3.0 AFFECTED ENVIRONMENT

The Project Area consists of 1.9 miles of beach within the Town of Palm Beach, Florida immediately south of Sloan's Curve. Three miles north of the Project Area between Sloan's Curve and Mid-Town Beach, the shoreline has a variety of armoring structures including rock revetments, seawalls, and groins. The combined effects of these structures and the construction of the jetties at Lake Worth Inlet in 1925 have caused a longshore transport deficit to the Project Area, which has resulted in erosion and exposure of nearshore hardbottom.

3.1 Coastal Environment

In general, beach erosion is attributable to wave induced transport of beach sediments either across the beach to the offshore region (cross-shore) or along the shoreline (longshore) to adjacent beaches. During storms, a beach is shaped by cross-shore wave-induced transport towards a condition in equilibrium with the waves and water level. Waves that approach the shoreline at an angle will induce longshore transport proportional to the square of the wave height (USACE, 1984). For any segment of beach, if more sand is transported out of the segment than into the segment, the beach will erode. Comparably, if more sand is transported into the segment than out of the segment, the beach will accrete.

The Bahama Banks partially shelter the Town and southeast Florida from east and southeast waves. As a result of the influence of the Bahama Banks, waves from the north and northeast dominate sediment transport in the region. Lake Worth Inlet is located at the northern boundary of the Town. Construction of the Inlet jetties in 1925 and the dominant southward flowing longshore sediment transport resulted in sediment accumulation against the Inlet's north jetty. This condition deprived the downdrift beaches of sand, created a longshore transport sediment deficit and caused erosion of the beaches (Dombrowski and Mehta, 1993).

Erosion of the beaches within the Town of Palm Beach is primarily attributable to a longshore sediment transport deficit caused by artificial and natural interruption of longshore transport. Erosion caused by Lake Worth Inlet prompted construction of groins, seawalls, and revetments. These structures further deprive the downdrift beaches of sand, translate the longshore deficit and cause downdrift erosion. In addition, erosion has exposed natural-rock-headland features, which also translates the longshore transport deficit to downdrift beaches. The following sections of this document address the sediment budget from Lake Worth Inlet to South Lake Worth Inlet and demonstrate the translation of the longshore sediment transport deficit to downdrift beaches between these inlets.

Figure 3.1 illustrates the configuration of the shoreline and fill areas, as proposed by the Town of Palm Beach, from Lake Worth Inlet to South Lake Worth Inlet.

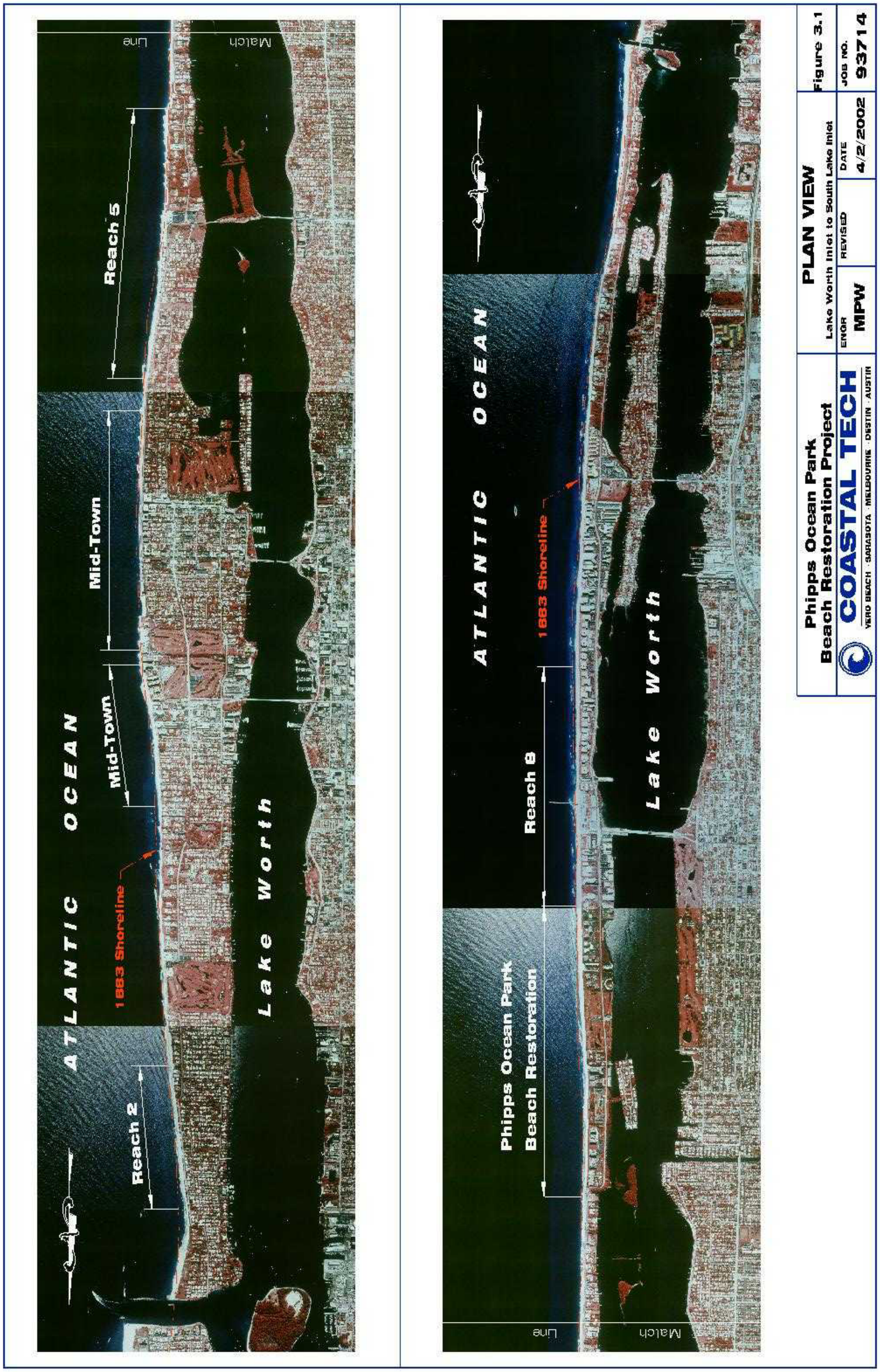
Match Line
Reach 5
Mid-Town
Mid-Town
ATLANTIC OCEAN
1883 Shoreline
Lake Worth
Reach 2
Reach 8
Phipps Ocean Park
Beach Restoration
Phipps Ocean Park
Beach Restoration Project
COASTAL TECH
VERO BEACH · SARASOTA · MELBOURNE · DESTIN · AUSTIN
PLAN VIEW
Lake Worth Inlet to South Lake Inlet
ENGR
MPW
REVISED
DATE
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Figure 3.1
JOB NO.
93714

3.1.1 Tides

The FDEP, formerly the Department of Natural Resources (DNR), has identified predicted tidal datums for Florida's east coast including the Palm Beach shoreline (DNR, 1987). FDEP has identified a Mean High Water (MHW) elevation of 1.92 feet NGVD and a Mean Low Water (MLW) elevation of -1.02 feet NGVD at reference DNR Monument R-76 immediately south of Lake Worth Inlet. This corresponds to a normal tidal range of 2.94 feet. FDEP has identified a MHW elevation of 1.89 feet NGVD and a MLW elevation of -0.95 feet NGVD at reference DNR Monument R-151 about 300 feet south of South Lake Worth Inlet. This corresponds to a normal tidal range of 2.84 feet.

3.1.2 Storm Surges

Storm surge entails a rise in the ocean surface above its normal level during a storm. Under these conditions, the beach and dune are subject to erosion as the storm shapes the shoreline towards a condition of equilibrium with the wave and sea level conditions. Storms and storm surges are commonly described by their return interval, probability of occurrence, and the expected maximum elevation of the ocean surface during the storm. The return interval prescribes the interval of time in which a storm is expected to occur, on average, over a long period of time. The probability of occurrence represents the probability that the storm will occur in any given year. The probability of occurrence is defined by the inverse of the return interval. For example, a 100-year return interval storm has a 1% probability of occurrence in any given year. State and federal agencies have developed storm surge predictions for Palm Beach County as summarized in Table 3.1 (USACE, 1992).

Table 3. 1 Predicted Peak Storm Surge (ft MSL)

Return Period (yrs)	Probability of Occurrence	University of Florida	NOAA	Flood Insurance Study
5	20%	5.1	------	------
10	10%	6.3	5.9	6.2
20	5%	7.9	7.3	-----
50	2%	10.0	9.4	8.9
100	1%	11.9	11.1	10.2

The last hurricane to directly impact the Town or Palm Beach County was Hurricane David on 9 September 1979, with winds reported at up to 110 mph. The storm passed near the northern end of Palm Beach County and did not cause extensive damage (USACE, 1987).

3.1.3 Currents

The Florida Current flows north about one mile offshore of the Town of Palm Beach. Current velocities have been measured at up to 8.2 ft/sec. Wave induced longshore currents have been measured at up to 7.5 ft/sec at Lake Worth Pier (USACE, 1987).

3.1.4 Waves

The USACE's Waterways Experiment Station conducted a shallow water wave hindcast study (WIS Report No. 9) including the nearshore waters fronting Palm Beach Island (USACE, 1992). The shoreline of Palm Beach Island is dominated by significant waves from the north and northeastern sectors (Figure 3.2).

In conjunction with the 1996 Coast of Florida Study, nearshore wave data were collected at Lake Worth and Hallandale, Florida over approximately fifteen months between 1989 and 1991. This data indicate a mean significant wave height of 1.6 feet at Lake Worth and 2.0 feet at Hallandale for this period in which the dominant wave directions were from the east and northeast (USACE, 1994).

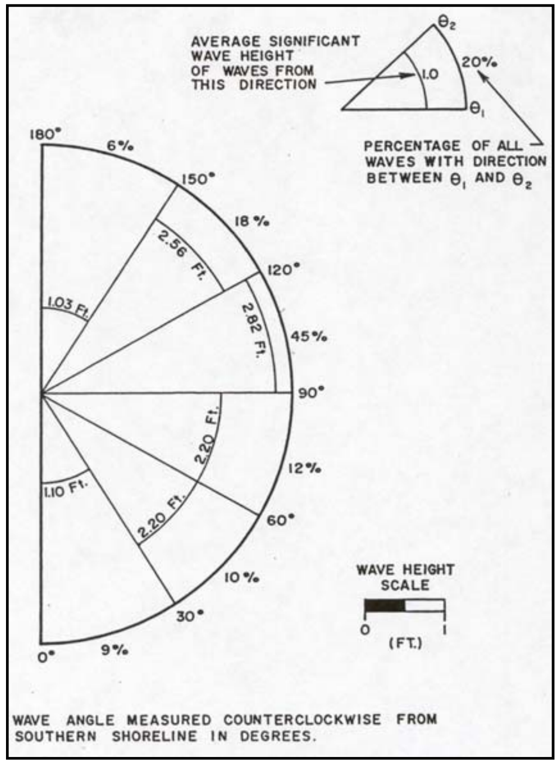


Figure 3.2 Shallow Water Wave Data for Station 158 Adjacent to Palm Beach, FL

3.2 Beach and Inlet Geomorphology

Inlets are documented to have a significant adverse impact upon adjacent downdrift beaches (Walther, 1989). Inlets are recognized as sediment sinks where net longshore transport is interrupted and littoral sediments are deposited within an updrift fillet, within the inlet channel and/or flood tidal delta, and within an ebb tidal delta (NRC, 1995).

Lake Worth Inlet is located at the northern limits of Palm Beach Island and constitutes a significant sediment sink that has directly caused significant erosion on Palm Beach Island (ATM 1998; Coastal Tech, 2000). With dominant wave energy and associated longshore transport to the south, the influence of Lake Worth Inlet dominates the littoral processes of Palm Beach Island.

The FDEP has designated the 10.9 miles of shoreline south of Lake Worth Inlet (DNR Monument R-76 to R-128) as an area of critical erosion. An additional 0.7 mile segment (DNR Monument R-133.5 to R-136.65) is also designated as critical (FDEP, 2001). The FDEP defines critical erosion as:

> *"Critical erosion area is a segment of the shoreline where natural processes or human activity have caused or contributed to erosion and recession of the beach or dune system to such a degree that upland development, recreational interests, wildlife habitat, or important cultural resources are threatened or lost. Critical erosion areas may also include peripheral segments or gaps between identified critical erosion areas which, although they may be stable or slightly erosional now, their inclusion is necessary for continuity of management of the coastal system or for the design integrity of adjacent beach management projects."*

3.2.1 Geomorphic Setting of Palm Beach Island

Florida is located on the Floridian Plateau, which separates the deep waters of the Atlantic and the Gulf of Mexico. This plateau is tilted along its longitudinal axis such that the east coast of Florida is elevated relative to the west coast (USACE, 1994).

The seaward edge of the marine terrace is located close to Palm Beach Island (Figure 3.3) (Randazzo and Jones, 1997). Water depths of 66 feet exist within about 5,500 feet of the shoreline (USC&GS, 1986). These conditions allow for long period deepwater waves from the north and northeast to impact the shoreline on Palm Beach Island.

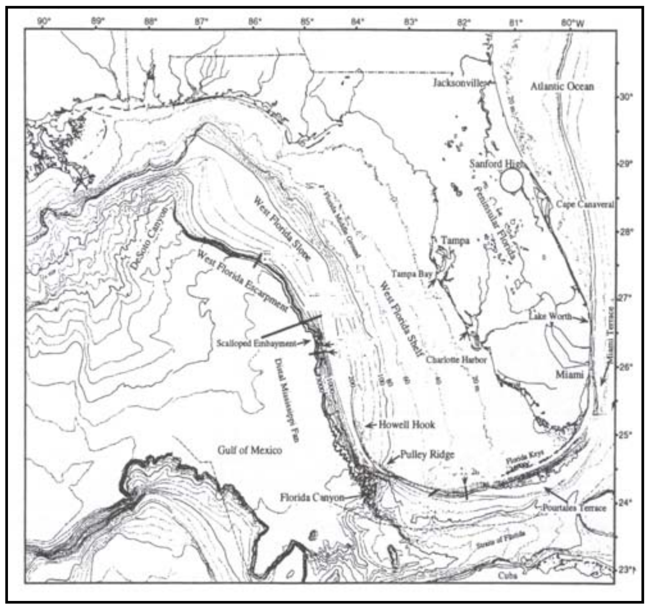


Figure 3.3 The Floridian Plateau

Florida's east coast beaches are typically anchored by the underlying Pleistocene Anastasia Formation (Randazzo and Jones, 1997). This rock formation appears as a submerged reef (hardbottom) roughly parallel to and along the shoreline of Palm Beach Island. The formation is emergent at several points near Phipps Ocean Park and the Lake Worth Pier. As is common in other areas of Florida's east coast, the emergent and intertidal rocky features of the Anastasia Formation act as a headland and translate any longshore transport deficit to downdrift beaches (Walther, 1995).

Much of the sediment on Palm Beach County beaches is silica quartz sand transported to the sea via Georgia and Carolina beaches and subsequently transported down the Florida peninsula by currents and wave action (USACE, 1994). Analysis of existing beach sediments indicates that about 50% of the sediments are carbonate or shell material.

3.2.2 Lake Worth Inlet Sediment Budget

Lake Worth Inlet is commonly called Palm Beach Inlet and forms the northern boundary of Palm Beach Island. Since the Inlet was created between 1918 and 1925, the Inlet has affected the surrounding beaches (Dombrowski and Mehta, 1993). In 1958, a sand transfer plant was constructed on the north side of the Inlet to provide for mechanical transfer of sand to the downdrift beaches. The sand transfer plant has not transferred sufficient quantities of sand to offset the downdrift erosion effects of the Inlet (ATM, 1995; Coastal Tech, 2000).

In 1995, the Town developed the "*Lake Worth Inlet Management Plan*" (ATM, 1995). This Plan estimates the Inlet's sediment budget for the period from 1974 to 1994 and recommends improvements to reduce downdrift erosion on Palm Beach Island. Improvements to the sand transfer plant were completed in 1996; although other recommended improvements have not been completed.

There are five sediment sink/loss areas (Coastal Tech, 2000) which capture or release sediment that migrates through the Lake Worth Inlet coastal domain in response to coastal processes and mechanical transfer:

(1) north beach
(2) ebb shoal
(3) south beach
(4) inlet throat
(5) flood shoal

Between 1998 and 2000, the Town conducted monitoring surveys of the Inlet domain. Based on these and previous surveys conducted in 1994, the Inlet's sediment budget was estimated for the period from 1994 to 2000. Regarding the Inlet's sediment pathways and cells, the Inlet's north beach, ebb shoal, throat, and flood shoal act as sediment sinks (Figure 3.4). USACE maintenance dredging and the sand transfer plant have partially offset Inlet impacts from 1994 to 2000.

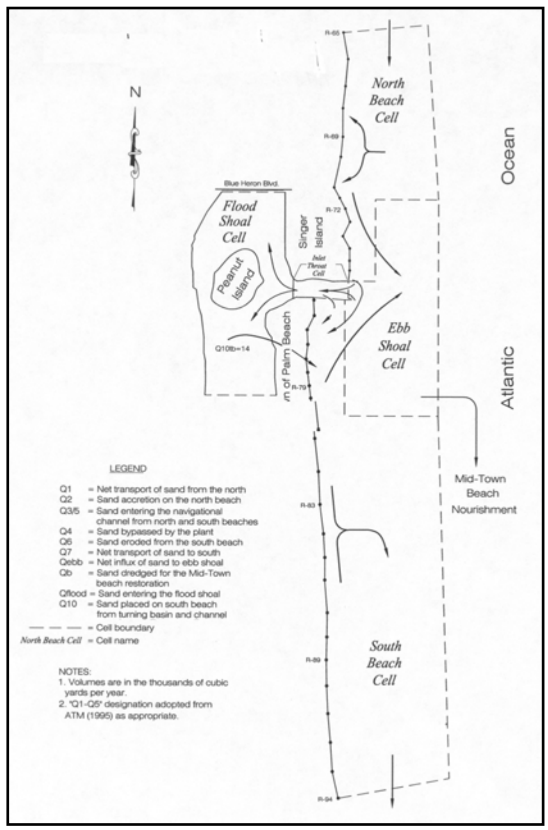


Figure 3.4 Lake Worth Inlet Sediment Budget Cells and Domain

The following summarizes the sediment budget of Lake Worth Inlet as estimated for the period from 1994 to 2000.

North Beach: Based solely on the surveys, the volume changes on the north beach averaged a loss of approximately 25,100 cy/yr. The average annual volume of mechanical transfer at the sand transfer plant was 182,100 cy/yr during this period. Plant operation was restarted in May 1996 after being shutdown in 1990. Based on the surveys and transfer data, about 157,000 cy/yr are estimated to deposit on the north beach.

Inlet Throat: Surveys of the Inlet throat indicate this reservoir lost approximately 1,600 cy/yr. A survey of the Inlet throat was not performed in 1999 and therefore no data are available for assessing the 1998 to1999 or 1999 to 2000 monitoring intervals. After adjusting the volume for the dredging of the Federal navigation channel, which removed sand at a mean rate of approximately 92,800 cy/yr, it appears that sediment is deposited in the Inlet throat at a rate of approximately 91,200 cy/yr.

Flood Shoal: Flood shoal survey data are only available for 1998 and 2000. A comparison of the survey data indicates a volume change of +23,000 cy/yr over the two year period. Mechanical transfer associated with maintenance of the Palm Beach Harbor turning basin removed an average of 14,000 cy/yr. The shoaling rate for the flood shoal is therefore estimated at 37,000 cy/yr.

Ebb Shoal: Based solely on the surveys, the volume changes within the ebb shoal averaged a loss of about 5,200 cy/yr during this time period. A significant mechanical transfer of approximately 800,000 cubic yards of sand from the ebb shoal occurred between October and December 1995 in association with the Mid-Town beach restoration project (Dean, 1997); this mechanical transfer is equivalent to a volume of 133,400 cy/yr. Based on the surveys and transfer data, the ebb shoal is estimated to have accreted 128,200 cy/yr.

South Beach: A comparison of the beach and offshore survey data indicate the south beach gained an average of 86,500 cy/yr (unadjusted mean annual change) during this period. Mechanical transfer by the plant and USACE maintenance dredging contributed approximately 288,900 cy/yr to the south beach cell. Approximately 182,100 cy/yr are placed on the south beach from the sand transfer plant which has been operational for approximately four years since May 1996. The USACE maintenance dredging of the turning basin (2-year mean) and Federal navigation channel (6-year average) has contributed approximately 106,800 cy/yr to the south beaches.

It is assumed that the south beach would have eroded by approximately 202,400 cy/yr (adjusted mean annual change) without the mechanical transfer of sand associated with the sand transfer plant and USACE maintenance dredging. It is reasonable to assume that the full longshore transport potential is realized over the approximately 2 miles of shoreline in the south beach cell so that the erosion from this cell is equivalent to the longshore transport across the southern boundary of the cell. Table 3.2 compares the Inlet sediment for the periods from 1974 to 1994, and from 1994 to 2000.

Table 3.2 Lake Worth Inlet Sediment Budget, 1974 to 1994 and 1994 to 2000			
Element	**Description**	**1974 to 1994 Value (1000cy/yr) (ATM, 1995)**	**1994 to 2000 Value (1000cy/yr) (CTC, 2000k)**
Q1	Net updrift longshore transport (ATM, 1995)	171.3	202
Q2	Sand accretion on updrift north beach	74.1	157
Q_{ebb}	Net influx of sand to ebb shoal	Not reported	128
Qb	Sand borrowed from ebb shoal dredged for Mid-Town beach nourishment	0	133
Q3 & Q5	Sand entering Inlet throat channel	61.7	91
Q4	Sand bypassed by the sand transfer plant	62.6	182
Q6	Sand eroded from south beach	85.8	202
Q7	Net downdrift longshore transport	58.7	202
Q8	Channel maintenance material placed offshore	13.7	0
Q9	Channel maintenance material placed on upland at Peanut Island	5.5	0
$Q10_c$ $Q10_{tb}$	Channel & turning basin maintenance dredge material placed on south beach.	42.5	93
Q_{flood}	Sand accretion in flood shoal & turning basin.	Not reported	37

From 1994 to 2000, the net updrift longshore transport (Q1) is assumed at the same value of the transport from the downdrift south beach cell since the volume of mechanically transferred sediment is nearly equivalent to the volume of sediment trapped in sinks surrounding the Inlet (Table 3.2). There are significant uncertainties in the values of gross and net transport along the open coast. These parameters are typically estimated by application of theoretical equations based on a quantitative characterization of the highly variable wave climate. The USACE has estimated the net longshore transport in the region at between 230,000 and 336,000 cy/yr (USACE, 1992). The University of Florida has estimated net transport for the period from 1993 to 1995 at "*on the order of 100,000 cy/yr*" (UF, 1995). Based on published values, 202,000 cy/yr appears reasonable from 1994 to 2000.

The accumulation of sand on the updrift beach (Q2) appears to have doubled (Table 3.2). This could be attributable to increased longshore transport, but more likely to the fact that the 1994 to

2000 value includes the sand bypassed by the sand transfer plant which was improved and reactivated in May 1996. The sand transfer plant did not operate from May 1990 to May 1996. During this six-year period, sand built up on the updrift beach but was subsequently removed by the sand transfer plant after it was reactivated in May 1996.

An ebb shoal growth rate (Q_{ebb}) was not included in the 1974 to 1994 sediment budget. The ebb shoal (Qb) was first used as a borrow source for the 1995 Mid-Town Beach Nourishment Project. The values of sand entering the Inlet throat (Q3 & Q5) are comparable, but could reflect a slight increase in gross longshore transport to the Inlet. A significant increase has occurred in the volumes of sand transferred by the sand transfer plant (Q4). In 1996, the plant was improved.

The sand that eroded from the south beach (Q6) increased significantly (Table 3.2). This is likely attributable to the increased quantities of sand placed on the beach that advance the shoreline seaward and become available in the littoral system.

Since at least 1994, sand obtained from maintenance dredging of the Inlet channel (Q9) has not been disposed at sea or placed on Peanut Island. Under modern management practices, sand dredged from Lake Worth Inlet is predominantly placed on the beach immediately south of the inlet by the USACE in concert with maintenance dredging. There is evidence that a significant quantity of the sand discharged in this location, which is north of a "nodal point" or divergence of the typical longshore sediment transport, is in fact re-circulated back into the inlet. The result of this is that the Town of Palm Beach does not receive the full benefit of the volume of sand discharged by the sand transfer plant nor from dredge disposal in this area. The volume of sand removed from the Inlet channel ($Q10_c$) and turning basin ($Q10_{tb}$) has increased (Table 3.2). A flood shoal growth rate (Q_{flood}) was not included in the 1974 to 1994 sediment budget.

The sediment budget elements described above appear reasonable in comparison to previously published values. In light of the above, *"the natural net annual longshore sediment transport"*, from 1994 to 2000, is estimated at 202,000 cy/yr.

The Inlet impacts the downdrift beaches by trapping sediment with the sinks surrounding the Inlet and depriving the downdrift beaches of this sediment. It is useful to consider the sediment sinks at the Inlet and the associated mechanical transfer of sand from these sinks as summarized in Table 3.3 from 1974 to 1994 and Table 3.4 from 1994 to 2000.

Table 3.3 Inlet Sediment Sinks and Mechanical Transfer - 1974 to 1994			
Sediment Sink		**Mechanical Transfer**	
Description (Sediment budget element)	**Deposition Rate (1000 cy/yr)**	**Description (Sediment budget element)**	**Transfer Rate (1000 cy/yr)**
Updrift north beach (Q2)	74.1	Sand transfer plant (Q4)	62.6
Ebb shoal (Q_{ebb})	Not reported	N/A	0
Inlet throat channel (Q3 & Q5)	61.7	Channel maintenance dredging ($Q10_c$)	42.5
Flood shoal & turning basin (Q_{flood})	Not reported	Turning basin maintenance dredging ($Q10_{tb}$)	0
Total	**135.8**	**Total**	**105.1**

Table 3.4 Inlet Sediment Sinks and Mechanical Transfer - 1994 to 2000			
Sediment Sink		**Mechanical Transfer**	
Description (Sediment budget element)	**Deposition Rate (1000 cy/yr)**	**Description (Sediment budget element)**	**Transfer Rate (1000 cy/yr)**
Updrift north beach (Q2)	157	Sand transfer plant (Q4)	182
Ebb shoal (Q_{ebb})	128	Sand borrowed for Mid-Town beach Nourishment (Qb)	133
Inlet throat channel (Q3 & Q5)	91	Channel maintenance dredging ($Q10_c$)	93
Flood shoal & turning basin (Q_{flood})	37	Turning basin maintenance dredging ($Q10_{tb}$)	14
Total	**413**	**Total**	**422**

From 1974 to 1994:

1. The total volume of sediment deposition within sinks at the Inlet is equivalent to an average of 135,800 cy/yr.
2. The total volume of sediment mechanically transferred from sediment sinks to the downdrift beaches is a mean of about 105,100 cy/yr.

3. For this period, a downdrift deficit of 20,700 cy/yr might be concluded. However, the actual deficit was likely greater in magnitude in association with deposition in the flood and ebb shoals at the Inlet which were not addressed in the sediment budget.

From 1994 to 2000:

1. The total volume of sediment deposition within sinks at the Inlet is equivalent to an average of 413,000 cy/yr.
2. The total volume of sediment mechanically transferred from sediment sinks to the downdrift beaches is equivalent to a mean of 422,000 cy/yr.
3. For this period, a downdrift surplus of 9,000 cy/yr might be concluded.

In summary, based on the above consideration of the Lake Worth Inlet sediment budget, to mitigate the Inlet's impacts about 413,000 cubic yards of sand should be placed south of the Inlet on the beaches of Palm Beach Island, annually. Based on 1994 to 2000 data, the sand transfer plant and maintenance dredging provide about 275,000 cy/yr to Reach 1; a deficit of about 138,000 cy/yr remain.

3.2.3 Palm Beach Island - Shoreline and Volumetric Changes

The FDEP established a system of survey reference monuments along the Atlantic and Gulf coasts of Florida in conjunction with regulation of coastal construction. These survey monuments are spaced at approximately 1,000-ft increments along the coasts. In most counties, the northernmost DNR Monument is designated R-1 and is adjacent to the county's northern boundary. Within Palm Beach Island, DNR Monument R-76 is located at the northern limits of the Island immediately south of the south jetty of Lake Worth Inlet. Comparably, DNR Monument R-151 is located near the southern limits of the Island about 300 feet north of the north jetty at South Lake Worth Inlet. FDEP has performed profile surveys of the beaches in Palm Beach County intermittently since 1974. These profiles provide a basis for determination of shoreline changes and volume changes along the coast. In addition, FDEP has also compiled historical shoreline data based upon maps, charts and photographs from the USGS, NOAA and others - geo-referenced to the State's reference monument system. The Town's *Comprehensive Coastal Management Plan Update* (ATM, 1998) identifies eleven reaches within the Town (Table 3.5).

Figure 3.5a illustrates shoreline (MHWL) change rates (ft/year) determined from FDEP profile and historical shoreline data for 1928 to 1974, 1974 to 1990, and 1990 to 2000 (Table 3.6). Figure 3.6 illustrates reported volume change rates (ATM, 1998) determined from FDEP profile data from 1974 to 1990, and 1990 to 1997 (Table 3.7). Table 3.8 summarizes reported volume change rates from 1929 to 1957 and 1957 to 1979 (USACE, 1987). These periods were selected to represent conditions after construction of Lake Worth Inlet and to make use of the FDEP profile data.

Table 3.5 Palm Beach Island Reaches		
Reach	**Upland Parcel or Street Feature**	**Reference Monuments**
1	Lake Worth Inlet south jetty to Onondaga Avenue (500 feet north of Reef Road)	R-76 to R-78
2	Onondaga Avenue to 1,080 feet north of Wells Road	R-78 to R-90 + 400 feet south
3	1,080 feet north of Wells Road to Via Bethesda	R-90 + 400 feet south to R-95
4	Via Bethesda to 270 feet south of Banyan Road	R-95 to R-102 + 300 feet south
5	300 feet south of Banyan Road to 170 feet north of Widener's Curve	R-102 + 300 feet south to R-110 + 100 feet south
6	170 feet north of Widener's Curve to Sloan's Curve	R-110 + 100 feet south to R-116 + 500 feet south
7	Sloan's Curve to the Ambassador Hotel	R-116 + 500 feet south to T -125
8	Ambassador Hotel to La Bonne Vie	T -125 to T -134
9	La Bonne Vie to Lantana Avenue access	T -134 to R-137 + 400 feet south
10	Lantana Avenue access to Chillingsworth Curve	R-137 + 400 feet south to R-145 + 740 feet south
11	Chillingsworth Curve to South Lake Worth Inlet	R-145 + 740 feet south to R-151 + 300 feet south

Although shoreline changes are affected by natural dynamics of the system, the dominant long-term influence is the longshore sediment transport deficit attributable to the man-made effects of

Lake Worth Inlet, groins, and armoring to the north of the Project Area. Storms induce cross-shore sediment transport from the dry beach and dune to the nearshore region. In the absence of a longshore sediment transport deficit, a beach is expected to recover after a storm. However, in the presence of a longshore sediment transport deficit, more sand is transported from a beach cell than enters the beach cell - resulting in erosion of the beach.

Figure 3.5b illustrates the historical shoreline positions in the Project Area from 1883 to 2003; note that the east-west scale is exaggerated to illustrate the relative historical shoreline positions. Since 1883, the shoreline throughout the project area has receded, likely in response to the effects of the construction of Lake Worth Inlet, which was constructed between 1918 and 1925, and subsequently, in response to the construction of seawalls, groins and other structures updrift (to the north) of the Project Area. In more recent periods since 1970, the shoreline has dramatically fluctuated.

North of Phipps Ocean Park, at DNR Monument R-116, the shoreline experienced nearly steady recession, over 130 feet, between 1881 and 2003. Conversely, at R-119 the shoreline receded significantly between 1881 and 1928 but has remained fixed at the same location since 1928. The fixed shoreline at DNR Monument R-119 is clearly due to the presence of an exposed, high relief rock outcrop (peak at +2.8' NGVD) at DNR Monument R-119. Section 3.2.4 characterizes the extent and impacts of existing rock outcrops or hardbottom that exist within the Project Area. These features clearly have limited shoreline recession in the Project Area. This is particularly evident in Figure 3.5b at DNR Monuments R-119, R-121, and R-122 where most historical shorelines (since 1970) are coincident.

Between DNR Monuments R-119 and R-121 the shoreline has fluctuated over time, about 100 feet between 1942 and 2003, leading up to the most recent recessional trend between 1999 and 2003 (almost 40 feet of erosion). Between DNR Monuments R-121 and R-122, after significant recession between 1881 and 1928, the shoreline accreted from 1928 and 1942 before receding to its current day position where it has remained relatively stable for the last 29 years (1970 to 2003). From DNR Monuments R-122 to R-126, the shoreline has historically fluctuated over time, on the order of 100 feet between 1942 and 2003.

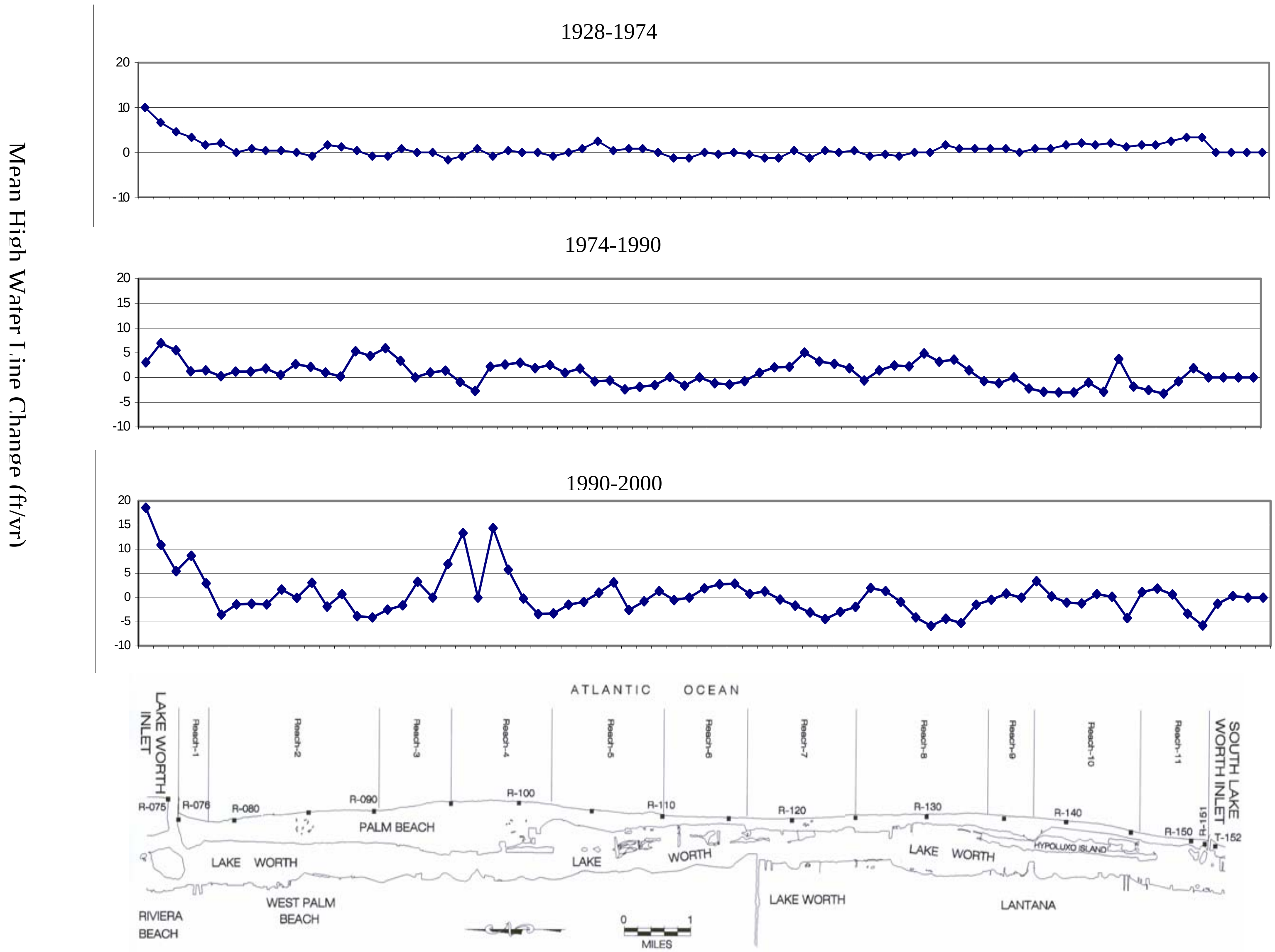


Figure 3.5a Mean High Water Line Change Rates (ft/yr)

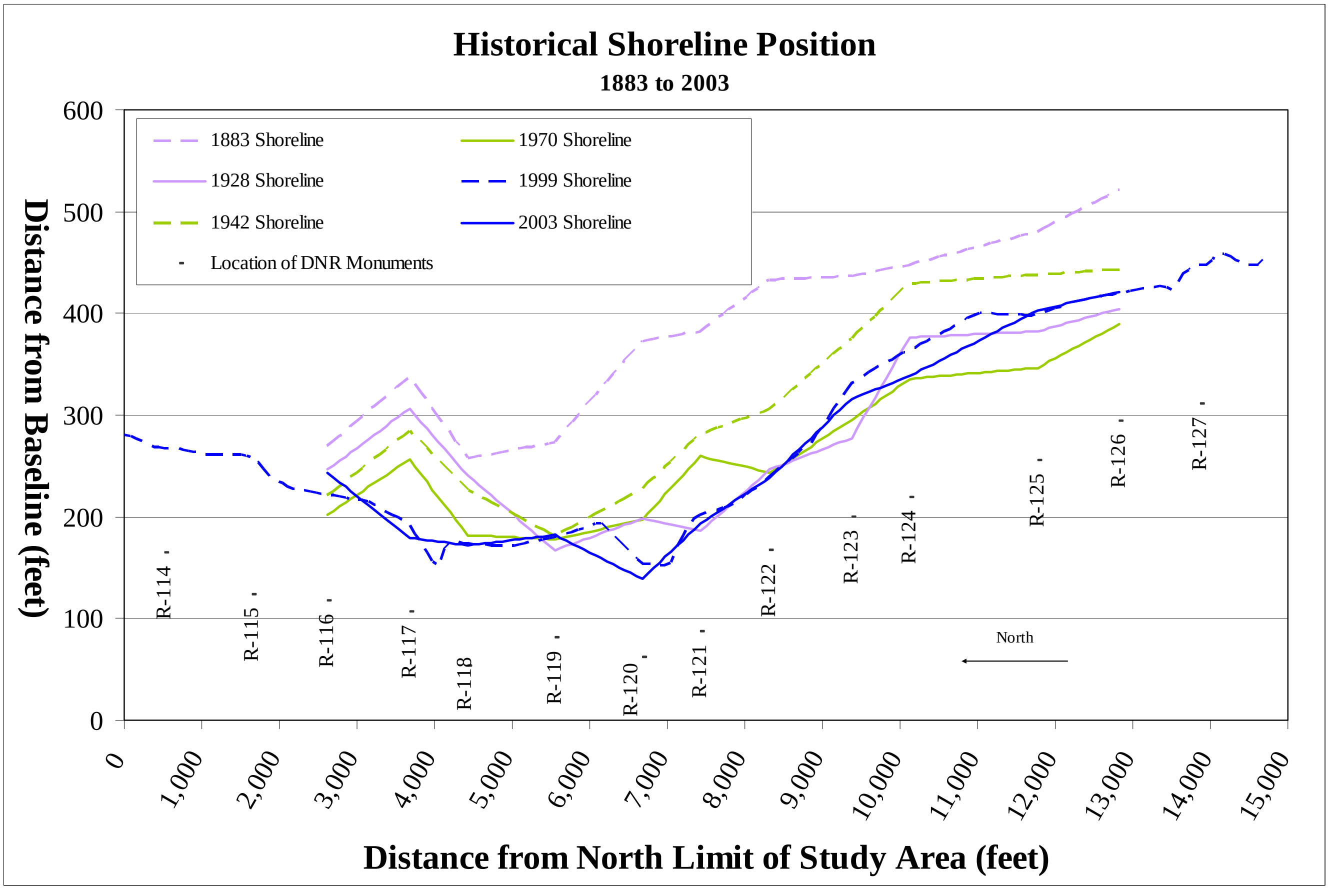


Figure 3.5b Historical Shoreline Positions

Table 3.6 Shoreline (MHWL) Change Rates From 1928-1974, 1974-1990, and 1990-2000

Reach	DEP Monument	1928 - 1974 Shoreline Change Rate (feet/year)	1974 - 1990 Shoreline Change Rate (feet/year)	1990 - 2000 Shoreline Change Rate (feet/year)
	R-76	10.12	3.08	18.61
Reach 1	R-77	6.50	6.90	10.90
	R-78	4.51	5.47	5.47
	R-79	3.38	1.27	8.68
	R-80	1.83	1.46	2.92
	R-81	1.89	0.28	-3.55
	R-82	0.09	1.17	-1.42
Reach 2	T-83	0.63	1.19	-1.29
	R-84	0.27	1.85	-1.42
	R-85	0.36	0.51	1.68
	R-86	0.12	2.69	-0.09
	R-87	-0.89	2.17	3.06
	R-88	1.47	1.03	-1.85
	R-89	1.13	0.24	0.69
	R-90	0.36	5.31	-3.82
	R-91	-0.73	4.35	-4.11
	R-92	-0.66	5.95	-2.47
Reach 3	R-93	0.78	3.41	-1.62
	T-94	NA	NA	3.30
	R-95	-0.07	1.00	NA
	R-96	-1.81	1.39	6.94
	R-97	-0.88	-0.94	13.33
	R-98	0.74	-2.75	NA
Reach 4	R-99	-0.76	2.19	14.35
	R-100	0.36	2.62	5.77
	R-101	-0.00	3.01	-0.19
	R-102	-0.07	1.86	-3.41
	R-103	-0.89	2.48	-3.30
	R-104	0.12	0.94	-1.48
	R-105	0.94	1.82	-0.92
Reach 5	R-106	2.35	-0.79	1.03
	R-107	0.50	-0.58	3.12
	R-108	0.93	-2.41	-2.54
	R-109	0.91	-1.91	-0.76
	R-110	-0.19	-1.51	1.32
	R-111	-1.27	0.05	-0.51
Reach 6	T-112	-1.40	-1.67	NA
	R-113	NA	NA	1.93

Reach	DEP Monument	1928 - 1974 Shoreline Change Rate (feet/year)	1974 - 1990 Shoreline Change Rate (feet/year)	1990 - 2000 Shoreline Change Rate (feet/year)
	T-114	-0.39	-1.16	2.75
Reach 6	R-115	-0.08	-1.40	2.90
	R-116	-0.55	-0.73	0.75
	T-117	-1.09	0.93	1.31
	R-118	-1.23	2.08	-0.41
	R-119	0.35	2.15	-1.65
Reach 7	R-120	-1.20	5.09	-3.07
	R-121	0.50	3.27	-4.40
	R-122	0.01	2.75	-2.95
	R-123	0.29	1.90	-1.92
	T-124	-0.64	-0.59	2.00
	T-125	-0.58	1.42	1.35
	R-126	-0.74	2.44	-0.91
	R-127	0.04	2.24	-4.09
	R-128	0.08	4.90	-5.81
Reach 8	R-129	1.67	3.20	-4.33
	R-130	0.63	3.61	-5.28
	T-131	0.65	1.46	-1.48
	T-132	0.70	-0.71	-0.44
	T-133	1.03	-1.17	0.85
	R-134	NA	NA	NA
	R-135	0.88	-2.22	3.39
Reach 9	R-136	0.78	-2.90	0.28
	R-137	1.78	-3.05	-1.04
	R-138	2.12	-3.03	-1.24
	R-139	1.49	-1.05	0.68
	R-140	2.01	-2.90	0.21
Reach 10	R-141	1.45	3.74	-4.22
	R-142	1.72	-1.85	1.17
	R-143	1.67	-2.54	1.84
	T-144	2.63	-3.29	0.66
	R-145	3.48	-0.82	-3.34
	R-146	3.38	1.88	-5.79
	R-147	NA	NA	-1.31
Reach 11	R-148	NA	NA	0.34
	R-149	NA	NA	NA
	R-150	NA	NA	NA
	R-151	NA	NA	NA

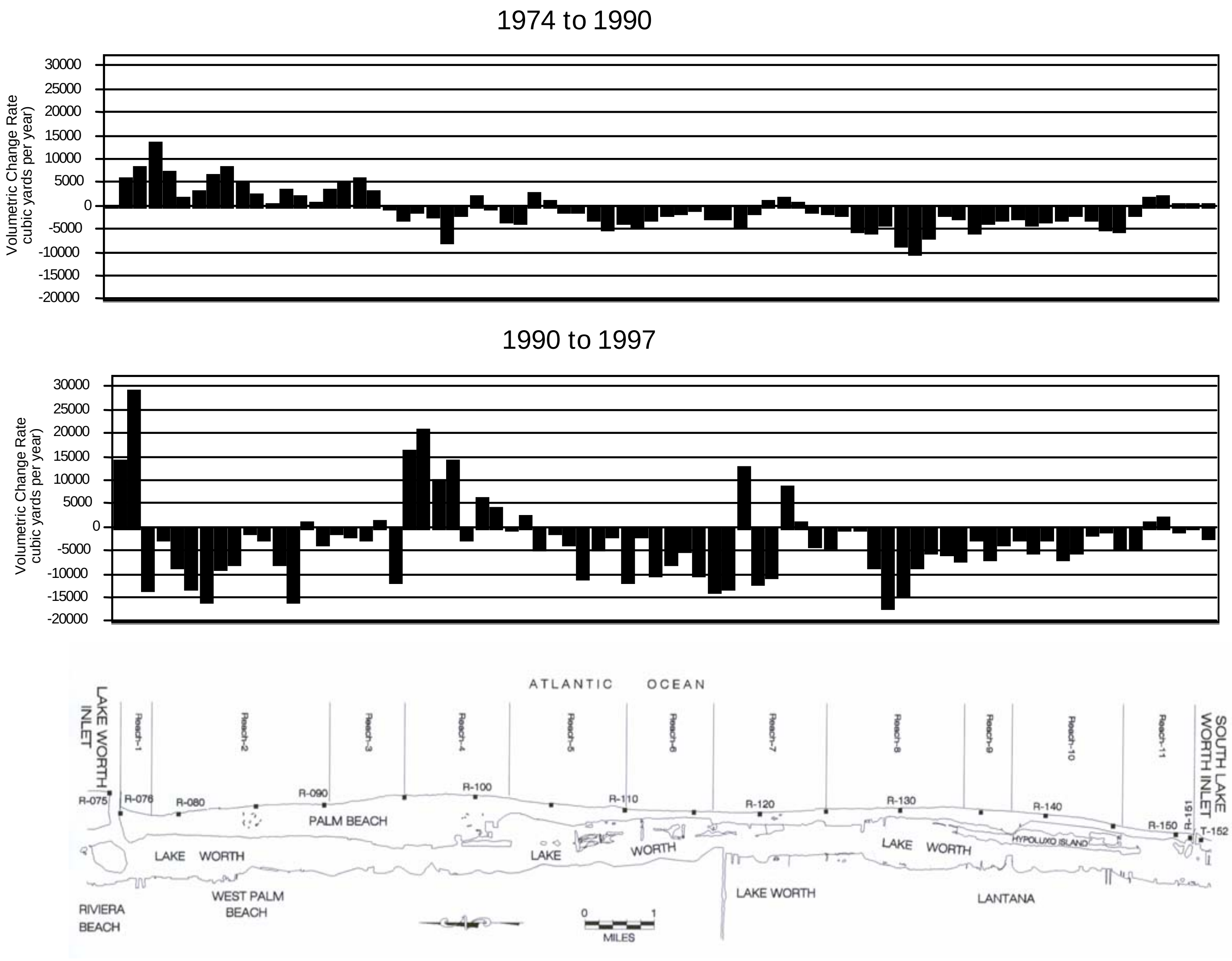


Figure 3. 6 Volume Change Rates (cy/yr)

Table 3.7 Volume Change Rates From 1974-1990 and 1990-1997

Reach	DEP Monument	1974-1990 Volume Change Rate (cy/yr)	1990-1997 Volume Change Rate (cy/yr)
Reach 1	R-76	0	14159
	R-77	5777	29146
	R-78	8299	-13208
Reach 2	R-79	13286	-2656
	R-80	7218	-8515
	R-81	1663	-12755
	R-82	2995	-15829
	R-83	6573	-8884
	R-84	8392	-7787
	R-85	4845	-1114
	R-86	2306	-2525
	R-87	325	-7646
	R-88	3429	-15767
	R-89	1983	894
	R-90	641	-3681
Reach 3	R-91	3470	-1027
	R-92	4925	-1848
	R-93	5964	-2481
	R-94	3103	1472
	R-95	-427	-11608
Reach 4	R-96	-2849	16188
	R-97	-1265	20840
	R-98	-2315	10028
	R-99	-7827	14132
	R-100	-1690	-2388
	R-101	2147	6119
	R-102	-475	4137
Reach 5	R-103	-3121	-277
	R-104	-3667	2277
	R-105	2643	-4523
	R-106	931	-1176
	R-107	-1256	-3528
	R-108	-953	-10826
	R-109	-2904	-4695
	R-110	-4959	-1712
Reach 6	R-111	-3655	-11524
	R-112	-4193	-1723
	R-113	-2979	-9985
Reach 6	R-114	-1858	-7568
	R-115	-1470	-4773
	R-116	-597	-10211
Reach 7	R-117	-2325	-13432
	R-118	-2597	-12832
	R-119	-4372	12649
	R-120	-1443	-12023
	R-121	1005	-10429
	R-122	1721	8495
	R-123	664	927
	R-124	-1240	-3930
	R-125	-1367	-4182
Reach 8	R-126	-1685	-584
	R-127	-5107	-546
	R-128	-5588	-8282
	R-129	-3769	-17093
	R-130	-8317	-14240
	R-131	-10283	-8355
	R-132	-6503	-5247
	R-133	-1690	-5498
	R-134	-2440	-7076
Reach 9	R-135	-5468	-2334
	R-136	-3555	-6742
	R-137	-2745	-3408
Reach 10	R-138	-2493	-2431
	R-139	-4024	-5320
	R-140	-3306	-2635
	R-141	-2976	-6524
	R-142	-1649	-5159
	R-143	-2971	-1364
	R-144	-4810	-737
	R-145	-5338	-4498
Reach 11	R-146	-1825	-4509
	R-147	1625	1071
	R-148	2003	1851
	R-149	382	-646
	R-150	129	-155
	R-151	201	-2175
	Total	-49704	-220239

Table 3.8 Volume Change Rates 1929-1957 and 1957-1979			
Reach	**USACE Monument**	**1929-1957 Volume Change Rate (cy/yr)**	**1957-1979 Volume Change Rate (cy/yr)**
Reach 1	400S	NA	26591
	1S	-6964	4227
	2S	-13179	818
Reach 2	3S	-12071	-2045
	4S	-9964	-4455
	5S	-8929	NA
	6S	-4107	NA
Reach 3	7S	-10964	-4500
	8S	-9500	NA
	9S	-1964	-182
Reach 4	10S	-11464	1909
	11S	-4286	-4364
	12S	11786	NA
Reach 5	13S	9643	-8955
	14S	-1929	NA
	15S	-4107	NA
Reach 6	16S	-4214	-591
	17S	857	NA
	18S	-7714	NA
Reach 7	19S	-3214	NA
	20S	-2250	NA
	21S	-1036	-6318
Reach 8	22S	750	NA
	23S	-429	NA
	24S	-1250	6500
Reach 9	25S	-6857	NA
	26S	-9607	NA
Reach 10	27S	-9714	NA
	28S	-8929	NA
Reach 11	29S	-24929	NA
	30S	3000	NA
	Total	**-153536**	**-17955**
	without north cell (400S)		

The data presented in Table 3.8 is based on survey monuments established by the USACE circa 1930. No USACE data exists for some monuments ("NA") within the Town as reflected in Table 3.8.

From 1974 to 1990 the data indicate net erosion on the Island at almost 50,000 cy/yr (Table 3.7). The data indicate net erosion at about 154,000 cy/yr (Table 3.8) and 220,000 cy/yr (Table 3.7) from 1929 to 1957 and from 1990 to 1997, respectively. This corresponds to the period in which the Town formulated its *Comprehensive Coastal Management Plan* (ATM, 1998).

The volume change data reflect a consistent pattern of net erosion on Palm Beach Island. The data indicate an annual sediment deficit ranging from about 50,000 to 220,000 cy/yr (Table 3.7). The following sections address shoreline changes, volumetric changes, and specific features within each reach of the island.

<u>Reach 1</u>: This reach is located immediately south of Lake Worth Inlet and includes about 2,400 feet of shoreline (Figure 3.7). The shoreline change and volumetric data indicate the beneficial effects (shoreline advance) in response to this nourishment.

From 1974 to 1994, an average of 105,100 cubic yards of sand was placed on the beach in Reach 1 annually. The plant was shut down between May 1990 and May 1996 when the plant pump and pipeline were upgraded and operation was resumed (ATM, 1998). Between 1994 and 2000, Reach 1 was nourished by approximately 289,000 cubic yards of sand annually via (a) operation of the sand transfer plant, and (b) USACE maintenance dredging of Lake Worth Inlet (Coastal Tech, 2000k).

Figure 3.7 Reach 1, South of Lake Worth Inlet Extending South (March 2001)

The volume change data indicate a net increase in the volume of sand on Reach 1 since 1974 - on the order of 14,000 to 30,000 cy/yr. Most (85% to 90%) of the sand placed on Reach 1 (105,000 to 289,000 cy/yr) is eroded from the beach. Erosion of Reach 1 partially reduces the longshore transport deficit whereas the eroded volume is transported south to downdrift beaches (Coastal Tech 2000k).

Reach 2: Downdrift of Reach 1, the beneficial effects of the Inlet sand transfer activities are variable or not apparent. The volume change data indicate a pattern of accretion between 1974 and 1990. This pattern was reversed from 1990 to 1997 when significant erosion occurred after the sand transfer plant was shut down. Over the 13,600 feet of this segment, a mean shoreline erosion rate of 6.7 cy/ft/yr occurred between 1990 and 1997 (ATM, 1998).

A seawall and a narrow beach front much of the shoreline in Reach 2, located at the Palm Beach Country Club near reference DNR Monument R-85 (Figures 3.8 and 3.9). Any seawall, rock revetment or other armoring prevents erosion of the dune and upland areas but also deprives the beach of littoral sediments.

Figure 3.8 Aerial Photograph of Reach 2 at Palm Beach Country Club (March 2001)

Figure 3.9 The Narrow Beach Front Along Reach 2 at Palm Beach Country Club (February 2002)

In addition to the effects of the seawall, the underlying Anastasia Formation is exposed. The exposed rock is quite durable and does not erode as compared to a sandy bottom which may erode and provide sediment to downdrift beaches; the seawall and hardbottom prevent landward migration of the shoreline (Walther, 1995). As a result, the rock hardbottom translates the erosion deficit attributable to Lake Worth Inlet.

Figure 3.10 Reach 3, Breakers Hotel (March 2001)

The volume change data indicate annual losses from Reach 2 at about 55,000 cy/yr from 1929 to 1957. Reach 2 gained sediment between 1974 and 1990, but eroded at about 86,000 cy/yr from 1990 to 1997.

<u>Reach 3</u>: Reach 3 extends over 5,800 feet of shoreline and is almost completely fronted by seawalls (ATM, 1998). The southern end of Reach 3 includes several groins at the north end of the Breakers Hotel (Figure 3.10). The seawalls and groins can deter updrift erosion and translate the longshore transport deficit to downdrift beaches.

Reach 4 (to the south) was nourished in 1995. Monitoring data indicate that the southernmost portion of Reach 3 may have benefited slightly (by spreading and shoreline advance) within the first year after nourishment of Reach 4, but no benefit was evident after two years.

The volume change data indicate annual losses from Reach 3 at about 20,000 cy/yr from 1929 to 1957. Reach 3 gained sediment between 1974 and 1990, but eroded at about 15,000 cy/yr from 1990 to 1997.

Figure 3.11 Reach 4, Mid-Town Region, (February 2002)

Reach 4: By 1987, over 80% of the shoreline in Reach 4 was fronted by a seawall (Figure 3.11). Virtually the entire shoreline included groins (Olsen, 1987). In December 1995, the Mid-Town Beach Restoration project was completed in Reach 4 (Dean, 1997). About 800,000 cubic yards of sand were placed on the beach between DNR Monuments R-95 and R-100. The fill area includes a groin field constructed from coquina rock and from concrete "PEP reef" units obtained from a previous experimental project.

On behalf of the Town, the University of Florida performed detailed monitoring of the Mid-Town project from 1995 to 1999. The investigation found that as of April 1999, approximately 70% of the volume placed in the 1995-1996 Mid-Town beach nourishment project remained in place (Dean, 1999). The investigation could not, however, definitively determine whether the groins caused or contributed to this fill retention. As of December 2002, follow-up investigations found that approximately 50% of the 1995-1996 fill remained in place. On an annual basis, sand losses from the Project Area were found to average about 50,000 cy/yr (Dean, 1997).

In January – February of 2003, an additional 1.29 million cubic yards of sand were placed on the Mid-Town beach. Although the groins may positively reduce fill losses in the Mid-Town Project, it is not reasonable to expect a similar result in the Phipps Ocean Park Project Area, because of the fundamentally different shoreline dynamics, as confirmed by modeling results (See Appendix M).

Figure 3.12
Aerial Photograph of Reach 5 at Widener's Curve (March 2001)

Reach 5: By 1987, over 80% of the shoreline in Reach 5 was fronted by a seawall or a rock revetment. The entire shoreline included groins (Olsen, 1987), which have significantly affected the shoreline (Figure 3.12). The "Monster Groin" (near DNR Monument R-110) improves the stability of the shoreline to the north in Reach 5, but deprives sand to the downdrift beaches in Reach 6.

The volume change data indicate that the shoreline of Reach 5 gained sediment from 1929 to 1957. This is attributable to the 1948 nourishment of the beaches in the area of Banyan Road at the northern portion of Reach 5 whereas about 1 million cubic yards were placed in 1948 (Olsen, 1987). Reach 5 eroded at about 13,000 cy/yr between 1974 and 1990, and 24,000 cy/yr from 1990 to 1997.

Reach 6: By 1987, over 90% of the shoreline in Reach 6 was fronted by a seawall or a rock revetment and included installation of numerous groins (Olsen, 1987). From 1990 to 1997, Reach 6 eroded at a mean rate of 6.2 cy/ft of shoreline per year along the 6,685 feet of shoreline.

In 1987, the FDOT constructed a rock revetment along the shoreline in Reach 6 to protect the upland road (Figure 3.13). The rock revetment and groins have further "hardened" the shoreline in Reach 6, deprived the downdrift beaches of sand, and translated the longshore transport deficit further south into the Phipps Ocean Park Beach Restoration Project Area. The volume change data indicate that Reach 6 eroded at about 7,500, 15,000, and 46,000 cy/yr from 1929 to1957, 1974 to 1990, and 1990 to 1997, respectively.

Figure 3.13 Rock and Groin in Reach 6 (February 2001)

Reach 7: Sloan's Curve is located at the northern boundary of Reach 7. The 3 miles of shoreline immediately north of Sloan's Curve and Reach 7 are fronted by numerous armoring structures including rock revetments, seawalls, and groins. The Mid-Town Beach Restoration Project is also located to the north of this 3 mile segment. In combination with the effects of Lake Worth Inlet, the armoring structures along this 3 mile segment have caused a significant longshore transport and sediment deficit to the proposed Project Area. The resulting erosion has exposed the Anastasia Formation in the form of nearshore hardbottom and emergent rock (Figure 3.14).

Figure 3.14 Exposed Anastasia Formation in Reach 7

Prior to construction of Lake Worth Inlet in 1925, FDEP historical shoreline data indicated that the shoreline was significantly more seaward than its present position. In the vicinity of the proposed Phipps Ocean Park Project (DNR Monument R-120 to R-122), the shoreline has receded by about 200 feet since 1878. This recession has resulted in the current "concave" shoreline where the shorelines at the northern and southern boundaries are further east than at the mid-point (Figure 3.15).

The short-term shoreline fluctuations reflected in Figure 3.5 and Table 3.6 are indicative of the concave shoreline configuration in the Project Area. This configuration allows for shoreline accretion against the headland features in concert with longshore transport reversals.

For example, during sustained transport from the south, the headland north of the Project Area (formed by groins, revetment and natural hardbottom) may trap sand on the updrift (south) side of the headland within the Project Area. However, this accretion is temporary, whereas with the long-term predominant net southerly transport, the Project Area is deprived of sand by the coastal structures over the three miles of shoreline to the north.

Figure 3.15 Oblique Aerial Photograph of The Concave Shoreline in Reach 7 (1999)

The existing groins north of Phipps Park deter southerly longshore transport to Phipps Ocean Park and the Project Area. In spite of beach nourishment at Mid-Town, southerly transport of this sand must fill the "monster" groin at Widener's Curve and others before the Project Area begins to receive sand transported downdrift from the Mid-Town beach nourishment. Perhaps after several decades of periodic nourishment at Mid-Town, the groins north of Reach 7 may become fully impounded and no longer interrupt longshore sediment transport to Reach 7 and the Project Area.

The volume change data indicate annual losses from Reach 7 at approximately 13,000 cy/yr from 1929 to 1957. The reach eroded at about 10,000 cy/yr between 1974 and 1990, and 35,000 cy/yr from 1990 to 1997.

Reach 8: Reach 8 is the southernmost reach within the Town of Palm Beach. By 1987 about 65% of Reach 8 was fronted by seawalls (Olsen, 1987). Many of these seawalls are now buried under the beach berm or dune likely due to windblown sand or dune restoration activities such as at Lake Worth Public Beach (Figure 3.16). At the southern limits of Reach 8, the existing seawalls are located in close proximity to the shoreline (Figure 3.17).

Figure 3.16 Lake Worth Public Beach, Immediately South of Lake Worth Pier (Reach 8)

Figure 3.17 Exposed Seawall Near R-135 (Reach 8)

The volume change data indicate annual losses from Reach 8 at approximately 2,000 cy/yr from 1929 to 1957. Reach 8 eroded at approximately 45,000 cy/yr and 67,000 cy/yr from 1974 to 1990 and 1990 to 1997, respectively.

<u>Reaches 9 and 10</u>: South Palm Beach and the public beach at Lantana comprise the 3,550 feet of shoreline of Reach 9. The northern 8,300 feet of shoreline in the Town of Manalapan form Reach 10 (ATM, 1998).

By 1987 over 80% of both Reaches were fronted by seawalls (Olsen, 1987) (Figure 3.18).

Figure 3.18 Typical Beach and Seawall Conditions Near R-143 Along Reaches 9 & 10

The volume change data indicate annual losses from Reaches 9 and 10 at approximately 35,000 cy/yr from 1929 to 1957. The Reaches eroded at approximately 39,000 cy/yr between 1974 and 1990, and 41,000 cy/yr from 1990 to 1997.

Reach 11: South Lake Worth Inlet is the southern boundary of Reach 11. By 1987 over 50% of this Reach was fronted by seawalls (Olsen, 1987). The volume change data indicate annual losses from Reach 11 at approximately 22,000 cy/yr from 1929 to 1957. Reach 11 gained sand at approximately 2,500 cy/yr between 1974 and 1990, but eroded at about 4,500 cy/yr from 1990 to 1997. The data indicate that the shoreline of Reach 11 is reasonably stable. This is apparently as a result of the updrift stabilizing influence of the north jetty at the Inlet (Figure 3.19).

Figure 3.19 South Lake Worth (Reach 11)

In general, Palm Beach Island is sediment starved. The man-made and natural physical barriers along the shoreline of Palm Beach Island have deprived the downdrift beaches of sediment and caused erosion.

Between 1934 and 1994, maintenance dredging at Lake Worth Inlet resulted in the direct removal of sediment from the littoral system. Over 4 million cubic yards of sediment were removed from the Inlet and deposited outside the littoral system - offshore or on Peanut Island (ATM, 1995). This translates to about 67,000 cy/yr over a 60 year period from just the navigation channel and turning basin. Additional material deposited on the updrift beach, flood shoal, and ebb shoal.

Since 1994, management of the Inlet has improved. Under existing Inlet management practices, the total annual deficit attributable to Lake Worth Inlet is estimated at 138,000 cubic yards of sand.

The history of Lake Worth Inlet reflects inadequate transfer to the downdrift beaches. Inadequate sand transfer at the Inlet has led to erosion of Palm Beach Island and prompted the Town, the FDOT, and property owners to construct seawalls, groins and rock revetments. About 75% of

Palm Beach Island shoreline is armored by a seawall or rock revetment, and about 35% of the shoreline includes groins (Olsen, 1987).

The existing seawalls and revetments cut-off the sand supply from the dune and, along with the groins, form artificial headlands that impound sediment on the updrift beaches and extend or translate a longshore sediment transport deficit to downdrift beaches. Natural hardbottom has become exposed by erosion, further depriving littoral sediments to downdrift beaches, and translating the longshore sediment deficit to downdrift beaches.

Table 3.9 Summary of Net Volume Change Rates

Reach	1929-1957 Volume Change Rate (cy/yr)	1974-1990 Volume Change Rate (cy/yr)	1990-1997 Volume Change Rate (cy/yr)
1	NA	14075	30097
2	-55214	53656	-86263
3	-20464	17035	-15491
4	-17714	-14275	69057
5	19500	-13285	-24460
6	-744	-14752	-45783
7	-13179	-9955	-34758
8	-1964	-45382	-66920
9	-6857	-11768	-12484
10	-28250	-27569	-28668
11	-21929	2515	-4564
Total	**-153536**	**-49704**	**-220239**

Based on the volume change data for each Reach of Palm Beach Island as determined from survey data, 50,000 to 220,000 cy/yr would be needed to offset erosion (Table 3.9). Actual eroded volumes are greater. Since 1929, some sand has been transferred at Lake Worth Inlet while some has been otherwise placed on the Island.

The sand transferred at the Inlet has been placed within Reach 1, which now appears to be stable or accreting. Since 1948, beyond that sand placed on the beach in Reach 1 through Inlet sand transfer activities, over 3.34 million cubic yards of sand have been placed on the beaches of Palm Beach Island (Olsen, 1987; Dean, 1997) (Table 3.10). This corresponds to about 62,000 cy/yr from 1948 to the present.

Table 3.10
Summary of Historic Nourishment Volumes, Reaches 2-11

Reach	Volume Placed (cy)	Location	Year
2	630,000	Eden Road	1948
2	454,600	Tangier Ave.	1948
4	86,000	Chilean Ave.	1977
4 & 5	1,035,000	Banyan Road	1948
4	800,000	Mid-Town	1995
6	334,000	Sloan's Curve	1949 to 1987
Total	**3,339,600**		

Accounting for this historical fill placement, the net volumes necessary to offset the longshore transport deficit are estimated at between 112,000 and 282,000 cy/yr. This range encompasses the current estimated longshore transport deficit at Lake Worth Inlet (138,000 cy/yr).

The volume change data, as presented above, reflect net volume changes. Actual volumes necessary to address eroding areas are expected to be greater until the groins and headlands become fully impounded and allow for uninterrupted longshore transport.

Table 3.11
Summary of Historic Erosion Volumes

Reach	1929-1957 Volume Change Rate (cy/yr)	1974-1990 Volume Change Rate (cy/yr)	1990-1997 Volume Change Rate (cy/yr)
1	-0	0	-13208
2	-55214	0	-87158
3	-20464	-427	-16964
4	-17714	-16422	-2388
5	-1929	-16859	-26738
6	-8321	-14752	-45783
7	-13179	-13345	-56828
8	-2714	-45382	-66920
9	-6857	-11768	-12484
10	-28250	-27569	-28668
11	-24929	-1825	-7486
Total	**-179751**	**-148349**	**-364624**

Based on this data, as much as 365,000 cubic yards of sand annually may be required to offset erosion on Palm Beach Island (Table 3.11). This volume may be necessary to offset the historical erosion and the ongoing effects of Lake Worth Inlet and existing seawalls, revetments, and groins.

Without placement of additional sand fill, the Town's beaches are expected to continue to erode to the face of the existing seawalls and revetments. This condition now exists in Reach 6 (Figure 3.13 and description for Reach 6). Sand placed in Reach 1 is expected to work its way downdrift to South Lake Worth Inlet through littoral processes.

In the scenario that Inlet sand transfer activities become adequate to offset Inlet effects, restored longshore transport would likely fill the beaches and advance the shoreline updrift of major headland features such as at the Breakers Hotel, “Monster Groin,” and groin fields in Reaches 5 and 6. Subsequent to this filling at each headland feature, longshore transport to downdrift beaches would then be restored. The timeframe to achieve this filling process is uncertain, but would occur from north to south. Since restoration of the sand transfer plant in 1996, the beach north of the Breakers Hotel does not appear to have become fully impounded (see Figure 3.10 and description for Reach 3). It is hypothesized that more than 50 years would be required to fully impound existing artificial and natural headland features and restore longshore transport on the island through improved sand transfer at Lake Worth Inlet. In such a scenario, beaches downdrift of the headland features would theoretically be expected to remain stable in their current condition after all headland features became filled.

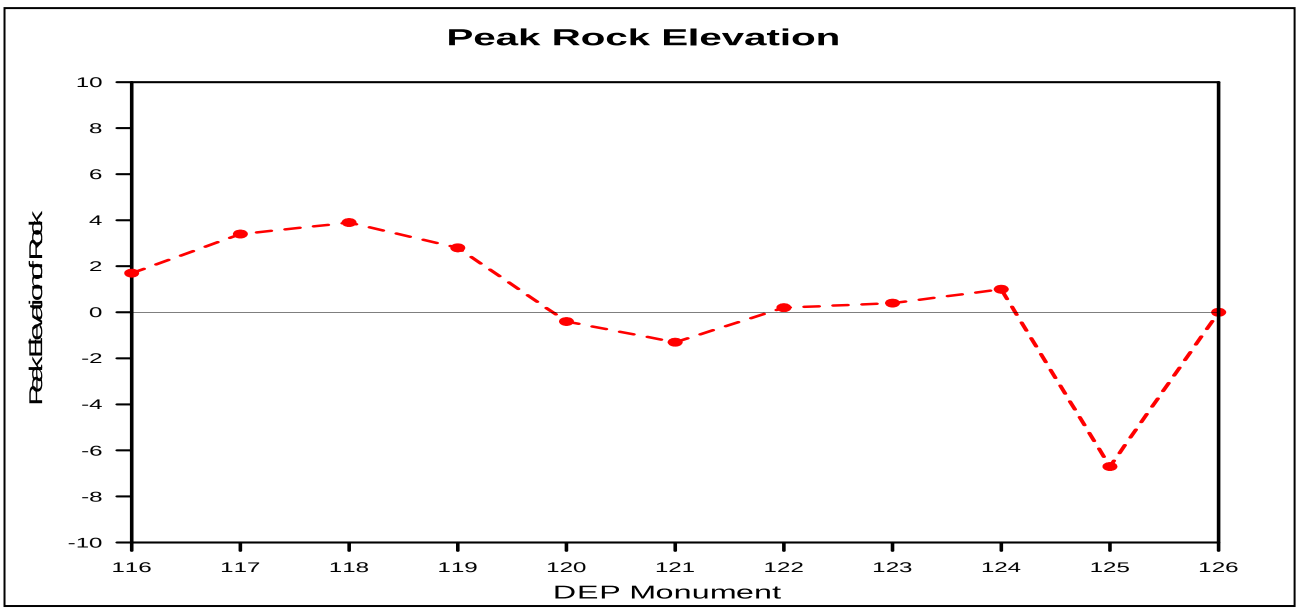
With the fill placement proposed by the Applicant, filling of these natural and artificial headland features would be, in part, directly achieved where sand is placed. The headland features downdrift of fill areas would gradually fill as described above. It is hypothesized that the proposed beach restoration may restore longshore transport throughout the island within 20 years and provide additional beach to address the needs of the Town.

3.2.4 Effects of Existing Rock Hardbottom

Exposed natural rock or “hardbottom” exists along most all of the shoreline of Palm Beach Island as illustrated in the “Hardbottom Maps” contained in Appendix C. Within the Project Area surrounding Phipps Ocean Park, inter-tidal formations of hardbottom are usually visible above the waterline between DNR Monuments R-118 and R-120. Most of the Project Area contains subterranean or subaqueous hardbottom features, buried beneath the beach grade or below the water surface. At the request of the Applicant, a field survey and a sub-surface probe investigation was conducted in November 2003 by Morgan & Ekland to identify the extent and elevation of natural rock and “hardbottom” within the Project Area. Results reveal the existence of rock both above and below the beach grade throughout most of the Project Area from DNR Monuments R-116 to R-124. Figure 3.20 shows the maximum elevation of rock located at each monument. Appendix O contains profiles illustrating the rock as surveyed in the Project Area.

The shoreline corresponds to the mean high water line at the mean high water elevation of +1.9 feet NGVD. Within Phipps Ocean Park and to the north of the park, from DNR Monument R-116 to R-124, the rock is at or above the mean high water elevation of +1.9, and, as a result, the rock prevents shoreline recession landward of the rock at or above the mean high water elevation. From R-124 to R-126, the rock is below the mean high water elevation and the shoreline may recede landward of the rock.

Figure 3.20 Highest Surveyed Elevation of Rock Within Project Area



During annually occurring severe northeast storms, waves are commonly observed in excess of 6 feet in height. The “high” rock formations can provide some minimal protection to the uplands during normal tides and low to moderate seas. However, under moderate seas or storm conditions, these rock formations are easily overtopped by storm surge and waves, and the upland property is vulnerable to erosion. These rock formations do not provide any significant storm protection, recreational beach area, sea turtle nesting habitat or correct sediment deficit caused by updrift structures or long-term sand management practices. Exposed rock outcrops can function as groin or a low profile seawall during normal sea conditions, and function as a groin and submerged breakwater during minor storms. Sand transferred at Lake Worth Inlet or placed at Mid-Town may migrate to the Project Area, however, such migration is not sufficient to offset erosion in the Project Area until all the groins and headlands to the north of the Project Area become fully impounded and then allow longshore transport to reach the Project Area.

The presence of variably exposed nearshore hardbottom, also referred to as "limestone outcrops" has been well known to the USACE for the last 20 years and was specifically taken into consideration in the 1987 Palm Beach Island GDM/EIS and 1996 COFS. However, in both Federal studies, the USACE made no finding that these low-elevation, natural nearshore limestone outcrops, are sufficient to provide upland storm protection on Palm Beach Island.

3.3 Sediment Characteristics of Borrow Area and Native Beach

3.3.1 Sand Quality/Grain Size

Native Beach: The U.S. Army Corps of Engineers investigated native beach sand characteristics along Palm Beach County beaches in 1979 and published the results in the 1987 Palm Beach Island GDM/EIS (Appendix B). The USACE results provide an historical representation of the sand characteristics of the beaches in the region of the Project Area. In the 1987 Palm Beach Island GDM (Table B-1), the USACE characterized beach sediment in south Palm Beach County as a medium-grain-moderately-sorted sand with a mean grain size of 0.34 mm and a Sorting Coefficient of 0.97 phi. These 1979 conditions best represent the native beach prior to the extensive erosion that subsequently occurred and resulted in reduction of the fines content of the native beach. As the shoreline has eroded, beach sediments were sorted, whereas the fines were removed, and the mean grain size of the native beach has increased.

In 1993, the Palm Beach County Department of Environmental Resources Management (ERM) published results of beach sample analysis ("Environmental Assessment of Coastal Resources in Palm Beach, Lake Worth, South Palm Beach, Lantana and Manalapan – Palm Beach County, Florida", May 18, 1993). ERM reported mean grain sizes at DNR Monuments R-116, R-118, R-121, and R-124 at 0.46 mm, 0.53 mm, 0.57 mm, and 0.44 mm respectively. As expected, these ERM values are significantly greater than the 1979 USACE data. The ERM values reflect the sorting of the native beach sediments due to wave action and erosion.

On behalf of the Applicant, in August 1999, Coastal Tech collected surface grab samples from the native beach in the Project Area at DNR Monuments R-116, R-120, and R-125. Samples were collected at three locations along each transect: (a) at the toe of the dune, (b) at the top of the foreshore slope, and (c) in approximately 5 feet of water. As presented in Appendix K, Supplementary Geotechnical Analysis, the grain size analysis of these samples was performed by Fraser Engineering and Testing; the existing beach sediments were found to have a composite mean grain size of 0.43 mm. Existing beach sediments were found to consist of moderately sorted coarse sand, with a Sorting Coefficient of 0.99 phi and a silt content of less than 1%. As the 1999 data is the most recent data, this data is used to best characterize existing beach sediments.

Borrow Areas: On behalf of the Applicant, the investigation of Borrow Areas III and IV were undertaken by CP&E and the result summarized in a report titled "Town of Palm Beach - Offshore Sand Source Investigation" dated March 2000 (CP&E, 2000). Appendix K includes the relevant excerpts from this report. The sand in Borrow Area III was found to have a mean grain size of 0.32 mm with a Sorting Coefficient of 1.1 phi, and the silt/clay content was found to be 2.9%. The sand in Borrow Area IV has a mean grain size of 0.22 mm with a Sorting Coefficient of 0.9 phi and a silt/clay content of 1.5%.

Table 3.12 summarizes the grain size characteristics of the existing native beach sediments and the sediments in Borrow Areas III and IV. The sediment characteristics are reported in the manner prescribed by the Unified Soil Classification system, except for coarse gravel and cobble which are shown as "% by volume."

Table 3.12
Native Beach & Borrow Area Grain Size Characteristics

Grain Size Characteristics	Existing Native Beach(3)	Borrow Area III(4)	Borrow Area IV(4)
Mean Grain Size (mm)	0.43	0.32	0.22
% Coarse Gravel & Cobble (1)	0 to 0.7	0.3	0.2
% Gravel	2.1	0.0(2)	0.0(2)
% Coarse Sand	2.0	6.6	3.2
% Medium Sand	40.7	33.4	12.2
% Fine Sand	55.2	57.1	83.0
% Silt / Clay	0.0	2.9	1.5
Sorting Coefficient (phi)	1.04	1.1	0.9

(1) % by volume – separate from normal grain size analysis (Appendix K)
(2) Gravel, coarse gravel, & cobble were excluded in Borrow Area samples for grain size analysis
(3) Native beach data source: Supplemental Geotechnical Analysis, Town of Palm Beach, Phipps Ocean Park Beach Restoration Project (Coastal Tech, 2000d), FSEIS Appendix K
(4) Borrow area data source: Town of Palm Beach - Offshore Sand Source Investigation, (CP&E, March 2000)

For the borrow areas, the vibracore logs indicate the presence of some coarse gravel and cobble in the borrow areas (CP&E, 2000). However, the gradation analysis results do not reflect this material. A *Supplemental Geotechnical Analysis* (Coastal Tech, 2000d) was conducted to quantify the content of coarse gravel and cobble in the borrow areas and the existing native beach. The results indicate that the content of coarse gravel and cobble in the borrow areas (0.2% to 0.3%) is within the range of values found on the native beach (0% to 0.7%).

Overfill Factor: The "overfill factor", R_a, is a ratio of the number of cubic yards of borrow area material needed to provide the equivalent of one cubic yard of native beach sediments. For example, for an overfill factor of 2, two cubic yards of borrow area material are needed to be equivalent to one cubic yard of native beach sand.

Based on the 1979 USACE data, the weighted overfill factor for the Project would be estimated at 1.9. Placement of the proposed 1.5 million cubic yards of sand from Borrow Areas III & IV would result in the equivalent placement of about 800,000 cubic yards of native beach sand.

Based on the most recent 1999 data, the overfill factor for Borrow Area III is 1.25 and for Borrow Area IV is 3. As part of the Applicant's Preferred Alternative, about 500,000 cubic yards of sand will be dredged from Borrow Area III to yield an "equivalent native beach volume" of 400,000 cubic yards (400,000 x 1.25 = 500,000). Since the Applicant's Preferred Alternative entails a total of 1.5 million cubic yards, the remaining design quantity of 1.0 million cubic yards will be acquired from Borrow Area IV, which has an overfill factor of 3. The 1 million cubic yards of sand obtained form Borrow Area IV will yield an "equivalent native beach volume" of about 333,300 cubic yards (333,300 cubic yards x 3 = 1.0 million cubic yards). Therefore, the total equivalent Project fill volume would be about 733,300 cubic yards.

Use of the most recent beach samples to calculate the overfill factor is appropriate and does not result in any substantive change in the required borrow area volume or expected performance of the Applicant's Preferred Alternative.

3.3.2 Composition and Mineralogy

Native beach sand samples were analyzed for grain size composition as described in Section 3.3.1. Mineralogy analysis was not performed on existing native beach sediments. Historical beach sediments are reported at about 38% carbonate (USACE, 1961).

For both borrow areas, the sediment consists of a mixture of quartz sand and shell fragments. However, no specific analysis of mineralogy has been performed. It is estimated that 50% of the sediment is quartz and the balance is carbonate material (i.e., shell, coral, and rock). Layers of coarse shell and cobble or boulder sized shell and coral fragments have been reported, especially along the eastern boundary of each borrow area. The material is similar in composition and mineralogy to the native beach (Supplementary Geotechnical Analysis, Coastal Tech 2000d).

3.3.3 Color

Visual characterization of the native beach and borrow area sand color was made. Sand sample cores from offshore Borrow Areas III and IV were collected and characterized for color and determined to be generally gray. Definitive characterization using Munsell Soil Color Chart classification was not undertaken. Typical beach sediments in this region of Florida are generally described as tan to pale brown in color. While no definitive characterization of the degree of difference in color after placement and exposure can be made, the Borrow Area sand placed on the beach has been approved by FDEP and these sands are specifically required to be "similar to that already existing at the beach site in both coloration and grain size distribution and shall be suitable for marine turtle nesting." (See FDEP Permit, Phipps Ocean Park Beach Restoration Project, Permit/Authorization No.: 0165332-001-JC, March 14, 2001).

The texture and composition of the native beach and potential borrow areas are very similar. Therefore, the native beach color reflects, in part, subaerial exposure in an oxidizing environment subjected to the physical mixing by waves and bioturbation. The majority of sand in the borrow areas is an oxygen depleted or anoxic condition which results in these sediments being darker in color. Exposure to sunlight will lighten the color of fill sediment over time.

3.4 Beach and Dune Vegetation and Wildlife

Beach and dune vegetation within Palm Beach County includes sea grapes (*Cocoloba uvifera*), the beach morning glory (*Ipomea pes-caprae*), beach bean (*Canavalia rosea*), sea oats (*Uniola paniculata*), and dune panic grass (*Panicum amarulum*). Within some communities beach berry (*Scaevola plumeri*), sea lavender (*Mallotonia gnaphalodes*), and beach star (*Remeria maritime*) are present. The coconut palm (*Coco nucifera*) is also common in some areas. Beach and dune vegetation provide valuable habitat for a variety of mammals including the raccoon (*Prycon lotor*), and house mouse (*Mus musculus*), as well as many bird species such as least terns (*Sterna albifrons*), which rely on this vegetation for foraging habitat and nesting.

3.5 Threatened and Endangered Species

This section describes the biology of federally protected species potentially affected by the proposed Project.

3.5.1 Sea Turtles

Five species of sea turtle are found in the waters offshore of Palm Beach County, three of which have been documented as nesting frequently on County beaches. The loggerhead (*Caretta caretta*) is responsible for the vast majority of the nesting, although data suggest increasing numbers of green (*Chelonia mydas*) and leatherback sea turtles (*Dermochelys coriacea*) nesting statewide. Green and leatherback sea turtles are listed under the U.S. Endangered Species Act, 1973 and Chapter 370, F.S. The loggerhead turtle is listed as a threatened species.

3.5.1.1 Nesting Habitat

Currently, sea turtle nesting surveys are conducted for individual incorporated areas within Palm Beach County; however, the Florida Fish and Wildlife Conservation Commission (FFWCC) Statewide Nesting Beach Survey (SNBS) program has collected data along County beaches since 1980. This data is collected along County beaches over a distance ranging from 46.2 km in 1988 to 63.6 km in 2000. Palm Beach County is within the normal nesting range of three species of sea turtles: the loggerhead, the green, and the leatherback. The Kemp's Ridley (*Lepidochelys kemp*) and hawksbill (*Eretmochelys imbricata*) are infrequent nesters along the east coast of Florida.

The Applicant has compiled all reasonably available sea turtle nesting data for the Palm Beach County area and the Phipps Project Area, which is presented in detail in Appendix C, Cumulative Impact Assessment Report (CIAR); (See also Section 4.5.3). The relationship between nesting densities and beach width and general nesting trends between Lake Worth and South Lake Worth Inlet are presented. The CIAR also discusses how beach nourishment can impact turtle nesting behavior and success.

Beach renourishment activities can impact nesting success both positively and negatively. If significantly different than the native beach, sand deposited on the nesting beach may affect nest site selection and digging behavior, the nests' incubation temperature, gas-exchange characteristics of the nest, and the nests' moisture content. These differences can affect the success of hatchling emergence from both egg and nest. In addition, if not treated, sand placement may result in compaction of the beach, which can also reduce nesting success.

One critical factor in nesting success is the availability of suitable sandy beach habitat for nesting; not just sand, but sand of sufficient depth and appropriate characteristics, such as grain size distribution, compaction, and color. As discussed in Section 3.2.3, sand volume is being lost at a significant rate within the Phipps Project Area (an average of 35,000 cubic yards per year from 1990 – 1997, Section 3.23, Reach 7). Loss of sandy shorelines and loss of a sufficient "sand lens" above the underlying rock substrate will over time result in greater exposure of the underlying rock substrate in the Project Area. If continued unabated, this result can be reasonably expected to interfere with future marine sea turtle nesting activity and hatch success. In addition, even if there is sufficient sand landward of rock outcrops at the water line, the beach may be inaccessible to nesting turtles if a rock barrier or "cliff" forms along the shoreline. Such conditions would be significantly reduced or eliminated by regularly scheduled program of beach nourishment and renourishment. The quality of sea turtle nesting habitat in the Project Area can be expected to decline if action is not taken to restore the necessary nesting conditions.

When beach renourishment is conducted during the nesting season, it can bury nests and adversely affect nesting turtles and hatchlings, and heavy machinery and pipelines associated with the beach renourishment activity can cause false crawls or entrap nesting females and hatchlings. To avoid these impacts, the renourishment process must be conducted carefully to ensure proper project timing, as provided in the FDEP permit for the Applicant's Preferred Alternative. Where sand compaction occurs during renourishment activities, tilling has been successfully used to soften the sand and preserve nesting success and is required by FDEP within the Project Area. As provided in Appendix L, the FDEP permit for the Phipps Ocean Park Project also requires regular post-construction monitoring of the suitability of the beach for turtle nesting and remediation of adverse conditions, such as sand compaction and formation of escarpments. In the first year following beach nourishment, there can be, nonetheless, a temporary reduction in nesting density in the fill area. In some cases, nesting density on adjacent beach areas can be expected to increase, offsetting this impact, however, the extent to which nesting females would seek suitable beaches nearby cannot be predicted.

Nesting data in Palm Beach County is regularly collected by State-licensed "Marine Turtle Permit Holders," such as Robert Schonfeld, currently employed by the Town of Palm Beach to monitor sea turtle nests in the Phipps Project Area as well as areas north and south of the Project Area. From 1998 to 2001, Mr. Schonfeld documented a total of 1,611, or an average of about 403, nests per year in an area generally described as "PAR III to Sloan's Curve, including Phipps Park." Definitive data on the specific shoreline reaches surveyed for nests was not recorded and is therefore unavailable. Based on the Schonfeld data, the number of turtle nests in the survey area appears to be stable or trending upward. This trend is generally consistent with the analysis of trends presented in Appendix C. According to Mr. Schonfeld, the beach at Phipps Ocean Park, where intertidal rock is frequently exposed along the shoreline, typically has less nesting density than the areas north and south of Phipps Ocean Park.

Restoration of the beach will likely benefit sea turtle nesting activity over the long-term and is preferable to allowing nesting conditions to continue to decline.

3.5.1.1.1 Loggerhead Sea Turtle

Loggerheads nest in the southeastern U.S. from April through September, with peak nesting occurring in June and July (NMFS and USFWS, 1991a). The nesting process is remarkably stereotyped, as described by Bustard et al. (1975). From 1988-2000 the mean number of loggerhead nests was 208 nests/km for the beaches surveyed (FFWCC SNBS, 2000). The estimated mean number of loggerhead nests for the entire County from 1988-2000 was approximately 12,040 nests per year, with 14,187 nests reported in 2000.

3.5.1.1.2 Green Sea Turtle

Green sea turtles nest during the summer months and numbers of nests for Palm Beach County were determined from FFWCC SNBS (NMFS and USFWS, 1991b). The mean nesting density for areas surveyed from 1988-2000 was 9.8 nests/km. Countywide, the mean is approximately 568 nests per year.

3.5.1.1.3 Leatherback Sea Turtle

For the same 13-year period, leatherback turtle nesting density was 1.86 nests/km on the surveyed County beaches (FFWCC SNBS, 2000). This yields an estimate of approximately 108 nests annually. In 2000, a total of 160 leatherback turtle nests were found along the 63.6 km of beach surveyed by FFWCC SNBS.

3.5.1.2 Nearshore Foraging and Offshore Habitat Utilization

Sea turtles use the offshore habitats of Palm Beach County differently during different life stages. During the summer months hatchlings utilize this habitat as a corridor to deeper waters farther off the coast. Juvenile and sub-adults use the offshore habitats as a foraging area and to travel to inshore areas. Adults are present year round with seasonally high abundances during the breeding season.

3.5.1.2.1 Loggerhead Sea Turtle

Hatchlings emerge primarily at night and swim offshore in a ”frenzy” until they arrive at offshore weed and debris lines (Carr, 1986; Wyneken and Salmon, 1992). Post hatchling turtles from the Florida coast enter currents of the North Atlantic Gyre, eventually returning to the western Atlantic coastal waters (Bowen et al., 1993). When loggerheads reach a carapace length (CL) of approximately 40-60 cm, they leave the pelagic environment and move into various nearshore habitats (Carr, 1986). These juvenile and sub-adults are found throughout the year in inshore habitats and the offshore reef habitats of Palm Beach County. Adults in South Florida utilize foraging grounds in the Caribbean basin, the Gulf of Mexico, and along the U.S. east coast (Meylan et al., 1983). The adult population in Florida waters increases during the nesting season (Magnuson et al., 1990).

3.5.1.2.2 Green Sea Turtle

Green turtles show a similar life history pattern as loggerheads, but they leave the pelagic phase and enter developmental habitats at a considerably smaller size (~20-25 cm CL) (Magnuson et al., 1990). Typical developmental habitats are shallow, protected waters where seagrasses are prevalent (Carr et al., 1978), but they are commonly found in reef habitats where algae is present (Coyne, 1994; Ehrhart et al., 1996). During this time they shift from an omnivorous diet to a more herbivorous diet, feeding primarily on seagrasses and algae. In Florida, these turtles feed primarily on a diet of seagrasses such as *Halodule wrightii*, *Syringodium filiforme*, and red (Rhodophyta) and green (Chlorophyta) algae (Lutz and Musick, 1997). Green turtles nesting in Florida have a minimum size of 83.2 cm CL, but they appear to leave Florida developmental habitats by about 60-65 cm CL (Witherington and Ehrhart, 1989), perhaps migrating to the southeastern Caribbean. Dietary needs of juveniles along with seasonal abundances of seagrasses and algae within the area may be factors influencing the habitat use within the area. As adults, offshore habitat utilization would be greatest during the nesting period.

3.5.1.2.3 Leatherback Sea Turtle

Leatherback turtles occur worldwide in pelagic waters from the tropics to near the Arctic and Antarctic Circles. Nesting is primarily on the Pacific coast of Mexico and the Caribbean coast of South America, with some continental U.S. nesting in Florida. The majority of nesting activity is located within St. Lucie, Martin, and Palm Beach counties (Meylan et al., 1995).

3.5.2 West Indian Manatee

The West Indian manatee (*Trichechus manatus*) is protected under both the Endangered Species and Marine Mammal Protection Acts, and is listed as protected under Florida State law. The manatee is generally restricted in range to the Georgia coast southward around the Florida peninsula. Manatees frequently inhabit shallow areas, and protected lagoons and freshwater systems, where seagrasses are present. Manatees occasionally use open ocean passages to travel between favored habitats (Hartman, 1979). Manatees migrate seasonally, particularly on the east coast of Florida. During the summer months, manatees utilize habitats all along the coast. During winter, when water temperatures drop, manatees use warm water refuges such as springs or warm water discharges from power plants.

Within Palm Beach County, manatees infrequently inhabit the nearshore waters; however, sightings are more common during the summer months. During winter months, as water temperatures drop, manatees congregate at warm water refuge areas within Palm Beach County (i.e. Riviera Beach) and some members of the resident population migrate north or south to other warm water refuge areas (i.e. Vero Beach, Port Everglades).

3.5.3 Southeastern Beach Mouse

The southeastern beach mouse (*Peromyscus polionotus neveiventris*) is listed as a threatened species at both the federal and state levels. The primary habitat of the beach mouse is coastal dune communities comprised of sea oats (*Uniola paniculata*), although grasslands and open sandy areas in the fore-dune area may also be utilized (Humphrey, 1992). This subspecies was originally endemic to coastal dunes along the Florida coast from Ponce Inlet in Volusia County to Hollywood Beach, Broward County. The decline in beach mouse populations has been attributed to habitat loss due to coastal development and beach erosion.

Southeastern beach mice have been historically documented within Palm Beach County (Humphrey, 1992). It appears however, that the southeastern beach mouse may recently have been extirpated from its local range due to habitat erosion.

3.5.4 Least Tern

The least tern (*Stern antillarum*) is a small member of the gull family (Laridae). The least tern is listed by Florida as a threatened species and is protected federally under the Migratory Bird Treaty Act. Least terns breed along the east coast of the United States from Massachusetts to Florida, with the Florida populations returning each year in April. The breeding season extends through the summer. Least terns traditionally choose open sandy substrates to form breeding colonies. Least terns forage along coastal areas on small fishes, and to a lesser extent crustaceans and insects. Within Palm Beach County, least terns have been known to nest on County beaches.

3.5.5 Northern Right Whale

The northern right whale (*Eubalaena glacialis*) is a federally listed endangered species and is protected under the Marine Mammal Protection Act. The current migratory population within the Atlantic region is less than 350 individuals (Humphrey, 1992). Right whales are highly migratory, spending their summers in the Canadian Maritime Provinces and migrating southward in the winter to the eastern coast of Florida. The breeding and calving grounds for the right whale occur off the coast of southern Georgia and north Florida. During these winter months right whales are routinely seen close to shore and have been sighted as far south as south Florida, with isolated sightings in the Gulf of Mexico. Within Palm Beach County, the peak occurrence of right whales would occur from December through March.

3.6 Offshore Borrow Area Resources

Offshore sand habitats support a diverse fauna, although there has been comparatively little research attention in this environment. There are several studies concerning invertebrates and fishes from the open sand habitat in the adjacent areas. Johnson (1982) collected over 188 species of invertebrates in benthic grab samples from the Capron Shoal area off Fort Pierce Inlet. In a study offshore of Hutchinson Island in St. Lucie County, Futch and Dwinell (1977) collected lancelets (jawless fish in the subphylum Cephalochordata) in densities as high as 1,750/m^2. Gilmore et al. (1981) collected 194 species of fishes from open shelf sand habitats in Indian River County. Flatfishes, searobins, and cusk eels, along with an assortment of baitfishes and skates, dominated the fish fauna. South of the study area, polychaetes and nematodes were the most dominant organisms (Dodge, 1991). During an infaunal study offshore of Hollywood Beach, the dominant taxa were polychaetes (52%), nematodes (14%), and crustaceans (9%). Macroalgal growth is also associated with these communities. The most abundant species were *Caulerpa* sp., *Halimeda* sp., and *Codium* sp. during the summer months. This is in contrast to the winter months where *Dictyota* sp. and *Sargassum* sp. are more common (USACE, 1996). Invertebrate fauna such as the Florida fighting conch (*Strombus alatus*), milk conch (*Strombus costatus*), king helmet (*Cassia tuberosa*), and the queen helmet (*Cassia madagascariensis*) may also utilize this softbottom area (USACE, 1996). This area, which lies within the second and third reef lines within the study area, may provide a corridor for reef species to travel between reef lines and also as an important foraging area for some fish species (Jones, et al. 1991). A Borrow Area Resource Video Survey was conducted January 14 and 15, 2002 and the report is located in Appendix H.

3.7 Hardbottom Resources

Hardbottom features on the shelf of the Project Area exist as Pleistocene beach ridges that roughly parallel the present day shoreline (Duane and Meisberger, 1969). These ridges form linear ledges that emerge from the sediment in discontinuous fashion along a north-south trend. Exposed rock surfaces are colonized by epibiota such as algae, sponges, soft corals, hard corals, and tunicates. When observed on a large enough spatial scale (100's of ft to 1mi) epibiotal assemblages represent a mosaic of different successional stages ranging from early to mature. Much of this mosaic pattern is directly related to physical environmental disturbances and water depth. Other factors associated with water depth that influence epibiota distribution and abundance are turbidity and light penetration. Wave-generated sediment scour or burial can dictate the increase or reduction of available hard substrate. As new patches of rock become available, new groups of colonists will settle from the plankton or in the case of motile organisms, emigrate from surrounding areas and start the process again. In shallow water where disturbance is high, epibiotal assemblages will rarely reach the mature successional stages. In deeper waters where mature assemblages have developed, there is less physical disturbance, and therefore the assemblages are composed of longer-lived larger size organisms. Disturbances (e.g., storms and ship groundings) occur with less frequency in deep waters than in shallow waters, where available space is constantly changing. Smaller, more opportunistic species tend to dominate in shallow water. Worm rock, for example, can completely cover exposed hard surfaces, preventing the successful settlement of other attached organisms.

Following this simple model, which is similar to one originally proposed to explain spatial patterns in rocky intertidal assemblages (Levin and Paine, 1974) and more recently incorporated as part of a general theory of assemblage organization (Wu and Loucks, 1995), a general depth-related scheme for epibiota assemblage patterns is presented in Table 3.13. Depending on the history of physical disturbance, the geomorphology (sediment overburden and absolute relief of underlying rock), water depth, and of course chance, the epibiota may or may not conform perfectly to the classification scheme. The table also includes the commonly occurring fishes and life stage ratios expected along the depth gradient. Because the same physical factors will influence the assembly of epibiota on structures deployed in various water depths for mitigation purposes, the table also includes a category that indicates expected success of mitigation for the different depth strata. Nearshore epibiota such as algae, worm rock, and boring sponge will colonize limestone structures placed in shallow or intermediate depth strata in less than 1 year. Replicating the mature offshore hardbottom assemblages would take much longer, possibly decades. Large sponges and soft and hard corals in particular would require considerable time to develop into assemblages that resemble those that may be currently present at water depths greater than 5 meters.

The value of assessing the mitigation potential for hardbottom resources is that it establishes the relative significance of potential impacts to each habitat type, based on the complexity of the resource and the difficulty of replicating both the physical structure and species composition of the type. As such, this tool may be useful in establishing appropriate mitigation ratios for future projects. For example, the physical structure and species composition of the "offshore hardbottom" habitat, such as the Breaker's Reef located offshore of DNR Monument R-94, would be difficult to replicate and could take decades. The complexity and density of the biological community, including algae, massive sponges, tube sponges, soft corals, hard corals, and tunicates can be sparse or dense, covering up to 100% of the substrate surface available. Impacts to this type of habitat – which does not exist offshore of the Phipps Project Area – could warrant a high mitigation ratio, if project impacts were permitted at all. Hardbottom in the intermediate category can be more easily replicated by placement of new substrate similar to the native hardbottom resources and in similar water depth and wave conditions. These substrates tend to be rapidly colonized by epibiota, developing a population of similar taxonomic composition in a relatively short period of time, compared to offshore reef features.

Nearshore hardbottom habitats are the most easily replicated, primarily because these features are buried and unburied by naturally shifting sands with some regularity and species tend to be adapted to quickly colonizing new substrates once exposed. These hardbottom features are typically located in high wave energy, high turbidity environments, unsuitable to colonization by delicate corals, sponges, or gorgonians. Species tend to be more robust, including turf algae, worm rock, boring sponges and occasional hard encrusting coral of limited size. These habits tend to be substantially less biologically diverse compared to intermediate and offshore hardbottom resources and can be readily replicated. Depending on specific local conditions, it may be logistically difficult to place rock in nearshore, shallow water depths. Mitigation reefs deployed in slightly deeper water are quickly colonized by fishes and invertebrates of similar taxonomic composition.

Video capture and still photo images of each habitat classification described in Table 3.13 are included in the subsections below as Figures 3.21a to 3.23. These images are from locations in the vicinity of the Project Area which were selected on the basis of photo quality. These images are representative of typical habitat types in the Project Area and are not necessarily from the Phipps Project Area itself.

Table 3.13 Mitigation Potential as Related to Provisional Classification of Nearshore Hardbottom Habitat on the Inner Shelf of Palm Beach County

(Tate, S. and D. Snyder, 2002)

Characteristics	Nearshore (<10 feet)	Intermediate (10-17 ft)	Offshore (>17 ft)
Physical	High wave energy and sediment scour; relief range from 0 to 3.3'; turbidity low to high; ephemeral and highly variable in configuration.	Intermediate wave energy and sediment scour; relief range 0 to 3.3'; turbidity low to medium; variable to highly variable in configuration.	Low wave energy and sediment scour only during storms; relief range 0 to 6.6', turbidity low to medium; stable in configuration.
Epibiota	Turf algae, worm rock, boring sponges, occasional hard coral, tunicates; cover ranging from 0 to 100%; density of organisms low.	Turf and macro algae, sponges, bryozoans, occasional soft and hard corals; patchy cover ranging from 0 to 100%; density of organisms low to medium.	Algae, sponges (massive and tube), soft corals, hard corals, and tunicates; patchy cover ranging from 10 to 100%; density of organisms low to high.
Fishes	Sailors choice, porkfish, black margate, hairy blenny, seaweed blenny, cocoa damselfish, silver porgy; ratio of juveniles to adults seasonally high.	Sailors choice, porkfish, black margate, tomtate, hairy blenny, seaweed blenny, cocoa damselfish; ratio of juveniles to adults intermediate.	French grunt, tomtate, bicolor damselfish, redband parrotfish, gray snapper, gag, black grouper, yellowtail snapper; ratio of juveniles to adults equal to 1 or lower.
Mitigation Potential	Can be replicated; may be logistically difficult to replicate within affected water depth. Mitigation reefs deployed in slightly deeper water are quickly colonized by fishes and invertebrates of similar taxonomic composition.	Can be replicated in similar water depths. Persistence is affected by rock under burden and mitigation reef materials/design. Fish and epibiota of similar taxonomic composition will colonize quickly.	Can be replicated in similar water depths, but complexity of biological communities nay take decades to establish. Fishes will rapidly colonize, epibiota may take decades to reach similar assemblage composition

3.7.1 Nearshore Hardbottom

In January and February 2000, the natural nearshore and intermediate depth hardbottom characteristics were documented by collecting video data and still photos along 31 transects established perpendicular to the shoreline within the Project Area (CSA, 2000). The transects were plotted between DNR Monuments R-113 and R-128, and water depths along the transect ranged from 4 to 30 feet. Video documentation was recorded using Integrated Video Mapping System (IVMS) and a diver towed behind a boat using surface-supplied air and a high-resolution color video camera (Figures 3.21a and 3.21b).

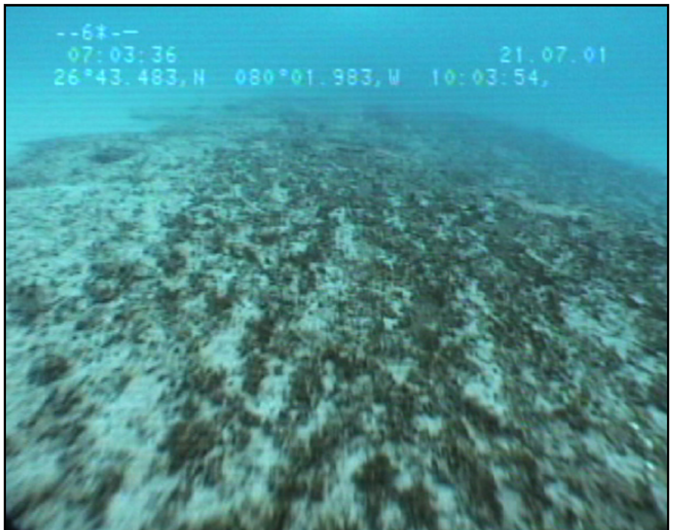


Figure 3.21a Typical Nearshore Hardbottom Habitat, Towed Video Survey, DNR Monument R-91

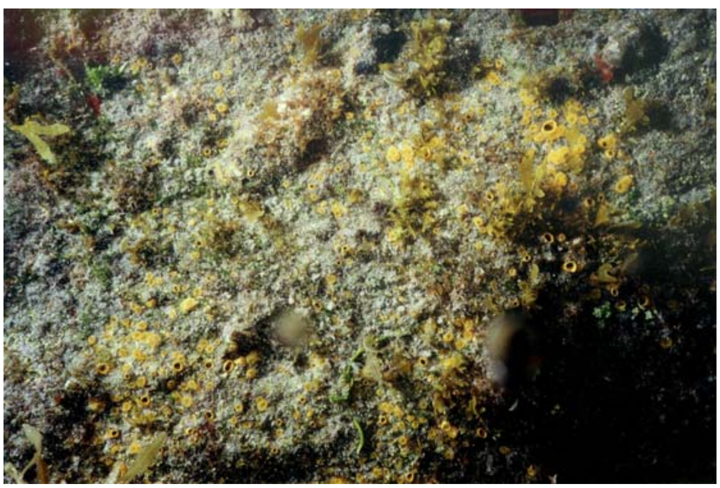


Figure 3.21b Typical Nearshore Algal Fouling Community, Still Photo, DNR Monument R-91

Hardbottom was documented along the northernmost transects (DNR Monuments R-113 to R-116) where the water depth varied from 4 to 10 feet. The outer portion of this hardbottom borders the intermediate depths described in Table 3.13. This area consisted of either exposed or sand-veneered rock. A small concrete artificial reef (PEP reef) located in approximately 6.6 feet of water was observed along the nearshore section of DNR Monument R-115. The reef, which was encrusted with algae, sponges, sabellariid worm rock, and hydroids, had a vertical relief of approximately 3.3 feet.

The remaining hardbottom area was located between DNR Monuments R-116 and R-125, and the region parallel to the shore and the breakwater at a depth of approximately 6.6 feet. Exposed rock, scattered rock and sand, and sand-veneered rock comprised this hardbottom area. Low vertical relief substrate consisting of sand-veneered rock and exposed rock was predominant in the northern nearshore (DNR Monuments R-116 to R-117.5) hardbottom region. This hardbottom area was located in shallow water and usually in the surf zone. Sabellariid worm rock and algae were common in this hardbottom area.

Exposed rock, sand-veneered rock, and scattered rock on sand comprised the center section of the nearshore survey area (DNR Monuments R-117.5 to R-122). Vertical relief along the eastern edge was approximately 1.6 to 3.3 feet with a maximum water depth of 6.6 feet. Although more fishes were observed in this area, attached biota on the rock was considerably less compared to the other nearshore survey areas.

The hardbottom present in the southern region of the nearshore survey area (DNR Monuments R-122.5 to R-125) consisted of exposed rock, sand-veneered rock, and rock on sand. The vertical relief in this area was less than that observed in the northern section and had less benthos attached to rocks than both the northern and central survey areas. A good deal of the rock substrate in the southern section appeared to be scoured by both wave action and sand.

3.7.2 Intermediate Hardbottom

As mentioned above, hardbottom was observed along the northernmost transects (1 through 6, DNR Monuments R-113 through R-116, respectively) in water depths ranging from four to ten feet. The hardbottom in this area consisted of exposed and sand veneered rock. The eastern edge of the hard bottom outcrop, which lies at the beginning of the intermediate depth zone, had the highest degree of relief, approximately one to three feet. The western edge had a relief of less than two feet. At the southern end of the hardbottom, as observed along transect 6, a thin layer of sand veneered the rock. The dominant biota on these deeper (intermediate) rock outcrops included algae, sabellariid worm rock, sponges, and soft corals (Figure 3.22).

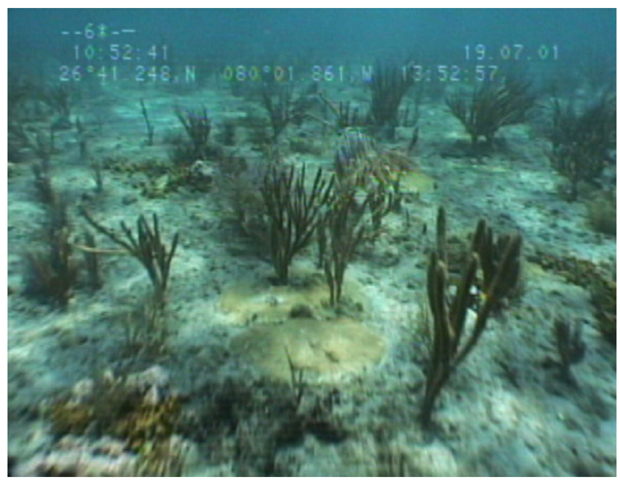


Figure 3.22 Typical Intermediate Hardbottom Habitat, Video Capture Image, DNR Monument R-103

3.7.3 Offshore Hardbottom

Within the offshore depths of the Project Area covered by the IVMS transects sand was the most abundant bottom type encountered. Biota observed within this zone included burrowing anthozoans (Order Ceriantharia) and the sand dollar (*Encope michelini*). *Encope michelini* was abundant starting at a depth of 20 feet and continuing eastward along each transect to a maximum depth of 30 feet. No offshore hardbottom or reef habitat of the type described in Table 3.13 is present in the offshore area seaward of the proposed Project limits.

On June 13, 2000, CSA videotaped the offshore reef area east of both proposed borrow areas in the Project Area (CSA, 2000). The survey was conducted along a parallel transect plotted along the western edge of the hardbottom areas using a mini-sled with a color video camera towed just above the bottom. Water depths along the north-south transect varied from 38 to 55 feet. The hardbottom area varied from minimally exposed low-relief rock with no attached biota to higher relief rock supporting mature epibiotal assemblages. In areas supporting mature assemblages, vertical relief varied from one to three feet, although vertical relief and reef complexity appeared much greater in several areas. Overall, these reef areas support a larger diversity and abundance of organisms compared to the nearshore hardbottom communities (Figure 3.23). A characteristic aspect of Palm Beach County's offshore hardbottom assemblages is the high density of gorgonians, primarily *Eunicea* spp., *Plexaura* spp., and *Pseudopterogorgia* spp. Hard coral species also make up a significant part of the offshore assemblages off southeastern Florida and include *Porites astreoides, Diploria clivosa, Siderastrea siderea,* and *Montastrea cavernosa* (Goldberg, 1973; Jaap, 1984; Dodge, 1991; Vare, 1991; CSA, 2000b). These hard coral species contribute to habitat complexity and cover on hardbottom of the offshore stratum but do not contribute appreciably to building of the reef (light enhanced calcification). True coral reefs, built by the accretionary growth of coral colonies themselves do not exist north of the Florida Keys on Florida's east coast (Jaap, 1984).

The Breaker's Reef is located offshore of DNR Monument R-94. The reef is not located within the area of impact for either the borrow or placement areas for the Applicant's Preferred Alternative.

Figure 3.23 Typical Offshore Hardbottom Habitat Breaker's Coral Reef, DNR Monument R-94

3.8 Beach and Sand Bottom Communities

The beaches of Palm Beach County are exposed and receive the full impact of wind and wave action. These habitats usually have low species richness, but localized species can become abundant. Typical beach fauna in the proposed Project Area includes the mole crab (*Emerita talpoida*), surf clam (*Donax variabilis*), and ghost crab (*Ocypode quadrata*). These and other beach infauna provide forage for a wide variety of shorebirds such as plovers (*Charadrius spp*.), willets (*Catoptrophorous semipalmatus*), and ruddy turnstones *(Arenaria interpres*). Drift algae and sargassum stranded on the beach may support large numbers of insects and other invertebrate life.

Polychaetes, gastropods, portunid crabs, and burrowing shrimp dominate nearshore shallow subtidal soft bottom habitats. As water depth increases, these habitats are dominated by amphipods, polychaetes, and bivalves (*Donax* sp., *Tellina* sp.). Within these surf zone habitats there are relatively few fish species present. Vare (1991) observed seven species of fishes in nearshore sand areas off Palm Beach County. These included Atlantic threadfin herring (*Opishonema oglinum*), blue runner (*Caranx crysos*), spotfin mojarra (*Eucinostomus argenteus*), southern stingray (*Dasyatis americana*), greater barracuda (*Sphyraena barracuda*), yellow jack (*Caranx bartholomaei*), and the ocean triggerfish (*Canthidermis sufflamen*). Many of the fishes within this nearshore zone are smaller species and juveniles. This nearshore area consists of habitats, fishes, and prey species managed under the Magnuson-Stevens Fishery Conservation and Management Act (PL 94-265).

3.9 Essential Fish Habitat

The South Atlantic Fisheries Management Council (SAFMC) (1998) has designated seagrass, nearshore hardbottom, and offshore reef areas within the study area as Essential Fish Habitat (EFH) (Table 3.14). The nearshore bottom and offshore reef habitats of South Florida have also been designated as Essential Fish Habitat-Habitat Areas of Particular Concern (EFH-HAPC) (SAFMC, 1998). As many as 60 species of corals can occur off the coast of Florida (SAFMC, 1998), all of which fall under the protection of the management plan. EFH consultation was initiated through the Draft Supplemental Environmental Impact Statement. A detailed description of EFH is found in Appendix D.

Table 3. 14 Essential Fish Habitat Areas

1	Live/Hardbottom
2	Coral and Coral Reef
3	Artificial Reefs
4	Sargassum
5	Water Column
Source: South Atlantic Fisheries Management Council, 1998	

Managed species that commonly inhabit the inshore and offshore habitats within the study area include pink shrimp (*Farfantepenaeus duorarum*), and spiny lobster (*Panularis argus*). Members of the 73 species Snapper-Grouper Complex include sailors choice (*Haemulon parra*), gray snapper (*Lutjanus griseus*), mahogany snapper (*Lutjanus mahogoni*), and porkfish (*Anisotremus virginicus*). These species utilize the inshore habitats as juveniles and sub-adults and the hardbottom and offshore reef communities as adults. In the offshore habitats, the number of species within the Snapper-Grouper Complex that may be encountered increases. Coastal migratory pelagic species also commonly utilize the offshore area adjacent to the study area. In particular, king mackerel (*Scomberomorus cava*lla) and Spanish mackerel (*S. maculatus*) are the most common.

3.10 Coastal Barrier Resources

Congress passed the Coastal Barrier Resources Act (CBRA) in 1982 to address problems caused by coastal barrier development. This Act defined a list of undeveloped coastal barriers along the Atlantic and Gulf coasts. No designated coastal barrier resources have been identified within or adjacent to the Project work area.

3.11 Water Quality

Waters off the coast of Palm Beach County are classified as Class III waters by the State of Florida. This area is suitable for recreation and fish and wildlife resources. One of the major limiting factors to coastal water quality within Palm Beach County is turbidity. Turbidity is measured in Nephelometric Turbidity Units (NTU), which measures the light scattering characteristics of water. The current State standards to minimize turbidity impacts are set at values under 29 NTU above ambient levels. The ambient turbidity within this region is generally lowest in the summer months and highest in the winter months, which corresponds to winter storm events. This is due to organic matter and sediments that become re-suspended by wave action during these storm events. High turbidity events usually return to ambient conditions within several days to several weeks, depending on the duration of the storm event.

According to FDEP, direct impacts to water quality resulting from the dredging of material from the borrow area and subsequent beach disposal should be minimal. The beach disposal could cause elevated turbidity at the edge of a 150-meter mixing zone originating from the point of discharge of fill material onto the beach. A variance from Rule 62-4.244(5)(c), F.A.C. was requested on January 31, 2000 and Turbidity Variance No. 0165332-003-EV was issued by FDEP on February 20, 2002 to establish a temporary mixing zone measured at two points: (1) 300 meters offshore, and (2) 1,000 meters alongshore from the point of sand discharge onto the beach, in an area within Class III Waters of the State. There may be no practicable means known to further minimize the potential for elevated turbidity using the borrow material selected and considering hydrodynamic processes in the nearshore area at the beach nourishment site. The beach nourishment work will be accomplished in a manner that minimizes the potential for elevated turbidity, including the use of construction dikes and a minimum set-back for the discharge pipe from open water at the beach. Hence, compliance with the issued Turbidity Variance is required by DEP.

Turbidity will be monitored during the beach disposal work to ensure compliance at these limits. The areas of nearshore hardbottom habitat adjacent to the Project Area are not anticipated to be impacted from the temporary increase in turbidity resulting from the beach disposal of material. The nearshore outcrops are subject to periodic increased turbidity by storms and wave activity. As a result, the biological communities that inhabit this nearshore zone are made up of stress-tolerant, opportunistic species. The offshore area adjacent to the beach fill site is characterized by sand bottom devoid of exposed rock or reef out to approximately 8,000 feet offshore. Therefore, extending the mixing zone from 150 to 300 meters offshore is not expected to have any adverse affect on conservation of fish, endangered or threatened species, or their habitat.

3.12 Hazardous, Toxic, and Radioactive Waste

The preliminary assessment indicated no evidence of hazardous, toxic, or radioactive waste (HTRW) on the Project lands. During Project construction, further HTRW awareness should be practiced. The proposed Project sites are mostly underwater, located adjacent to popular recreational beaches.

3.13 Air Quality

Air quality along the Palm Beach County coastline is good due to the presence of either on or off shore breezes. The FDEP does not regulate marine or mobile emission sources (dredge and construction equipment) within Palm Beach County. No air quality permits are required for this Project.

3.14 Noise

Ambient noise levels in the Project Area are low to moderate. The major noise producing sources are breaking surf and adjacent residential areas. The sources are expected to continue at their present noise levels.

3.15 Aesthetic Resources

The coastline of Palm Beach County possesses visually pleasing attributes including the waters of the Atlantic Ocean and existing beaches. Over the long-term, the nourishment of the beach will maintain the natural appearance of the protective beach along the ocean.

3.16 Recreation Resources

Phipps Ocean Park, which is located near the center of the Project Area, is the primary source of public access to this section of beach. Erosion of the beach has resulted in exposure of the near shore hardbottom and intertidal rock outcrops. Consequently, this area is unsuitable for conventional beach bathing. Historical data has shown that from August 1983 to December 1999, the exposed hardbottom acreage has increased almost five fold (Coastal Tech, 2000c). In addition, as the nearshore rock has become exposed, public use of the Park has decreased. From 1993 to 1999, public use of the park in respect to parking lot revenues and hours of use has declined 62% (Coastal Tech, 2000c).

3.17 Navigation

The waters offshore of Phipps Ocean Park are used primarily for recreational boating traffic traveling to and from Lake Worth Inlet or South Lake Worth Inlet. The area is also used for SCUBA diving and as a navigation area for fishing charters coming from these adjacent inlets.

3.18 Cultural Resources

An archival and literature review, including a review of the Florida State Master Site File and the current National Register of Historic Places listing, has been conducted to determine if significant cultural resources are located within the area of impact for the proposed Project. A remote sensing survey was conducted in two borrow areas off of Palm Beach County in 2000 to locate potentially significant submerged cultural resources. Magnetic anomalies were recorded in both Borrow Areas III and IV (Baer, 2000). In coordination with the SHPO, buffer areas have been established around each magnetic anomaly in the borrow areas to avoid impacts to potential cultural resources (see section 4.16).