rollover Pass and a point seven miles east of the Galveston Entrance Channel, or about at Crystal Beach.

In 1966 , Terrence R. Leary of the Texas Parks and Wildlife Department applied to the COE for a permit to place dredge material along 2000 ft of beach southwest of Rollover Pass. Parks and Wildlife recognized that they had a problem with excess erosion southwest of Rollover Pass. They did not apply for a permit to place sand northeast of the pass. The amount placed since the pass was re-opened averaged only 4250 cu yd/yr which was less than ¼ of the amount recommended by COE.

Texas A&M University's study of Rollover Pass by Prather and Sorenson (1972) indicated that while the beaches east of Rollover Pass seemed relatively stable, there was recession of the west beach.

In a Bureau of Economic Geology (the State Geological Survey) Brown *et al.* (1974) reported recent erosion rates in the vicinity of Rollover pass increased from 5 feet per year to over 10 feet per year.

Lockwood, Andrews and Newnam, the firm that designed Rollover Pass in 1953, prepared a 1974 report titled :Localized Erosion at Rollover Fish Pass, Bolivar Peninsula" for the Texas Parks and Wildlife Department. They noted the earlier recommendations by COE that an ongoing program of beach nourishment be instituted had not been accomplished. They stated: "However, for a distance of about 4,000 feet immediately southwest of the inlet, the rate of erosion is double that in adjacent areas since the inlet was cut, based on cross-section surveys in 1956 and 1974. The increase can be attributed to the presence of the inlet as explained in this report" (Lockwood, Andrews and Newnam, 1974, p. 19)

Robert W. Morton, a geologist in the Bureau of Economic geology, wrote in 1975: "The opening of Rollover Pass contributed to local erosion in that area."

In 1979, the Texas Parks and Wildlife Department considered closing Rollover Pass. "During its February 1978 and February 1979 Executive Sessions, the Commission reviewed reports on the background and condition of the Rollover Fish Pass. During its June 1979 Public Hearing Session, the Commission authorized the Executive Director to take the necessary action to discontinue the operation of Rollover Pass" (Proposed Agenda Item, Texas Parks and Wildlife Department, September, 1979). In the June, 1979 meeting they stated: "The existing Rollover Fish Pass is causing accelerated erosion of that portion of the Gulf Beach southwest of the pass and is causing deposition of silt in Rollover Bay which is a degradation of the biological quality of the bay." "It is in the best interests of the people of Texas that said beach erosion and biological degradation of Rollover Bay be halted." The staff recommendation was: "*Due to economic necessity, the Commission authorizes the Executive Director to take necessary action to discontinue operation of Rollover Pass* (emphasis mine)."

A Parks and Wildlife Department Memorandum dated February 27, 1978 from Clarence E. Ham to Paul E. Schlimper states the following:

> On February 27, 1978, Mr. George Rochen of the Corps of Engineers in Galveston provided me certain information regarding the Corps dredging operation of the intracoastal canal of Rollover Fish Pass. The intracoastal canal was originally constructed in the late 1930's at a depth of 9 feet. It was later deepened to 12 feet. George stated that their records of the work on the canal prior to 1954 were not very detailed, that is the new work and the maintenance work were not separated. Although between 1938 and 1954, the canal was dredged one time. The canal was dredged in the following years: 1954, 1959, 1962, 1964, 1966, 1968, 1970, 1973, 1975, 1976, and scheduled for 1978. The requirement for dredging for this portion of the canal was always dictated by that portion adjacent to Rollover Fish Pass. By this I mean that the other section of the canal could have waited until sometime later, but this section was becoming impassable and had to be dredged (Clarence E. Ham, Head, Master Planning, 1978).

The Executive Session of the Parks and Wildlife Commission in February, 1979 considered the following staff recommendations:

> A. The Pass is causing a severe biological impact on Rollover Bay. Sand from the lateral (sic) drift along the gulf beach is traveling through the Pass and being deposited in the Bay.
>
> B. The diversion of this and from the lateral (sic) drift is causing beach erosion southwest of the Pass.
>
> C. The deposition of the sand in the bay is causing severe siltation of the intracoastal canal which crosses the bay. This is causing not only a monetary impact for the dredging operation by the Corps of Engineers, but an environmental impact on lands for spoil deposition. Thus the Corps of Engineers favorably considers filling the Pass.

In a Texas Parks and Wildlife memorandum (February 21, 1978) from Clarence E. Ham and Harry W. Arfman to Paul E. Schlimper a field inspection of Rollover Fish Pass is described.

> 2. Accelerated erosion of the Gulf Beach southwest of the fish pass opening continues. This beach erosion is of considerable concern to land owners that have improvements along this approximately 4,000 feet stretch of beach. If the fish pass continues to function as it presently does, this accelerated erosion can be expected to continue to diminish the beach and associated dunes.
>
> 3. Heavy loads of sediment are still being discharged into Rollover Bay and the intra-coastal waterway that crosses it. This siltation is expected to continue if the exchange pass continues to operate as it presently does.
>
> 5. Deceptive channel currents and deep scour holes at each end of the pass may have contributed to the loss of several lives during the past year.

Working for the U.S. Army Corps of Engineers, Mason (1981) showed the amount of erosion caused along the beaches west of Rollover Pass was a function of distance from the pass. He documented erosion due to the presence of the pass extending at least 14,000 feet west of the pass. He estimated the annual sand loss through the pass was about 28,000 cu yd/yr, up from the 18,000 cu yd/yr earlier estimated by COE.

Morton, Pilkey, Pilkey, and Neal (1983) in their book *Living With the Texas Shore* stated: "One aspect to consider, however, is that sand flows through the inlet and is deposited in Rollover Bay. This sand would normally have gone to the beach westward along Bolivar Peninsula where it would have reduced erosion or contributed to accretion near the Bolivar Roads jetties."

In their exhaustive 1985 report published by another State agency, the Center for Research in Water Resources of the University of Texas and in their later 1989 report, Bales and Holley presented detailed evidence that sand loss through Rollover Pass was causing accelerated beach erosion in the vicinity of the pass and especially southwest of the pass. They gathered all of the Corps of Engineers dredge data for the Gulf Intracoastal Waterway and conclusively demonstrated that the amount of material removed from the GIWW since Rollover Pass was opened exceeded the amount dredged prior to opening of the pass by 240,000 to 290,000 cu yd/yr. They further showed that there is no other source for this material other than beach sand flushed through the pass from the littoral drift system of the Gulf shoreline. This raises the annual loss of beach materials through the pass from the 28,000 cubic yard per year estimated by Mason (1981) to ten times that amount, or well over 200,000 cu yd/yr. This is an actual measured volume of material carried into the GIWW by Rollover Pass. Appendix I contains dredge data obtained for this present report that shows the excess dredging in the vicinity of Rollover Pass continues to this day. The presence of the pass is requiring bi-annual dredging by the Corps of Engineers at a cost well in excess of $720,000 per year (based on a volume of 240,000 cubic yards at $3.00 per cu yd). Bales and Holley noted that the excess erosion was extending two miles southwest of the pass. It is apparent as more time passes, the effect of the pass in causing Gulf beach erosion will extend further and further southwest of the pass.

In 1989, Paine and Morton writing for the State Bureau of Economic Geology noted: “The shoreline 1.5 mi in either direction of the pass was also stable to slightly accretionary between 1930 and 1956-57 but retreated rapidly between 1956-57 and 1974, after completion of the pass.”

Professor Y.K. Wang (1989) and his students at Texas A&M University in Galveston concluded the beach erosion southwest of the pass was caused by sediment loss through the pass. They recommended rebuilding the beaches and dunes southwest of the pass with 830,000 cubic yards of sand to be removed from Rollover Bay.

Dannenbaum Engineering *et al.* (1992) in the massive Galveston County’s Shore Line Flood Protection, Restoration and Implementation Plan stated that shore erosion in the vicinity of Rollover Pass was due to sand loss from the beaches through the pass. They recommended a large beach nourishment program extending from High Island to Rollover Pass and from Rollover Pass to Caplen. These areas were determined to be critical beach erosion areas with imminent loss of structures and probable loss of the only road connecting Bolivar Peninsula with the mainland if beach nourishment was not accomplished. They also recommended modifying Rollover Pass to stop sand loss through it.

In 1995, the Galveston District of the Corps of Engineers, in response to a request from the General Land Office (GLO) of the State of Texas again studied the erosion problem of the beaches in the vicinity of Rollover Pass, to determine if materials dredged during the maintenance of the GIWW could be used for beach nourishment southwest of the pass. By this request, it is apparent that the GLO recognized the pass was causing erosion of the beaches southwest of the pass. The study made by King (1995) noted: “At least three previous studies of the beach erosion problem have been conducted in this area (U.S. Army 1959, 1971, and 1985). These studies concluded the Gulf shoreline in the study area was seriously erosional, and recommended beach nourishment.....”

King (1995) noted the determination by Bales and Holley that the excess dredging of the GIWW due to sediment flowing in through Rollover Pass amounted to 240,000-290,000 cu yd/yr. Further studies showed this material was suitable for beach nourishment, as was the sand in disposal areas 35 and 36 at each end of Rollover Bay. King concluded beach nourishment projects should be implemented as quickly as possible, and he recommended the material stored in disposal sites 35 and 36 be returned to the beaches, as well.

As part of the 1995 study by COE, James Kieslich noted: “Meanwhile, the present trend has been slight accretion for the area east of the Pass and severe erosion immediately to the west of the Pass. *This is mainly caused from the predominent east to west sediment* *transport and configuration changes of the Pass due to recent structural improvements by the Texas Parks and Wildlife Department* (emphasis mine).

In a 1996 letter from Garry Mauro, then Commissioner, Texas General Land Office to Governor George W. Bush, Mauro, among other emergency measures to alleviate beach erosion in the wake of tropical storm Josephine, requested: "*Direct the Texas Parks and Wildlife Department to undertake the emergency closure of Rollover Pass using concrete removed from Caplen Beach and Gilchrist (*emphasis mine)." It is apparent Commissioner Mauro recognized the role of Rollover Pass in accelerating beach erosion in its vicinity.

The Texas Coastwide Erosion Response Plane (Mauro, 1996b) recommended beach nourishment of the beaches west of Rollover Pass and either the installation of a sand bypassing system *or closure of Rollover Pass.*

Again writing for the Bureau of Economic Geology, Robert Morton (1997) states: "Slightly higher rates of erosion for this beach segment compared with those to the northeast are partly attributable to sand losses from the littoral system. Some sand migrating along the beach is transported through Rollover Pass into East Bay, where it is deposited as a flood-tidal delta. This deposit has increased the shoaling rates in the Gulf Intracoastal Waterway."

Gibeaut and Gutierrez (1999) studied the effects of tropical storms Josephine and Frances in causing beach erosion on the Bolivar Peninsula. They found the greatest shoreline retreat, vegetation line retreat, and loss of sand on the beach was in the immediate vicinity of Rollover Pass. The erosion was greatest where foredunes and beach sand storage were the least. "Overall, TS Josephine {I think the authors mean TS Frances, RLW} caused the greatest change during the storm and for at least one year after the storm where the shoreline is experiencing relatively high rates of long-term retreat..... This correlation is explained by low dunes, no dunes, or the presence of scarps when the storm struck and by a lack of sand for recovery during the year after the storm in areas of high long-term shoreline retreat."

Forty years of sand loss through Rollover Pass is what provided these conditions described by Gibeaut and Gutierrez. The long-term sand loss through Rollover Pass set the stage for massive shoreline erosion by tropical storm Josephine and tropical storm Frances in the Rollover Pass vicinity.

In the light of this knowledge of long term beach erosion in the vicinity of Gilchrist and Caplen caused by sand loss through Rollover Pass, The Texas Parks and Wildlife Department should not have "improved" Rollover Pass in 1994-95 without at the same time beginning a large and permanent beach nourishment program along with a sand bypassing system to stop sand loss through the pass.

CONCLUSIONS AND RECOMMENDATIONS

The wealth of scientific and engineering studies of Rollover Pass and erosion of beaches in the vicinity of the pass all indicate that loss of beach sand through Rollover Pass into the GIWW and Rollover Bay is causing accelerated beach erosion of the beaches west of Rollover Pass. There are indications the sand loss is also causing erosion of the beaches east of Rollover Pass, but to a lesser extent.

Dredging data from the U.S. Army Corps of Engineers (Bales and Holley, 1985, 1989) indicates that 240,000-290,000 cubic yard of beach materials are transported through Rollover Pass and deposited in the Gulf Intracoastal Waterway annually. This means that almost 10 million cubic yards of sand has been lost from the beaches through Rollover Pass since it was built in 1956.

All of Bolivar Peninsula has been eroding for many years, with the exception of the 7 miles of beaches east of the Galveston north jetty. The long-term erosion rate has been about 5 feet per year. Since Rollover Pass opened in 1956, beaches west of Rollover Pass have been eroding much faster than the general long-term rate for the area. Since 1995, and the occurrence of tropical storms Dean, Josephine, and Frances, the beach erosion within about 5 miles west of Rollover Pass and a short distance to the east of Rollover Pass has accelerated with losses as great as 60 feet in a single storm. Losses this great have never occurred near Rollover Pass in the past.

This massive new erosion is not just due to these three tropical storms. Bolivar Peninsula has been subjected to attack by tropical storms and hurricanes throughout its history. Rather, this extreme erosion is because there were 40 years of sand loss greater than 200,000 cu yd/yr from the beaches through Rollover Pass. This has resulted in the total removal of the normal sand reservoir in the offshore bars, on the beach and backbeach and in the dunes for over three miles west of the pass. This is clearly shown by the clay beach exposed by tropical storm Dean in 1995. There is no sand left. It all went into the GIWW and Rollover Bay. The beaches continue to erode as longshore sediment transport carries the remaining sand westward where it accumulates north of the Galveston jetty.

The 40 years of sand lost through Rollover Pass have removed the natural sand storage in the offshore bars, beach and dunes. As a result, the beach cannot rebuild between storms by moving sand onshore from the bars back onto the beach, as would normally be the case. This is going to result in ever increasing acceleration of erosion with each succeeding storm because the profile inland from the present vegetation line contains even more clay and less sand.

The Parks and Wildlife Department has known of the sand loss through Rollover Pass and the need for beach nourishment of 20,000 to 200,000 cu yd/yr since at least 1959. This estimate was raised to 240,000 to 290,000 cu yd/yr in 1985.

The sand flowing into the Gulf Intracoastal Waterway requires that that the channel be dredged about every two years at a an annual cost of over $720,000 to the Corps of Engineers.

If Rollover Pass is not closed, and if the material lost from the beaches into Rollover Bay and disposal sites 35 and 36 is not replaced on the beaches, rapid scarp erosion of the beaches near Rollover Pass will continue with each new storm, since the bluff that is now eroding has little sand to nourish the beaches. This will result in the loss of even more land and structures and may eventually result in a permanent breach turning Bolivar Peninsula west of Rollover Pass into Bolivar Island.

We recommend, as has been recommended by every scientific and engineering study for 40 years, that a beach nourishment program be initiated. Most of the sand lost through Rollover Pass into the GIWW has been stored in dredge material disposal sites 35 and 36. All of this material should be placed back onto the beaches west of Rollover Pass. (Additional material can also be taken from Rollover Bay). At least 1 million cubic yards of sand should be placed on the five miles beaches west of Rollover Pass before the next hurricane season.

We recommend that Rollover Pass be permanently closed, to stop the annual loss of tremendous amounts of sand from the critically eroding beaches of Bolivar Peninsula. There is no other way to effectively stop beach sand loss through Rollover Pass. This is the same recommendation made by Parks and Wildlife Department Officials in 1979 and by General Land Office Commissioner Mauro in 1996 (Mauro 1996 and Mauro 1996b). This will also reduce the dredge maintenance costs for the adjacent Gulf Intracoastal Waterway by over 3/4 million dollars annually.

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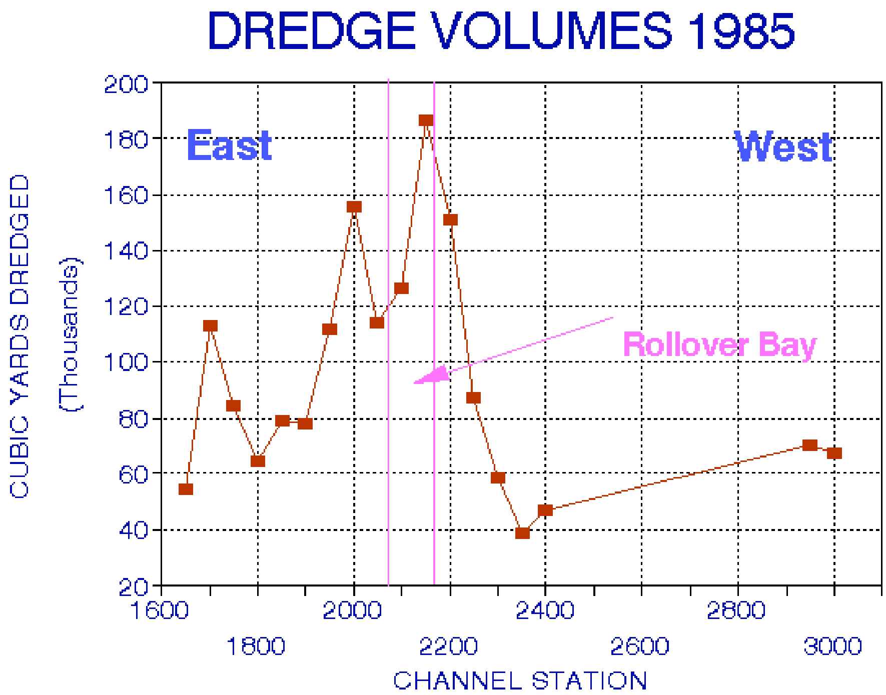
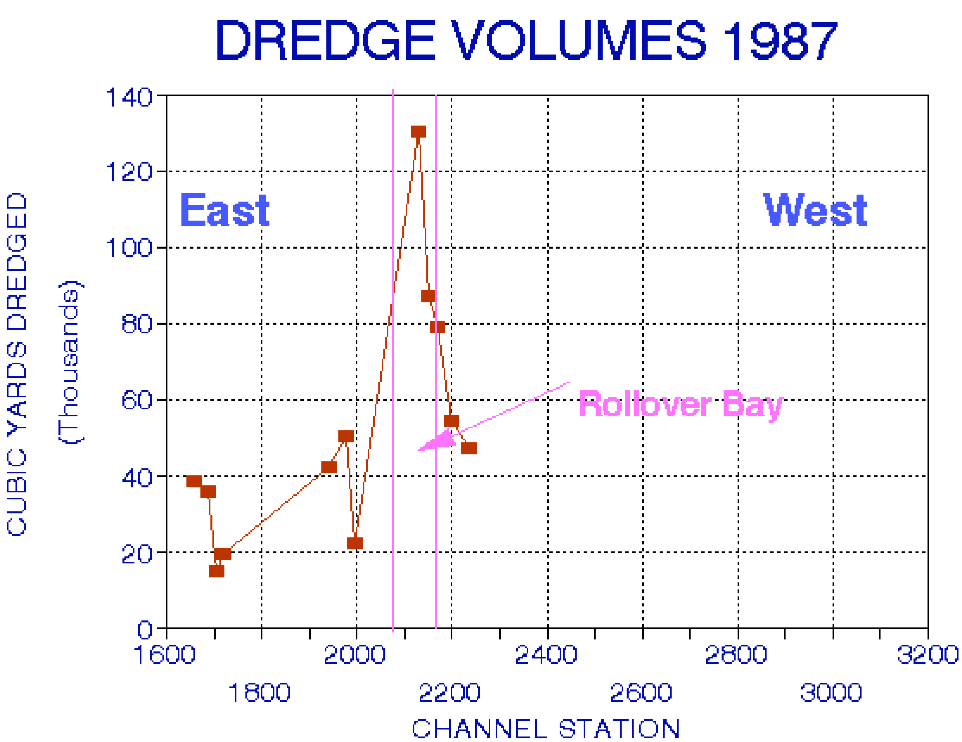
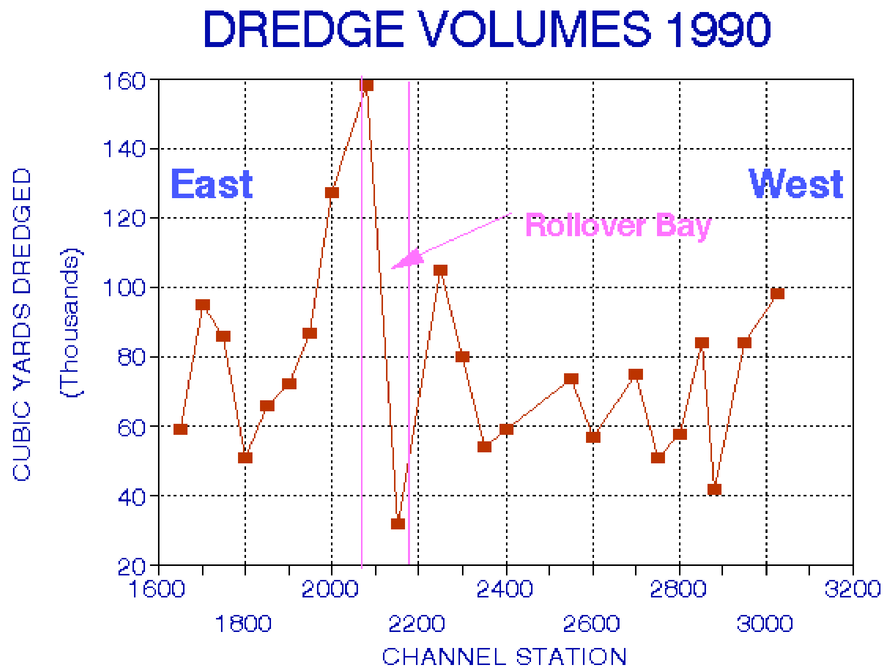
APPENDIX I

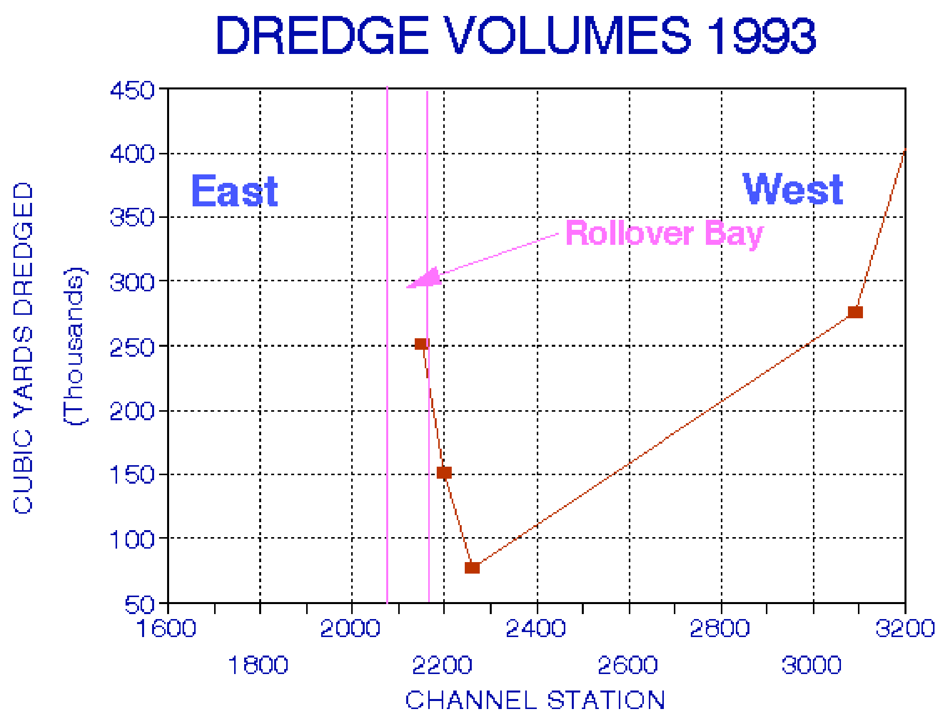
Post 1985 GIWW Dredging Volumes

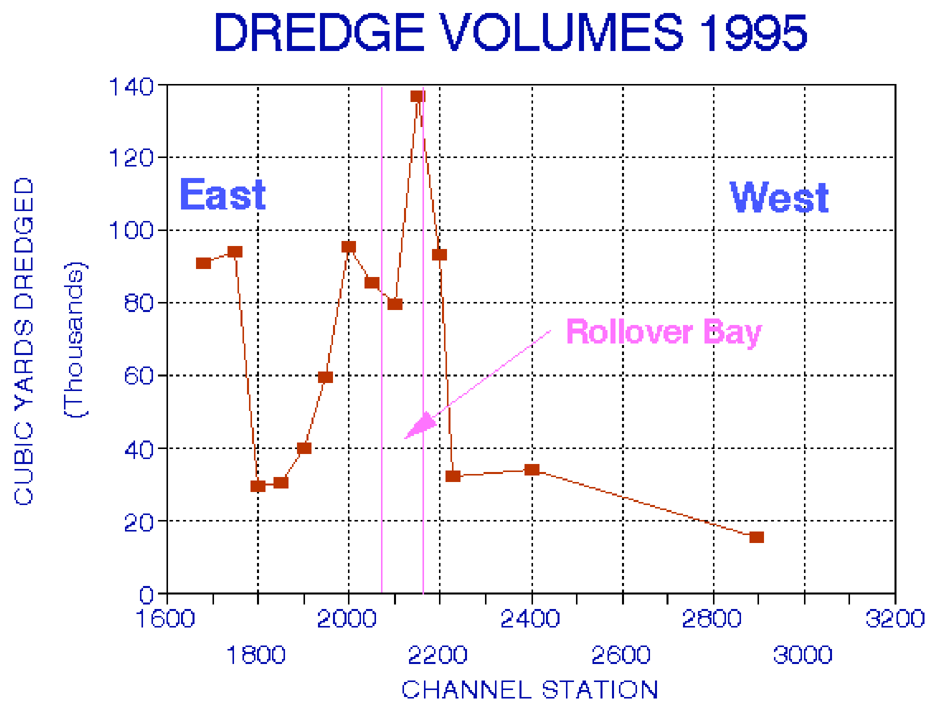
Near Rollover Bay


DREDGE VOLUMES 1985
East
West
Rollover Bay
CUBIC YARDS DREDGED
(Thousands)
CHANNEL STATION
200
180
160
140
120
100
80
60
40
20
1600
1800
2000
2200
2400
2600
2800
3000


DREDGE VOLUMES 1987
East
West
Rollover Bay
CUBIC YARDS DREDGED
(Thousands)
CHANNEL STATION
140
120
100
80
60
40
20
0
1600
1800
2000
2200
2400
2600
2800
3000
3200


DREDGE VOLUMES 1990
CUBIC YARDS DREDGED
(Thousands)
160
140
120
100
80
60
40
20
East
West
Rollover Bay
1600
2000
2400
2800
3200
1800
2200
2600
3000
CHANNEL STATION


DREDGE VOLUMES 1993
CUBIC YARDS DREDGED
(Thousands)
450
400
350
300
250
200
150
100
50
East
West
Rollover Bay
1600
2000
2400
2800
3200
1800
2200
2600
3000
CHANNEL STATION


DREDGE VOLUMES 1995
East
West
Rollover Bay
CUBIC YARDS DREDGED
(Thousands)
0
20
40
60
80
100
120
140
1600
2000
2400
2800
3200
1800
2200
2600
3000
CHANNEL STATION

APPENDIX II

Photographs Showing Erosion

at

Selected Properties

PHOTOGRAPHS SHOWING CHANGES AT INDIVIDUAL PRIVATE PROPERTIES

This section will demonstrate the dramatic loss of shoreline relative to particular properties near Rollover Pass.

The Green House 1996

Green House 1998 (Post TS Frances)

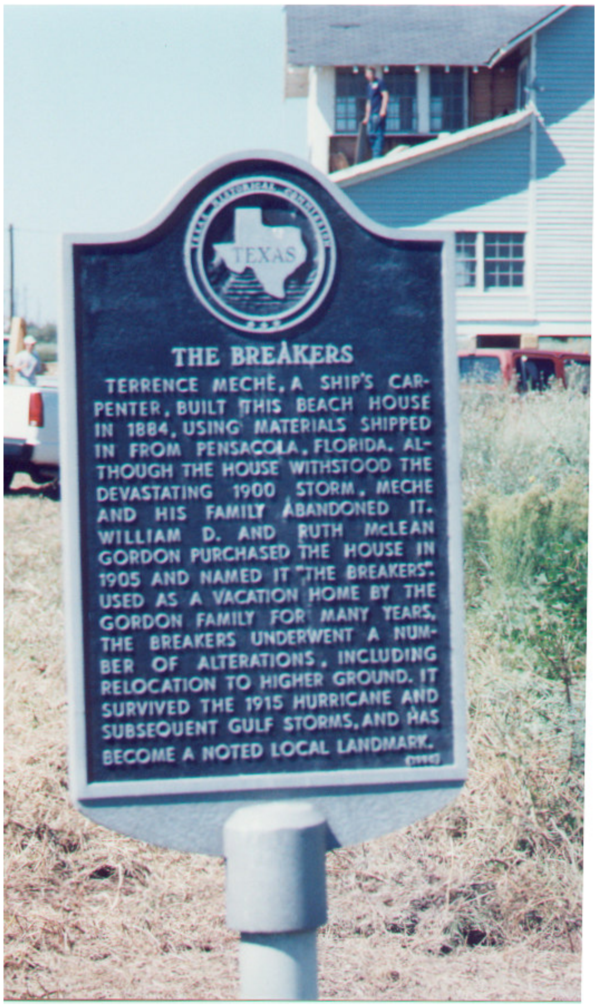
Green House September 1999

Seewald House Post Frances

This house will not be moved because the owner does not own any land to the north. He will lose the house unless the beach is restored.

Gordon House, *The Breakers*

This historic landmark built in 1884 was just moved 200 feet inland after the devastating beach erosion by tropical storms Josephine and Frances



The above picture shows the Gordon house, *The Breakers* in September 1999 just after it has been moved 200 feet inland from its old location where the posts are in the foreground.

The picture to the right shows the house in 1998 before it was moved back 200 feet.

The Sauer House

1991

Wide front yard 1992

Front yard 1996

The Sauer House after TS Josephine and Frances

After Tropical Storm Frances, 1998

Erosion under Sauer house and beach in front of Gordon and Sauer houses showing exposed clay beds.

The Sauer house in September, 1999 after new support has been added and fill placed under and in front of house. The only erosion protection that is currently allowed is hay bales and fill. This will be rapidly eroded during the next storm. The beach sand lost through Rollover Pass needs to be replaced in a major beach nourishment program.

House with pool 1 mile west of Rollover Pass

January 31, 1995

January 15, 1999

The photo on the left shows the vegetation line and scarp eroded right up to the pool in July 1999. The photo on the right shows how the pool actually extends beyond the scarp along most of the beach in September 1999.