Regional Sediment Management

Southwest Gulf Coast Regional Sediment Budget

by
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for

U.S. Army Corps of Engineers

The development of a regional sediment budget is an important element of the Regional Sediment Management (RSM) program. As an extension of the RSM program, the U.S. Army Corps of Engineers (USACE), requested Taylor Engineering of Jacksonville, Florida to develop a sediment budget that covers the southwest Gulf Coast region. Taylor Engineering applied the software tool SBAS2001, developed by the USACE Engineering Research and Development Center, to develop the sediment budget and documents the results in this report. This sediment budget reflects volume change and littoral drift data located within the literature. It does not reflect any new work involving volume calculations. As a word of note, the absence of data over certain time frames required volume estimates based on shoreline change at a conversion rate of 0.67 cubic yards per year (cy/yr) for every foot per year (ft/yr) of shoreline change (CPE, 1992).

A sediment budget represents an accounting of all sediment movement, both natural and mechanical, within a defined area over a specified time. The delineation of specific transport pathways establishes sources or sinks for an area and the magnitudes of trapped or lost sediment volumes. Near tidal inlets, complex interacting mechanisms drive sediment transport. Typically, wave action, inlet tidal currents, sediment characteristics, mechanical bypassing, salinity and thermal stratification patterns, aeolian processes, and vegetation-associated sediment trapping govern sediment behavior and pathways. Data availability and model limitations restrict this degree of detail. However, the USACE's SBAS model can account for sediment gain or loss, such as trapping, transport, nourishment, and dredging within a system. As mentioned above, this document describes the application of SBAS to develop the southwest Gulf Coast regional sediment budget.

The first step in applying the SBAS model involves dividing an area of interest into regions of similar, littoral characteristics. Unique erosion or accretion occurrences, data coverages, dredging activities, or geographic areas define these regions or cells. Because of the numerous inlets that line the southwest coast of Florida, cells generally represent the entire island between inlets or the inlets themselves. Flux arrows connect these cells to indicate specific pathways of sediment transport. The sand fluxes into and out of any cell balance with the net accretion or erosion within the cell. The coupled balancing of sediment fluxes and accretion/erosion magnitudes for each cell determines the magnitudes and pathways of sediment transport within the entire region of interest. This process defines the sediment budget. The sediment budget also identifies and quantifies the sand deficit volumes for the regions adversely impacted by the inlets of study.

This sediment budget, generated from multiple literature sources, dredging records, and nourishment placements, covers from 1970 to 2000. The selection of this period reflects the most common overlap of the available data. The 65-cell model, Figures 1-14, extends 180 coastal miles from Honeymoon Island just south of the Pinellas County line through Cape Romano Island in Collier County. Each cell represents a separate component of sand storage. Arrows across any cell represent a sediment flux either into the cell (sediment gain) or out of the cell (sediment loss). The sum of the fluxes affecting each cell determines the net storage (accretion) or removal (erosion) of sediment within the cell.

Florida’s southwest coast is drastically different than its east coast. The lower wave climate and limited sediment source results in a significantly lower sediment transport rate along the west coast of Florida. The vast barrier island system with multiple inlets and limited tidal prism allows for frequent inlet migration and closure. This complicated system has seen limited maintenance or study. This makes a literature composite of a sediment budget particularly challenging.

Given the north to south net littoral drift that characterizes this environment, presentation and explanation of the sediment budget proceeds from the northernmost cell to the southernmost cell. For easier reference, this report presents the budget county by county. Figures representing the cells of the sediment budget within the county discussed are presented at the section's beginning for easy referral. The figures show the fluxes into and out of the individual cell and volume changes associated with the cell. Arrows that connect one cell to another represent transport between the cells, while arrows into or out of a cell that do not connect two cells represent either nourishment or removal. The color associated with the cell indicates volume change — a green cell is accreting, a red cell is eroding, and a white cell is stable. A table summarizing the cell number, location, and volume change of each cell in the county is given at the end of each section.

Pinellas County

Pinellas County comprises fifteen cells that extend from Honeymoon Island at the north end of the county to Mullet Key at the south end. Figures 1 and 2 present the sediment budget cells within this subregion of the sediment budget. Mullet Key is included in Figure 3 (see page 12) with Hillsborough County. The paragraphs following the figures explain the values associated with each cell. The section is concluded with Table 1 that summarizes the cell number, location, and volume change associated with each cell.

The sediment budget begins at the first cell, Honeymoon Island, located immediately south of the Pinellas County line. An estimated 120,000 cubic yards per year (cy/yr) enters the Honeymoon Island cell from the north. Honeymoon Island has received two known nourishments — 1,440,000 cy in 1969 and 230,000 cy in 1989. As the first nourishment lies outside the period considered, nourishment input into the cell consists of 8,000 cy/yr. Although the 2002 FDEP Critical Erosion Report indicates the southern portion of Honeymoon Island, R6-R12, is critically eroding, 1974 to 1997 Mean High Water (MHW) shoreline changes indicate substantial accretion. Therefore, an assumed volume change of 50,000 cy/yr for the entire island results in a southern transport of 75,000 cy/yr out of the cell.

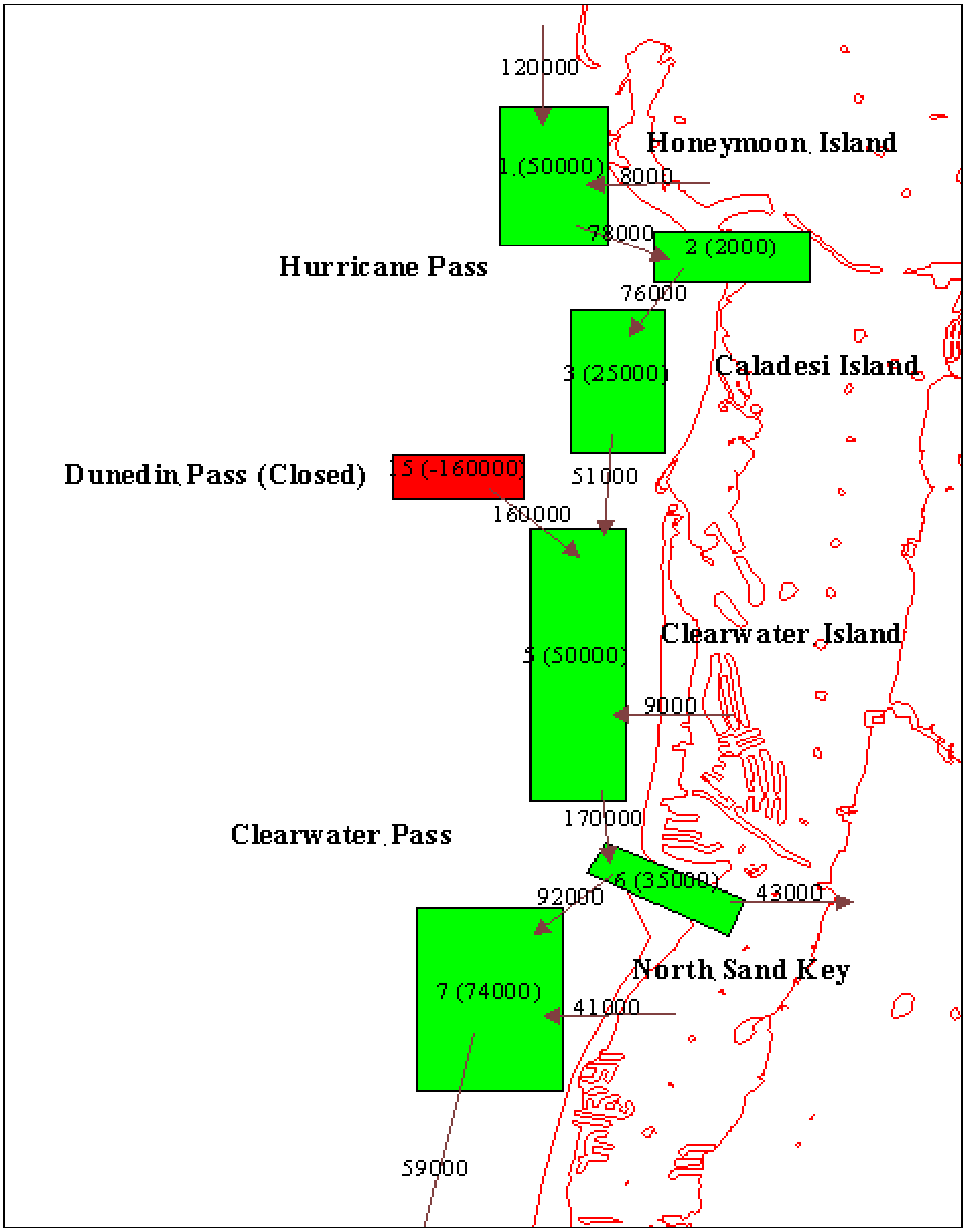

Figure 1. Northern Pinellas County Sediment Budget

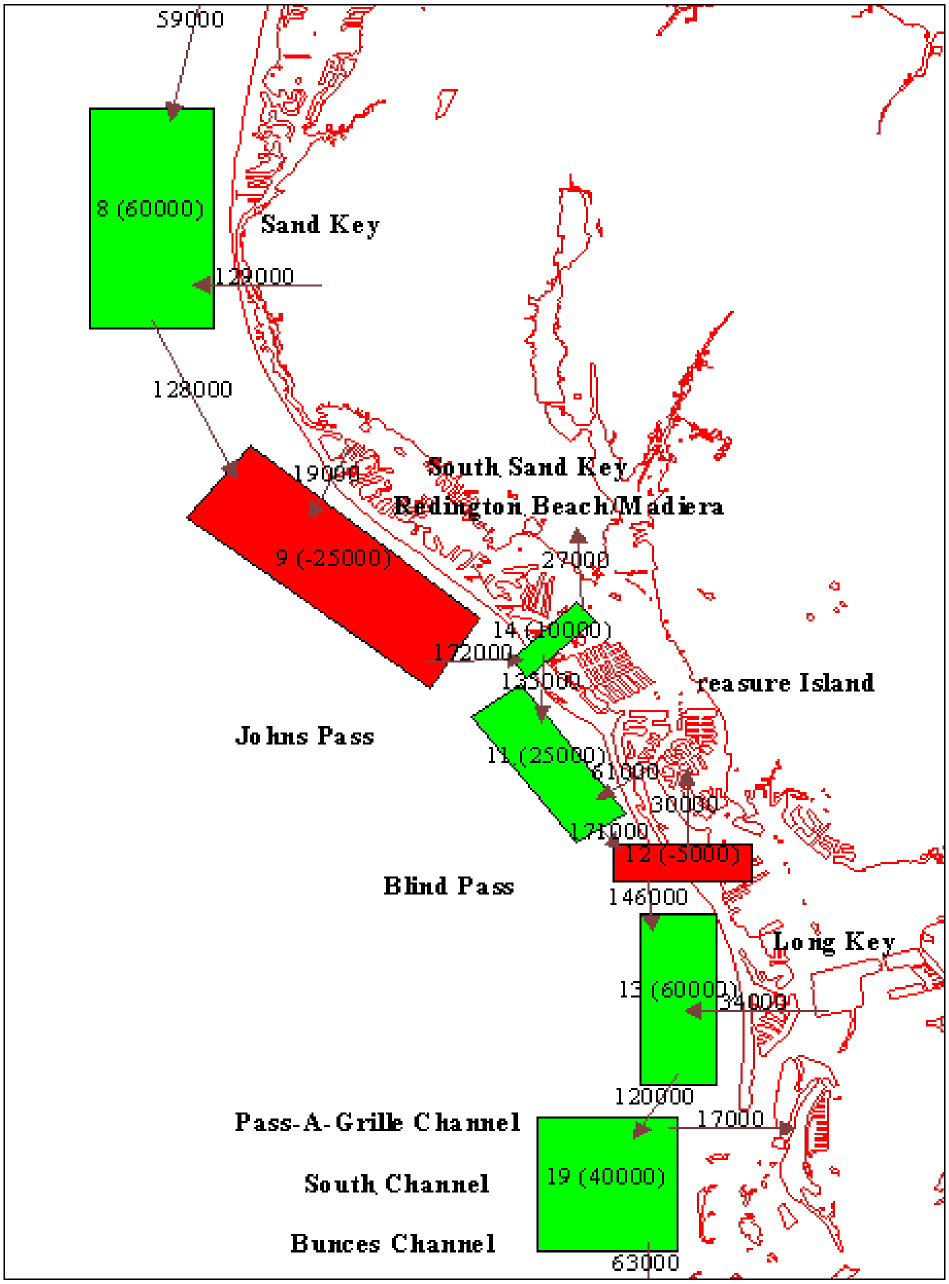

Figure 2. Southern Pinellas County Sediment Budget

Table 1. Summary of Cell Location and Volume Change for Pinellas County

Cell Number	Location	Volume Change (cy/yr)
1	Honeymoon Island	50,000
2	Hurricane Pass (Pinellas County)	2,000
3	Caladesi Island	25,000
15	Dunedin Pass	-160,000
5	Clearwater Island	50,000
6	Clearwater Pass	35,000
7	North Sand Key	74,000
8	Middle Sand Key	60,000
9	South Sand Key	-25,000
14	Johns Pass	10,000
11	Treasure Island	25,000
12	Blind Pass (Pinellas County)	-5,000
13	Long Key	60,000
19	Pass-a-Grille Channel/ South Channel/ Bunces Channel	40,000
17	Mullet Key	50,000

The sediment leaving the southern tip of Honeymoon Island enters Hurricane Pass, cell 2. A hurricane opened the Pass in 1921. A 1984 ebb shoal volume approximation of 100,000 cy suggests an ebb shoal accretion rate of approximately 2,000 cy/yr. Hurricane Pass supplied the sediment for the 1969 Honeymoon Island nourishment project. In 1989 a navigation channel was dredged through Hurricane Pass; however, given unknown sediment volumes and unknown placement location, the sediment budget reflects no sediment removed from Hurricane Pass. The sediment influx and the 2,000 cy/yr shoaling rate results in transport of 76,000 cy/yr out of the cell. A Walton study based on offshore wave data suggests a transport of 75,000 cy/yr south from Hurricane Pass. The sediment budget, therefore, corresponds to the published volumes.

Caladesi Island, cell 3, consists entirely of a state park. Therefore, little literature exists for this area. None of the literature indicates any nourishment activity. Because FDEP (2002) designated only a small portion of the northern end of Caladesi Island as a noncritical erosion area and shoreline changes from 1974 to 1999 indicate accretion, the island appears to accrete an estimated 25,000 cy/yr. This accretion rate, coupled with the sediment influx, leaves 51,000 cy/yr transported south.

In 1984, the ebb shoal of Dunedin Pass (cell 15) contained an estimated 4,800,000 cy of sediment, and, according to the USGS website (http://coastal.er.usgs.gov/wfla/vft/dunedin/), Dunedin Pass closed in 1988. If the ebb shoal completely eroded, as the 1995 aerial found on the above website appears to indicate, this would equate to 160,000 cy/yr introduced into the littoral environment over a 30-year period. Therefore the sediment budget reflects a volume change and out flux of 160,000 cy/yr from the ebb shoal.

Sediment from the relic Dunedin Pass ebb shoal and the transport from Caladesi Island result in an influx of 211,000 cy/yr into cell 5, Clearwater Island. Clearwater Beach has received two beach nourishments since 1970 — 180,000 cy in 1981 and 80,000 cy in 1984. As the sediment budget reflects yearly fluxes and volume changes, the nourishment volume is annualized over a 30-year period. The annual placement of the above beach nourishment volumes is 9,000 cy/yr. Volume change estimates are limited, however. Dean reports a volume change of +1,800,000 cy over approximately 5,000 ft north of Clearwater Pass from 1950 – 1985. FDEP MHW shoreline changes confirm this degree of accretion. Therefore, the cell's volume change totals an assumed +50,000 cy/yr. This results in 170,000 cy/yr bypassed to cell 6, Clearwater Pass.

Dredging records between 1970 and the late 1990s indicate three maintenance dredging events for Clearwater Pass (cell 6) — approximately 126,000 cy in 1974, 186,000 cy in 1977, and 6,000 cy in 1994. The north end of Sand Key received the 1974 and 1977 material while an upland confined disposal area on Sand Key received the 1994 material. The literature also indicates the USACE dredged approximately 970,000 cy between 1980 and 1985 from Clearwater Pass and placed the material on Sand Key and Clearwater Beach. The average removal rate of these combined events totals 43,000 cy/yr. An investigation of ebb shoal contours estimates an increase of 4,990,000 cy from 1885 to 1984 (Hine, 1986), which equates to a +50,000 cy/yr accretion rate. As one expects the inlet to become more stable over time, the cell reports a slightly lower annual deposition of +35,000 cy. A total of 92,000 cy is available for transport along the coast to Sand Key. Reported south transport from Clearwater Pass range from 38,000 to 100,000 cy/yr.

Due to its length and available data, Sand Key comprises three cells — the north end extending from the inlet to R66, the middle (monuments R66 – R99), and the south end (monuments R99 – R125). Within the north end cell (cell 7), five nourishments have resulted in an average placement of 41,000 cy/yr over a 30-year period. These nourishments include a 1973 nourishment of 126,000 cy, a 1977 nourishment of 186,000 cy, a 1981 – 1983 nourishment of 600,000 cy, a 1984 nourishment of 240,000 cy, and a 1992 – 1993 nourishment of 82,000 cy. The volume change associated with the northern cell totals a gain of 2,600,000 cy from Clearwater Pass to 6,600 ft south from 1950 – 1985, or an average rate of +74,000 cy/yr. Therefore, 59,000 cy/yr becomes available for influx into the middle Sand Key cell.

Middle Sand Key (cell 8) receives an average of 129,000 cy/yr from nourishment. This value includes a 1990 nourishment of 1,300,000 cy, a 1992 nourishment of 480,000 cy, and a 1997 nourishment of 2,079,000 cy. Some of these projects certainly overlap with the north and south cells representing Sand Key. The volume change, estimated from MHW shoreline change rates, totals approximately +60,000 cy. The south Sand Key cell thus receives the 128,000 cy of residual sediment.

South Sand Key, cell 9, includes Reddington and Madiera Beaches. These beaches have received an annualized 19,000 cy/yr of sediment. This annual rate consists of a 1981 – 1983 nourishment of 19,000 cy, a 1986 nourishment of 30,000 cy, and a 1988 nourishment of 529,000 cy. The *Johns Pass Inlet Management Plan for Pinellas County, Florida* indicates three different values for volume change for south Sand Key from 1974 to 1992: -25,000 cy/yr above closure, +7,300 above -5 ft-NGVD, and +3,300 above 0 ft-NGVD. These volume changes occur between monument R-120 and the inlet. To include as much of the system as possible, the volume change above closure accounts for the volume change in the South Sand Key cell. However, the substantial difference in volume change calculated for above closure and 0 ft-NGVD might skew trends between cells. As mentioned in the introduction, when no published volume changes were found, MHW shoreline changes approximated the volume changes. This method of determining volume changes does not consider accretion or erosion in the near shore as the above closure calculation of volume change does. With this caveat, a calculated 172,000 cy/yr leaves Sand Key and enters Johns Pass.

Johns Pass (cell 4), initially opened by a hurricane in 1848, became a Federal project in 1964. This inlet received four maintenance dredging events and provided one nourishment borrow site since 1970 for an annualized removal rate of 27,000 cy/yr. Maintenance dredging occurred in 1979 – 1980 with 118,500 cy removed, in 1982 with 52,000 cy removed, 1985 with 60,500 cy removed, and 1990 – 1991 with 56,000 cy removed. The ebb shoal provided 529,000 cy in 1988 for the Sand Key Phase I project. Volume change estimates vary substantially within the literature. The inlet management plan for Johns Pass (Coastal Tech, 1993) reports volume changes of 20,000 cy/yr to 22,000 cy/yr from 1926 to 1952 and -66,000 cy/yr to -62,000 cy/yr from 1952 to 1992, shoaling rates of 26,000 cy/yr for 1980 – 1982, 17,000 cy/yr from 1980 – 1990, and 11,000 cy/yr from 1985-1990, and borrow site filling rate of 31,000 cy/yr that decreases with time. It also reports Johns Pass ebb shoal as stable. The volume change for the sediment budget assumed accretion of 28,000 cy/yr minus 18,000 cy/yr for the change in ebb shoal volume associated with the 1988 borrow site for a total accretion rate of +10,000 cy/yr. Several literature sources (Dean, 1987; Coastal Tech, 1993) report a net southerly transport between 30,000 and 50,000 cy/yr from Johns Pass before the Dunedin Pass closure. Although somewhat higher at 135,000 cy/yr, the sediment budget value required to balance the cell appears reasonable given the additional sediment expected from the closure of Dunedin Pass.

Treasure Island, cell 11, received substantial nourishment between 1970 and 2000. Eleven nourishment projects resulted in an annualized nourishment rate of 61,000 cy/yr. This placement, combined with a volume increase of 25,000 cy/yr, results in a 171,000 cy/yr transport into Blind Pass. The estimated volume change reflects the above closure volume change of +7,000 cy/yr for the 6,000 ft south of the inlet (Coastal Tech, 1993). A comparison of MHW shoreline change rates confirmed the accretion trend.

Blind Pass (cell 12), the borrow site for numerous beach nourishments projects on the adjacent islands, supplied approximately 30,000 cy/yr. These removals consisted of 550,000 cy in 1972–1976, 75,000 cy in 1975, 50,000 cy in 1978, and 220,000 cy in 1983. The large volumes extracted from the ebb shoal results in a volume loss of approximately -5,000 cy/yr. The Blind Pass cell thus transports an estimated 146,000 cy/yr south.

The sediment from Blind Pass flows into Long Key, cell 13. Long Key received nourishment six times between 1970 and 2000. The nourishments of Upham Beach include a 1975–1976 nourishment of 80,000 cy, a 1979 nourishment of 254,000 cy, a 1980 nourishment of 243,000 cy, a 1986 nourishment of 175,000 cy, and a 1996 nourishment of 230,000 cy. Nourishment of St. Petersburg Beach consisted of a 1971–1975 nourishment of 25,000 cy. This nourishment activity results in an annualized sediment placement of 34,000 cy/yr. A 2000 nourishment (volume unknown) also occurred in this area. The volume change associated with Long Key, estimated from MHW shoreline changes, totals +60,000 cy/yr. The calculated sediment transport rate from Long Key totals 120,000 cy/yr.

Cell 19, the cell following Long Key, represents the inlets of Pass-a-Grille, South Channel, and Bunces Pass. The literature references only two indications of dredging events of Pass-a-Grille Channel — 160,000 cy in 1960, outside of the period of interest, and 520,000 cy in 1986–1987 for placement on Treasure Island as an emergency response to Hurricane Elena. Therefore, the annual removal rate totals 17,000 cy/yr. The volume change estimated by ebb shoal contours approximates an annual accretion rate of 106,000 cy/yr from 1895–1979. The shoals have most likely become more stable since 1895 with a much lower accretion rate. The estimated volume change, +40,000 cy/yr for the three inlets, accounts for the volume lost due to the 1986 nourishment dredging. A transport of 63,000 cy/yr feeds Mullet Key.

Mullet Key (cell 17), the southern most island of Pinellas County, is situated just north of the littoral block of Tampa Harbor, composed of Egmont Channel, Southwest Channel, and Passage Key Inlet. The close proximity of Mullet Key to Tampa Harbor makes it a prime recipient of beach-suitable dredged material. Mullet Key received such nourishment in 1977 with 1,350,000 cy placed within monuments R173 to R179 and R181 to R191. Mullet Key also received nourishment in 1972 – 1973 with 505,000 cy from an offshore borrow site. These two nourishments equate to an annualized placement rate of 62,000 cy/yr. The extensive nourishment, in part, accounts for the accretion indicated by a comparison of MHW shorelines. The estimated volume change of Mullet Key totals +50,000 cy/yr. The Mullet Key cell transports 75,000 cy/yr to Tampa Harbor.

Hillsborough County

Hillsborough County comprises Egmont Channel ebb shoal (cell 66), Egmont Channel (cell 21), Tampa Harbor (cell 18), Egmont Key (cell 16), Southwest Channel, and Passage Key Inlet (cell 68). Figure 3 introduces the sediment budget for Hillsborough County. The paragraphs following the figure explain the values associated with each cell. The section concludes with Table 2 that summarizes the cell number, location and volume change associated with each cell in Hillsborough County.

The first cell within Hillsborough County corresponds to the Egmont Channel ebb shoal, cell 66. This cell receives sediment from Mullet Key to the north, Egmont Key to the south, and Egmont Channel to the east. Similarly, the cell supplies sediment east to Egmont Channel and to nourishment projects denoted by the flux arrow out of the cell to the west. Tampa Harbor ebb shoal, composed of Egmont Channel, Southwest Channel and Passage Key Inlet, trapped an estimated 540,000 cy/yr from 1885 to 1979 (Hine, 1986). Due to increasing stability of ebb shoals over time, this value appears high. Therefore, the Tampa Harbor ebb shoal trapped an assumed 340,000 cy/yr — a value divided evenly between the Egmont Channel cell (cell 21) and the Southwest Channel/Passage Key Inlet cell (cell 68). Two dredging events removed sediment from the Egmont Channel ebb shoal for nourishment — 1,300,000 cy in 1990 and 480,000 cy in 1992 for an annualized removal value of 59,000 cy/yr. Due to the trapping of Tampa Harbor and dredging records within Tampa Harbor that indicate silt characterizes the harbor's shoal, an assumed minimal value of 7,000 cy/yr of littoral introduced sediment transports into Tampa Harbor. The cell receives an estimated value of 53,000 cy/yr from Egmont Key and 108,000 cy/yr from Egmont Channel. The opposing flux arrows between Egmont Channel ebb shoal (cell 66) and Egmont channel (cell 21) illustrate that a small amount of littorally introduced sediment flows into Tampa Bay, although the net transport consists of fine sediment from Tampa Bay to Egmont Channel and Egmont Channel ebb shoal. This is also the case between Egmont Channel and Tampa Bay Harbor (cell 18).

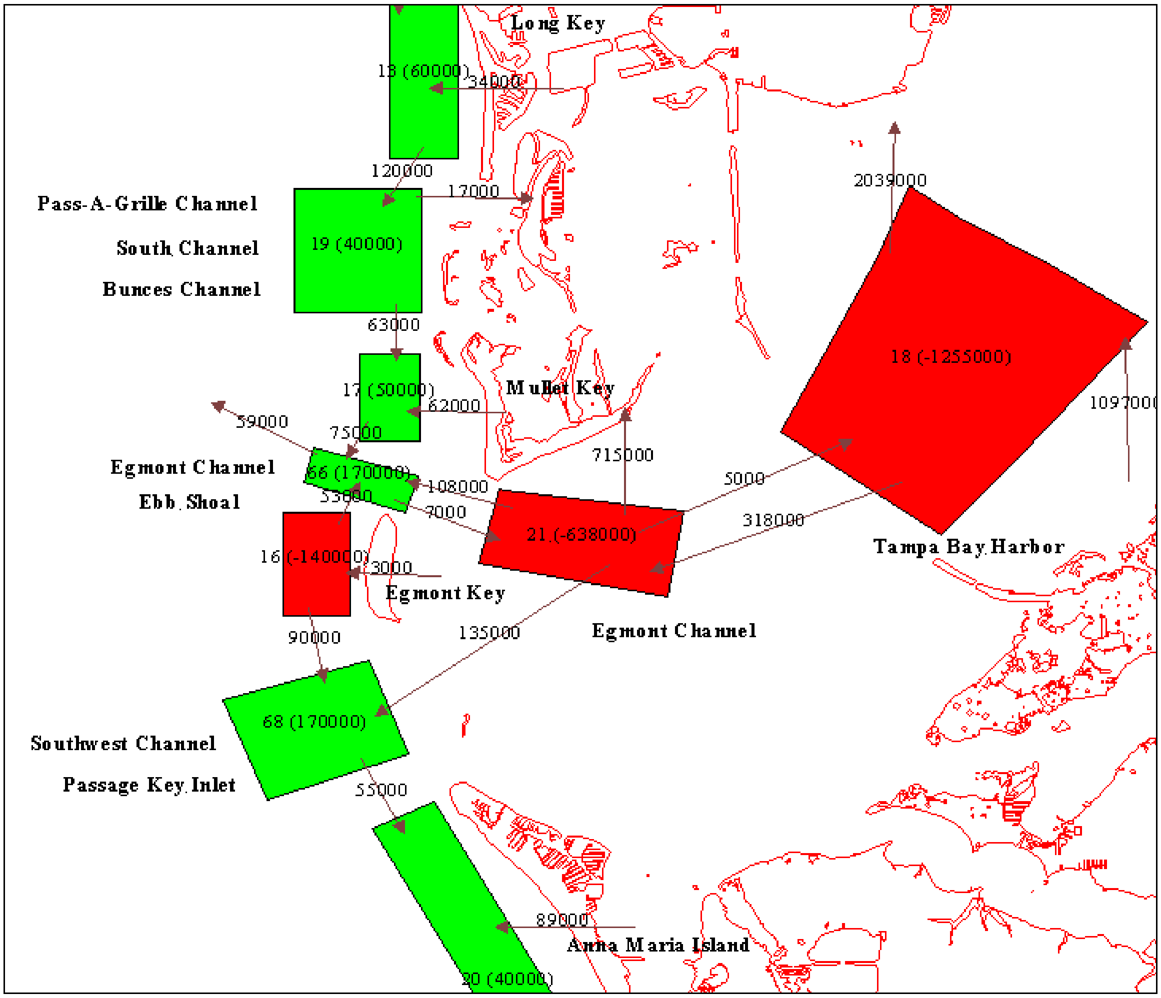

Figure 3. Hillsborough County Sediment Budget

Table 2. Summary of Cell Location and Volume Change for Hillsborough County

Cell Number	Location	Volume Change (cy/yr)
66	Egmont Ebb Shoal	170,000
21	Egmont Channel	-638,000
18	Tampa Harbor	-1,255,000
16	Egmont Key	-140,000
68	Southwest Channel/Passage Key Inlet	170,000

The second cell in Hillsborough County represents Egmont Channel (cell 21). Due to channel deepening as indicated in USACE dredging records, this cell experiences a volume change of -638,000 cy/yr. The combined new work and maintenance dredging volume totals 715,000 cy/yr indicated by the flux arrow leaving the cell. Egmont channel supplies sediment to the Egmont Channel ebb shoal described above, to Southwest Channel/Passage Key Inlet ebb shoal, and to Tampa Harbor. The cell receives sediment from Egmont Channel ebb shoal and Tampa Harbor. For a balanced cell, the required values for sediment transport out of the cell total 108,000 cy/yr to Egmont ebb shoal, 150,000 cy/yr to Southwest Channel/Passage Key Inlet ebb shoal, 5,000 cy/yr of littorally introduced sediment to Tampa Harbor, and 715,000 cy/yr that represents dredged material described above. The required values for sediment transport into the cell equal 7,000 cy/yr of littorally introduced sediment from Egmont Channel ebb shoal and 318,000 cy/yr from Tampa Harbor.

The USACE dredging records indicate an annual dredging rate of 2,039,000 cy/yr for the interior of Tampa Harbor, cell 18. This value includes both channel deepening and maintenance dredging between 1970 and 2000. Channel deepening resulted in a -1,255,000 cy/yr volume change. Tampa Harbor receives the majority of sediment from its tributaries as indicated by the large percentage of silt removed during dredging. Egmont Channel contributes a minimal amount of sediment to Tampa Harbor; the majority of sediment transport, however, occurs in the opposite direction, from Tampa Harbor to Egmont Channel. For a balanced cell, the required values total 1,097,000cy/yr of siltation from the Tampa Harbor tributaries, 5,000 cy/yr from Egmont Channel, and 318,000 cy/yr to Egmont Channel.

Egmont Key, cell 16, is situated between Egmont Channel and Southwest Channel, two of the three channels that compose Tampa Harbor. According to the USGS website (http://coastal.er.usgs.gov/wfla/vft/mullet/), Egmont Key has lost over 200 acres in the last decade. A nourishment project (volume unknown) occurred in December 2000 (FDEP, 2002). Apparent north and south transport feeds the extensive Tampa Harbor shoal system. Estimated values of 3,000 cy/yr received from the 2000 nourishment, 7,000 cy/yr received as southern transport from Egmont Channel ebb shoal, 60,000 cy/yr transport north, 90,000 cy/yr transport south and a volume change of -140,000 cy/yr seem reasonable.

As discussed, the southern Tampa Harbor ebb shoal cell (cell 68), comprised of Southwest Channel and Passage Key Inlet, experiences an estimated volume change of +170,000 cy/yr. The cell receives 135,000 cy/yr from Egmont Channel and 90,000 cy/yr from Egmont Key for a southerly transport of 55,000 cy/yr.

<u>Manatee County</u>

Three cells represent Manatee County. Manatee County extends from Anna Maria Key through half of Longboat Key. Figure 4 shows the coverage of Manatee County and presents the sediment budget for this region. The paragraphs following the figure explain the values associated with each cell. The section concludes with Table 3 — a summary of the cell number, location and volume change associated with each cell in Manatee County.

Anna Maria Island, cell 20, received three nourishments from 1970 to 2000. These nourishments consisted of 206,000 cy between 1977 and 1978, 148,000 cy in 1985, and 2,320,000 cy in 1993 for an annualized rate of +89,000 cy/yr. Because of the large volume of nourishment Anna Maria Island receives, cell 20 shows an overall accreting trend. A 1946–1985 shoreline volume change estimated an accretion rate on the southern end of the island of 100,000 cy/yr from Longboat Pass to 9,000 ft north (Dean, 1987). The MHW shorelines indicated an eroding northern shoreline from 1974 to 1998. These data translate to an assumed +40,000 cy/yr volume change. A transport of 104,000 cy/yr out of the cell balances the cell.

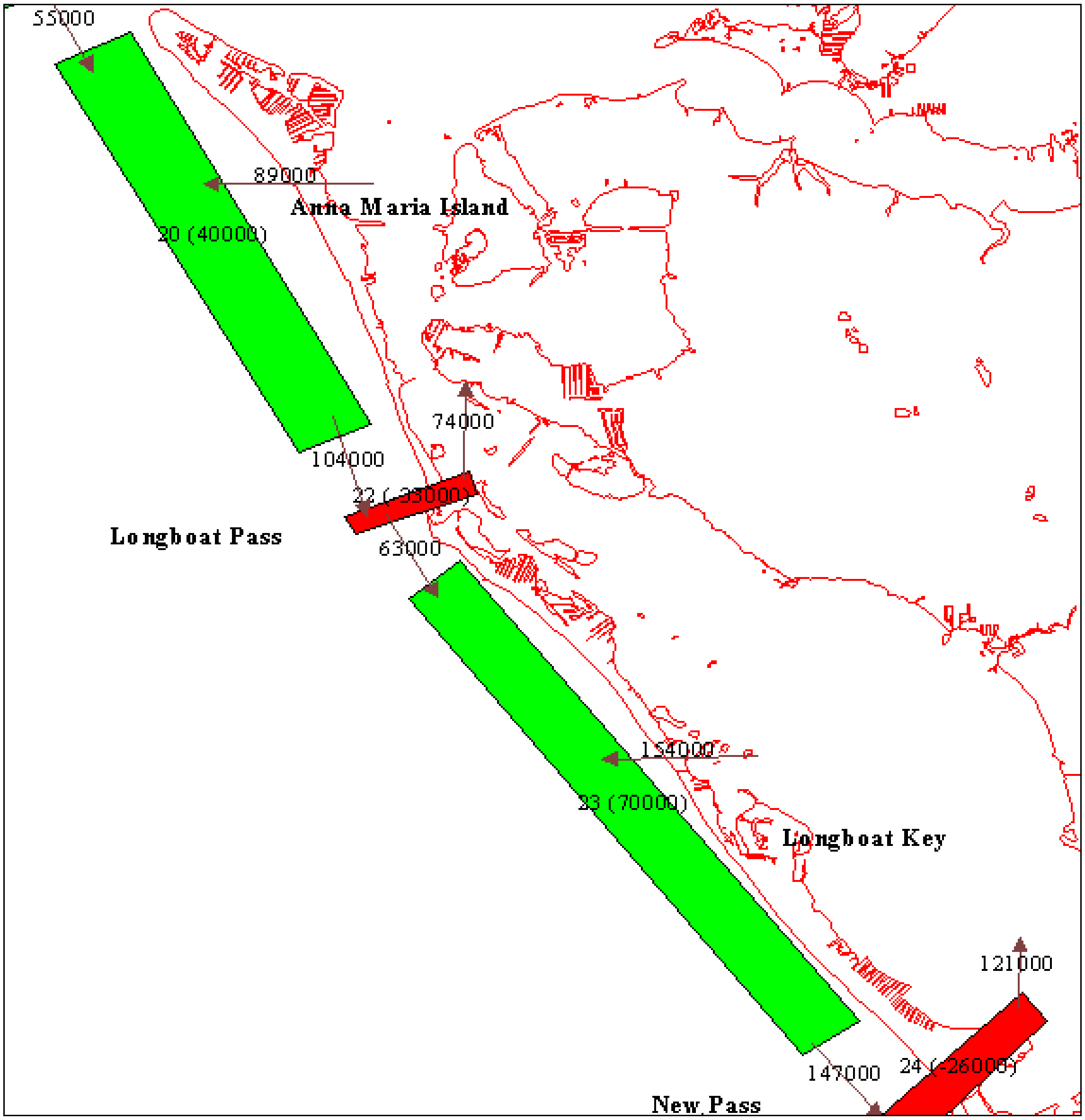

Figure 4. Manatee County Sediment Budget

Table 3. Summary of Cell Location and Volume Change for Manatee County

Cell Number	Location	Volume Change (cy/yr)
20	Anna Maria Key	40,000
22	Longboat Pass	-33,000
23	Longboat Key	70,000

Cell 22, the second cell in Manatee County, represents Longboat Pass. Similar to other inlets, Longboat Pass has provided sediment for numerous nourishment projects, primarily to Anna Maria Key and Longboat Key. Six dredging events resulted in a removal rate of 74,000 cy/yr — 308,000 cy in 1977, 164,000 cy in 1982, 165,000 cy in 1985, 214,000 cy between 1990 and 1991, 1,158,000 cy in 1993, and 168,000 cy in 1997. The 1993 dredging occurred in conjunction with New Pass dredging for a total placement of 3,130,000 on Longboat Key. The exact volumes dredged from Longboat Pass and New Pass are unknown, but based on previous nourishment projects (USACE dredging records) that combined sediment from Longboat Pass and New Pass, an assumed 37% came from Longboat Pass and 63% from New Pass. The volume change of -33,000 cy/yr considers 10,000 cy/yr removed for channel deepening, 39,000 cy/yr removed for nourishment projects, 24,000 cy/yr removed for maintenance dredging, and 40,000 cy/yr added for expected deposition (CEC, 1991). A value of 63,000 cy/yr enters the next cell. Walton (1973) estimated a longshore transport of 61,000 cy/yr from Longboat Pass based on offshore wave data.

Longboat Key, cell 23, begins in Manatee County and extends into Sarasota County. It has received approximately 133,000 to 154,000 cy/yr through nourishment: 101,000 cy in 1977, 100,000 cy in 1982, 3,130,000 cy in 1993, and an unknown volume in 1997. Approximating the volume based on project length (R62M to R14S) yields a volume of 1,277,000 cy for the 1997 event. The nourishment rate, including the 1997 event (factored into this sediment budget), totals 154,000 cy/yr; the rate without the 1997 event totals 133,000 cy/yr. Estimates based on MHW shoreline changes from 1974 to 1998 and reported volume changes (before 1970) adjacent to the inlets yields an associated volume change of +70,000 cy/yr. A calculated transport of 147,000 cy/yr south balances the cell.

Sarasota County

Sarasota County stretches from Longboat Key, discussed above, to Gasparilla Island. Figures 5 and 6 indicate the sediment transport associated with the eight cells of Sarasota County. The paragraphs following the figures explain the values concerning each cell. Table 4, located at the end of the section, summarizes the cell location and volume changes.

The first cell within this county represents New Pass — cell 24. Since 1970, New Pass has undergone maintenance dredging six times with the dredged material placed on the near beaches, particularly Lido Key. The dredging events totaled 1,663,904 cy. The 1993 nourishment project for Longboat Key dredged approximately 1,972,000 cy. As discussed, this shared project with Longboat Pass totaled a nourishment amount of 3,130,000 cy for Longboat Key. Therefore, the total extracted volume of 3,635,900 cy over a 30-year period yields an annual dredging rate of 121,000 cy/yr. The shoaling rate, based on maintenance dredging and ebb shoal contour changes, suggests approximately 30,000 to 50,000 cy/yr of deposition. Subtracting an average shoaling value of 40,000 cy/yr from the volume change due to the 1993 beach nourishment project of 66,000 cy/yr, results in a volume change for the cell of -26,000 cy/yr. This leaves a calculated 52,000 cy/yr influx into Lido Key.

Lido Key, cell 25, received an annualized 70,000 cy/yr from eight nourishment projects: 350,000 cy in 1970,246,000 cy in 1974,400,000 cy in 1977,185,000 cy in 1980,92,000 cy in 1982,239,000 cy in 1985,274,000 cy in 1991, and 314,000 cy in 1997. The estimated volume change, derived from reported volume changes for 6,000 ft south of New Pass and MHW shoreline change rates, totals +25,000 cy/yr. Transport out of the cell, therefore, equals 100,000 cy/yr.

The transport from Lido Key flows into the cell representing Big Sarasota Pass, cell 26. Shoaling within Big Sarasota Pass totals approximately +45,000 cy/yr (CEC, 1991) with no reported dredging activity. This reduces the southern littoral transport to Siesta Key to 55,000 cy/yr

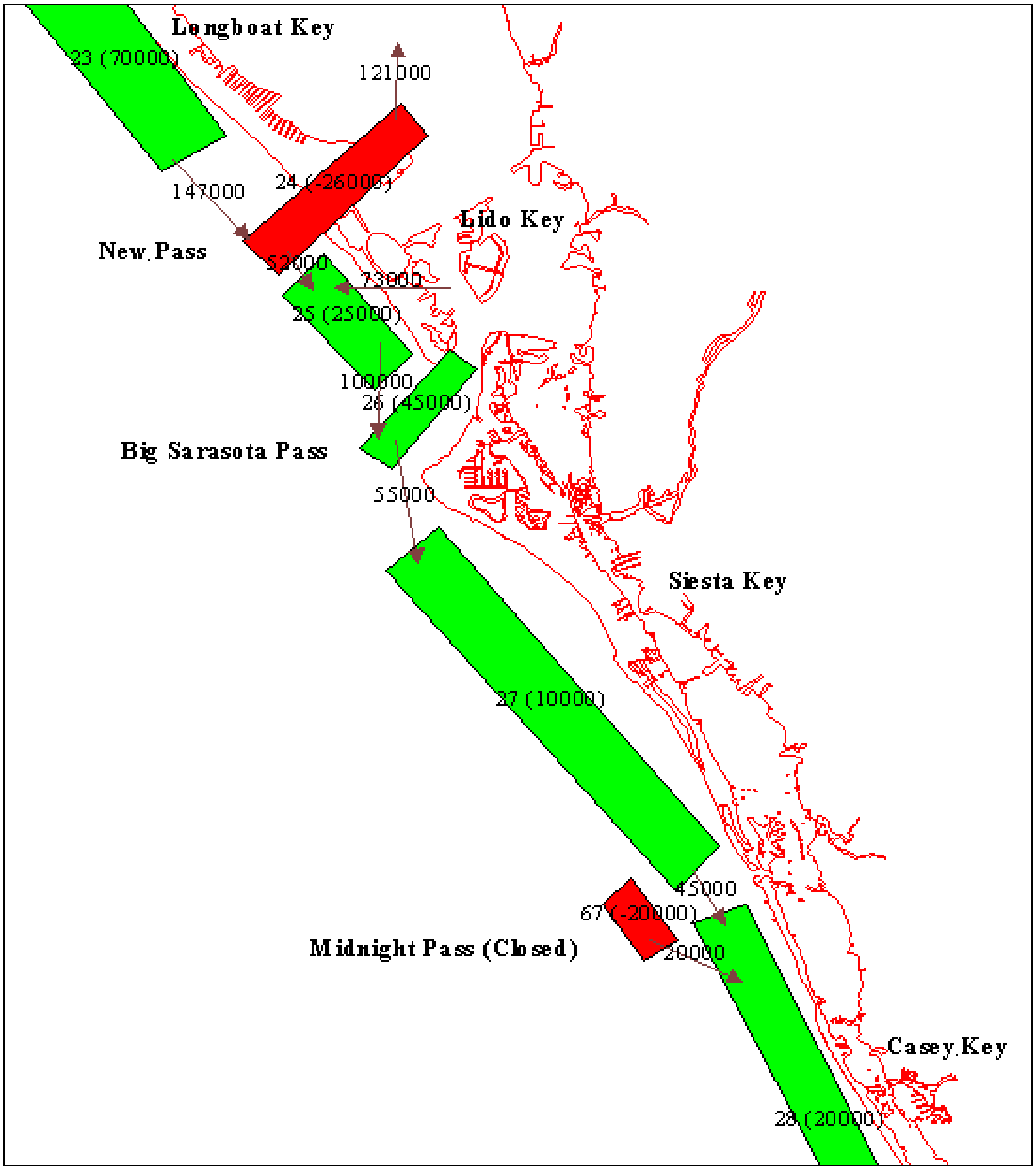

Figure 5. Northern Sarasota County Sediment Budget

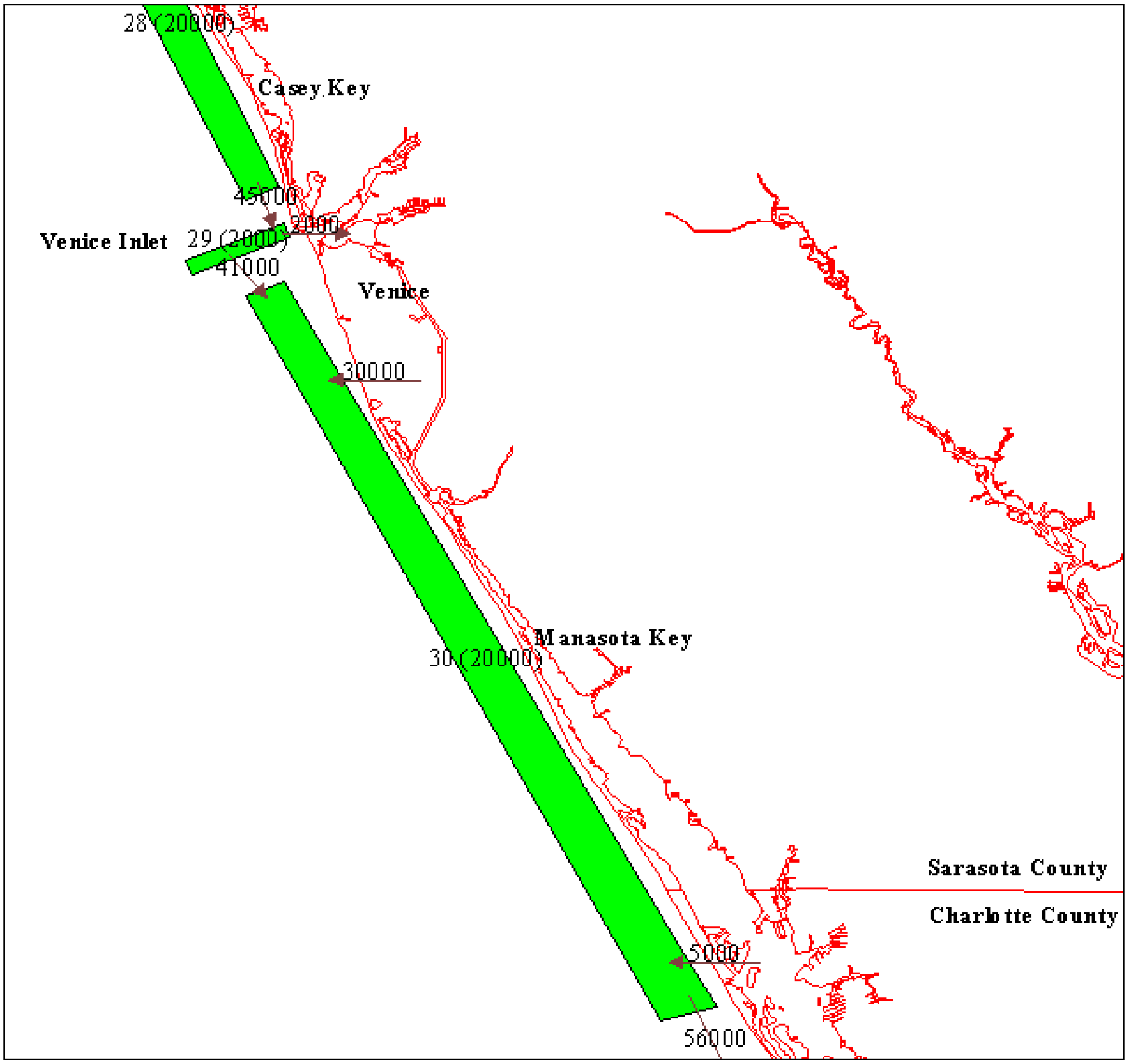

Figure 6. Southern Sarasota County Sediment Budget

Table 4. Summary of Cell Location and Volume Change for Sarasota County

Cell Number	Location	Volume Change (cy/yr)
24	New Pass (Sarasota County)	-26,000
25	Lido Key	25,000
26	Big Sarasota Pass	45,000
27	Siesta Key	10,000
67	Midnight Pass	-20,000
28	Casey Key	20,000
29	Venice Inlet	2,000
30	Manasota Key	20,000

No record of nourishment exists for Siesta Key, cell 27. This island accretes at approximately +10,000 cy/yr (CEC, 2002). Revetments along the island suggest eroding areas or periods of erosion, however. A net transport south of 45,000 cy/yr balances this cell.

Midnight Pass, cell 67, has had a history of migrating, closings, and openings. In 1983, the pass closed and required dredging to reopen. The amount or placement location, however, went unreported. The inlet, closed again in 1987, remains closed. The Midnight Pass cell represents the return of the ebb shoal into the littoral system. The 1982 estimated shoal volume of 600,000 cy, (Dean, 1987) divided by the 30-year period, yields a return of 20,000 cy/yr into the system.

Casey Key, cell 28, receives sediment from both Siesta Key and the relic ebb shoal of Midnight Pass. Again, no nourishment activities have occurred along this island. The volume change, calculated at +20,000 cy/yr, is based on an erosion study of Sarasota and Charlotte County (CEC, 2002) that calculated volumetric changes from 1974 to 2001 profile surveys. From Casey Key, 45,000 cy/yr of sediment transports south into Venice Inlet.

Venice Inlet, cell 29, has seen minimal dredging since it became a Federal project in 1937–1938 when the USACE jettied and initially dredged the inlet. Three dredging events occurred: a 1938 project removed 68,800 cy, a 1964 project removed 22,000 cy, and a 1971 dredging removed a “negligible” amount of sediment (CEC, 1991). An inlet management plan adopted in 1998 suggests placing 64,000 cy/yr from dredging or offshore borrow on downdrift beaches (FDEP, 2002). Assuming plan implementation, removal of sediment would equal approximately 2,000 cy/yr over the 30-year period. The minimal 4,000 cy/yr deposition (CEC, 1991) in Venice Inlet of, results in a volume change of +2,000 cy/yr and an out flux of 41,000 cy/yr. Estimated rates of transport range from 56,000 cy/yr to 70,000 cy/yr south (CEC, 1991; Dean, 1987).

Manasota Key extends from Venice Inlet into Charlotte County. Between 1994 and 1996, Manasota Key (cell 30) received a large, two-phased nourishment project between R116 to R133 from an offshore borrow site. In 1980, Manasota Key received another smaller-volume project along the Charlotte Beach State Recreation Area from Stump Pass dredging. The total volume of 1,042,000 cy over a 30-year period yields an annual placement of 35,000 cy/yr — 30,000 cy/yr in the northern area of Manasota Key and 5,000 cy/yr on the southern end. The volume change for the island is uncertain. One report indicates severe erosion of approximately -94,000 cy/yr from the inlet to 27,000 ft south between 1974 and 1988 (USACE, 1990). Another report calculates the volumetric changes from monuments R135 (Sarasota) to R21 (Charlotte) as -2,000 cy/yr from 1974 to 2001 (CEC, 2002). The report, however, did not calculate volume changes for the northern monuments (R116 – R135). Shoreline changes reflected an accreting shoreline over the length of the island from 1974 to 1993/2000. (The 1993/2000 notation indicates varying survey dates of either 1993 or 2000 for the monuments reported.) The shoreline between monuments R116–R135 showed substantial accretion between 1993 and 2000. Therefore, the severe erosion indicated in the USACE's 1990 document does not represent the trend of the island over the entire 1970 to 2000 period. An assumed, slightly accreting volume of +20,000 cy/yr seems reasonable for Manasota Key. Roughly 56,000 cy/yr transports into Stump Pass.

Charlotte County

Charlotte County extends from the lower section of Manasota Key to the northern portion of Gasparilla Island. The sediment budget represents Charlotte County with four cells: cells 63, 32, 33, and 34. Figure 7 presents the cells and sediment budget for Charlotte County. Following this figure, the text explains the values associated with each cell based on the literature available.

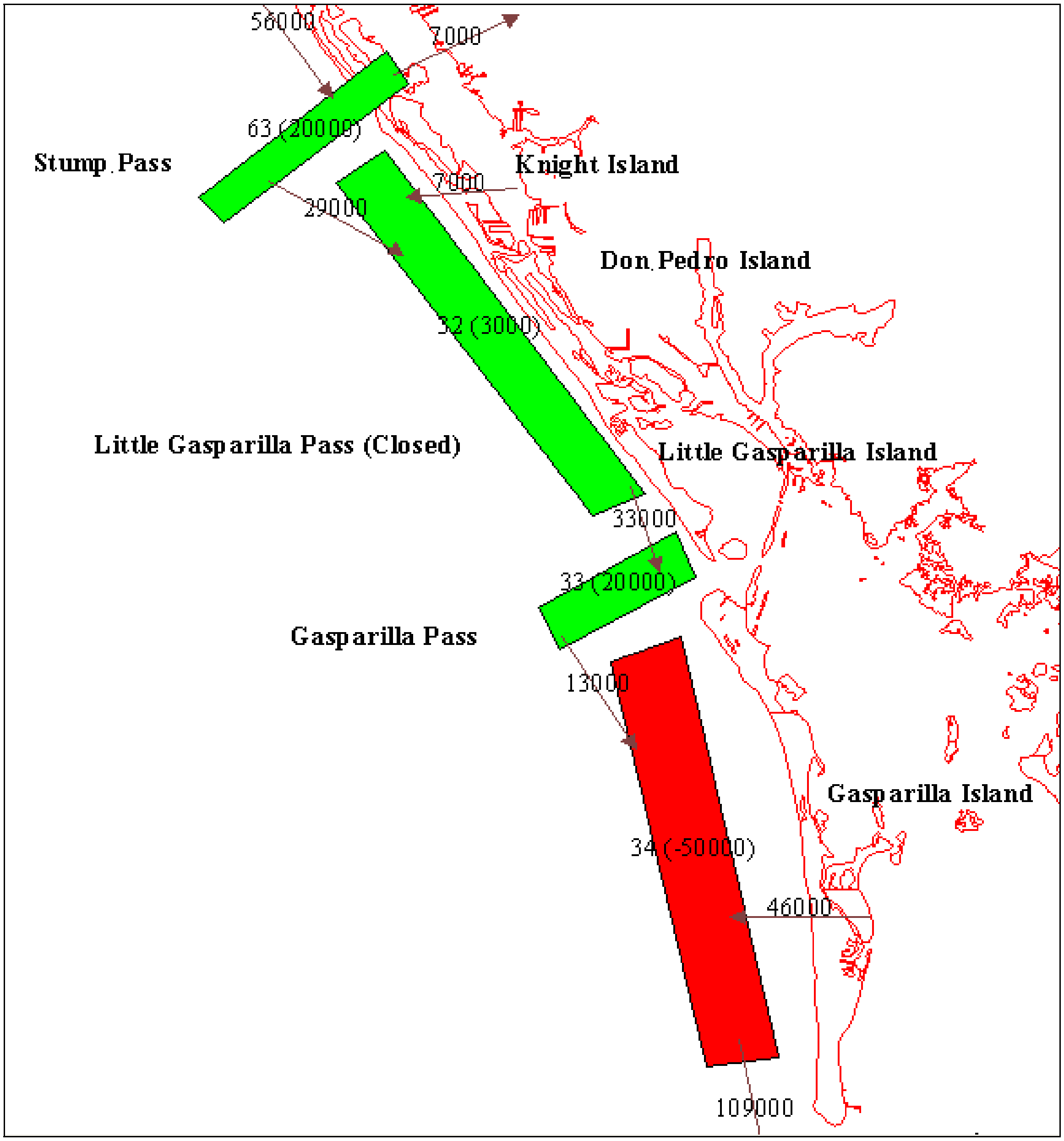

Figure 7. Charlotte County Sediment Budget

This section concludes with Table 5 that summarizes the cell location and volume change for each cell in Charlotte County.

Table 5. Summary of Cell Location and Volume Change for Charlotte County

Cell Number	Location	Volume Change (cy/yr)
63	Stump Pass	20,000
32	Knight Island/Don Pedro Island	3,000
33	Gasparilla Pass	20,000
34	Gasparilla Island	-50,000

The first cell within Charlotte County represents Stump Pass (cell 63). Three dredging events occurred within Stump Pass: 140,000 cy removed in 1980 and unknown volumes removed in 1994 and 1998. Dividing the 1980 dredged volume over a 20-year period yields an approximate removal rate of 7,000 cy/yr. Stump Pass received sediment from the north end of Knight Island (USACE, 1980) in addition to the sediment received from Manasota Key. The combined northern transport from Knight Island with the southern transport from Manasota Island, yields an expected deposition of 30,000 cy/yr in Stump Pass (Dean, 1987). This would indicate an approximate change in volume of +20,000 cy/yr. A net transport of 29,000 cy/yr flows to Knight Island/Don Pedro Island.

Knight Island, which comprises the northern portion of Don Pedro Island (cell 32), received nourishments (volumes unknown) in 1994 and 1998. This sediment budget assumes a minimal placement amount of 7,000 cy/yr, which multiplied over a 30-year period would equate to the 1994 and 1998 nourishment projects consisting of 100,000 cy each. This supposition is strictly to indicate that nourishment occurred. Again, one should note that the actual volume of placement is unknown. The *Erosion Analysis Report, Task 1, Sarasota/Charlotte County Beach Study* reported a volume change of +3,000 cy/yr, a value that agrees with the extent of critical eroding areas along Knight Island and Bocilla Island and MHW shoreline change rates from 1974–1998. As discussed, the sediment budget assumes a net transport into Knight Island of 29,000 cy/yr. The combination of these values reduces the transport south to 33,000 cy/yr.

Gasparilla Pass (cell 33), similar to Stump Pass, receives sediment from both adjacent islands — a southern transport of 33,000 cy/yr from Knight Island/Don Pedro Island and a northern transport from the north end of Gasparilla Island. The net transport, however, is south shown in Figure 7. Gasparilla Pass (no dredging history) traps an estimated 20,000 cy/yr for the purposes of this sediment budget. This value is lower than an expected deposition of 50,000 cy/yr reported by Coastal Engineering Consultants (1991). The net transport south totals 13,000 cy/yr.

Gasparilla Island (cell 34), the last cell within Charlotte County, extends into Lee County. This island received four substantial nourishments from dredging of Boca Grande Pass. The four events, corresponding to an annual placement of 46,000 cy/yr, occurred in 1981, 1993, 1997, and 1998 – 1999 with volumes of 264,000 cy, 437,800 cy, 245,600 cy, and 445,000 cy. The USACE (1969) reported a -66,000 cy/yr volume change estimate for the southern five miles of Gasparilla Island from 1863–1967. MHW shoreline changes also indicate an overall eroding shoreline from 1974–1998 for the part of Gasparilla Island within Charlotte County and from 1972 – 1989 for the part of Gasparilla Island within Lee County. Therefore, a volume change of -50,000 cy/yr is assigned to the Gasparilla Island cell. An out flux of 109,000 cy/yr balances the cell.

Lee County

Lee County, composed of sixteen cells, extends from the southern portion of Gasparilla Island to Little Hickory Island. Figures 8–11 present the sediment budget for Lee County. The text following the figures indicates the sources of the values derived for the sediment budget. Table 6, found at the end of the section, summarizes the cell locations and volume changes for the cells of Lee County.

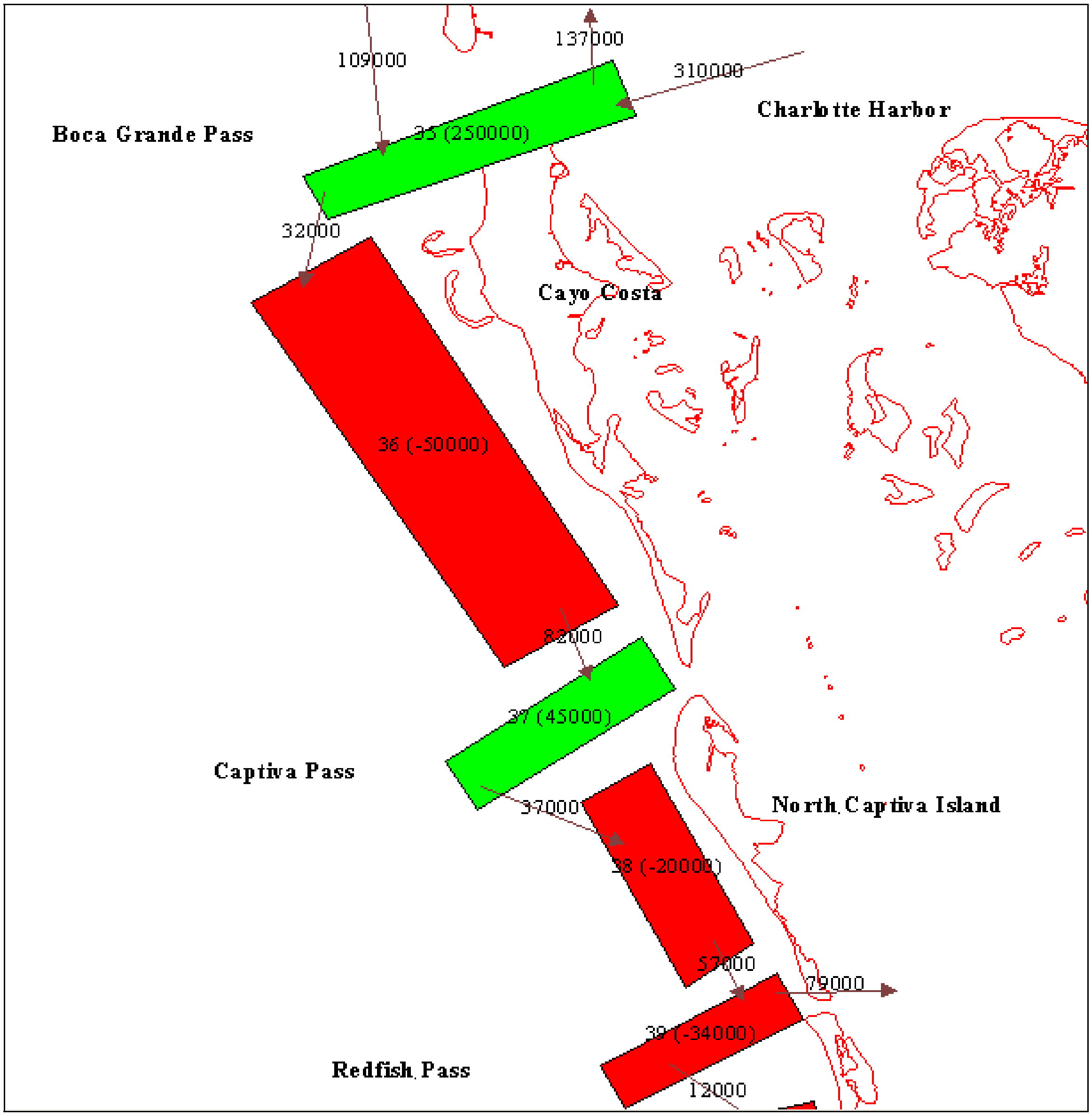

Figure 8. Northern Lee County Sediment Budget

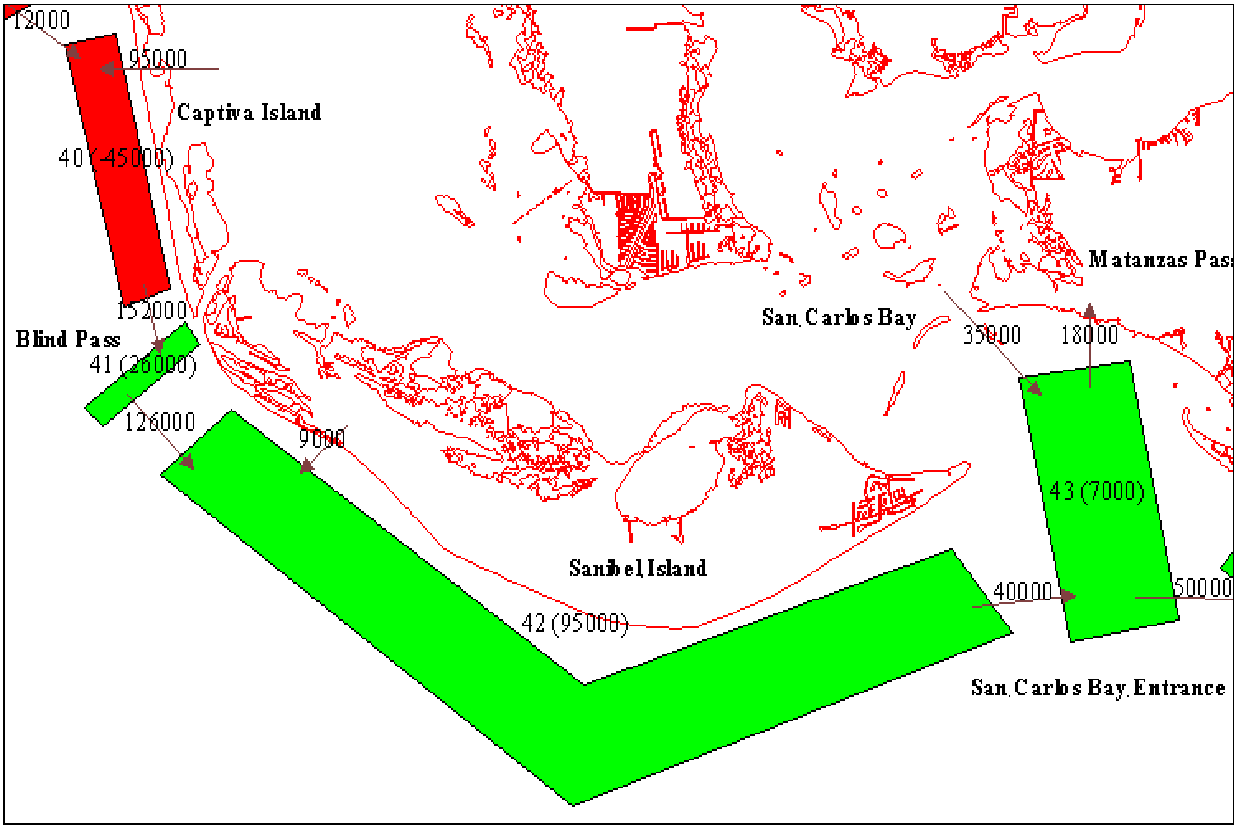

Figure 9. Sanibel Island Area of Lee County Sediment Budget

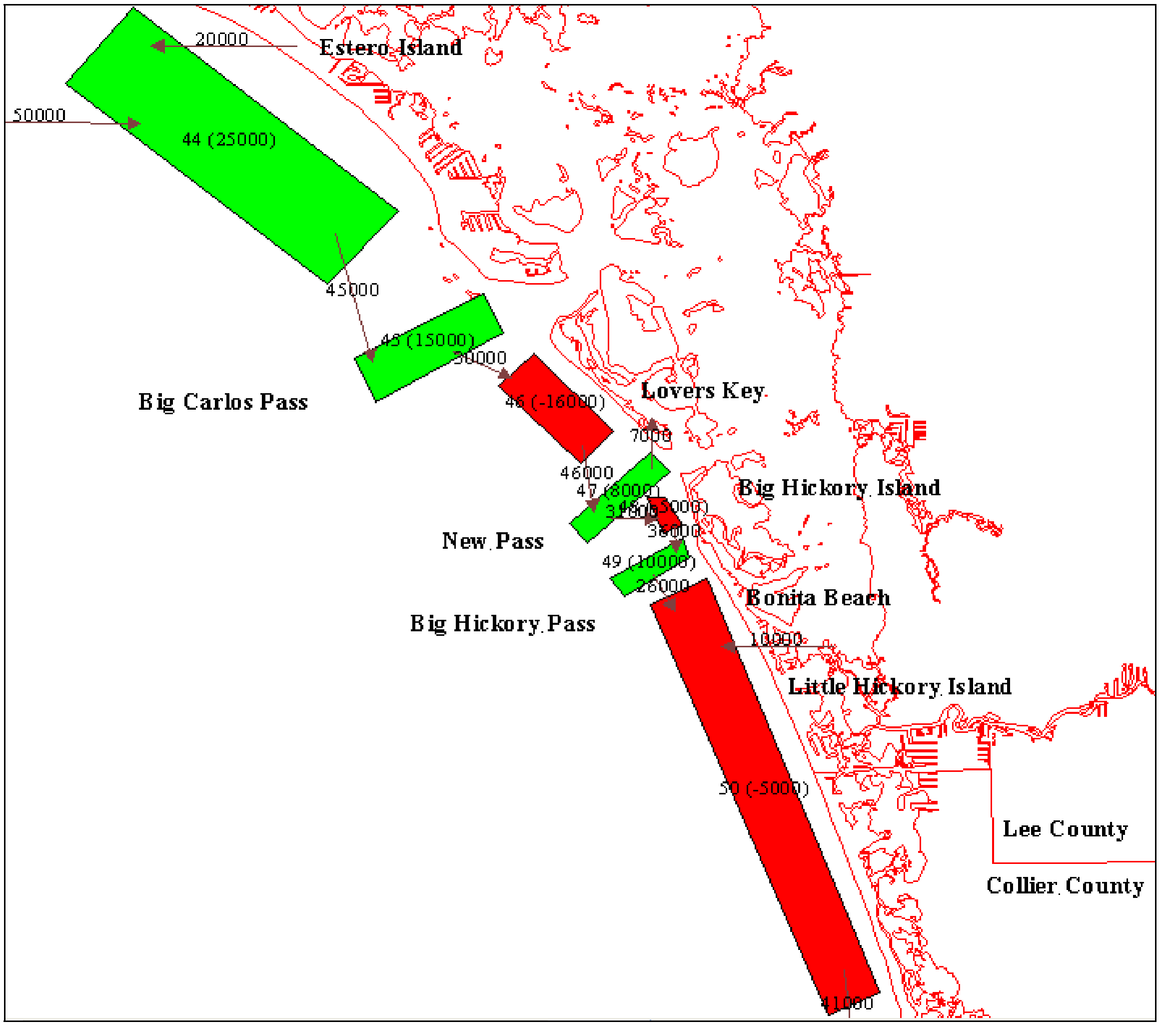

Figure 10. Southern Lee County Sediment Budget

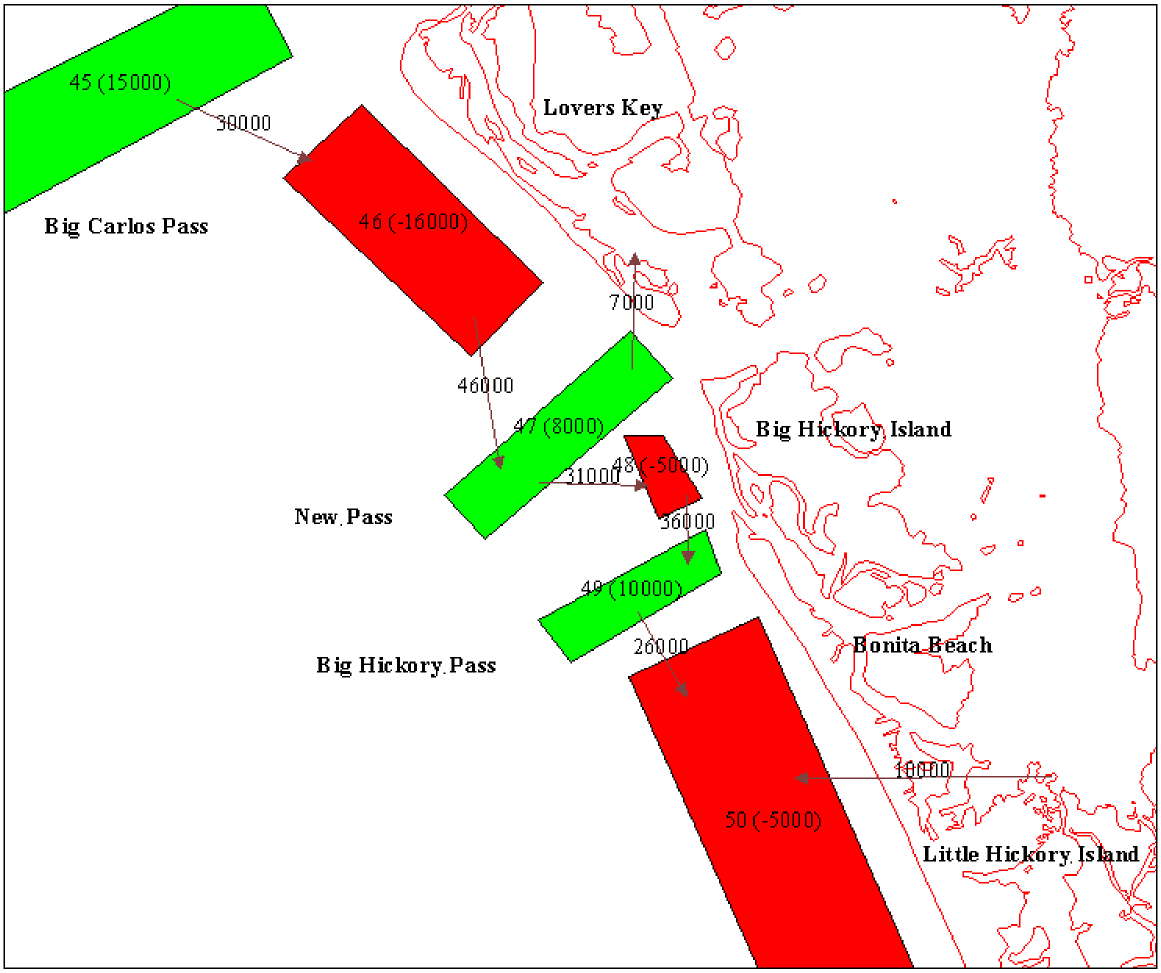

Figure 11. Enlargement of SBAS Sediment Budget Around New Pass and Big Hickory Pass

Table 6. Summary of Cell Location and Volume Change for Lee County

Cell Number	Location	Volume Change (cy/yr)
35	Boca Grande Pass	250,000
36	Cayo Costa	-50,000
37	Captiva Pass	45,000
38	North Captiva Island	-20,000
39	Redfish Pass	-34,000
40	Captiva Island	-45,000
41	Blind Pass (Lee County)	26,000
42	Sanibel	95,000
43	San Carlos Bay Entrance	7,000
44	Estero Island	25,000
45	Big Carlos Pass	15,000
46	Lovers Key	-16,000
47	New Pass (Lee County)	8,000
48	Big Hickory Island	-5,000
49	Big Hickory Pass	10,000
50	Bonita Beach/Little Hickory Island	-5,000

The first cell within Lee County represents Boca Grande Pass (cell 35), a Federally maintained inlet since its initial dredging in 1912. From 1970 to 2000, the annual dredging rate totaled 137,000 cy/yr. The majority of the dredged material was disposed of offshore with only 46,000 cy/yr placed on Gasparilla Island. The ebb shoal increased dramatically from 1883 and 1985 with an estimated volume change of +47,100,000 cy (Hine, 1986). This equates to an annual accretion rate of 460,000 cy/yr. As the shoal matures, one expects the shoaling rate to become lower. Assumed recent shoaling rates applied to the sediment budget, are approximately half of the 460,000 cy/yr reported — +250,000 cy/yr. In addition to the sediment received from Gasparilla Island, Boca Grande ebb shoal receives sediment from Charlotte Harbor. Approximately 310,000 cy/yr introduced to Boca Grande Pass balances the cell. The northern end of Cayo Costa supplies sediment to Boca Grande Pass, however the net transport from Boca Grande Pass is to the south at a value of 32,000 cy/yr. Estimated transport rates based on offshore wave studies suggest southern transport of 110,000 cy/yr (Walton, 1973).

The limited transport from Boca Grande Pass enters Cayo Costa cell — cell 36. The cell receives no additional sediment from nourishment. Early estimated volume changes indicate an accreting shoreline. A 1909–1985 investigation indicates a volume change of +232,000 cy/yr over the 22,000 ft south of Boca Grande Pass (Dean, 1987). A USACE report (1969) indicates a net gain of 94,000 cy/yr from 1927–1961. However more recent data (Hine, 1987 and FDEP shoreline changes) reflect overall erosion. Therefore, the Cayo Costa cell reflects an assumed volume change of -50,000 cy/yr. Southern transport out of the cell equals 82,000 cy/yr.

The volume change associated with Captiva Pass, cell 37, varies in the literature. A review of the ebb shoal contours from 1883 to 1982 suggest a gain of +3,770,000 cy — an annual value of +38,000 cy/yr (Hine, 1986). Coastal Engineering Consultants (1991) reports an expected deposition within the inlet of 70,000 cy/yr. *Redfish Pass Inlet Management Plan* (CPE, 1992) describes Captiva Pass as stable over the last 100 years. Based on these varying reports and the lack of dredging in the inlet, the sediment budget assumes a volume increase of 45,000 cy/yr. The literature indicates some degree of northern transport from North Captiva Island into Captiva Pass. Coastal Planning and Engineering (1992) recorded a northern transport of 25,000 cy/yr from 1988– 989. As variations in transport are known to occur (Hine, 1987; Dean, 1987), the sediment budget assumes a lower average transport north for the 30-yr period reflected in the net southern transport of 37,000 cy/yr to North Captiva Island. The reported, estimated littoral drift ranges from 38,000 cy/yr (CPE, 1992) to 100,000 cy/yr (CEC, 1991; Dean, 1987).

North Captiva Island's only sediment source comes from the southern transport of sediment from Captiva Pass; nourishment of North Captiva Island (cell 38) has never occurred. The *Redfish Pass Inlet Management Plan* (CPE, 1992) reports an estimated volume change from 1970 – 1994 of -20,000 cy/yr, which leaves 57,000 cy/yr transported south.

Cell 39 represents Redfish Pass, opened by a hurricane in the early 1920s. This cell receives sediment from North Captiva Island and the northern end of Captiva Island, transports sediment south to Captiva Island, experiences a volume change of -34,000 cy/yr, and shows a loss of 79,000 cy/yr due to dredging. Dredging in Redfish Pass provided sand for two Captiva Island nourishment projects — dredging removed 765,000 cy from the ebb shoal in 1981 and

1,595,000 cy in 1988–1989. The cell shows a volume change of -34,000 cy/yr determined by subtracting the sediment lost due to dredging from the expected annual deposition of 45,000 cy reported by Coastal Engineering Consultants (1991). CPE reported a northern transport from Captiva Island of 11,000 cy/yr from 1988–1989 to the Redfish Pass cell. Although the sediment budget does not show this northern transport, the limited net southern transport of 12,000 cy/yr reflects this value. Estimated values of sediment transport from Redfish Pass range from 60,000 to 138,000 cy/yr (CPE, 1992).

Cell 40, Captiva Island, received four nourishments between 1970 and 2000. Given the unknown volume placed during the 1996 nourishment, determining the rate of sediment placement required dividing the total volume (2,372,000 cy) from the 1981, 1985, and 1988 – 1989 nourishments by a 25-year period. This resulted in an annual nourishment rate of 95,000 cy/yr with an associated volume change of approximately -45,000 cy/yr from 1970 to 1991 (CPE, 1992). However, MHW shoreline change suggests a slightly accreting shoreline from 1972 to 2000. As described above, this cell shows a northern transport of 11,000 cy/yr out of the cell. Balancing the cell requires a southern transport of 152,000 cy/yr.

Blind Pass, opened by Hurricane Donna in 1960, has frequently closed and reopened during its brief history. Although never dredged, the inlet features a north jetty, constructed in 1972 and extended in 1988, to control erosion of Captiva Island. Currently, the inlet is closed. However, historically, the reported ebb shoaling rates range between 24,000 cy/yr and 28,000 cy/yr (CPE, 1992). The ebb shoaling rate, combined with an estimated flood shoaling rate of 2,000 cy/yr (CPE, 1992), gives a total volume change of +26,000 cy/yr. A transport rate of 126,000 cy/yr leaves Blind Pass (cell 41) to Sanibel Island (cell 42).

Sanibel Island traps much of the littoral transport from the north. It experiences an annual accretion rate of approximately +95,000 cy/yr as determined from volume change rates reported in *Blind Pass Inlet Management Plan – Draft* and *Captiva Island Beach Nourishment Project Monitoring Report*. MHW shoreline changes confirmed the reported accretion rate. Nourishment activity occurred on the northern portion of Sanibel Island in conjunction with the 1996 Captiva Island nourishment (volumes unknown). The nourishment project extended from R110-R114 and

R129-R132, for an estimated project length of 7,000 ft. The project, then, required 280,000 cy of sand given an assumed average nourishment rate of 40 cy/ft over the estimated project length. This results in an annual nourishment rate of approximately 9,000 cy/yr over 30 years. An estimated out flux of 40,000 cy/yr balances the cell.

San Carlos Bay Entrance, cell 43, receives sediment from Sanibel Island to the west, San Carlos Bay to the north, and Estero Island to the east. San Carlos Bay supplies an assumed 35,000 cy/yr, and Estero Island supplies approximately 22,000 cy/yr (USACE, 1969). Because the net transport is to the south, the sediment budget does not directly reflect this value. Based on three events, dredging removes an average 18,000 cy/yr from San Carlos Bay, including Matanzas Pass. Given unknown volumes from the 1998 dredging, the total volume dredged of 441,000 cy through 1995 was divided over a 25-year interval. The downdrift shoreline of Estero Island received the majority of the sediment. The estimated volume change totals +7,000 cy/yr derived from an approximate +25,000 cy/yr of deposition minus the annualized dredging volume of 18,000 cy/yr. Volume changes and fluxes require southerly transport of 50,000 cy/yr. Reported net littoral transport rates range from 35,000 cy/yr north (Dean, 1987) and 84,000 cy/yr south (CEC, 1991).

The sediment from San Carlos Bay Entrance flows south to Estero Island, cell 44. Here, Estero Island traps much of sediment, approximately 25,000 cy/yr. This value reflects recent MHW shoreline change rates and sediment needs in adjacent cells. Historic volume changes (1866–1967) indicate severe erosion, as much as -138,000 cy/yr (USACE, 1969). Estero Island receives approximately 20,000 cy/yr of sediment from nourishment. This value includes nourishments in 1979–1980 and 1986. The literature cites evidence of a 1998 nourishment (FDEP, 2000) but does not report volumes. For this reason, a 25-year period determined the annual rate of nourishment. As mentioned in the discussion of San Carlos Bay Entrance, Estero Island supplies some sediment to the north. A net south transport of 45,000 cy/yr must leave from Estero Island to balance the cell.

Big Carlos Pass (cell 45), a non-maintained inlet, receives the sediment from Estero Island. The ebb shoal contours from 1889–1982 indicate a shoaling rate of +35,000 cy/yr (Hine, 1986). If the shoal has stabilized somewhat since its initial development, deposition should decrease. Thus the sediment budget assumes an estimated volume change of +15,000 cy/yr. The resulting volume available to leave the cell totals 30,000 cy/yr.

From Big Carlos Pass, littoral drift encounters Lovers Key (cell 46). Bodge (1994) suggests an eroding shoreline of -16,000 cy/yr, an erosion rate similar to the -19,000 cy/yr estimated from MHW shoreline changes. As Lovers Key has received no nourishment, a balanced cell requires 46,000 cy/yr transported south from the cell.

New Pass, cell 47, draws sediment from both Lovers Key to the north and Big Hickory Island to the south. The northern transport from Big Hickory Island has resulted in a northern migration of the island. Bodge (1994) reports an accretion rate of 42,300 cy/yr on the north end of Big Hickory Island from northern transport of sediment, as well as a shoaling rate of 57,700 cy/yr within New Pass. The volume change associated with the New Pass cell assumes Big Hickory Island's northern migration value of 42,300 cy/yr is included in the shoaling rate value of 57,700 cy/yr, such that the ebb shoal experiences a net volume change of +15,000 cy/yr. The dredging rate of 7,000 cy/yr subtracted from the effective volume change of +15,000 cy/yr arrives at an estimated volume change of +8,000 cy/yr. (A 1994 removal of 198,000 cy determines the 7,000 cy/yr dredging rate.) Despite the northern transport from Big Hickory Island, a net transport south from New Pass of 31,000 cy/yr occurs.

The northern migration of Big Hickory Island (cell 48), experienced during the period of interest, makes estimations of volume change difficult. A 1979–1990 study reports a loss of 21.2 acres along the Gulf shorefront and a gain of 19.2 acres on the north end into New Pass (Bodge, 1994). Erosion along the southern tip of Big Hickory Island during different periods from 1970–1990 ranged from 18,000 to 69,000 cy/yr (Bodge, 1994). Reported accretion at the northern end of the island totaled as much as 42,000 cy/yr. Due to the variation in reported accretion and erosion rates, the sediment budget assumed a volume change of -5,000 cy/yr for the Big Hickory Island cell. Big Hickory Island has received no sediment from nourishment. Therefore, the available sediment for transport into Big Hickory Pass totals 36,000 cy/yr.

Big Hickory Pass competes for conveyance with New Pass. Because of New Pass's growing dominance, Big Hickory Pass has experienced frequent closures and openings. Dredging reopened the inlet two months after its first closure in September 1976. Beaches south of the inlet received the dredged material (volume unknown). Dredging again reopened the inlet nine years after another closure in January 1979. Again, beaches south of the inlet received the dredged material (volume unknown). Given unknown dredged volumes, for these events, this sediment budget does not reflect removal or placement rate estimates for the inlet or for the beaches south of the inlet. Rather, the volume change estimated for this cell reflects expected deposition of 10,000 cy/yr (CEC, 1991). Sediment flux of 26,000 cy/yr leaves the cell for Bonita Beach and Little Hickory Island.

The cell representing Bonita Beach and Little Hickory Island extends from Lee County into Collier County. This area has received several nourishments (some volumes unknown) between 1970 and 2000. From the available nourishment volumes, the cell received an estimated influx of 10,000 cy/yr of sediment from placement. The four known nourishment volumes consist of a 1990 project of 33,000 cy/yr and a 1991 project of 34,000 cy/yr that placed sediment between monument R13 and R14 in Collier County, a 1993 placement of 35,000 cy/yr on Wiggins State Park, and a 1995 placement of 198,000 cy/yr on Bonita Beach. A 1991 report indicates a fairly stable shoreline over the last 100 years (Foster, 1991). Also, volume change estimates for the four miles north of Wiggins Pass from 1970–1988 indicate slight erosion of approximately -5,000 cy/yr (CPE, 1995), the value associated with volume change in the sediment budget for the Bonita Beach/Little Hickory Island cell. The out-flux from this cell totals 41,000 cy/yr.

Collier County

Collier County is the final county investigated for the sediment budget of southwest Florida presented here. Figures 12-14 give the fourteen cells that comprise Collier County beginning with Wiggins Pass and ending with Cape Romano. The text details the sediment fluxes and volume changes associated with each cell. The section concludes with Table 7, which summarizes the volume change and location of each cell number.

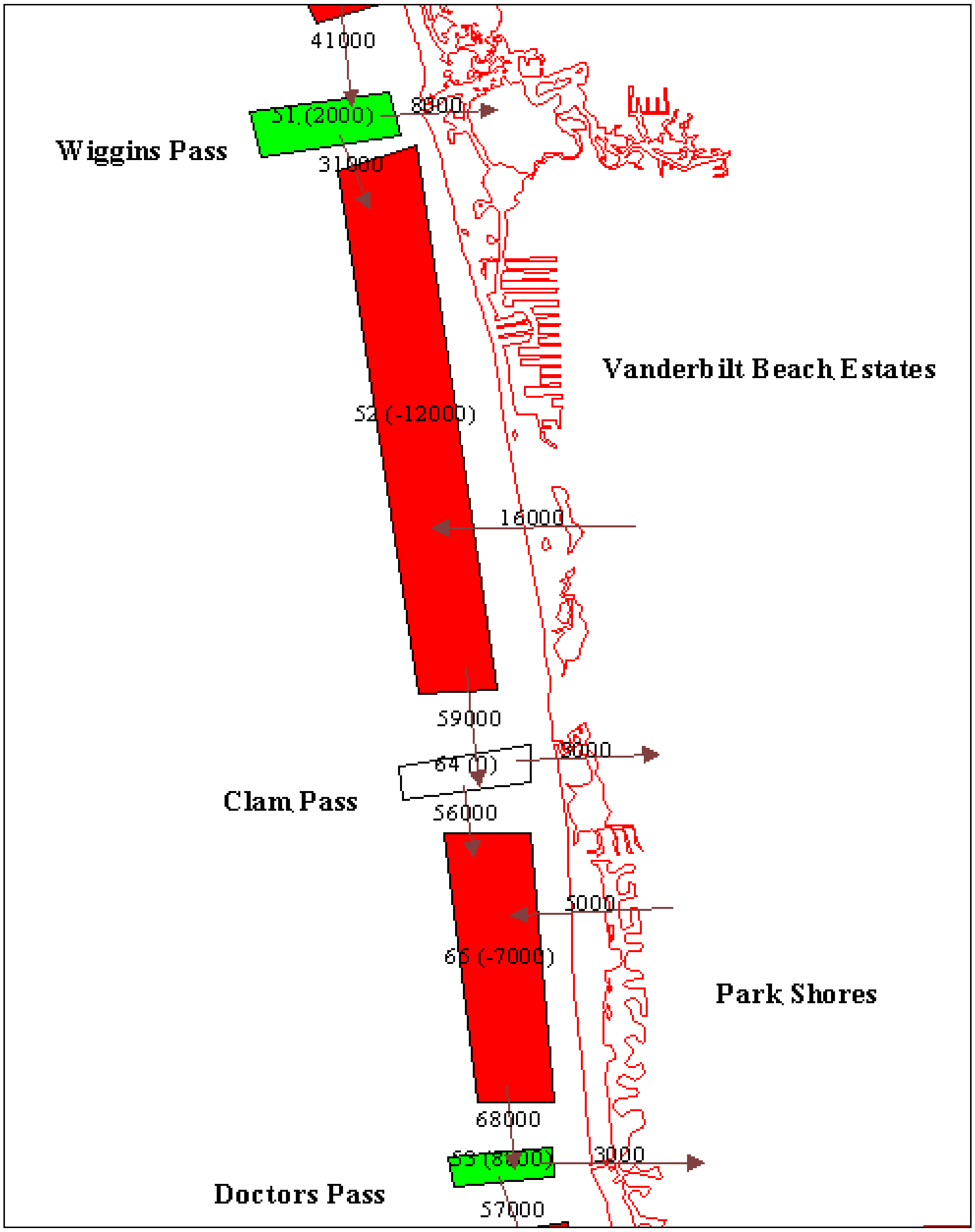

Figure 12. Northern Collier County Sediment Budget

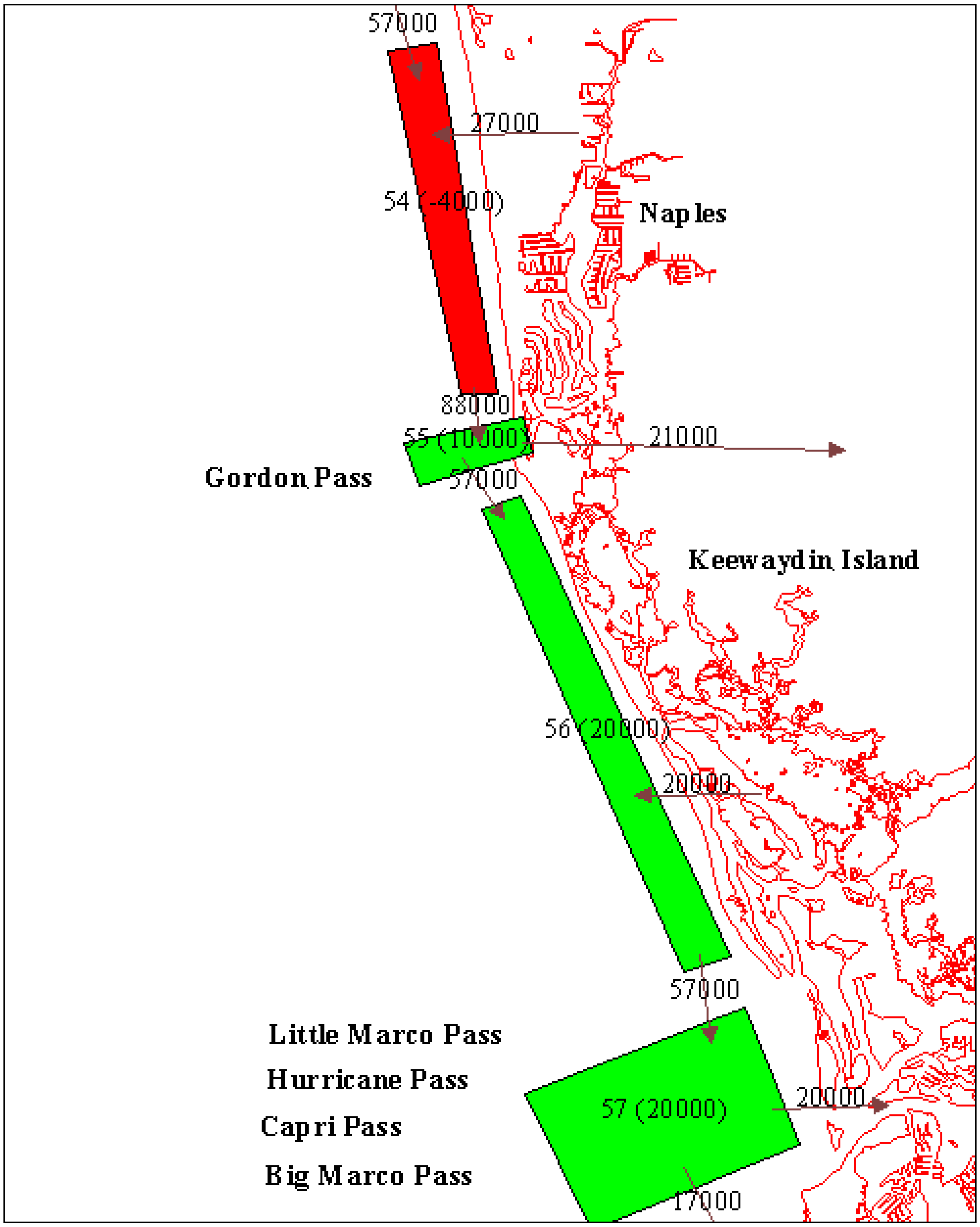

Figure 13. Middle of Collier County Sediment Budget

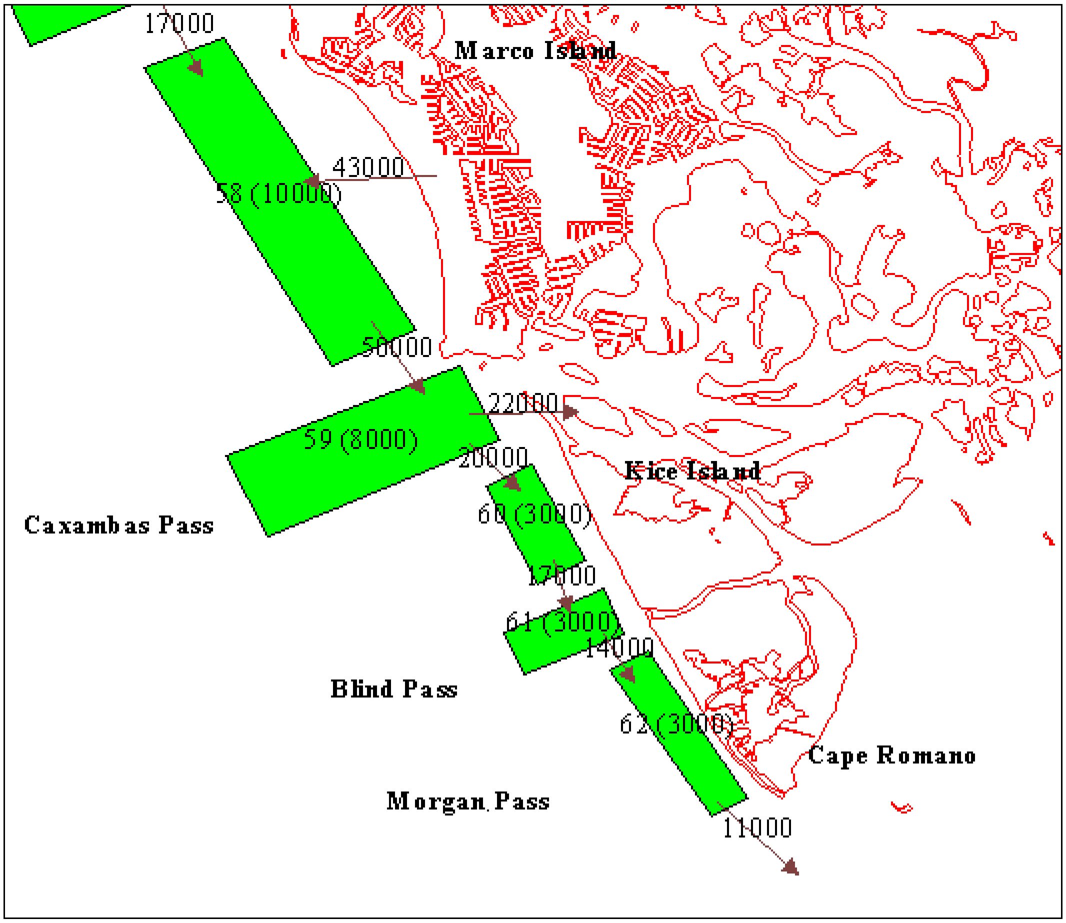

Figure 14. Southern Collier County Sediment Budget

Table 7. Summary of Cell Location and Volume Change for Collier County

Cell Number	Location	Volume Change (cy/yr)
51	Wiggins Pass	2,000
52	Vanderbilt Beach Estates	-12,000
64	Clam Pass	0
65	Park Shores	-7,000
53	Doctors Pass	8,000
54	Naples	-4,000
55	Gordon Pass	10,000
56	Keewaydin Island	20,000
57	Little Marco/Hurricane/Capri/Big Marco Pass	20,000
58	Marco Island	10,000
59	Caxambas Pass	8,000
60	Kice Island	3,000
61	Blind Pass (Collier County)	3,000
62	Cape Romano	3,000

Wiggins Pass (cell 51), the first cell in Collier County, experienced frequent closures before 1952. However, in 1952 the tidal prism increased 50% (Dean, 1987) and effectively stopped the closures. Wiggins Pass, first dredged in 1984, has received frequent, small volume dredging events. The annual removal rate totals approximately 8,000 cy/yr (CPE, 1995; Humiston and Moore, 1993). The volume change associated for Wiggins Pass totals approximately +2,000 cy/yr based on comparisons of ebb shoal surveys from 1978 to 1990 (CPE, 1995). Estimated transport rates south of Wiggins Pass range from 46,000 cy/yr to 86,000 cy/yr (Humiston and Moore, 1993; Dean, 1987; CEC, 1991). A calculated transport rate of 31,000 cy/yr balances the cell.

The next cell (cell 52) encompasses Vanderbilt Beach Estates. This area has received nourishment from Wiggins Pass dredging events as well as from offshore borrow site. The nourishment projects include a 1983–1984 placement of 48,000 cy from Wiggins Pass dredging, a 1993 placement of 35,000 cy also from a Wiggins Pass dredging, a 1995–1996 pay volume placement of 302,000 cy from an offshore site, and a 1995–2000 additional fill placement of 83,000 cy from dredging. The result is an annual placement rate of 16,000 cy/yr. The calculated volume change associated with Vanderbilt Beach Estates totals -12,000 cy/yr from USACE (1994) estimates of volume change. Therefore, the net transport out of the cell to Clam Pass totals 59,000 cy/yr.

Clam Pass (cell 64), similar to Big Hickory Pass, experienced several openings and closures. The two closings took place in 1976 and 1981. In both instances dredging opened the inlet and sand placement (volumes unknown) occurred on the southern beach. Between 1997 and 1999, Coastal Engineering Consultants (2001) reported the dredging of 46,000 cy/yr of sediment from Clam Pass and placement on the Park Shores beaches. Annualizing this value over a 14-year period gives an estimated removal rate of 3,000 cy/yr. The Clam Pass ebb shoal, insignificant in size (Dean, 1987), receives an estimated 3,500 cy/yr of sediment (CEC, 1991). For this sediment budget, the volume change associated with Clam Pass totals 0 cy/yr. A value of 56,000 cy/yr bypassed to the south balances this cell. Two literature sources give net southern littoral drifts on the order of 85,000 cy/yr (Walton, 1973; CEC, 1991).

Park Shores, cell 65, received 89,000 cy of sediment as part of the 1995 – 1996 renourishment project that included Vanderbilt Beach Estates and Naples. Nourishment between 1997 and 1999 added 46,000 cy of sediment. Based on these documented projects, the annual placement totals 5,000 cy/yr. The USACE (1994) reported an overall volume change of -7,000 cy/yr for Park Shores. Suboceanic Consultants, Inc. (1980) reported an accretion of 10,000 cy/yr north of Doctors Pass since 1968. This sediment budget assumes a volume change of -7,000 cy/yr. Thus, 68,000 cy/yr must leave the cell to achieve balance.

Littoral drift flows from Park Shores into Doctors Pass (cell 53). This inlet has experienced minimal dredging with only three reported events. The first removed 10,000 cy in 1984, the second removed 10,000 cy in 1989, and the third event dredged 76,000 cy in 1996. The annual removal rate due to dredging equals 3,000 cy/yr. Shoaling estimates range from 2,000 cy/yr to 8,000 cy/yr (Coastal Engineering Consultants, 1991; Suboceanic Consultants, 1980). The higher shoaling rate of 8,000 cy/yr, selected for this sediment budget, requires that 57,000 cy/yr leave the cell for Naples.

The 1995–1996 nourishment project with Vanderbilt Beach Estates and Park Shores included the Naples cell — cell 54. Monuments R58 to R78 received a total of 811,000 cy, and downdrift of the project area received 6,000 cy. This results in an annual placement volume of 27,000 cy/yr over a 30-year period. The volume change associated with the Naples cell totals approximately -4,000 cy/yr based on estimated volume changes of -15,000 cy/yr between monuments R58 and R74, -14,000 cy/yr between monuments R74 and R89 (USACE, 1994), and +25,000 cy/yr for the beach area north of Gordon Pass (Suboceanic Consultants, 1980). Estimations of transport south from Naples include 34,000 cy/yr, 50,000 cy/yr, and 86,000 cy/yr (USACE, 1994; Suboceanic Consultants, 1980). The calculated transport of 88,000 cy/yr required to balance this cell lies close to this range.

The USACE first dredged Gordon Pass (cell 55) in 1962 – 1963 when it became a Federal project. According to available dredging records, the USACE conducted four maintenance dredging events from 1970 to 2000. These included a 1970 removal of 181,000 cy, a 1979 – 1980 removal of 236,000 cy, a 1986 removal of 120,000 cy, and a 1993 removal of 95,000 cy. Therefore, the sediment budget reflects an annual dredging rate of 21,000 cy/yr from Gordon Pass. For comparison, the Database of Federal Inlets and Entrances, website http://cirp.wes.army.mil/cirp/inletsdb/inletsdbinfo.html, estimates an annual dredging volume of 48,000 cy/yr, while Suboceanic Consultants (1980) report needed maintenance dredging of 23,000 cy/yr. Estimated shoaling rates of 31,000 to 35,000 cy/yr (CEC, 1991; Suboceanic Consultants, 1980) combined with a maintenance dredging rate of 21,000-23,000 cy/yr, results in an approximated volume change of +10,000 cy/yr. As such, 57,000 cy/yr transports south to Keewaydin Island.

Because of its limited development, few studies focus on Keewaydin Island — cell 56. Therefore, the literature contains little information regarding accretion and erosion rates and trends for this cell. Keewaydin Island received approximately 20,000 cy/yr of nourishment from the bypassing of dredged material from Gordon Pass (Suboceanic Consultants, 1980). These nourishment events occurred in 1970 (140,000 cy), 1980 (235,000 cy), 1986 (120,000 cy), and 1993 (95,000 cy). The volume change of +20,000 cy/yr estimated for this cell reflects MHW shoreline change rates from 1972 to 1988. To balance the placement rate, influx from Gordon Pass, and volume change, this cell requires an out flux of 57,000 cy/yr.

The close proximity of Little Marco Pass, Hurricane Pass, Capri Pass, and Big Marco Pass to each other and the limited maintenance of the area allow one cell, cell 57, to represent these four inlets. Little Marco Pass and Hurricane Pass are not maintained and were never dredged. Now a Federal navigation project, Capri Pass — which opened naturally in 1967 — was dredged as part of the Marco Island nourishment project. The estimated deposition and transport south for these inlets totals 25,000 to 30,000 cy/yr and 71,000 cy/yr (CEC, 1991). Big Marco Pass, also a Federal project, contributed to the Marco Island Project along with Capri Pass and Caxambas Pass. The estimated removal volume from Big Marco Pass and Capri Pass totaled approximately 600,000 cy (CEC, 1991 and 1996), roughly half the total volume of the nourishment project. Dredging (volumes unknown) in Big Marco Pass occurred in 1997(FDEP, 2000). Given the unknown volumes, however, the estimated annual removal rate of 20,000 cy/yr does not reflect the 1997 event. The volume change in the ebb shoals of these inlets is difficult to approximate. As mentioned above, the reported, expected deposition rate for these inlets totals 25,000 to 30,000 cy/yr. The changes in ebb contours for Big Marco Pass indicate a loss in volume of 55,000 cy/yr. Thus, a volume change of +20,000 cy/yr seems reasonable. This leaves 17,000 cy/yr available for transport to Marco Island.

As indicated, Marco Island (cell 58) received an abundant amount of sediment in an attempt to control erosion. The estimated placement rate, 43,000 cy/yr, reflects nourishment records and monitoring reports. The volume change estimate for Marco Island proved difficult. MHW shoreline changes from 1971 to 2000 indicate substantial accretion along Marco Island. Part of the *Caxambas Inlet Management Plan* (CEC, 1996), a 1991 to 1995 monitoring effort at the southern end of Marco Island, indicated severe erosion. Based on these two conflicting trends, the cell reflects an assumed minimal volume change of +10,000 cy/yr. A southern transport rate necessary for a balanced cell totals 50,000 cy/yr. Historic and estimated transport rates range from 10,000 cy/yr to 46,000 cy/yr (CEC, 1996).

From Marco Island, littoral drift encounters Caxambas Pass. The Caxambas Pass ebb shoal supplied sediment for the Marco Island nourishment in 1991 and 1997. The estimated removal rate from these two projects totals 22,000 cy/yr. The expected deposition of Caxambas Pass of +30,000 cy/yr (CEC, 1991), combined with the annual removal of sediment due to nourishment projects, results in a volume change rate of +8,000 cy/yr. Therefore, 20,000 cy/yr becomes available for southerly transport to Kice Island. This value, although much lower than the estimated transport rate of 56,000 cy/yr south (CEC, 1991), agrees well with a modeled transport rate of 20,000 cy/yr south along Kice Island (CEC, 1996) and an estimated rate of 28,300 cy/yr by Humiston and Moore (CEC, 1996).

The remaining three cells (cells 60-62) of the sediment budget represent Kice Island, Blind Pass, and Cape Romano. For this area, the literature review found only the modeled transport rate of 20,000 cy/yr, mentioned above, along Kice Island. The sediment budget reflects an assumed volume gain of +3,000 cy/yr for each cell. With no dredging events or nourishment events present, the resulting transport south from Cape Romano totals 11,000 cy/yr.

Table 8 provides a summary of the volume changes for each cell comprising the southwest Florida sediment budget. Given a lack of data and periods of coverage that did not necessarily coincide, the sediment budget represents a “best guess” effort based on the available data. It does indicate the areas of needed data coverage and consolidates much of the current literature and data available on dredging and nourishment activity along the southwest coast of Florida from Pinellas through Collier County.

Table 8. Summary Table of Volumetric Change for Each Cell

Cell Number	Location	Volume Change (cy/yr)
1	Honeymoon Island	50,000
2	Hurricane Pass (Pinellas County)	2,000
3	Caladesi Island	25,000
5	Clearwater Island	50,000
6	Clearwater Pass	35,000
7	North Sand Key	74,000
8	Middle Sand Key	60,000
9	South Sand Key	-25,000
11	Treasure Island	25,000
12	Blind Pass (Pinellas County)	-5,000
13	Long Key	60,000
14	Johns Pass	10,000
15	Dunedin Pass	-160,000
16	Egmont Key	-140,000
17	Mullet Key	50,000
18	Tampa Harbor	-1,255,000
19	Pass-a-Grille Channel/ South Channel/ Bunces Channel	40,000
20	Anna Maria Key	40,000
21	Egmont Channel	-638,000
22	Longboat Pass	-33,000
23	Longboat Key	70,000
24	New Pass (Sarasota County)	-26,000
25	Lido Key	25,000
26	Big Sarasota Pass	45,000
27	Siesta Key	10,000
28	Casey Key	20,000
29	Venice Inlet	2,000
30	Manasota Key	20,000
32	Knight Island/Don Pedro Island	3,000
33	Gasparilla Pass	20,000
34	Gasparilla Island	-50,000
35	Boca Grande Pass	250,000
36	Cayo Costa	-50,000

Table 8 (continued). Summary Table of Volumetric Change for Each Cell

Cell Number	Location	Volume Change (cy/yr)
37	Captiva Pass	45,000
38	North Captiva Island	-20,000
39	Redfish Pass	-34,000
40	Captiva Island	-45,000
41	Blind Pass (Lee County)	26,000
42	Sanibel	95,000
43	San Carlos Bay Entrance	7,000
44	Estero Island	25,000
45	Big Carlos Pass	15,000
46	Lovers Key	-16,000
47	New Pass (Lee County)	8,000
48	Big Hickory Island	-5,000
49	Big Hickory Pass	10,000
50	Bonita Beach/Little Hickory Island	-5,000
51	Wiggins Pass	2,000
52	Vanderbilt Beach Estates	-12,000
53	Doctors Pass	8,000
54	Naples	-4,000
55	Gordon Pass	10,000
56	Keewaydin Island	20,000
57	Little Marco/Hurricane/Capri/Big Marco Pass	20,000
58	Marco Island	10,000
59	Caxambas Pass	8,000
60	Kice Island	3,000
61	Blind Pass (Collier County)	3,000
62	Cape Romano	3,000
63	Stump Pass	20,000
64	Clam Pass	0
65	Park Shores	-7,000
66	Egmont Ebb Shoal	170,000
67	Midnight Pass	-20,000
68	Southwest Channel/Passage Key Inlet	170,000

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