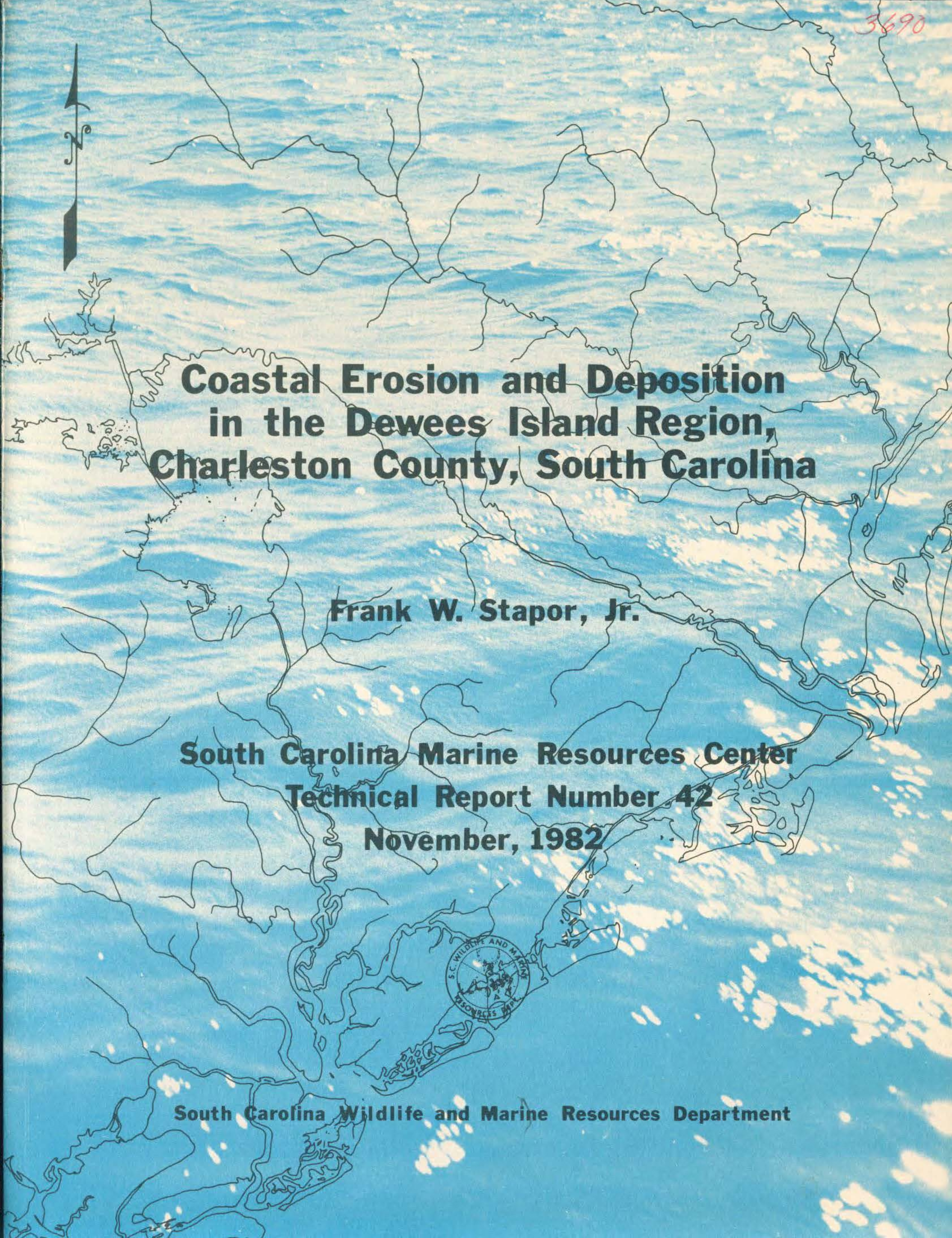

Coastal Erosion and Deposition in the Dewees Island Region, Charleston County, South Carolina

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South Carolina Marine Resources Center
Technical Report Number 42
November, 1982

South Carolina Wildlife and Marine Resources Department

COASTAL EROSION AND DEPOSITION
IN THE DEWEES ISLAND REGION,
CHARLESTON COUNTY, SOUTH CAROLINA

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Coastal Erosion and Deposition in the Dewees Island Region, Charleston County, South Carolina

Introduction:

Dewees Island, a barrier island facing the Atlantic Ocean in Charleston County, South Carolina, is composed of sandy beach ridges. It is flanked to the northeast by Capers Island and to the southwest by the Isle of Palms (Fig. 1). Dewees Island is separated from Capers Island and the Isle of Palms by Capers and Dewees Inlets, respectively. These inlets are the mouths of tidal creeks draining the mud flat and salt marsh-filled lagoon separating these islands from the mainland. Extensive ebb-tidal deltas are present at both Dewees and Capers Inlets. These shoals extend out into the Atlantic on each side of Dewees Island (Fig. 1).

During the 107-year period between 1857 and 1964, the dates of the first and most recent accurate topographic and bathymetric surveys, the Dewees Island shoreline facing the Atlantic Ocean has retreated approximately 750 ± 80 m (Fig. 2). The northeastern beach fronting on Capers Inlet migrated 1100 ± 60 m to the northeast (Fig. 2). This study is an attempt to identify, quantify and rank in importance the processes responsible for coastal erosion and deposition in the Dewees Island region.

Methods:

Littoral drift (sand transported on the beach and in the breaker-zone by waves) was estimated by the computer modeling technique of May (1974).

Bottom tidal currents were measured during June 1978 at seventeen stations with General Oceanics Model 2010 inclinometer-type current meters (Fig. 3). Each station was occupied for approximately 4 days, with the meter mounted to measure currents 1 m above the bottom. Stations 1, 2, 3, 4, 6, 7, 8, and 10 were monitored between 5 June 1978 and 9 June 1978; stations 5, 11, 12, 13, 14, 15, and 16 between 12 June 1978 and 16 June 1978; and stations 9 and 17 between 25 June 1978 and 30 June 1978. The current meters recorded data at a rate of 16 measurements per hour at each station.

Long-term erosion and deposition sites were identified and rates of change quantified by developing detailed sand budgets using the technique of map differencing (Pierce, 1969; Stapor, 1971). Map differencing involves the following procedures: "For specific areas along these barrier islands, two sets of charts were compared; the isobaths on the younger set were subtracted or added to those on the older set (depending on whether erosion or deposition had taken place in a particular area); a new number field was thus generated; these new numbers were contoured. The areas of erosion and deposition defined in this subtraction/addition procedure were planimetered and volumes of material gained or lost were computed" (Stapor, 1971).

Geological Setting:

Dewees Island is a Holocene barrier island formed during the rise of sea level since the last continental glaciers melted some 10,000 years ago. The island is composed of sub-parallel beach ridges which mark individual positions of the beach as the island grew. These ridges are organized into two major masses (Fig. 1). The geographic pattern of these beach ridges suggests that sand moved directly toward the shoreline during their formation (Stapor, 1975).

The diurnal tide at Dewees Island has a mean range of 1.52 m and a spring range of 1.8 m. Average significant wave height (average of the one-third highest waves) can be estimated from data collected by the U. S. Army Corps of Engineers at Holden Beach, North Carolina, the closest site in their network of wave monitoring stations. Using 27 months of data collected over the period April 1971 to December 1974, the average significant wave height at Holden Beach was 0.61 m (Thompson, 1977). This height, measured very close to shore at a fishing pier is smaller than the 0.90 m measured at the Savannah Light Tower, the next closest station, which stands in 15.8 m of water (Thompson, 1977).

Erosion and Deposition History:

Net erosion and deposition rates can be determined by measuring actual changes in the volumes of coastal sand bodies through time. The greater the time span covered by these measurements, the better they reflect average or everyday conditions and the more they minimize effects of sudden, intense storms.

Erosion and deposition volumes were measured for the Dewees Island region extending from the Isle of Palms northeast to Bull Island using bathymetric charts compiled from U. S. Coast and Geodetic Survey data obtained in 1857, 1886, 1921, and 1964. These results are tabulated in Table 1 and shown graphically in Fig. 4.

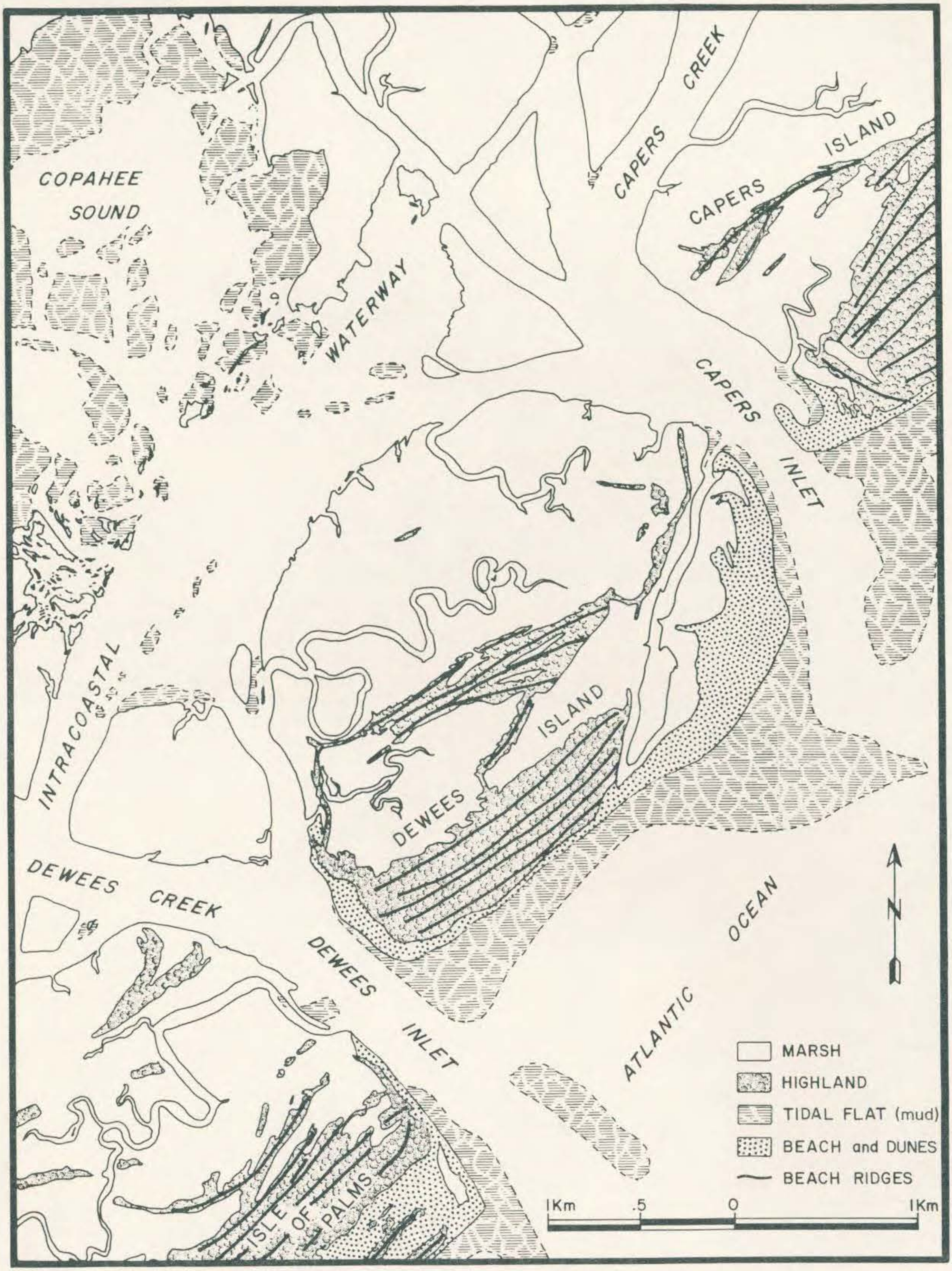

Figure 1. Generalized location map of the Dewees Island region, central Charleston County, South Carolina.

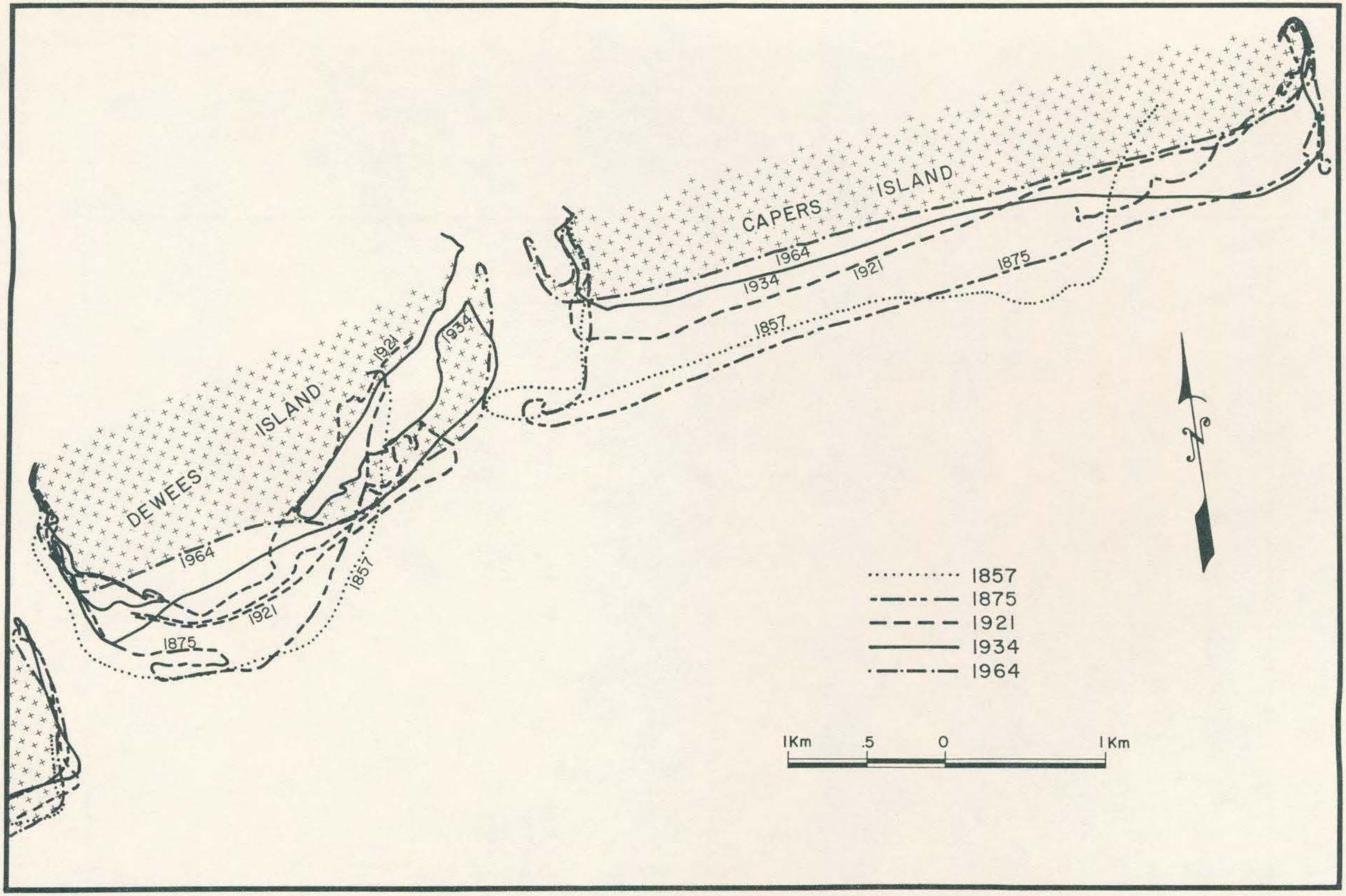

Figure 2. Historic shorelines mapped at Dewees Island between 1857 and 1964 by the U. S. Coast and Geodetic Survey.

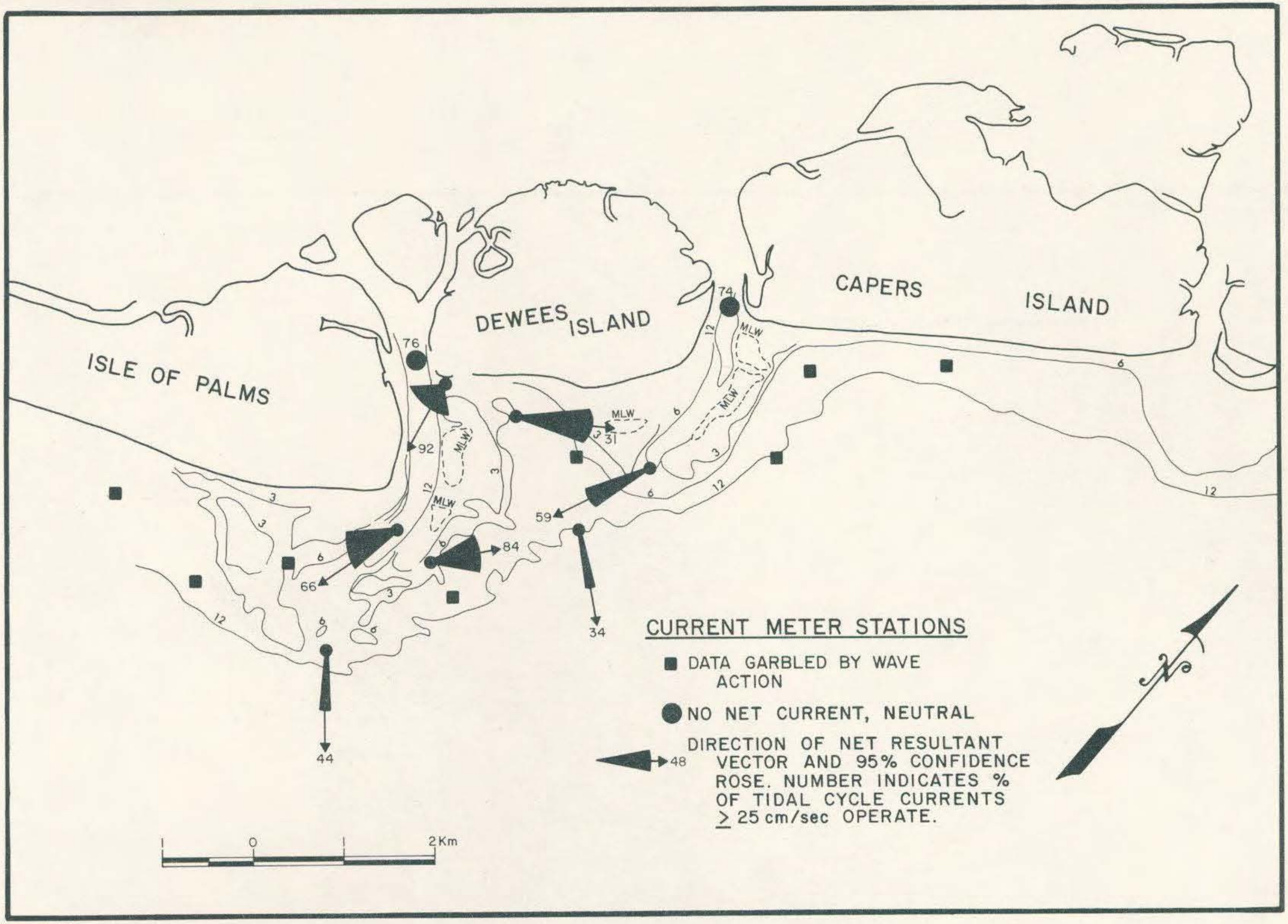

Figure 3. Stations monitored with General Oceanics Model 2010 inclinometer-type current meters to measure bottom tidal currents. Ebb- and flood-tide averages vectors labeled (E) and (F), respectively, and in centimeters/sec. Only those measurements above the threshold for sand movement ($\geq$ 25 cm/sec) were used to compute these average vectors.

Table 1. Net erosion and deposition volumes determined by map differencing for the Dewees Island region.

	1857 to 1886		1886 to 1921		1921 to 1964	
	EROSION	DEPOSITION	EROSION	DEPOSITION	EROSION	DEPOSITION
Dewees Island:						
NE tip:	$152^{+72}_{-58} \times 10^4 m^3$	—	—	$184^{+64}_{-54} \times 10^4 m^3$	—	$91^{+45}_{-35} \times 10^4 m^3$
SE shore:	—	—	$71^{+33}_{-26} \times 10^4 m^3$	—	$157^{+68}_{-55} \times 10^4 m^3$	—
SW shore:	$171^{+75}_{-61} \times 10^4 m^3$*	—	—	—	—	—
Offshore channel:	$82^{+28}_{-24} \times 10^4 m^3$	—	$15^{+13}_{-9} \times 10^4 m^3$	—	$25^{+16}_{-12} \times 10^4 m^3$	—
Capers ebb-tidal delta:	—	$112^{+46}_{-37} \times 10^4 m^3$	$53^{+23}_{-19} \times 10^4 m^3$	—	—	—
Dewees ebb-tidal delta: (Seaward of Dewees Island)	—	—	$42^{+30}_{-21} \times 10^4 m^3$	$37^{+19}_{-15} \times 10^4 m^3$	$210^{+99}_{-72} \times 10^4 m^3$	$84^{+49}_{-36} \times 10^4 m^3$
Capers Island:	$100^{+49}_{-39} \times 10^4 m^3$	—	$396^{+92}_{-79} \times 10^4 m^3$	$51^{+26}_{-18} \times 10^4 m^3$	$328^{+100}_{-86} \times 10^4 m^3$	—
SW Bull Island:	—	$333^{+66}_{-60} \times 10^4 m^3$	—	$425^{+77}_{-71} \times 10^4 m^3$	$24^{+12}_{-9} \times 10^4 m^3$	—

*Conservative estimate, mostly involves erosion along the SW shore facing Dewees Inlet.

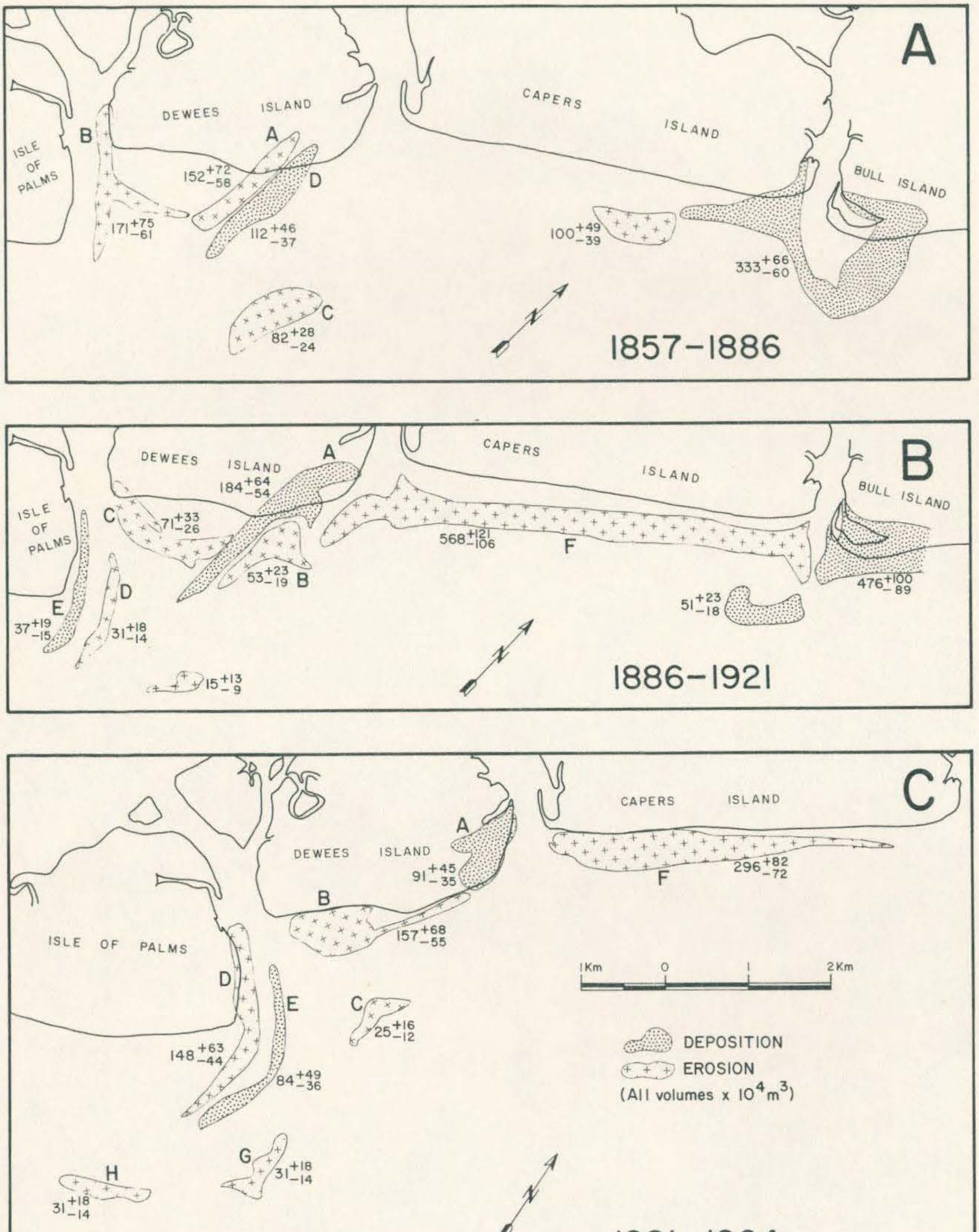

Figure 4. Erosion/deposition volumes measured in the Dewees Island region for the intervals 1857-1886 (A), 1886-1921 (B), and 1921-1964 (C).

1857 to 1886 (Fig. 4A and Table 1):

The Capers Inlet main channel migrated west toward Dewees Island, eroding the island's eastern shore (area "A" of Fig. 4A). In addition, the Dewees Inlet main channel migrated northeast toward Dewees Island, eroding the island's western shore (area "B" of Fig. 4A). Unfortunately, the 1857 bathymetric chart does not extend far enough up Dewees Inlet to allow a complete definition of this eroded mass. However, the value of $171^{+75}_{-61} \times 10^4$ m^3 is a conservative estimate. Of probable equal significance to Dewees Island, a tidal channel running east/west in front of the island was cut and the seaward side of the Capers Inlet ebb-tidal delta (area "C": of Fig. 3A) eroded. This erosion site of 1857/1886 is the mouth of the tidal channel presently sweeping in front of Dewees Island (Fig. 1).

The westward migration of the Capers Inlet main channel was apparently driven by the deposition of sand on the channel's eastern bank (area "D" of Fig. 4A). The geographic position of this particular deposition site suggests that tidal and wave currents moving west over the ebb-tidal delta were more likely responsible for the sand transport than littoral drift moving southwest along Capers Island. Sand eroded from the eastern shore of Dewees Island (area "A" of Fig. 4A) was introduced into the Capers Inlet main channel and in all likelihood, given the ebb-dominated nature of this inlet, transported seaward towards the Dewees Inlet ebb-tidal delta.

1886 to 1921 (Fig. 4B and Table 1):

The Capers Inlet main channel broke through its ebb-tidal delta north of its 1886 position at some time during this period. The relocation of this main channel had the effect of introducing sand to the northeastern portion of Dewees Island by the driving ashore of a portion of the original Capers Inlet ebb-tidal delta (area "A" of Fig. 4B). This depositional mass was separated from the main body of Dewees Island by a shallow lagoon, a remnant of which exists today (Fig. 1).

The southern third of Dewees Island facing the open Atlantic experienced relatively minor erosion during this period (area "C" of Fig. 4B). Dewees Inlet main channel seaward of Dewees Island migrated to the northeast (area "D" of Fig. 4B) most likely as a result of deposition occurring on the northeastern tip of the Isle of Palms (area "E" of Fig. 4B).

Capers Island, as well as the oceanward position of the Capers Inlet ebb-tidal delta, suffered severe erosion during this period (areas "B" and "F" of Fig. 4B). These areas probably served as sources for the sand deposited at northeastern Dewees Island.

1921 to 1964 (Fig. 4C and Table 1):

The spit formed during the previous period at the northeastern tip of Dewees Island grew northward at a minimum rate of 20,000 m^3/yr into Capers Inlet (area "A" of Fig. 4C) during this interval. This growth resulted from flood tidal currents sweeping into Capers Inlet, onshore movement by waves traversing the adjacent ebb-tidal delta, and northeasterly moving littoral transport.

The southern third of Dewees Island facing the Atlantic Ocean was considerably eroded (area "B" of Fig. 4C) during this period. A minimum of 36,000 m^3/yr was eroded from this location during the 43-yr interval. In addition, the region immediately offshore was eroded (area "C": of Fig. 4C). This area is today the mouth of the tidal channel, sweeping east to west in front of Dewees Island, which separates the Dewees' and Capers' ebb-tidal deltas.

Dewees Inlet main channel seaward of Dewees Island migrated to the southwest (area "D" of Fig. 4C), most likely as a result of deposition (area "E" of Fig. 4C) on the northeastern border of the inlet's ebb-tidal delta.

Capers Island continued to erode (area "F" of Fig. 4C) during the period at a minimum rate of 70,000 m^3/yr, much reduced from the minimum rate of 160,000 m^3/yr for the period 1886-1921. In addition, portions of the seaward edge of the Dewees Inlet ebb-tidal delta suffered measurable erosion (areas "G" and "H" of Fig. 4C).

In summary, deposition at the northeastern and erosion along the southeastern shores have characterized Dewees Island over the 107-year period between 1857 and 1964.

Littoral Drift:

The movement of sand parallel to the beach or along the coast by waves is littoral drift. Results obtained from the WAVENRG computer simulation model of May (1974) indicate that wave action erodes approximately 12,500 m^3/year from the eastern portion of the open ocean southeastern-facing beach, transports it westward, and deposits it on the western portion of this beach. This prediction is based on U. S. Naval Oceanographic Office (1963) and U. S. Army Corps of Engineers (Thompson, 1977) wave data. Waves with a deep-water height of 1.0 meters and a period of 6.5 seconds approaching from the east, southeast, and south (Table 2) were modeled. Deep-water waves approaching from the northeast did not reach the South Carolina coast but rather exited the model grid to the southwest and thus were excluded from this analysis.

Table 2. Approach directions and their respective proportions of sea and swell for the Dewees Island region (data from U. S. Naval Oceanographic Office, 1963).

Approach Direction	Sea	Swell
NE	16%	22%
E	11%	16%
SE	9%	10%
S	11%	7%

Using mid-nineteenth century nearshore bathymetry, the WAVENRG simulation model predicts that wave action was delivering sand to Dewees Island at an approximate rate of 9,000 m^3/year, 4,500 m^3/year coming from both the Isle of Palms and Capers Island. The same input wave data used in the modern-day simulation were employed in the nineteenth century simulation.

These computer simulation models consider only wave action on a sandy beach, tidal inlet effects are completely ignored. Furthermore, as the significant wave height (average of the highest one third waves) was modeled as occurring all of the time, these results are liberal estimates of littoral drift. A comparison of the predicted littoral drift delivery rate of 9,000 m^3/year for Dewees Island during the nineteenth century with the measured erosion rate of 52,000 m^3/year for the 1857-1886 interval suggests that littoral drift played a minor role in the island's sand budget. The modern-day WAVENRG-predicted littoral drift erosion, transportation, and deposition pattern demands no net change in the island's sand budget, merely a relocation of material from the northeast to the southwest along the open ocean southeastern-facing beach. The measured net erosion of 36,000 m^3/year for this beach between 1921-1964 suggests that, again, littoral drift played a minor role in the island's sand budget. Other processes operated to cause both the northeast deposition adjacent to Capers Inlet and the erosion along the southeastern beach.

Bottom Tidal Currents:

The General Oceanics Model 2010 inclinometer-type current meter will not function reliably in waves or in turbulent conditions. A garbled signal is recorded which cannot be meaningfully interpreted other than to conclude that non-turbulent, unidirectional currents are absent. This situation occurred at stations 1, 2, 6, 8, 13, 14, 15, and 16 (50% of the total stations monitored, see Fig. 3 for locations).

The resultant flood-and ebb-tide current vectors for those stations at which tidal flow could be reliably measured are presented in Figure 3 and Table 3. Only those velocities capable of entraining sand ≥25 cm/sec (Inman, 1963), were used in calculating these vectors as well as their durations. A station is considered to be dominated by that tidal current which operates for the statistically significant longer period of time at velocities capable of entraining sand.

Table 3. Flood and ebb average net resultant vectors and durations (in minutes). A 95% confidence interval accompanies each duration. An asterisk (*) indicates the dominant tidal current.

Station	Tide	Duration	Resultant Vector
3	Flood	206±30	31 cm/sec, 15°
	Ebb*	289±15	45 cm/sec, 200°
4	Flood	180±97	25 cm/sec, 282°
	Ebb*	315±37	30 cm/sec, 128°
5	Flood*	300±25	42 cm/sec, 320°
	Ebb	247±17	41 cm/sec, 140°
7	Flood	266±90	22 cm/sec, 345°
	Ebb	319±41	39 cm/sec, 145°
9	Flood	315±34	32 cm/sec, 292°
	Ebb	311±22	47 cm/sec, 86°
10	Flood	146±52	26 cm/sec, 251°
	Ebb	206±41	29 cm/sec, 61°
11	Flood	289±19	42 cm/sec, 313°
	Ebb	266±15	44 cm/sec, 140°
12	Flood	221±67	30 cm/sec, 360°
	Ebb	270±41	45 cm/sec, 185°
17	Flood	330±60	37 cm/sec, 245°
	Ebb	319±60	37 cm/sec, 79°

Station 3 and 4 are ebb-dominant, a predictable result for station 3 as it is located in a main channel widely recognized as being ebb-dominant in the Sea Islands region of South Carolina and Georgia (Oertel, 1972; Fitzgerald, 1977; and Nummedal, et al., 1977). However, station 4 is located in the open ocean at the mouth of the broad, funnel-shaped tidal channel running east to west in front of Dewees Island. Station 5, also located in a main channel, is flood-dominant, an anomalous result suggesting that perhaps the Atlantic Intracoastal Waterway has affected the original tidal circulation in this region. All of the remaining stations are neutral, neither ebb- nor flood-dominant with respect to the duration of flows ≥25 cm/sec.

A somewhat different approach to the interpretation of bottom tidal current data can be made by assuming that sand is always available for entrainment and subsequent transport. Thus the direction of the net resultant vector of all tidal current vectors greater than or equal to 25 cm/sec indicates the net, long-term direction of sand past any given station. The geographic area over which Eulerian measurements can be reasonably extrapolated is dependent on a site's bottom geometry. Measurements made in narrow, deep tidal channels may not reflect immediately adjacent conditions while measurements made at open, relatively unconfined sites may reflect conditions prevailing over a considerable area. Unless the tidal channel has bare bedrock exposed on its floor sand will be available for entrainment and transport. This approach attempts to estimate the direction only of Lagrangian transport from Eulerian or point measurements. These net resultant directions along with their 95% confidence intervals are presented in Figure 5.

Stations 7, 9, 10, and 12 yield net resultant vectors all oriented to mvoe sand in an ebb direction. Southeasterly transport toward the open Atlantic Ocean is indicated by the net resultant vector at station 7. At station 9 the net resultant vector indicates northeast transport into the broad, funnel-shaped channel separating the Dewees Inlet and Capers Inlet ebb-tidal deltas. Easterly transport toward the Capers Inlet ebb-tidal delta is indicated at station 10. Southwesterly transport toward that portion of the Dewees Inlet ebb-tidal delta immediately adjacent to the Isle of Palms is indicated for station 12.

The net resultant vector at station 17 indicates sand transport into the Dewees Inlet main channel and directed away from Dewees Island. This implies that although flooding tidal currents are primarily responsible for the direction of net transport this direction is, as far as Dewees Island is concerned, ebb-oriented.

Stations 5 and 11 have no net resultant vector and are truly neutral - there is no net sand transport through these localities. This situation occurs when the confidence ellipse of the net resultant vector includes the origin or the point of no current.

The net resultant vectors of stations 3 and 4 are not significantly different from those of the dominant ebb-tidal vectors shown in Figure 3.

The stations probably most critical to the Dewees Island erosion problem are 17, 10, and 4 located along the funnel-shaped tidal channel running east/west in front of the island. This channel separates the ebb-tidal deltas of Capers and Dewees Inlets. From its position and shape, this channel should be serving as a conduit for flood currents sweeping into Dewees Inlet. However, bottom tidal currents at the source (station 17) move sand offshore into the Dewees Inlet ebb-channel, at an intermediate location (station 10) move sand toward the Capers Inlet ebb-tidal delta, and at the mouth (station 4) move sand toward the open Atlantic Ocean. Thus this tidal channel transports sand toward the adjacent ebb-tidal deltas and toward the ocean but not toward Dewees Island. Erosion has been observed in the vicinity of this channel over the 107-yr period covered by detailed bathymetric charts (area "C" of Fig. 4A and 4C). This channel may be an extremely important factor in the Dewees Island beach erosion in that the Dewees Island southeastern beach is a potential source to supply sand to this ever emptying sink or hold.

Sand Transport in the Dewees Island Region:

The sand budgets developed by map differencing, the bottom tidal current measurements, and the computer simulation model of wave-induced littoral transport indicate that tidal current action is and has been the process most responsible for sand transport in the Dewees Island region. The predicted littoral transport rates are significantly lower than measured rates of erosion and deposition.

During the 1857-1886 interval, erosion of the island's eastern shore (area "A" of Fig. 4A) supplied sand to the Capers Inlet main ebb-tidal delta. This erosion was caused by the westward migration of the Capers Inlet ebb-tidal delta (area "D" of Fig. 4A). The net deposition driving this migration occurred at an approximate rate of 39,000 m^3/year. Littoral drift is predicted to have been able to supply only 4,500 m^3/year leaving the majority to have been supplied by tidal current action and direct on-shore wave transport. Tidal current erosion occurred along the southwestern and southeastern shores (area "B" of Fig. 4A) with the material being introduced into the Dewees Inlet main channel and in all likelihood transported toward the Dewees ebb-tidal delta.

The 1886-1921 interval saw a portion of the Capers Inlet ebb-tidal delta transported toward Dewees Island, contributing significantly to the formation of the spit at the island's northeastern tip. The approximate deposition rate at the northeastern tip was 53,000 m^3/year. Sand eroded from the island's southern shore (area "C" of Fig. 4B) could have supplied a maximum of approximately 20,000 m^3/yr, leaving the remainder to come from the Capers ebb-tidal delta (areas "B" and "F" of Fig. 4B). Tidal current action and direct on-shore wave transport moved the sand from the Capers Inlet ebb-tidal delta to the northeastern tip of Dewees Island. Tidal current action was, in all likelihood, responsible for the erosion of the Dewees Island southern shore and probably transported sand toward the northeastern tip. This is perhaps the earliest evidence of the present-day funnel-shaped tidal channel running east/west in front of Dewees Island.

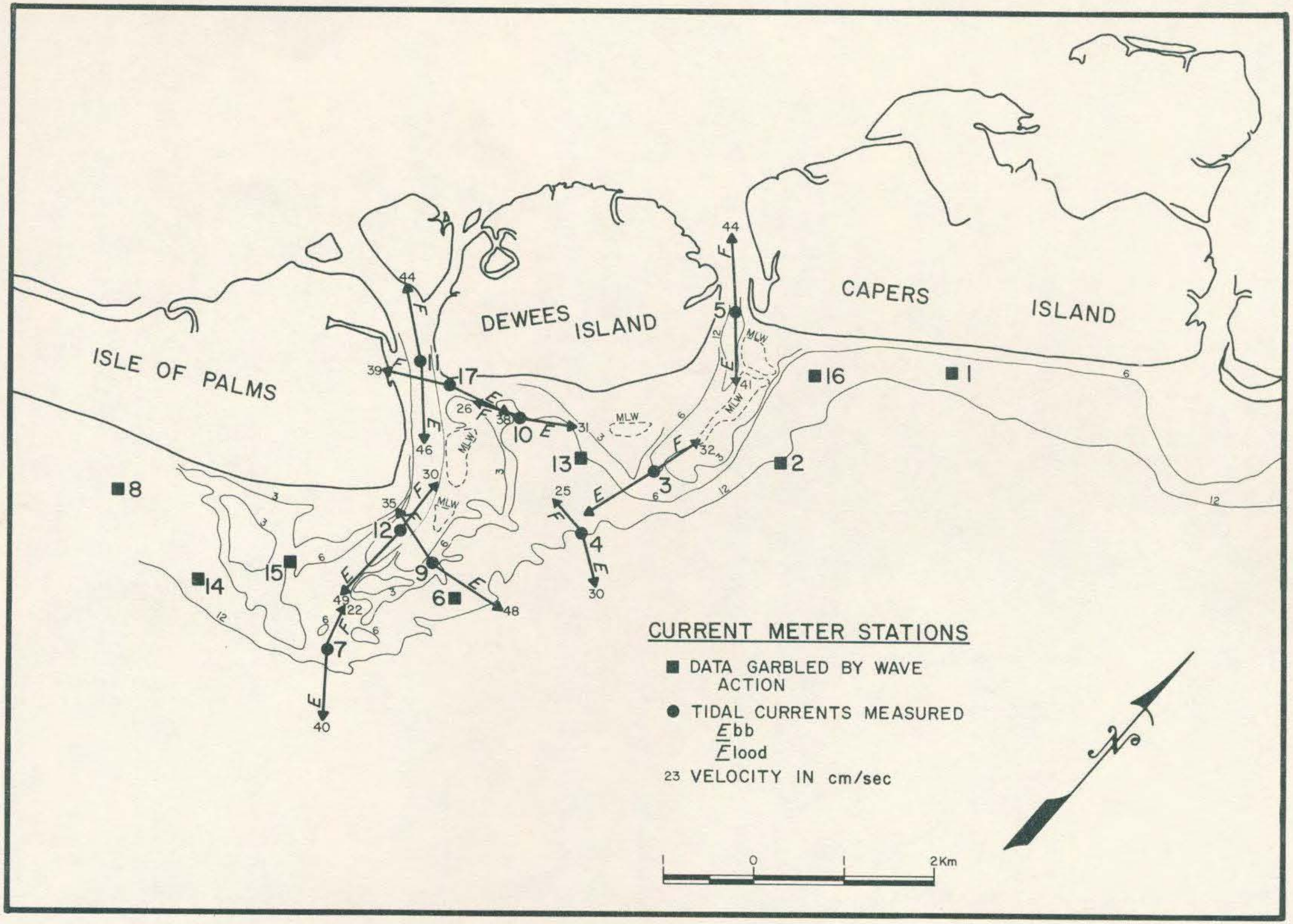

Figure 5. Directions of the net resultant vectors of all bottom tidal current measurements greater than or equal to 25 cm/sec. The 95% confidence rose of each respective direction is given along with the duration of the tidal cycle (expressed as a percentage) over which currents $\geq$ 25 cm/sec operate. At those stations designated neutral, the 95% confidence ellipse of the net resultant vector includes the origin or point of no current.

Significant additions of sand to Dewees Island from that portion of the Capers Inlet ebb-tidal delta immediately adjacent to Capers Island may have ceased during the period 1921-1964. The east/west tidal channel running in front of the island had become even more important to the erosion along the southeastern beach: erosion increased approximately 80% from 20,000 to 36,000 m^3/yr. This channel moves sand primarily to the east, toward 1) that portion of the Capers Inlet ebb-tidal delta immediately adjacent to Dewees Island and 2) toward the open Atlantic Ocean. Littoral drift is predicted to erode sand from the northern portion of the southeastern beach, transport it southwestward, and then deposit it along the southern portion of the southeastern beach. No net change is accomplished by tidal currents sweeping into Capers Inlet across the shallow ebb-tidal delta adjacent to Dewees Island.

The following sand transport path is hypothesized for Dewees Island:

1) net erosion of the southeastern beach at a rate of approximately 36,000 m^3/year
2) tidal currents transport this material to that portion of the Capers Inlet ebb-tidal delta immediately adjacent to Dewees Island and deposit it along the Dewees Island northeastern shore at a net rate of approximately 20,000 m^3/year.
3) tidal currents transport material eroded from the southeastern beach along the east/west channel toward the Atlantic Ocean at a minimum net rate of approximately 22,000 m^3/year (16,000 m^3/year from the southeastern beach and 6,000 m^3/year from offshore erosion).

Recommendations:

As the primary cause of erosion along Dewees Island is a shortage or deficit of sand, a replenishment followed by regularly repeated nourishments is probably the most sensible erosion control plan. Sand could be mined or borrowed from the Dewees Inlet ebb-tidal delta or the northeastern tip of Dewees Island.

Approximately 40,000 m^3/yr (50,000 yd^3/yr) would be needed to equal the amount lost through beach erosion.

Groins constructed along the southeastern beach might not function adequately because there is significant offshore sand movement into the tidal channel as well as longshore movement to the southwest. Any proposed groins should be filled with sand and constructed with a "T" on their seaward tips. In addition, closing the tidal channel separating the Dewees Inlet ebb-tidal delta and the southeastern corner of Dewees Island might help prevent sand loss from the beach to the east/west tidal channel running in front of Dewees Island. This closing could be accomplished by a jetty running out to the ebb-tidal delta.

The final recommendation is to plan for beach erosion and zone the island accordingly, with no houses to be built within several hundred meters of the southeastern beach and maintenance of the northeastern tip in an undeveloped state.

ACKNOWLEDGEMENTS

Mrs. M. J. Clise is acknowledged for her invaluable assistance during the field and laboratory phases of this study. Deborah Kowalski and Tom Bessent helped in reading the current meter data films. Karen Swanson drafted the figures, and Louise Hodges typed the report. Dr. A. G. Gash is gratefully acknowledged for his work in developing the computer program used in analyzing the current meter data. Funding for this study was provided by the Dewees Island Company and the South Carolina Wildlife and Marine Resources Department.

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