Inlet Management and Sediment Budget Study for Gordon Pass, Collier County, Florida

T. L. Walton Jr., S. R. Wang, M. Manausa

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Florida State University

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1. Purpose of Study and Objectives

In accord with amended Section 161.142, Florida Statutes, the Florida Legislature finds that it is in the public interest to maximize inlet sand bypassing to ensure that beach-quality sand is placed on adjacent eroding beaches. Within the legislation, the FDEP-BBCS has been directed to maintain a current estimate of sand budgets within inlet complexes for purposes of prioritizing, planning, and permitting activities of the state. Wise management of limited natural resource beach sediment at its inlet systems for addressing mitigation of beach erosion and consequent flood damage to coastal areas adjacent to inlet systems will benefit the State of Florida.

The objective of the present study is to update/develop a "best estimate" sediment budget and recommendations for sediment resource allocation to adjacent beaches for Gordon Pass in Collier County, Florida.

Results of the present study are summarized in this report and include data findings of sediment budget based on data obtained by the FDEP and its subcontractors. The results address inlet impact and quantities of bypassing necessary to mitigate erosion problems in the vicinity of the inlet.

2. Historical Perspectives- Gordon Pass

Gordon Pass is located at the south end of the City of Naples, Florida and is part of a federally authorized navigation project initiated in the early 1960's. The inlet had been stabilized on the north side with numerous groins and seawalls built in the 1950's and 1960's (in response to ongoing erosion problems on the north side of the inlet at that time) and a terminal groin just north of the inlet (see Figure 1). Along with the federal navigation project, a 1400 foot long hooked jetty was constructed on the south side of the inlet to reduce sand loss back into the inlet anticipated with placement of dredged material just south of the south jetty on Keewaydin Island. Since initial construction of the south jetty, three sand tightening projects have been undertaken to reduce losses of south beach material placement to the ebb shoals and inlet channel.

Historical survey data show that from 1930's to 1957 prior to the commencement of dredging, the Gordon Pass ebb shoal system had been growing (Daubees and Moore (2010)). The growth was noted to be in response to increases in tidal prism from the closure of an inlet that existed approximately one to two miles south of Gordon Pass prior to 1944, and from development of tributary waterways, primarily development along Naples Bay and the Port Royal Canal system. In the 1960's Daubees and Moore (2010) note that the Golden Gate canal system was connected to the north end of Naples Bay resulting in a significant increase in freshwater flowing through the bay system and out thru Gordon Pass although from the 1960's through the 1990's they show that the inlet ebb shoals actually decreased in volume (see Daubees and Moore (2010) figures 10 and 11). In 2003 a series of 3 T-groins were constructed on the south side of the pass to help stabilize the shoreline. Humiston and Moore (2009) show that in recent years the total ebb shoal volume in recent years has remained relatively stable except for dredging episodes which reflect comparatively small changes to the overall ebb shoal volume.

Daubees and Moore (2010) have noted that the cumulative effects of management of the inlet system through maintenance dredging and downdrift beach disposal have been insufficient in addressing the erosion of adjacent beaches to the inlet.

Figure 1. Gordon Pass 2002 with overlay of marked channel.

Table 1 provides the dredging and disposal history of Gordon Pass available at the time of this report (CPE 1998 and Humiston and Moore (2009)).

Table 1. Gordon Pass Federal Navigation Project Dredging History

Date	Description	Dredged Quantity(cy)	Disposal&Location
1961	Jetty Constructed on north end of Keewaydin Island		
1962	Initial Federal Dredging of Naples Bay, Inland Shoals and Gordon Pass	524,574	230,000/North Keewaydin
1963	(?)	11,000	North Keewaydin
1967	(?)	8,817	North Keewaydin
1970	Navigation Maintenance	181,373	North Keewaydin
1980	Navigation Maintenance	235,831	North Keewaydin
1985	Navigation Maintenance	120,483	North Keewaydin
1993	Navigation Maintenance	94,796	North Keewaydin
2003	Navigation Maintenance	175,000	North Keewaydin
2009	Navigation Maintenance	52,000 (estimated)	North Keewaydin

Note: If number is not provided in disposal column it is assumed that the total amount dredged was disposed in the location noted.

Table 2 provides historical sand material placed on the beaches and nearshore (CT, 1997 and CPE, 2008).

Table 2. Nourishment History of Gordon Pass Areas

Date	Quantity Placed (yd^3)	Disposal Area
1996	759,150	R-58 to R-77
1998	15,516	Naples Beach
2000	7,420	Naples Beach
2001	39.800	Naples Beach
2002	45,047	Naples Beach
2006	347,381	Naples Beach
2006	53,630	Naples Beach

Figure 2. provides an aerial photo of the study area with FDEP range locations.

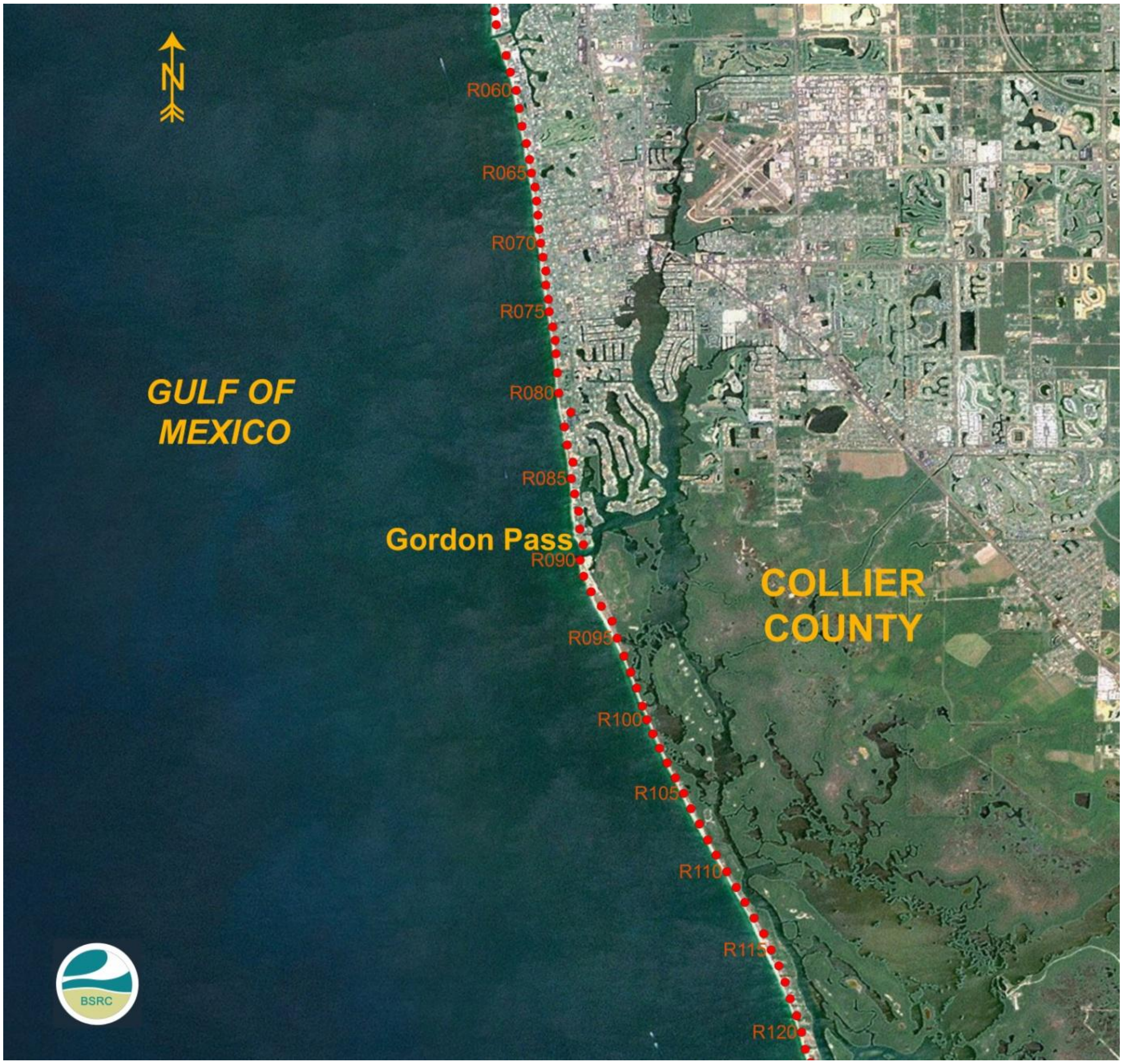


Figure 2. Aerial photograph of study area with FDEP Range locations.

3. Analysis of Climatologic Data and Historical Aerial Photos

3.1 Tides

Tides at the Gordon Pass area should be considered of a mixed type, i.e. showing features of both a semi-diurnal tide and a diurnal tide depending on the phase of the various astronomical components although the semi-diurnal is dominant. Mean and spring ranges are 2.1 ft. and 2.8 ft. respectively.

3.2 Waves

A 20 year Wave Rose graph is presented in Figure 3 for a WIS station. It shows that 20% of waves are from the west, 23% from the southeast, and 7% from the northwest. Waves with heights between 1 and 5 ft. are the most frequent ones.

3.3 Winds

The 20 year Wind Rose graph is presented in Figure 4 for WIS station 73299. It shows that 38% of winds are from the east, 14% from the southeast, and 15% from the northeast. Winds with speeds between 5 and 15 knots are the most frequent ones.

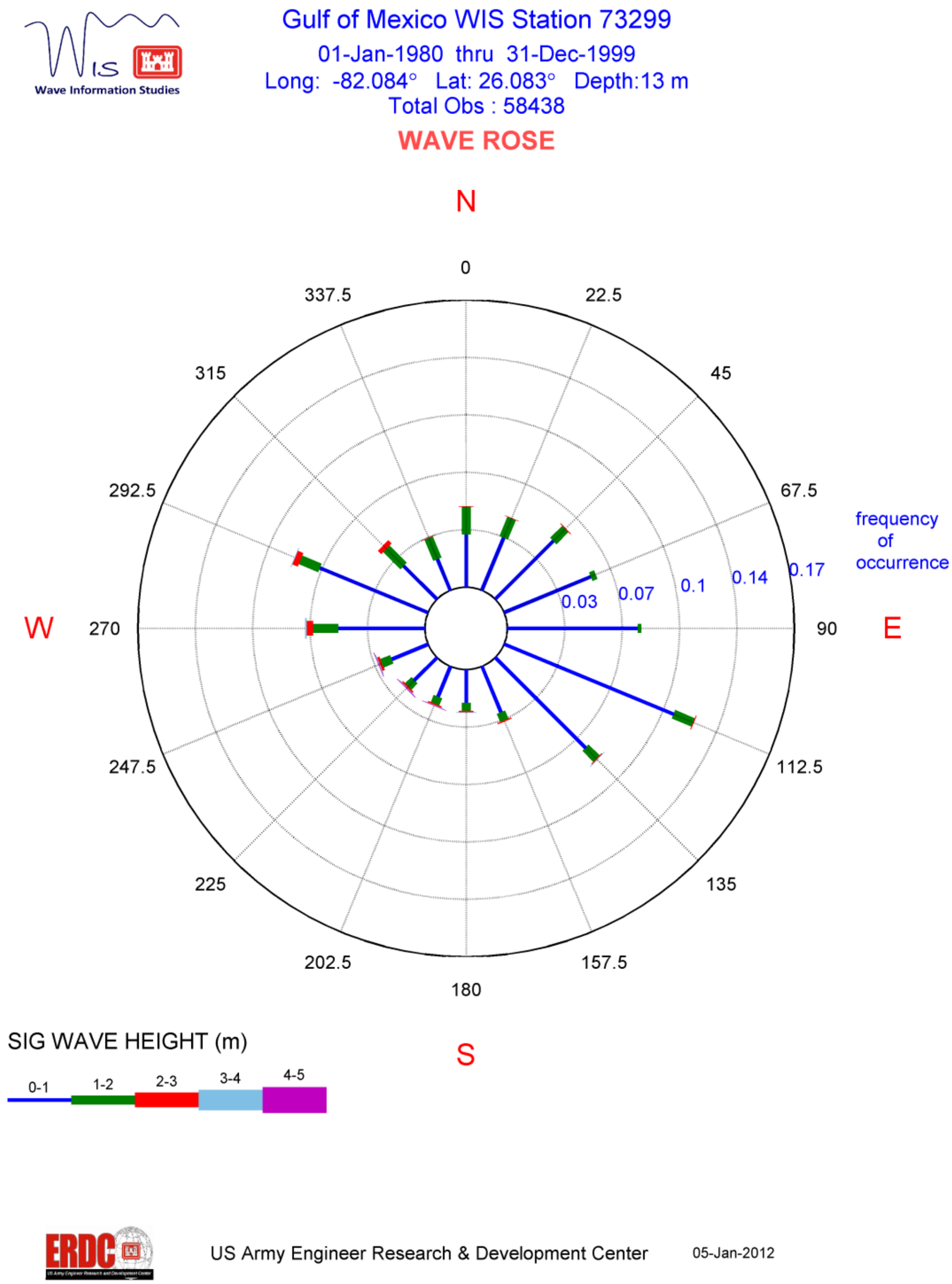


Figure 3. Wave Rose for WIS Station 73299.

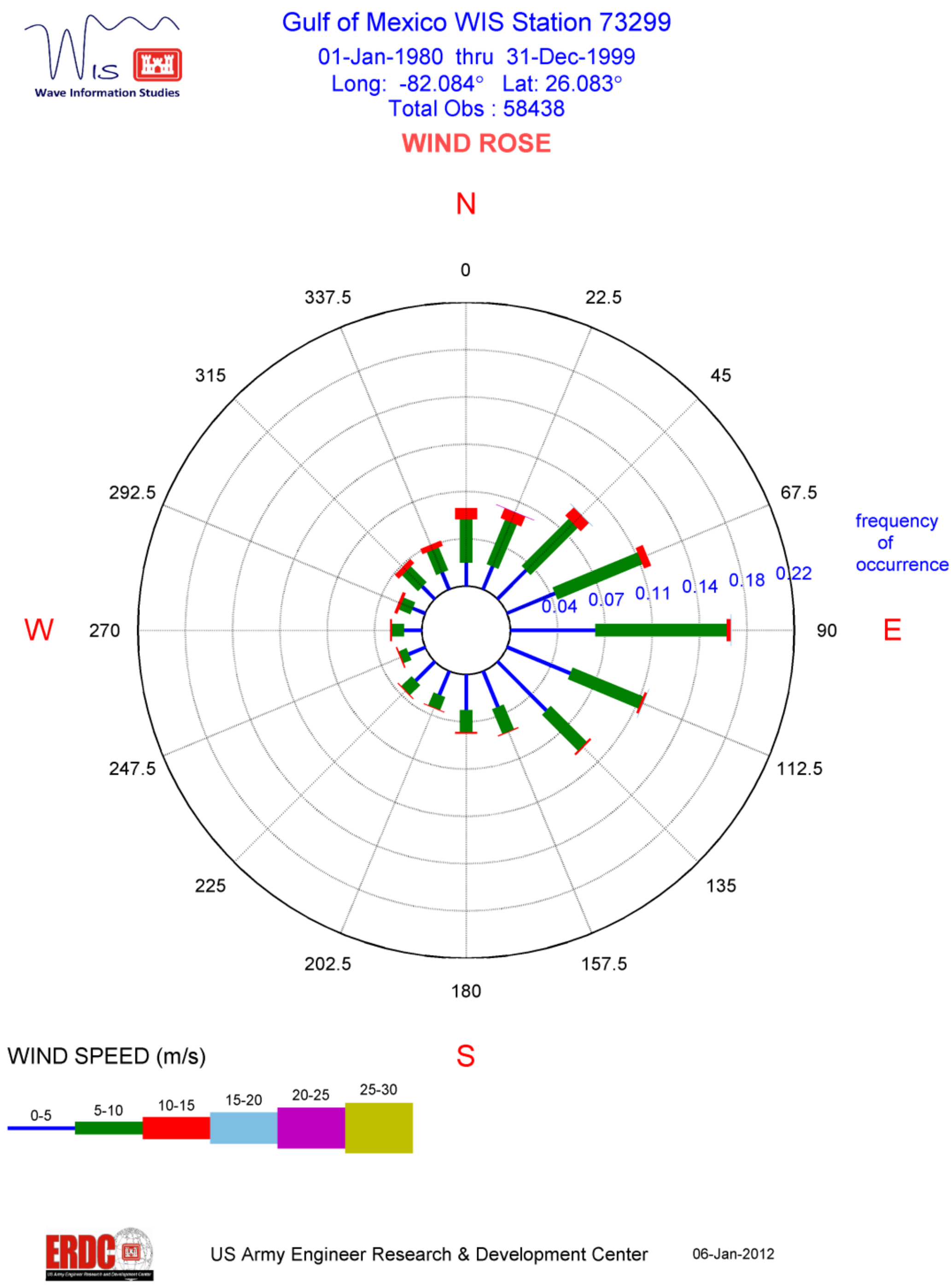


Figure 4. Wind Rose for WIS Station 73299.

3.4 Historical Storms

Tropical storms and hurricanes since 1900 that passed within a 50 mile radius from the Gordon Pass are listed in Table 2 and plotted in Figure 5. A total of 24 storms occurred in 101 years implies the Gordon Pass can expect a storm every 4 years. In addition to the storms of a tropical nature, long duration northeasters have the potential to contribute significant damage to the inlet areas during winter and spring.

Table 3. Summary of historical storms affecting Gordon Pass

	Date	Name	Type*
1	10/8/1906		E
2	9/18/1907		E
3	9/24/1909		L
4	10/9/1910		L
5	10/15/1921		L
6	10/14/1924		L
7	9/19/1929		E
8	8/26/1932		E
9	6/12/1936		L
10	7/27/1936		E
11	10/3/1941		E
12	9/4/1947		E
13	8/28/1953		L
14	8/29/1960	DONNA	A
15	10/1/1969	JENNY	L
16	7/21/1985	BOB	L
17	8/16/1992	ANDREW	E
18	11/8/1994	GORDON	L
19	10/22/1998	MITCH	L
20	9/19/1999	HARVEY	L
21	9/2/2004	IVAN	E
22	10/15/2005	WILMA	L
23	8/15/2008	FAY	L
24	7/22/2010	BONNIE	E

* L: Landfalling ; E: Exiting; A: Alongshore

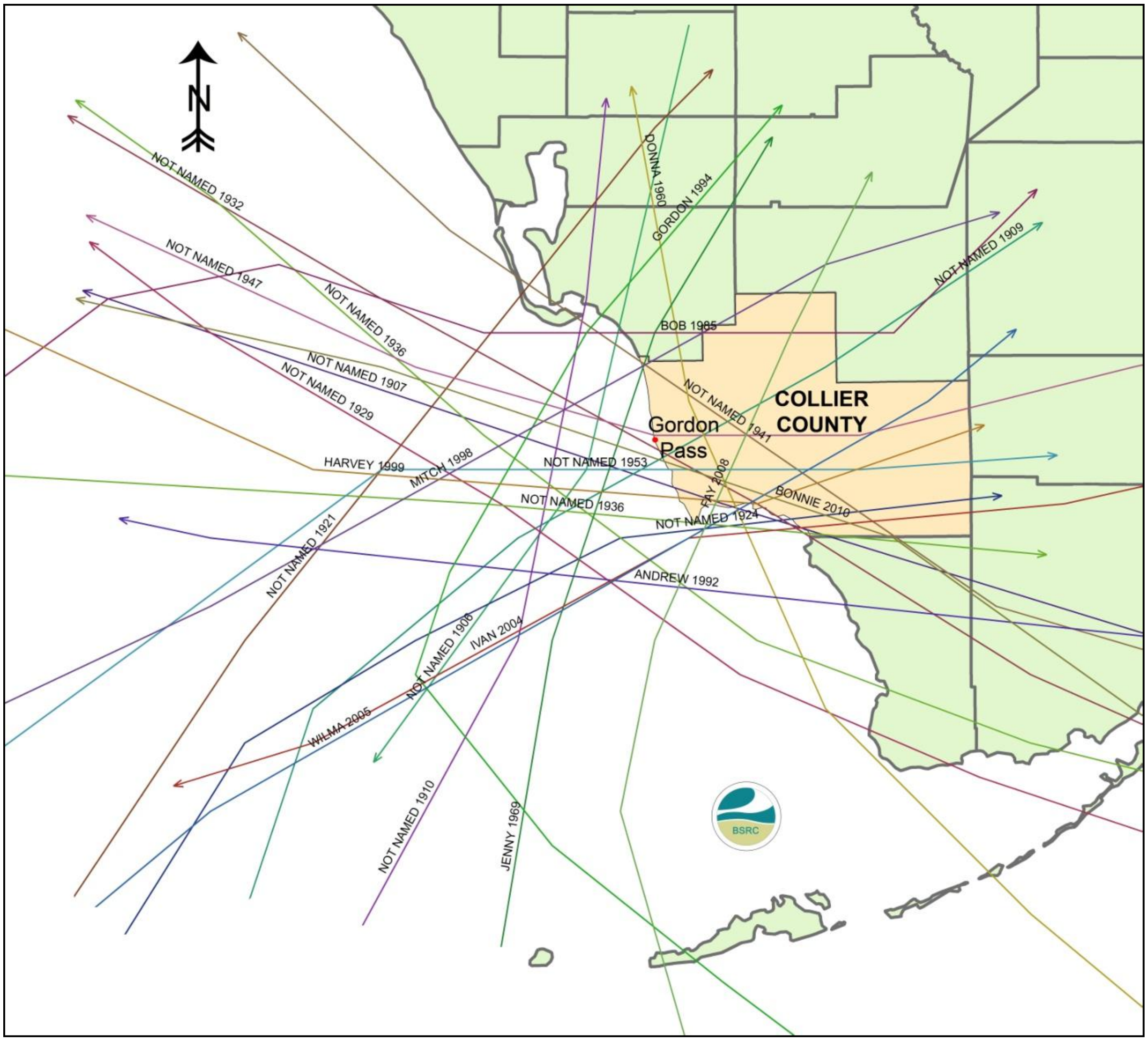


Figure 5. Storm tracks in the Gordon Pass area.

3.5 Historical Aerial Photography

Overhead Aerial Photographs of the inlet and shoal complex were collected from numerous sources, NOAA, Corps of Engineers, internet web sites, and Google Earth. Some of the inlet photos may be accessed on the BSRC web site. Aerials are provided in Appendix A.

4. Analysis of Wave Data

4.1. Winds and Wave Climate

4.1.1 Wave and Wind Information

Wave information for the study area and adjacent regions can be found in the sources as follows:

U.S. Naval Weather Service Command, SSMO (see Walton (1979));
Wave Information Study (USACE – internet and COE request);
NOAA-Wave Watch (NOAA-internet and NOAA request); and
NDBC- NOAA- buoys

USN-WSC-SSMO
The U.S. Naval Weather Service Command provides wind and wave diagrams based on shipboard observations. The accuracy of the data has been discussed previously by Walton (1973) where it has been used to predict littoral drift. Both wave roses and littoral drift roses are presented in Walton (1973) and are investigated in this study (along with other noted data sets) for the estimation of longshore sand transport (i.e. littoral drift). For most shoreline orientations of interest the net longshore transport in this area would be southward directed.

UF-COEL
The University of Florida Coastal and Oceanographic Department gathered limited wave information at two sites on the southwest coast of Florida, one near Sarasota and one near the Venice Pier. Neither of the gages was a directional gage and no gage data were able to be located in the time frame of the existing study. Additionally, the gages are a considerable distance away from the study site. As the gages were both non-directional, no information could be utilized for sediment transport information regardless.

USACE-WIS
Wave Information Study (WIS) is a wave hindcast modeling program aimed at providing a long term data base of wave height, period, and direction information. Existing *new* data posted on the WIS web site of the Corps of Engineers consists of wave data from 1980 through 1999 and is noted to include tropical storm and hurricane hindcast data in the data set. Previous WIS data for an earlier periods were requested (hindcast dating from 1956 through 1975) although were not furnished. The new web based data sets (1980-1999) were investigated within the present study for the estimation of longshore sand transport (i.e. littoral drift).

WAVEWATCH-NOAA
The National Oceanic and Atmospheric Administration (NOAA) also has a wave hindcast modeling program. The model utilized in the NOAA approach is Wavewatch and data are available on the NOAA-Wavewatch web site. This data was investigated for the present study but it was found that limited data existed which was considerably shorter (3-5 years) than the WIS data time series information of 20 years and does not provide wave data in a

time series parameterized file form. As a result of the limited data series, this set of data was not pursued for purposes of sediment transport computations.

A wave height rose and a wave energy rose (as represented by the square of the wave height multiplied by the square of the wave period) utilizing the Wavewatch data are provided in Figures 6 and 7.   Again, the predominant wave activity is noted to be from the Northeast. The Wavewatch data source is discussed in another section of this report.

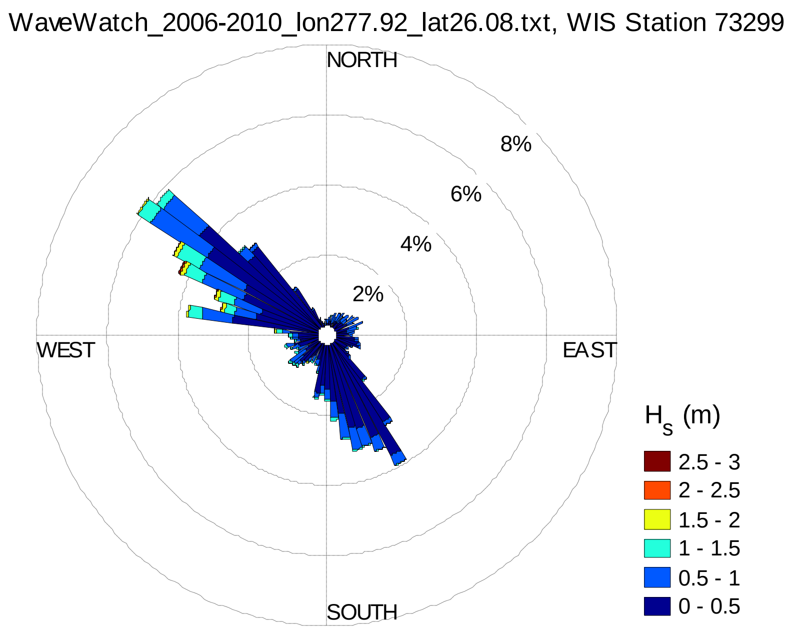


Figure 6. Wave Height Rose for Wavewatch data, 2006 through 2010 (Lat 26.08 N. , Long 277.92)

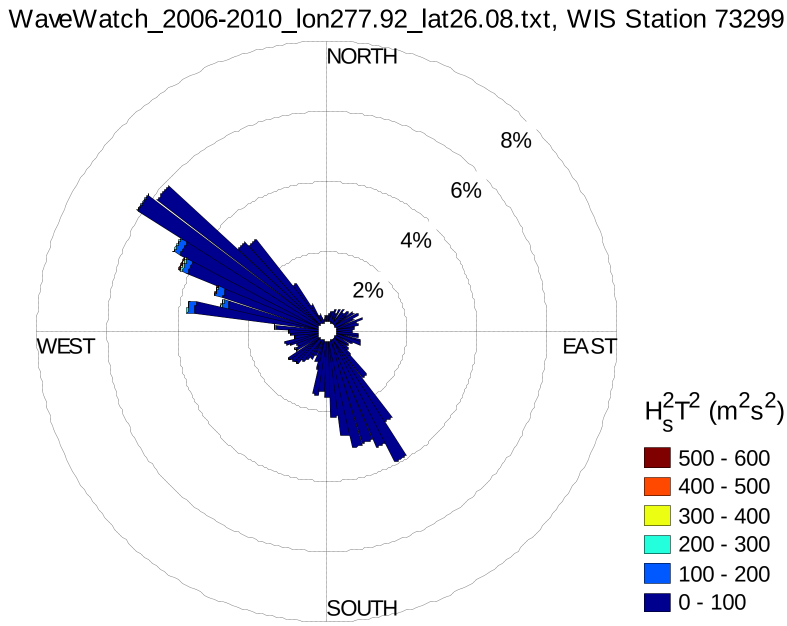


Figure 7. Wave Energy Rose for Wavewatch data, 2006 through 2010
(Lat 26.08 N. , Long 277.92)

NDBC-NOAA buoys

The National Oceanic and Atmospheric Administration (NOAA) operates a number of buoys in the Atlantic Ocean which collect both meteorological data as well as wave data. Although large heave-pitch-roll buoys as well as a smaller Datawell Waverider buoy have existed in the Gulf of Mexico, the data collected from the buoys is sporadic (numerous gaps in records) and is available for only limited data periods (four years for the longest non-continuous record). As the data is collected in deeper water (typically much greater than 15 meters) and often utilized in calibration of the wave hindcast programs that produce longer wave records, this data was not pursued further.

4.2 Longshore Sediment Transport

Previous studies related to longshore transport characteristics at Gordon Pass and nearby shorelines are discussed below. For the purposes below, net rates are provided where a net positive drift rate implies a net directed littoral drift to the right when looking offshore unless otherwise noted in accord with terminology by Walton (1972) and Walton and Dean (2010).

SSMO (1973)
Walton (1973) using SSMO data constructed littoral drift roses (LDR) for the coast of Florida, one of which provides information on the Gordon Pass area. The LDR provided covered the area from Wiggins Pass to Cape Romano. No specific littoral drift estimate is shown herein for the study region since the study region encompasses a wide variety of shoreline orientations and hence estimates must be made from the LDR's dependent on the orientation of the shoreline at that location.

USACE (1980)
CPE(1998) note that USACE(1980) provided a value of net littoral drift of approximately 50,000 c.y./yr. southward although the reference was not provided and it is not known how this figure was arrived at.

Davis and Gibeaut (1990).
Davis and Gibeaut (1990) provide a net sediment transport estimate of approximately 58,000 c.y. /yr southward in the study area (per CPE (1998)).

Suboceanic Consultants (1994)
As part of a wave refraction study at Doctor's Pass, computations suggested an annual net sediment transport rate of 30,000 to 40,000 c.y./yr although wave refraction at Gordon Pass was not part of the study.

CEC(1991)
Coastal Engineering Consultants provide an estimated net southward littoral drift of 71,000 (as per CPE).

CPE (1995)
Coastal Planning and Engineering (1995) reviewed historic survey data, dredging data, published estimates of longshore sediment transport, and shoal volume changes and arrived at a longshore sediment transport estimate of approximately 32,000 c.y./yr (net southward) based on the assumption that the material volume transported by waves past the channel was negligible.

CPE(1996)
Coastal Planning and Engineering (1996) made a revised estimate of net sediment transport equal to 35,000 c.y./yr via utilizing added information along with consideration of the wave refraction study made by Suboceanic Consultants(1994).

Harvey (1984)

Harvey (1984) estimated a net southward sediment transport of 100,000 c.y./yr on the north side of Gordon Pass using shoreline characteristics.

Summary of Historical Estimates
The estimated rates of longshore transport vary significantly due to differences in the data sets and methods used although insufficient details are provided in the many studies to determine reasons for the differences and/or even how the computations were made. All methodologies utilized show a southward directed net sand transport and a southward directed net sand transport appears reasonable based on historical information of drift rates in Southwest Florida. No studies identified in this literature evaluate sediment transport due to tidal currents.

Analysis of Transport Rates for Present Study

Estimates of longshore transport made for the present study boundaries of the sediment budget are based on the Littoral Drift Rose (LDR) concept (Walton 1973, Walton and Dean 1973, Walton and Dean 2010) where drift magnitude (away from inlet influence) is dependent on shoreline orientation. Recent Wave Information Study (WIS) wave information sets of the Corps of Engineers as well as the previous work of Walton (1973) have been investigated herein to assess the reasonableness of the drift magnitude and angular rotation of the LDR in the study area. The recent 20 year hindcast model wave information data set of the Corps of Engineers for WIS Stations 73299 and 73301 (1980 through 1999) at depths 13m and 12m respectively were used for calculation of sediment transport in development of magnitudes of sediment transport in a littoral drift rose for the present study. The CERC equation for sediment transport as utilized by the Corps of Engineers program SEDTRAN was utilized along with linear wave theory to calculate the littoral drift at wave breaking for a range of values of shoreline outward azimuth angles at one degree increments to construct a composite LDR for this data set. In a first approach to the problem of assessing the proper littoral drift climate for the sediment budget area, magnitudes were considered of secondary importance compared to the rotational aspects of the wave climate due to the fact that drift estimates with WIS data have historically overestimated the littoral drift using standard analysis techniques (see Bodge and Kraus (1991)). Further explanation and examples of LDR usage can be found in Walton (1973), Walton and Dean (1973), and Walton and Dean (2010). The value of littoral drift at a given point is based on the orientation of the azimuth of the outward normal to the shoreline at the location of interest with a corresponding value of littoral drift as:

$$Q = Q_{max} \cdot \sin\left(2 \cdot (\beta_N - \alpha_T)\right)$$

where $\beta_N =$ azmuth of the outward normal to the shoreline, $\alpha_T =$ azmuth of the null point for the LDR, Q_{max} = absolute magnitude of LDR, and where a positive value represents transport to the right when looking offshore and a negative value represents transport to the left when looking offshore.

The variability of the directional aspects in the wave climate shown by the hindcast wave information (WIS) data set and one transformed SSMO data set for the region (found to be similar to that provided in Beaches and Shores Resource Center (2011) with slight refinement) were compared. The directionality of the wave climate is different between the new WIS wave data and the older SSMO data. In the assessment of sediment budget in this report, the estimates of net longshore transport for the WIS hindcast data directionality appeared more reasonable and consistent with calculated sediment gradients at the inlet, hence the WIS orientations were used herein for the assumed LDR. Present analysis was utilized to adjust rotation of the LDR with the WIS data results, along with additional magnitude adjustment of the LDR due to the directional spread of the waves and the bottom frictional wave energy dissipation to obtain a reasonable LDR for the present sediment budget study. The results of this further study to determine the LDR are similar to those documented in (Beaches and Shores Resource Center, 2011) although no shoreline change adjustment was utilized due to insufficient curvature of the shoreline. Historical estimates of erosion losses and knowledge of sediment transport along this area of coast is very limited and subject to potential error, hence estimates of littoral drift should only be considered rough guesses until improved data are available to better assess magnitudes and directions of the littoral drift in this area. A final modified LDR was utilized as follows:

$$Q = \hat{Q}_{max} \cdot \sin\left(2 \cdot (\beta_N - \hat{\alpha}_T)\right)$$

where $\hat{Q}_{max}$ = 46,000 m^3/yr (=60,000 c.y./yr) and α_T = 285 degrees.

5. Survey Data Availability, Limitations, and Analysis

5.1 COE Navigation/Channel and Ebb Shoal surveying

Surveys of the inlet and inlet complex by the Jacksonville District COE were requested in digital form for the present study but existing information provided by the District was not sufficient to identify missing information regarding the sediment budget in the ebb shoal area of the inlet. As typical survey coverage in inlet areas is typically very limited or constrained to the area of channel dredging only, significant information concerning sediment budget for this inlet does not exist. More will be mentioned regarding this lack of data in a later section of this report.

Dredging activity information (i.e. quantities dredged, locations of dredging, locations of dredge spoil, etc.) exist for the inlet area but, due to the lack of historical information regarding quality/type of material dredged, this information is not sufficient to allow conclusions regarding gains or losses to the inlet complex.

5.2 FDEP Shoreline and Profile availability

The study area for Gordon Pass is located in Collier County starting at FDEP Monument R-58 just south of Doctors Pass and extends southward past Gordon Pass to R-119. Gordon Pass itself is located between Ranges R-89 and R-90. This is approximately 5.5 miles north of Gordon Pass to 5.5 miles south of Gordon Pass. Numerous data sets for beach profiles in Collier County exist on the FDEP web site for this study area. The surveys with data for most monuments in the study area were taken in the years 1973, 1988, 2001, and 2009. The 1973 and 1988 surveys extend offshore to deeper water for approximately every third Range. The 2009 survey has no offshore data for many monuments south of Gordon Pass. The survey of 2001 has full beach and offshore data for all Ranges in the study area. The surveys in which the data collected is sufficient for area and/or volume calculations are the CCCL survey of 1973, the CCCL survey of 1988, and the survey of 2001. All surveys have sufficient data for shoreline change calculations but note that the CCCL survey of 1973 is missing data for R-80, R-87, and R-99.

5.3 Analysis of Profile and MHW Shoreline Data for Volumetric Change Trends

Figure 8 shows the shoreline changes from 1973 to each survey year for ranges R-58 to R-119. The shoreline is defined as the Mean High Water (MHW) line which is 0.33 feet NAVD88. A careful study of the graph shows the study area can be seen as four separate regions. Region I encompasses R-58 to R-79 which is the Naples Beach area. This region was subjected to major beach fill activity in 1996 and 2006 which is evident in the graph. Region II is just north of Gordon Pass and encompasses R-79 to R-89 and shows alternating shoreline changes of +/- 50 feet. Region III is adjacent to Gordon Pass to the south from R-90 to R-95. Very dynamic shoreline changes are found in this region due to inlet effects, dredge fill disposal, and jetty construction. Region IV comprises R-95 through R-119 and is the southernmost section of the study area. The shoreline for this down drift section indicates both erosion and accretion biases.

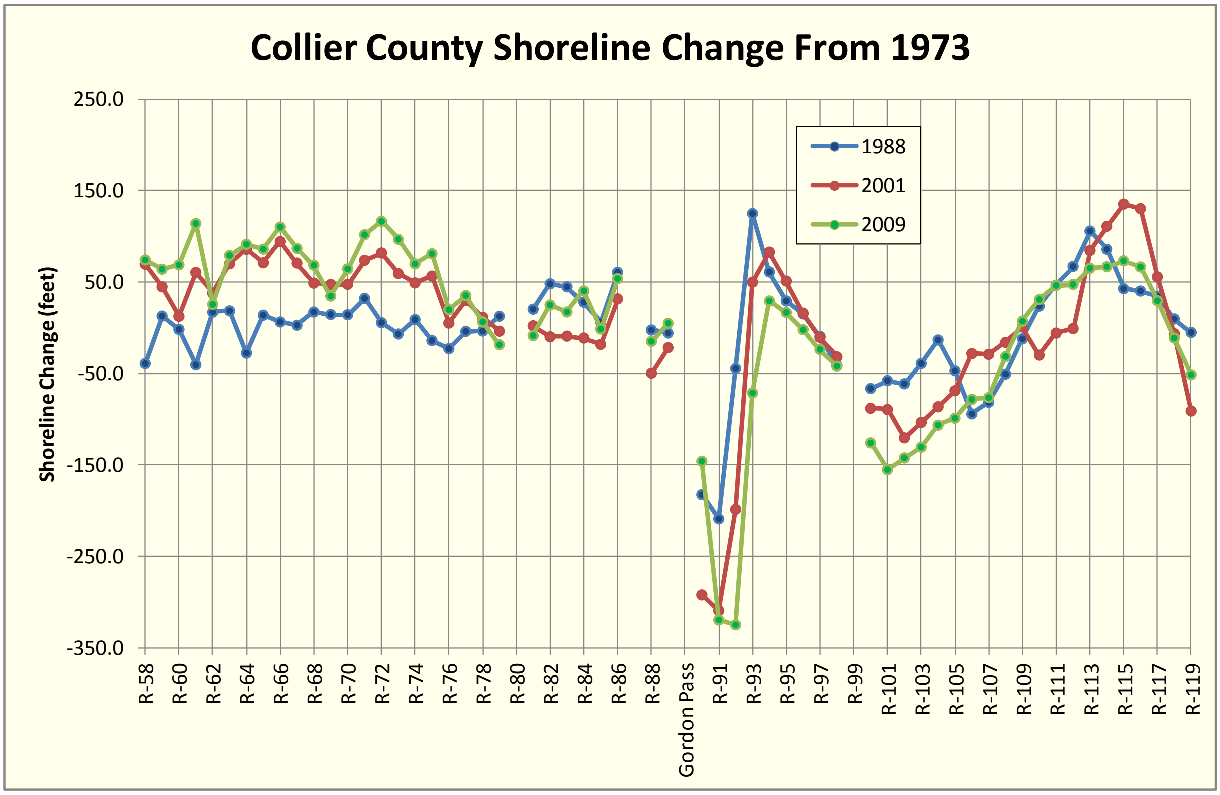


Figure 8. Collier County Shoreline Changes from 1973

5.4 Volume Change Methodology from Historical Profiles

The Profile volume change for each segment of the area of interest was cumulated for this study using the equation

$$\int dA(i) \cdot dx$$

where $dA(i)$ = area change between two surveys of different years at a given Range i and dx is the alongshore distance between Monuments. The distance between adjacent Monuments is roughly 1000 feet but due to survey availability where the offshore portion was completed for only every third Monument the value for dx is approximately 3000 feet. The area *A(i)* was defined within the vertical distance of the active profile between the Depth of Closure (DOC) to the landward most surveyed point. The DOC used was -13.3 feet NAVD88.

5.5 Volume Change Summary

Table 4 summarizes volume change calculations where full offshore survey data exists based on the methodology and data described in the previous section. Regions II and III next to Gordon Pass exhibit erosion which is in agreement with the shoreline changes. Region I within the Naples Beach area had an accretion as expected due to the nourishments that took place in 1996 and 2006. Region IV in the down drift section of the inlet has a slight net erosion rate.

Table 4. Historical Volume Changes for Gordon Pass Area

Time Periods	Data Sources	Volume Changes Per Year (x 1000 cy)			
		Beach Top to DOC			
		R58 - 79	R79 - 89	R90 -95	R95 -119
1996	Nourishment	759,150			
1988 - 2001	Surveyed Profiles	38.4	-26.8	-26.4	-2.4
1973 - 2001	"	6.9	n/a	-8.3	9.5
1988 - 2009	"	43.1	-15.3	n/a	n/a

5.6 Other Hydrographic Survey Data availability

Limited NOAA hydrographic survey coverage is available from hydrographic surveys although more recent NOAA surveys do not provide survey coverage inshore of the closure depth making comparative change survey coverage of the near-shore area and ebb shoal non-existent. Based on this limited information it is not clear from the data available at the time of this report as to whether the overall volume of the ebb shoal is changing.

6. Sediment Budget

6.1. Sediment Budget Considerations

Although the present study has made the utmost attempts to check survey datum and data quality to the extent that it can be checked within existing limitations (i.e. data was received from three different government agencies), BSRC cannot vouch for data or datum accuracy. Questions have come into play concerning the quantity of the data for surveys. Often surveys have closely spaced data along survey lines (typically oriented perpendicular to the shoreline trend in the area) although there may be a lack of data along perpendiculars to the survey lines where the data may change appreciably. Datum is not always specified to a land based vertical datum in NOAA surveys and consequently, changing water levels effect the datum plane location. Given these data and datum limitations, it is important to assess potential error due to some of these limitations although, in some instances, insufficient information exists to address the potential error and answers provided simply remain as estimates without quantifiable errors.

A first *potential* source of error is due to vertical bias problems in profile surveys. The vertical bias in many early surveys has been noted to be sufficiently large on portions of the Florida coast and there are questions as to whether meaningful results can be obtained from these data (Dean (2011)). As an example, in recent surveys of St. Johns County for 1999 and 2007 a bias of 0.24 feet was found in the offshore portions of the survey which falls within an often cited potential error of 1 foot due to hydrographic surveying. If one considers that the offshore portion of a survey line extends to (on the order of) 800 feet which is reasonable for the St. Johns County area (where this distance was found to range from approximately 700 to 1000 feet), a total error even this small and within hydrographic survey error can be estimated to be approximately 0.24*(800) c.f. per lineal foot or approximately 7.1 c. y. per lineal foot of shore. Over 30 FDEP ranges (~ 1000 ft. per range) this would amount to an error of approximately 210,000 c. y. For a typical hydrographic survey wherein the offshore error could be as high as 1 foot, this error would be on the order of 840,000 c.y. for an area spanning over 30 FDEP ranges.

A second *potential* source of error is due to survey error in datum over a region. A simple datum error of 0.25 feet between surveys would lead to an error of approximately $3.7 \cdot 10^{6}$ c. y. for a plan area of 400 million s.f. (i.e. error is considerably larger than the estimated net sediment transport for the plan area noted). Any sediment budget projected estimate results are subject to potentially large errors which should be kept in mind when assessing study results. Results of datum error would amount to the area of survey coverage multiplied by the vertical datum error.

A third *potential* source of error exists when developing changes in volume between survey time periods where the survey coverage does not cover the spatial region synoptically. A lack of data coverage in ebb or flood shoal portions of surveys (where they exist) along with the fact that survey results for a given survey may incorporate non-synoptic data could impact volume change answers substantially. Unfortunately a lack of data in these situations does not allow reasonable estimates of error to be developed. Given the error possibilities within the surveys and standard hydrographic survey capabilities, as well as earlier limitations in the typical hydrographic surveys, present estimates of sediment budget must be considered speculative and further sediment budget refinement must await better data collection in regions where such data is available.

Although studies cited and work herein have provided various potential boundaries for addressing the sediment budget, the limitations of the data do not allow for addressing all inlet management concerns. Constraints mentioned here suggest that <u>it is impossible to address a totally meaningful sediment budget at the present time</u> although a sediment budget will be constructed herein for the purposes of an updated inlet sediment management plan. Recommendations for inlet management provided in a later section of this report will take into account that at present, <u>there is still considerable uncertainty in a realistic sediment budget for the inlet.</u>

The various data sets were investigated in attempts to provide a reasonable sediment budget with the decision to utilize what is believed to be the best available data at present to address inlet management concerns while recognizing that no present data set is both synoptic and comprehensive in coverage as discussed previously. Boundaries for the sediment budget were chosen primarily on the basis of offshore bathymetric contours in hydrographic charts as well as volumetric or shoreline changes in longshore directions. Figure 9 shows the extensive portion of the ebb shoal on the south side of the channel much of which is not included in any available survey. Various permutations of data sets were considered in an attempt to make a reasonable sediment budget closure for the inlet system within the boundaries discussed above. A best estimate of sediment budget is presented herein with data described in this report.

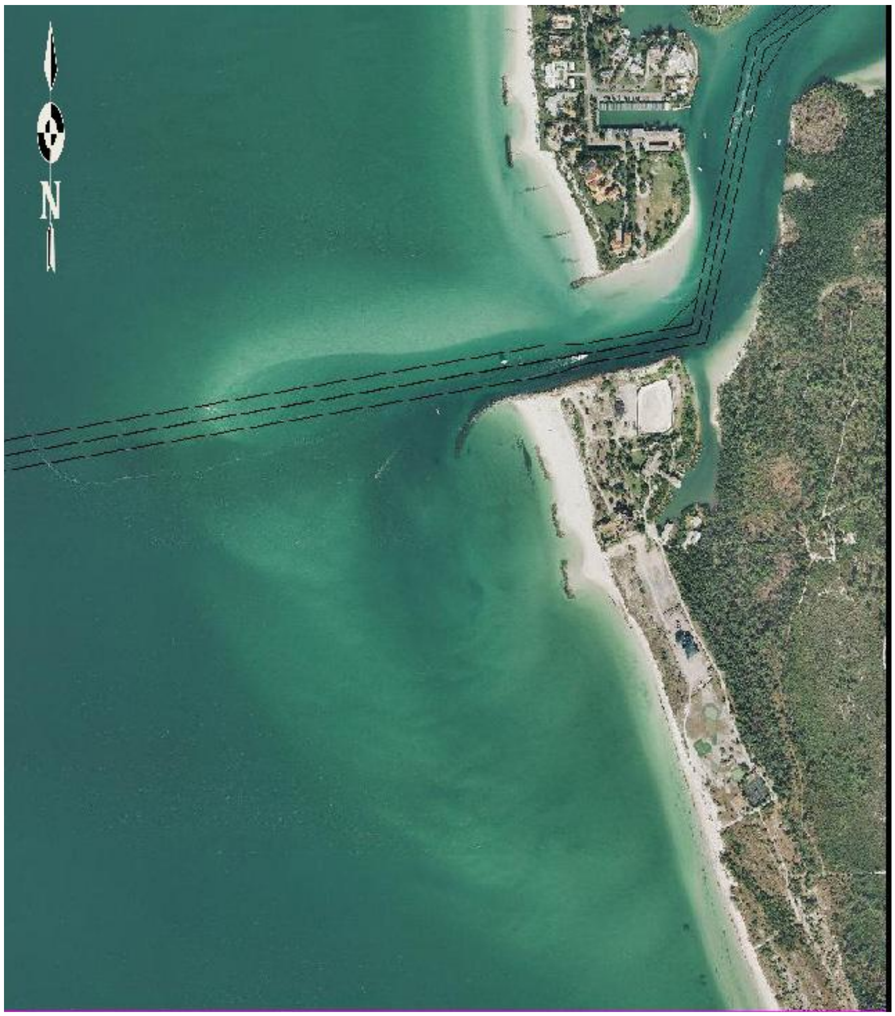
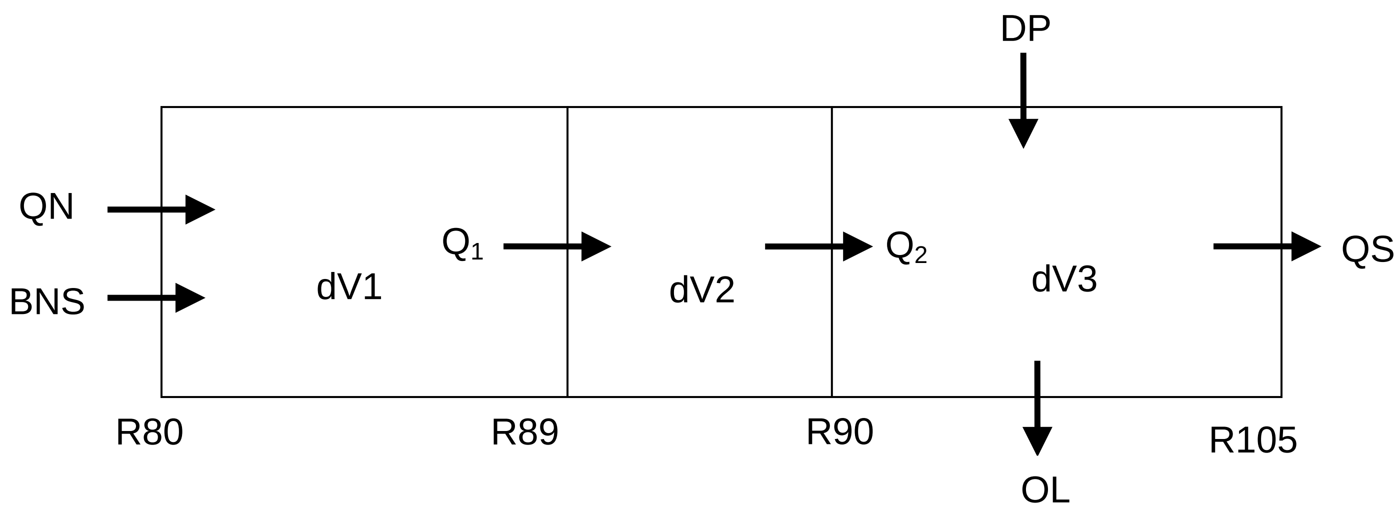


Figure 9. Gordon Pass 2008 with navigation channel overlay on photo. (Note the extensive offshore extent of the ebb shoal on the south side of the inlet).

Totaling the volume of sand placed on the south beach since dredging the pass in the early 1960's (i.e. see Table 1) along with the volume of sand stored in the entire ebb shoal (see Humiston and Moore (2009)), it is estimated that a rough estimate of sand lost to the south beaches is on the order of 55,000 c.y./yr . Noting that the shoreline of Keewaydin Island has actually lost ground since at least the late 1980's as suggested by the littoral transport environment as well as evidenced by the revetment built shoreward of the CCCL line in the late 1980's (i.e. behind the T-groin system at the north end of Keewaydin Island), it would be expected that the total loss of sand may be due to combined effects of the inlet, the structures, and the imbalance of sediment transport north and south of the inlet. In the sediment budget herein proposed, recent jetty sealing has suggested that the jetty is no longer leaking sand to the inlet and this assumption has been made within the budget. For budget closure it has also been assumed that there are offshore losses of sand on the south side to the southern portion of the ebb shoal which is dominant on the south side of the pass. Based on the sedment budget provided herein, it is suggested that there should be a bypassing of approximately 39,000 to 50,000 c.y./yr depending on the amount of beach nourishment provided on Naples Beach to the north of the sediment budget area. Further good data collection and a revised sediment budget should provide an improved desired bypassing quantity.

6.2. Sediment Budget Schematic and Equations



Equations for Sediment Budget (with rates in thousands of c. y./year) :

QN +BNS –Q1 = dV1

Q1 - Q2 = dV2

Q2 +DP –QS -OL = dV3

where
QN = 39.0
QS = 59.0
BNS = 11.1 (beach fill spreading)
DP = 12.0 (dredge material placement)
OL = 22.0 (offshore losses)
dV1 = -15.0
dV3 = -25.0

and therefore:
Q1 = 65.1
Q2 = 0.0 (assumed as of jetty sealing)
dV2 = 65.1

Figure 10. Sediment Budget Schematic for Gordon Pass.

7. Recommendations/Conclusions

Recommendations for the State Inlet Management Plan of Gordon Pass are as follows:

- Conduct on a routine basis a monitoring study of sand lost to inlet flood shoals (and hence to adjacent beaches). Survey data should be made digital and made available to the public.

- The maintenance of the navigation project at Gordon Pass should continue to be coordinated with beach nourishment for beach erosion control projects both north and south of Gordon Pass. All beach quality sand obtained from dredging should be recycled to the beaches south of the south jetty except in times of major storms where channel filling could occur from either side and maintenance should be provided to the areas in most need. A consensus history should be put together by the Corps of Engineers (COE) for public record documentation on dredging events at the Gordon Pass and this record should be maintained by COE for future dredging permits.

- It is recommended that the ebb shoal of the Gordon Pass be extensively surveyed at intervals of at least every 5 years (and prior to any channel deepening or channel maintenance project) to assess effects of channel dredging/maintenance and deepening on the ebb and flood shoal sand volumes. Additionally, prior to any dredging a hydraulic survey should be made to assess the tidal prism of the inlet. Survey data should be made digital and made available to the public.

- Additional cross sectional profile surveys out to closing depth should be completed at the same time on both north and south beaches at State Range Monuments over the area extending from five ranges north to five ranges south of the designated sediment budget area (within the present report) as well as within the sediment budget area.

- A longer terminal groin and flexible sand bypassing plant should be designed, constructed, and built concurrently for the north side of Gordon Pass. Such design is well beyond the scope of the present inlet study but should not be so long as to extend far beyond the general shoreline trend on the north side of the inlet. Considerations for filling or at least partial filling of the terminal groin should be considered at the time of construction such that the structure will not cause added erosion on the south beach.

- A dye study (and possibly sediment tracing study should be performed at the south jetty to help determine if any substantial sediment is still flowing through jetty. If significant amounts of sediment are transported through the jetty, the jetty should be re-sealed.

- At present it is believed that more extensive data collection and analysis as well as a better knowledge of long term wave climate is needed in the vicinity of Gordon Pass. Improved knowledge on longshore transport in this area should be addressed prior to any major jetty lengthening or shortening considerations. A continuously recording directional wave gage operating on the southwest coast of Florida is important to a better understanding of inlet processes on this coast.

All disposal of beach material on the south beaches should be made south of the T-groin field to assure that the dredged material (and any bypassed material) inlet is capable of reentering the southward net sand transport regime that exists away from influence of Gordon Pass.

Additional Recommendations

It is additionally recommended that the State of Florida approach Congress for funding of a Section 111 restudy for the Gordon Pass area. At present erosion problems in the area south of the south jetty at Gordon Pass are noted by all previous studies to be due to the inlet's interference with the natural processes of sediment transport. Due to the sparse nature of the available data and fact that much of the data is not synoptic, a fair percentage of Federal costs is not possible at present for any erosion problems caused by the inlet. Part of a Section 111 Study (or study precursor) should be the collection of synoptic detailed surveys of the ebb shoal and flood shoal complex at Gordon Pass (on a 5 year schedule), and the digitization of all historical COE or other surveys of the area. Additional cross sectional profile surveys out to closing depth should be completed at the same time on both north and south beaches at State Range Monuments over the area extending from five ranges north to five ranges south of the designated sediment budget area within the present report. Such survey data collection, digitization, and public archiving of collected data is well beyond the scope of the existing study.

8. References

Beaches and Shores Resource Center (1989).
Combined Total Storm Tide Frequency Analysis for Collier County, Florida,
Institute of Science and Public Affairs, Florida State University, Tallahassee, Florida.

Beaches and Shores Resource Center (1988).
Coastal Construction Control Line Review and Reestablishment Study for Collier County, Florida, Institute of Science and Public Affairs, Florida State University, Tallahassee, Florida.

Beaches and Shores Resource Center (2011).
Inlet Management Restudy for St. Augustine Inlet, St. Johns County, Florida,
Institute of Science and Public Affairs, Florida State University, Tallahassee, FL.

Bodge, K. B. and Kraus, N. K.(1991).
Critical Examination of Longshore Transport Rate Magnitude,
Proceedings. Coastal Sediments, ASCE, 139-155, Reston, VA.

Bruun, P. and Gerritsen, F. (1960).
Stability of Coastal Inlets,
North Holland Publishing Company,
Amsterdam, NL.

CPE (1995)
Phase 1-Gordon Pass Inlet Management Study
Coastal Planning and Engineering,
Boca Raton, FL

CPE (1996)
Phase 2-Gordon Pass Inlet Management Study
Coastal Planning and Engineering,
Boca Raton, FL

CPE (1998)
Gordon Pass Inlet Management Study
Coastal Planning and Engineering,
Boca Raton, FL

CPE (2008)
Collier County Beach Nourishment Project Post Tropical Storm Fay Storm Report, Florida,
Coastal Planning and Engineering,
Boca Raton, FL.

CoastalTech (1997)
Shore Protection Project, Phase I and II, Annual Monitoring Report 1996, Beach Fill Performance For City of Gordon Pass", Coastal Technology Corp.,

Vero Beach, FL.

Daubees, M. and Moore, B. (2010).
Evaluation of Inlet Management Practices in Southwest Florida, USA.
Proceedings Coastal Engineering Conference,
World Scientific, New York, N.Y.

Dean, R. G. and Walton, T. L. Jr. (1973).
Sediment transport processes in the vicinity of inlets with special reference to sand trapping,
Second International Estuarine Research Conference,
Estuarine Research Vol. II, Academic Press, 129-149.

Dean, R. G. and Dalrymple, R. A. (2002).
Coastal Processes with Engineering Applications,
Cambridge University Press,
Cambridge, UK

Dean, R.G. (2002).
Beach Nourishment, Theory and Practice
World Scientific Press, New York, N.Y.

Dean, R.G. (2011). Analysis of Historic Nearshore Profiles to Determine Volume Changes,
FSBPA presentation (Fall 2009) and personal conversations with.

Hind, A., Davis, R., Mearns, D. and Bland, M. (1986).
Impact of Florida Gulf Coast Inlets on the Coastal Sand Budget,
Florida Department of Natural Resources, Division of Beaches and Shores,
Tallahassee, FL.

Humiston & Moore Engineers (2009)
North Keewaydin Island and Gordon Pass Modeling and Analysis
North Keewaydin Island Erosion Control Project – Phase II
Naples, FL.

Humiston & Moore Engineers (2010)
Design Optimization Modeling and Analysis of Alternatives for North
Keewaydin Erosion Control Project Phase II
Naples, FL.

Humiston & Moore Engineers (2007)
Wiggins Pass Study, Hydrodynamic and Sand Transport Modeling
Naples, FL.

Swail, V.R. and A.T. Cox (2000)
On the Use of NCEP/NCAR Reanalysis Surface Marine Wind Fields for a Long Term North
Atlantic Wave Hindcast, Journal of Atmospheric Technology, Vol. 17, No.4, pp.532-545.

Taylor Engineering, Inc. (2002).
Regional Sediment Management Southwest Gulf Coast Regional Sediment Budget,
prepared for USACE, Corps of Engineers Jacksonville District Office,
Jacksonville, FL.

USACE (1971)
National Shoreline Study, Regional Inventory Report,
South Atlantic-Gulf Region, Puerto Rico and Virgin Islands,
U.S. Army Corps of Engineers, U.S. Government Printing Office
Washington, D.C.

Walton, T. L. Jr. (1973).
Littoral drift computations along the coast of Florida by means of ship wave observations,
Coastal and Oceanographic Engineering Laboratory Report No. 15,
University of Florida, Gainesville, FL.

Walton, T.L. Jr. (1996).
Unpublished report on effects of Port Canaveral on Downdrift Beaches,
provided in response to work for Jacksonville District Corps of Engineers,
Jacksonville, FL.

Walton, T.L. Jr., and Adams, W. D. (1976).
Capacity of Inlet Outer Bars to Store Sand,
Proceedings 14th International Coastal Engineering Conference, Honolulu, HI, July 1976,
ASCE, New York, N.Y.

Walton, T. L. Jr. and Dean, R. G. (1973).
Application of littoral drift roses to coastal engineering problems,
Conference on Engineering Dynamics in the Surf Zone,
Institute of Engineers, Sydney N.S.W., Australia.

Walton, T. L. Jr. and Dean, R. G. (2010).
Longshore Sediment Transport via Littoral Drift Rose,
Ocean Engineering, Vol. 37, 228-235,
Elsevier Publishing, The Netherlands.