MORPHOLOGICAL CHANGES AT THE 32nd STREET BREAKWATER PROJECT MIAMI BEACH, FLORIDA

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Abstract

Miami-Dade County is located at the southeast terminus of the Florida Peninsula. The County's sandy beaches are on the Atlantic Ocean side of several coastal barrier islands that are separated from the mainland by Biscayne Bay. The shoreline at the 32nd Street area in Miami Beach has historically experienced severe erosion due to an exposed location and abrupt change in the shoreline orientation. In July 2002 three shore-attached breakwaters were constructed at the 32nd Street Hot Spot to address the erosional problems in this area. The breakwaters were constructed as a demonstration project with the purpose of "stepping" the shoreline around the abrupt change in shoreline orientation. In addition, the project incorporated a unique approach to beach management by filling the breakwaters with sand backpassed from the accretional beach to the south to reduce downdrift effects.

The complex geometry of the breakwaters in conjunction with the shoreline orientation requires a thorough monitoring program to evaluate project performance. LIDAR high-density survey data from May 2004 was utilized along with surveys from the ongoing monitoring program of the breakwaters. This data was compiled utilizing GIS spatial analysis tools for coastal engineering evaluation and a detailed morphological study.

The construction of the breakwaters altered the general shoreline orientation in the breakwater vicinity, which influenced the sediment transport. The high density survey data allowed a detailed study of the nearshore morphological changes including the evaluation of shoreline impacts, updrift and downdrift of the breakwaters.

The two years of monitoring data and the morphological study will be utilized by the County to address long-range beach and hot spot management as part of the county-wide regional beach management program. The 32nd Street demonstration project has overall performed satisfactorily based on the monitoring surveys. The diminishing sources of offshore beach compatible sand for beach nourishment make hot spot management an increasingly important component of county-wide beach management.

Introduction

Miami-Dade County is located at the southeast terminus of the Florida Peninsula, and is bordered to the north by Broward County, to the south and west by Monroe and Collier Counties, and to the east by the Atlantic Ocean (see Figure 1). Miami-Dade County's sandy beaches are located on the Atlantic Ocean side of several coastal barrier islands that are separated from the mainland by Biscayne Bay. The 32nd Street Breakwaters are located on a 9-mile long barrier island between Bakers Haulover Inlet and Government Cut with elevations ranging from 5 to 10 feet above Mean Low Water.

Upland development along Miami Beach has occurred relatively recently with major growth occurring in the 1930's. According to the U.S. Army Corps of Engineers (USACE), seawalls almost continually lined the shoreline with abutting groins between Bakers Haulover Inlet and Government Cut measuring approximately 49,000 linear feet. Of these seawalls, approximately 27,500 feet of seawall had little or no beach in front of them. After World War II, many hotel owners on Miami Beach obtained permits to construct new bulkheads 75 feet seaward of the existing one, which, in most instances, were seaward of the existing Mean High Water Line.

Given the need for hurricane protection and the demand for beach area, a decision was made to nourish the beach and improve the shoreline conditions. USACE initiated a beach erosion study of the Dade County shoreline. The Miami-Dade County Beach Erosion Control and Hurricane Protection Project (BEC&HP) was authorized according to the 1968 Flood Control Act. Modifications to the BEC&HP project made in 1974 provided the basis for beach erosion control and hurricane protection along the shoreline.

In 1997, Coastal Systems International (Coastal Systems) completed a study of the long-term shoreline and volumetric changes from 1980 to 1996. Based upon these changes, a regional sediment budget for the entire shoreline from Port Everglades in Broward County to Government Cut was established and the erosional Hot Spot at the 32nd was identified. The area had been renourished several times since the reconstruction of the beach in 1980 and had experienced high erosion rates.

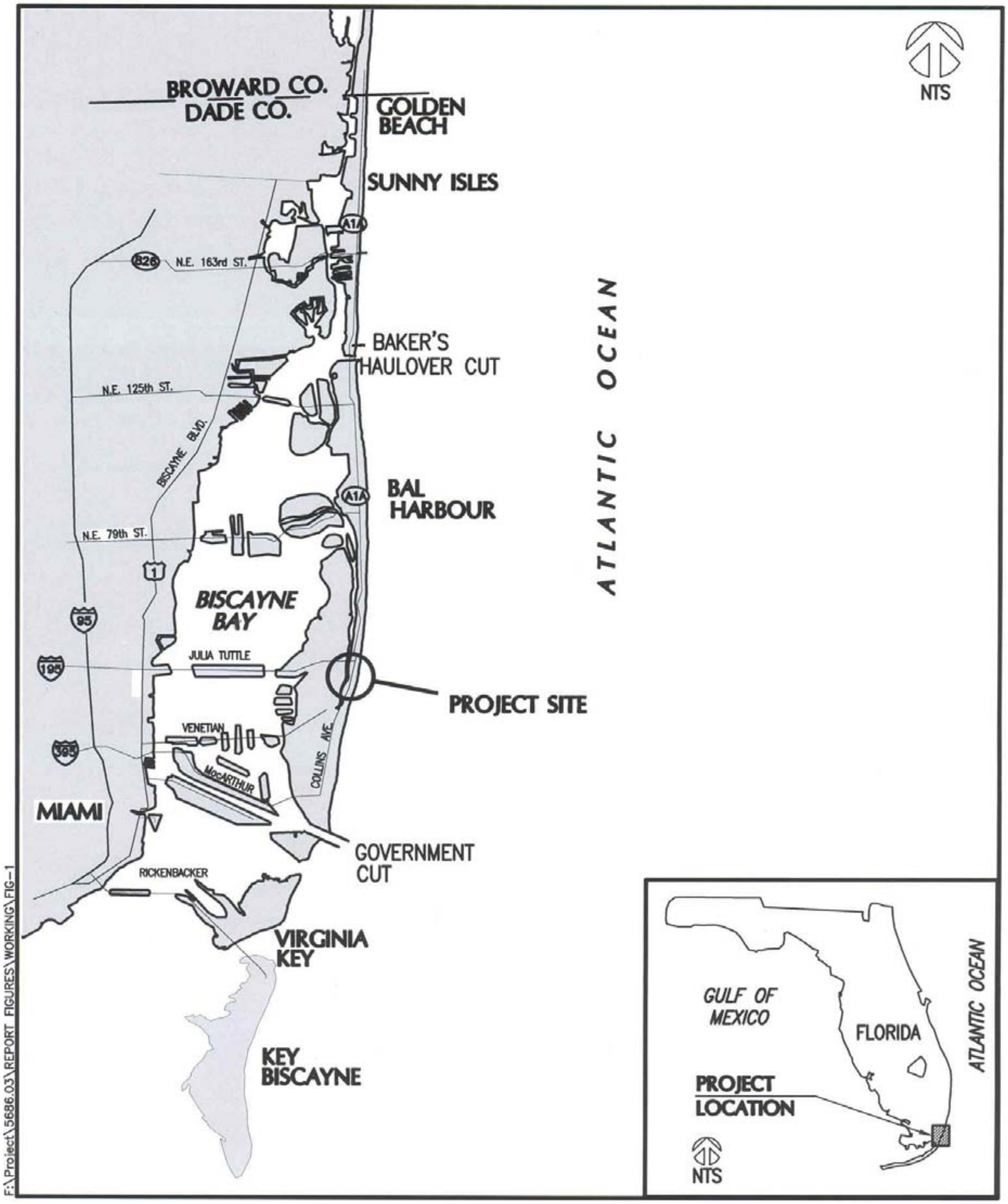
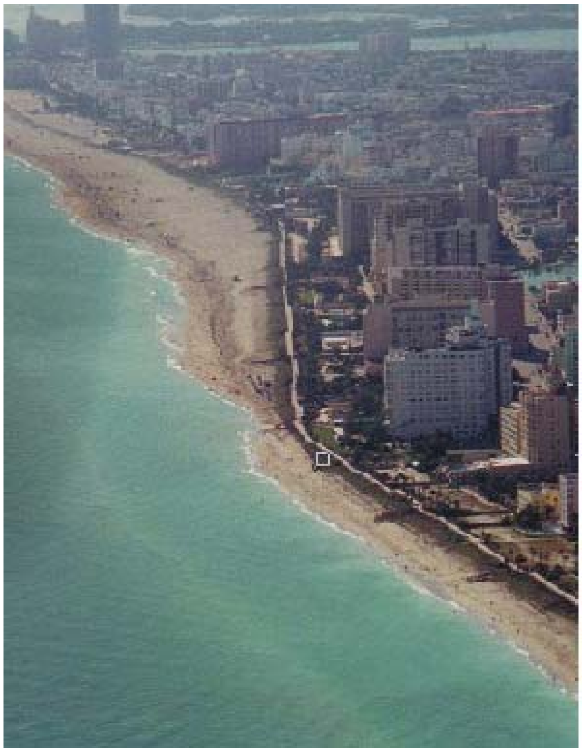


FIGURE 1

Location Map



In 2000, Coastal Systems conducted an analysis of the 32nd Street Hot Spot. Following the analysis, shoreline stabilization consisting of 3 shoreline attached breakwater serving as head-lands were recommended to reduce the continuing erosion experienced and stabilize the shoreline. The analysis showed that the shoreline orientation changes abruptly at the 32nd Street resulting in high erosion rates. As the beach in this area eroded at higher rates compared to the adjacent areas, the nourishment frequency of the area was dictated by the erosion rates at the 32nd Street. The narrow pre-construction beach along with the accretional beach further south is illustrated in Figure 2, which shows the conditions in 1996.

FIGURE 2

Pre-construction Conditions 1996

In July 2002, 3 shore-attached breakwaters were constructed. The area behind and north of the breakwaters (R-58 to R-60) was filled with 125,000 cubic yards of material to minimize down-drift impacts. The sand fill was recycled from the accretional South Beach area and truck hauled approximately 10,000 feet to the 32nd Street Project.

The 32nd Street Breakwater Project has been continually monitored in accordance with regulatory requirements, and preliminary results indicate an overall satisfactory performance. The construction of the breakwaters has changed the general shoreline orientation in the breakwater vicinity, which in turn affects the sediment transport and the overall sediment budget.

The morphological changes at the breakwaters will be described in the following sections. In the analysis, a general southern sediment transport direction is assumed. The direction of the sediment transport is dictated by the wave direction. Along the southeast coast of Florida, northeasterly waves dominate in the winter, while milder southeasterly waves dominate in the summer. Though the larger winter waves dominate the overall transport direction, a transport of material towards the north can be observed during the summer months.

Data and Calculation Method

In the study data from a LIDAR survey and six conventional monitoring surveys were utilized. As part of the permit requirements associated with the construction, extensive monitoring has been conducted. Forty transects were surveyed with approximately 100 feet interval between R-58 and R-62, while only 500 feet apart between R-57 and R-58. A total of 6 surveys have been conducted, with the December 2004 2-year post-construction survey as the latest. The monitoring will continue until October 2006 where the 4-year post-construction survey will be conducted. The available survey data are summarized in Table 1.

TABLE 1
Available Survey Data

Survey Date	Survey Type
October 2002	Conventional
February 2003	Conventional
July 2003	Conventional
October 2003	Conventional
February 2004	Conventional
May 2004	LADS
December 2004	Conventional

Preceding studies on morphological changes have generally been based on cross-sectional profiles. The total volume has subsequently been estimated by the average change of neighboring profiles multiplied by the length of the section. This method in general gives satisfactory estimates of volumes, while the overall morphological changes are more difficult to analyze.

To analyze morphological changes a 3-dimensional surface was generated for each survey, and the volumetric changes were calculated by subtracting the surfaces from each other.

Morphological Changes

The surface generated utilizing the October 2002 (post-construction) survey served as a baseline for the comparison, and was subtracted from each of the following surveys to compute the morphological changes. Figures 3A through 3F illustrate the morphological changes for each of the surveys from October 2002 to December 2004. In the Figures, the red color indicates erosion, while the blue indicates accretion.

The following paragraphs discuss the morphological changes in the breakwater vicinity relative to each survey. While evaluating Figures 3A through 3F, an overall southern sediment transport should be considered, though during the summer months a transport of material towards the north can be observed.

February 2003 Survey:

At the time of construction the northern breakwater protruded from the adjacent shoreline. Therefore, during the winter months when the sediment transport direction is towards the south, material impounded this area. Figure 3A illustrates this impoundment for the period October 2002 to February 2003. Immediately north of the breakwaters, accretion is shown as a dark blue area. This accreted area extended approximately 600 feet north of the structures in the upper region of the beach profile, thus creating a wider beach. Further north local erosion and accretion was observed, but these areas were likely not affected by the breakwaters at this stage. Immediately seaward of the northern breakwater some accretion was noted at water depths from 5 feet to 10 feet. This accretion was likely the formation of a near-shore bar, which was forced seaward by the breakwaters.

Directly south of the breakwaters a small area of erosion was observed, illustrated as a dark red area. The area covered approximately 300 feet of shoreline. Sand trapped on the north side of the structures lead to a reduction in the littoral transport bypassing the structures. Portion of the erosion observed south of the breakwaters could likely be attributed to this bypassing effect.

July 2003 Survey:

At the July 2003 survey the sediment transport direction reversed towards the north, thus the accretion observed between R-58 and R-59 shifted to erosion. However, the accretion observed seaward of the northern breakwater shifted further south to the middle breakwater. The erosion observed at the February 2003 survey immediately south of the structures decreased, though increased erosion was experienced close to R-61.

October 2003 Survey:

Based on the October 2003 survey, sand started again to impound the north area. The erosion observed in July 2003 directly north of the breakwaters was replaced by minor accretion. A sand bar began to build up northeast of the northern breakwater indicating that the area was adjusting to the structures as some material was bypassed around the breakwaters.

South of the breakwater erosion was observed from R-60 almost continuously to R-61 as illustrated by an increase in size of the dark red area.

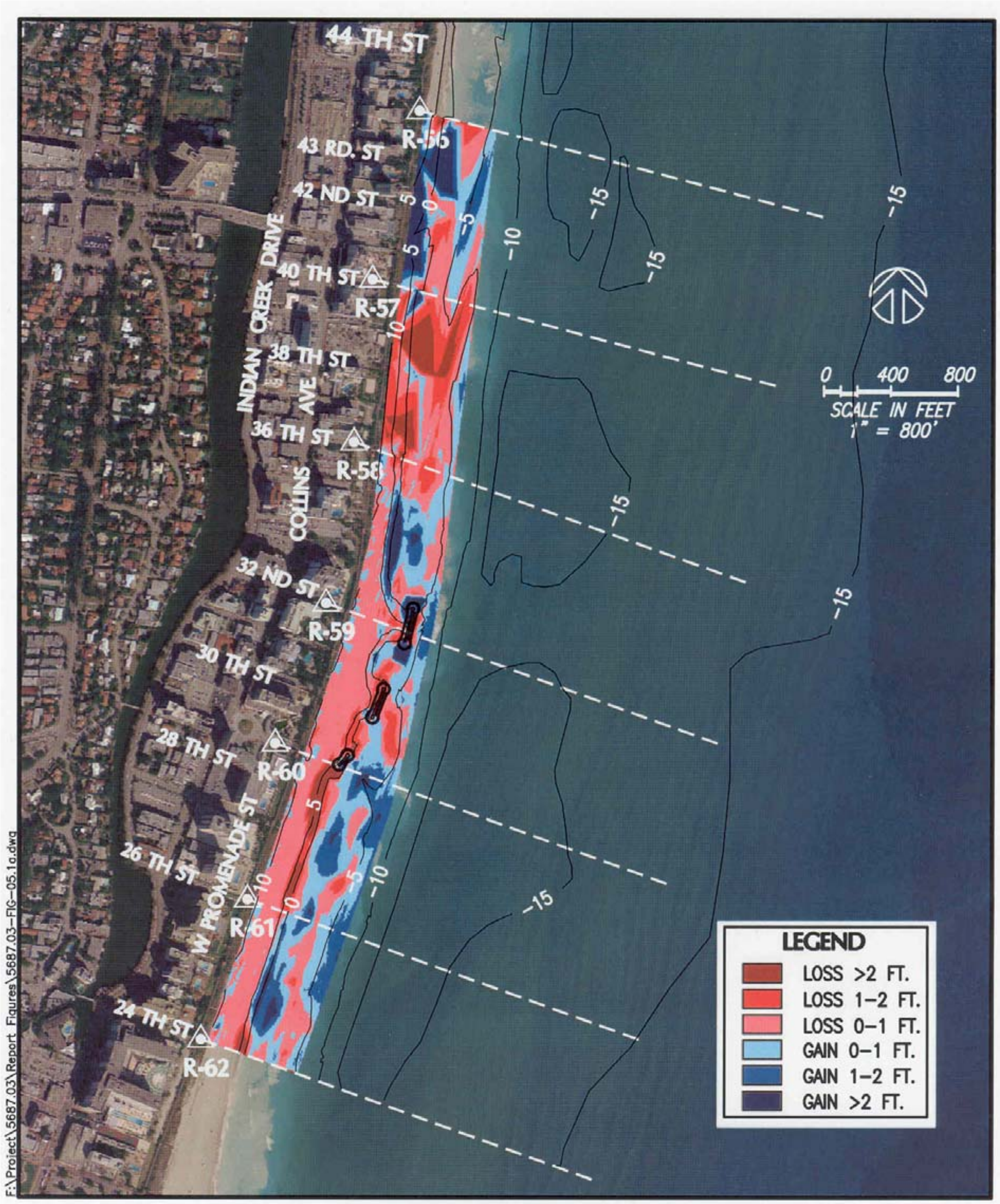


FIGURE 3 A

Morphological Changes at the 32nd Street Breakwaters from Oct. 02 – Feb. 03

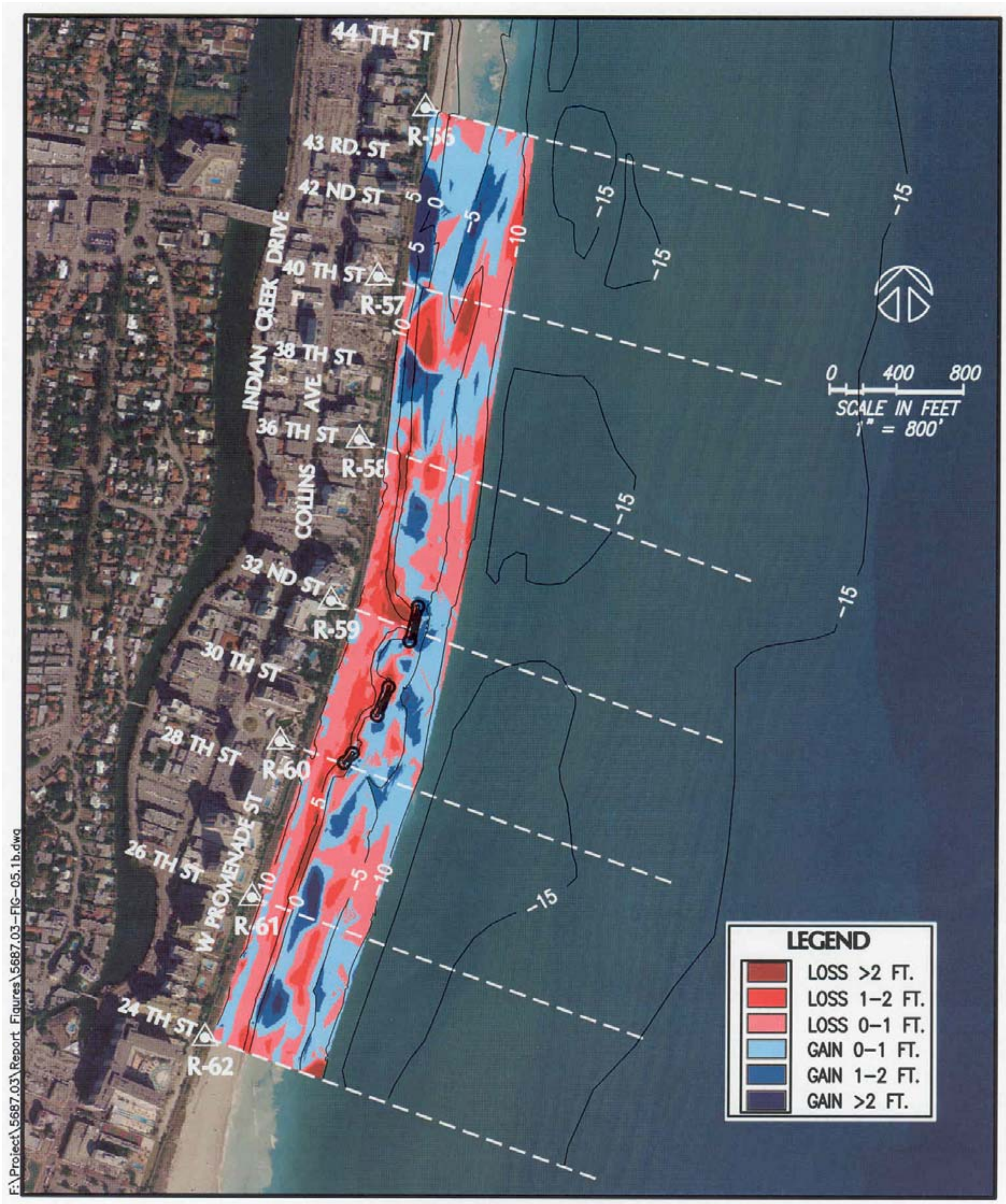


FIGURE 3 B

Morphological Changes at the 32nd Street Breakwaters from Oct. 02 to July 03

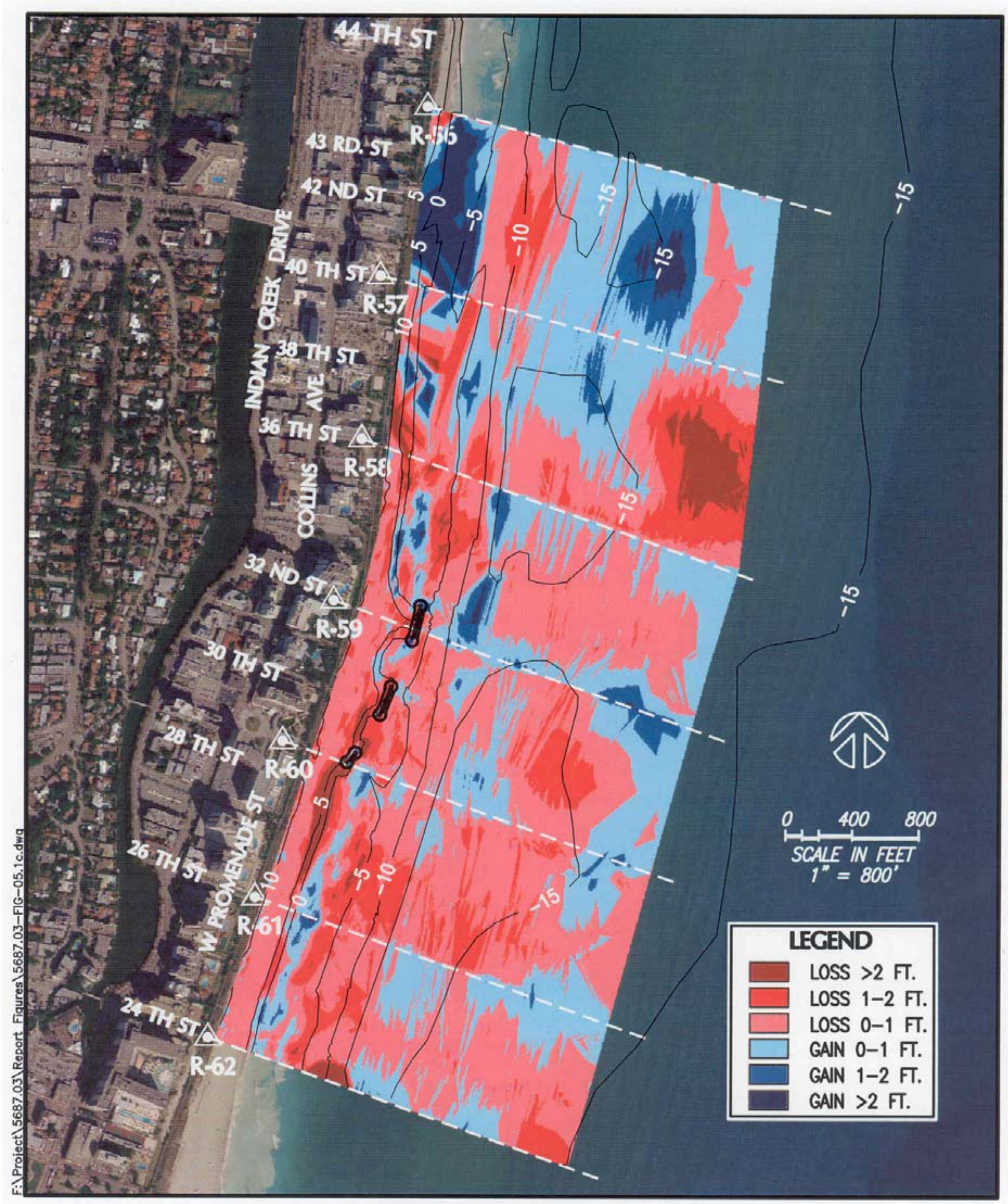


FIGURE 3 C

Morphological Changes at the 32nd Street Breakwaters from Oct. 02 to Oct. 03

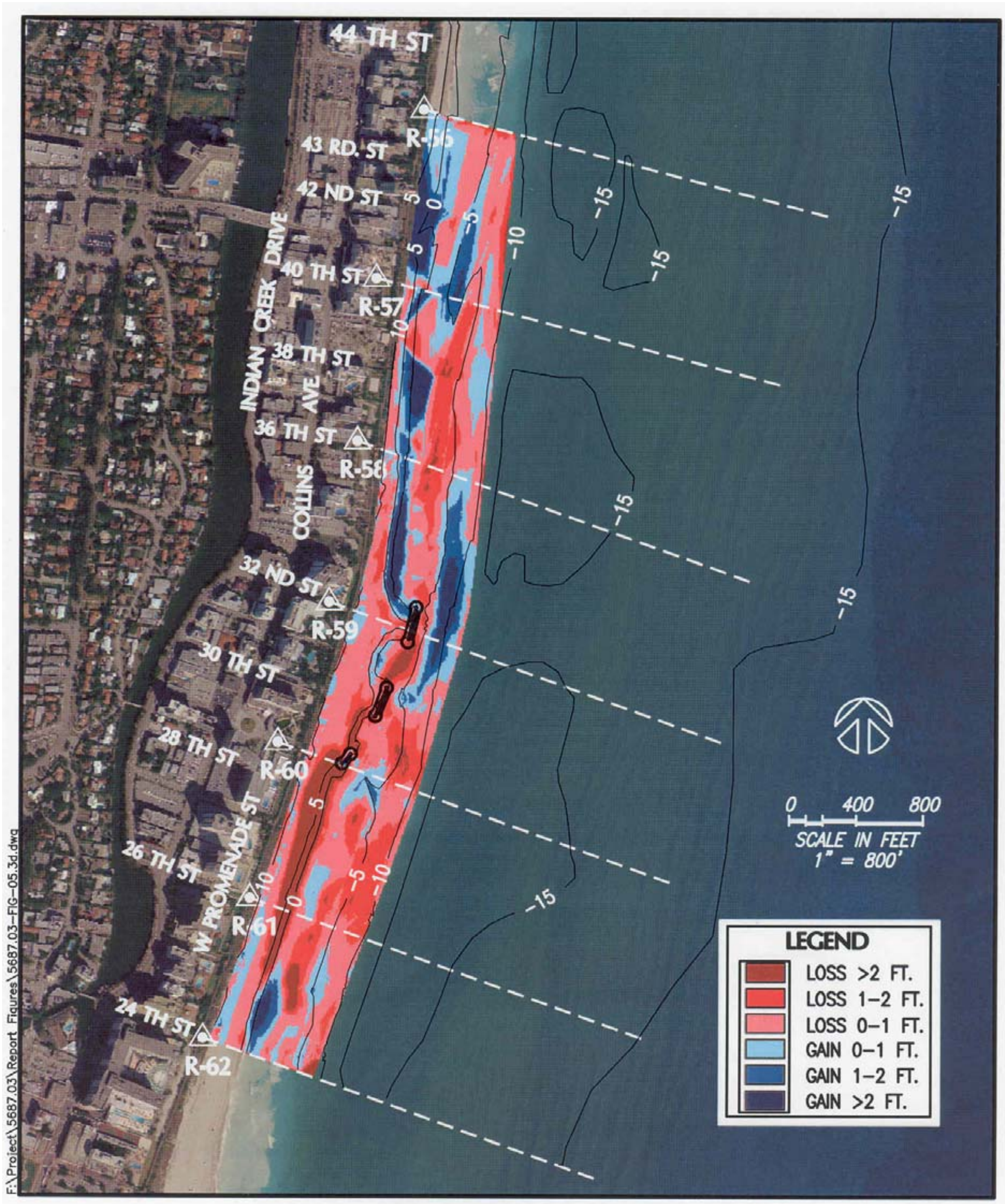


FIGURE 3 D

Morphological Changes at the 32[nd] Street Breakwaters from Oct. 02 to Feb. 04

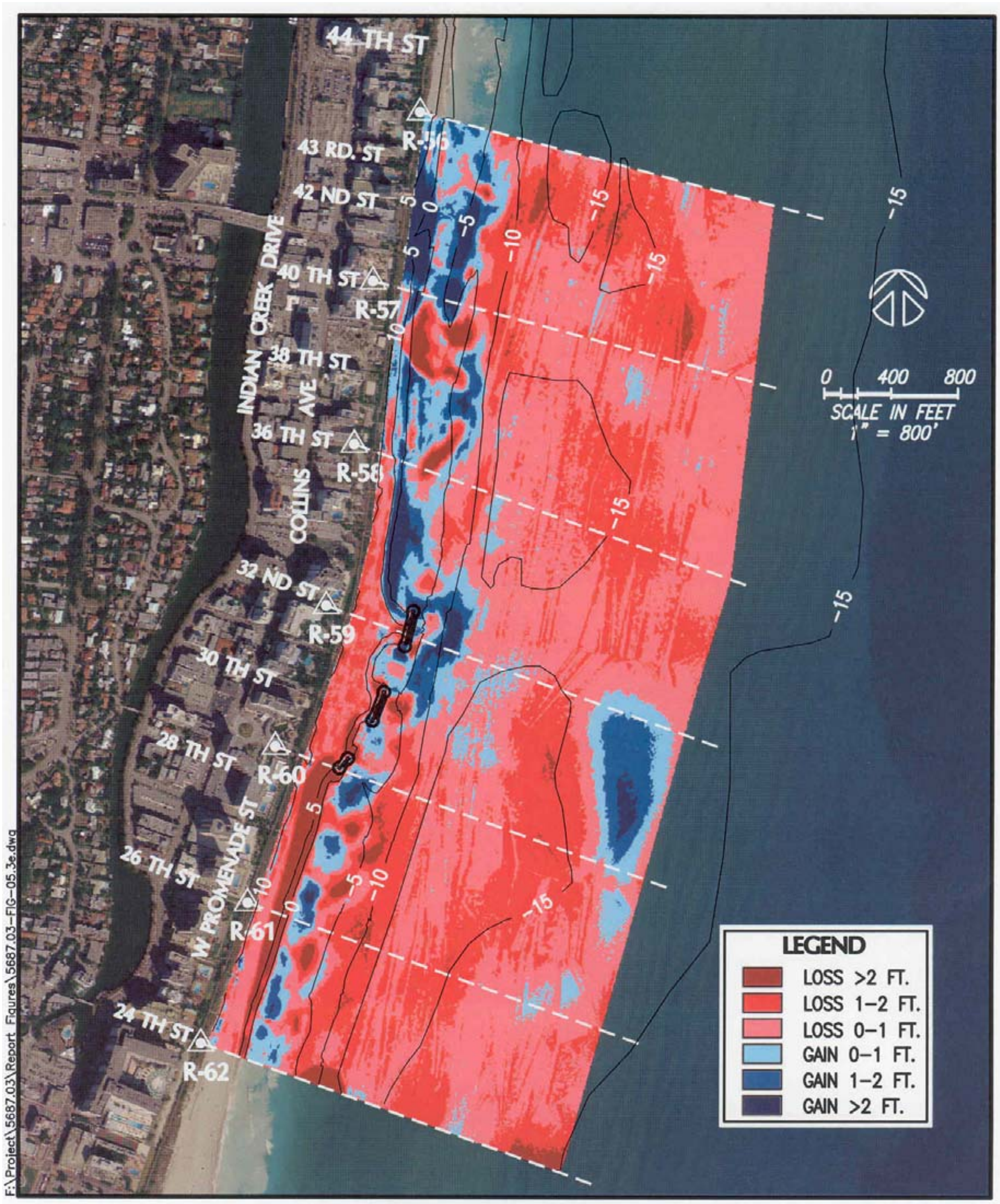


FIGURE 3 E

Morphological Changes at the 32nd Street Breakwaters from Oct. 02 – May 04

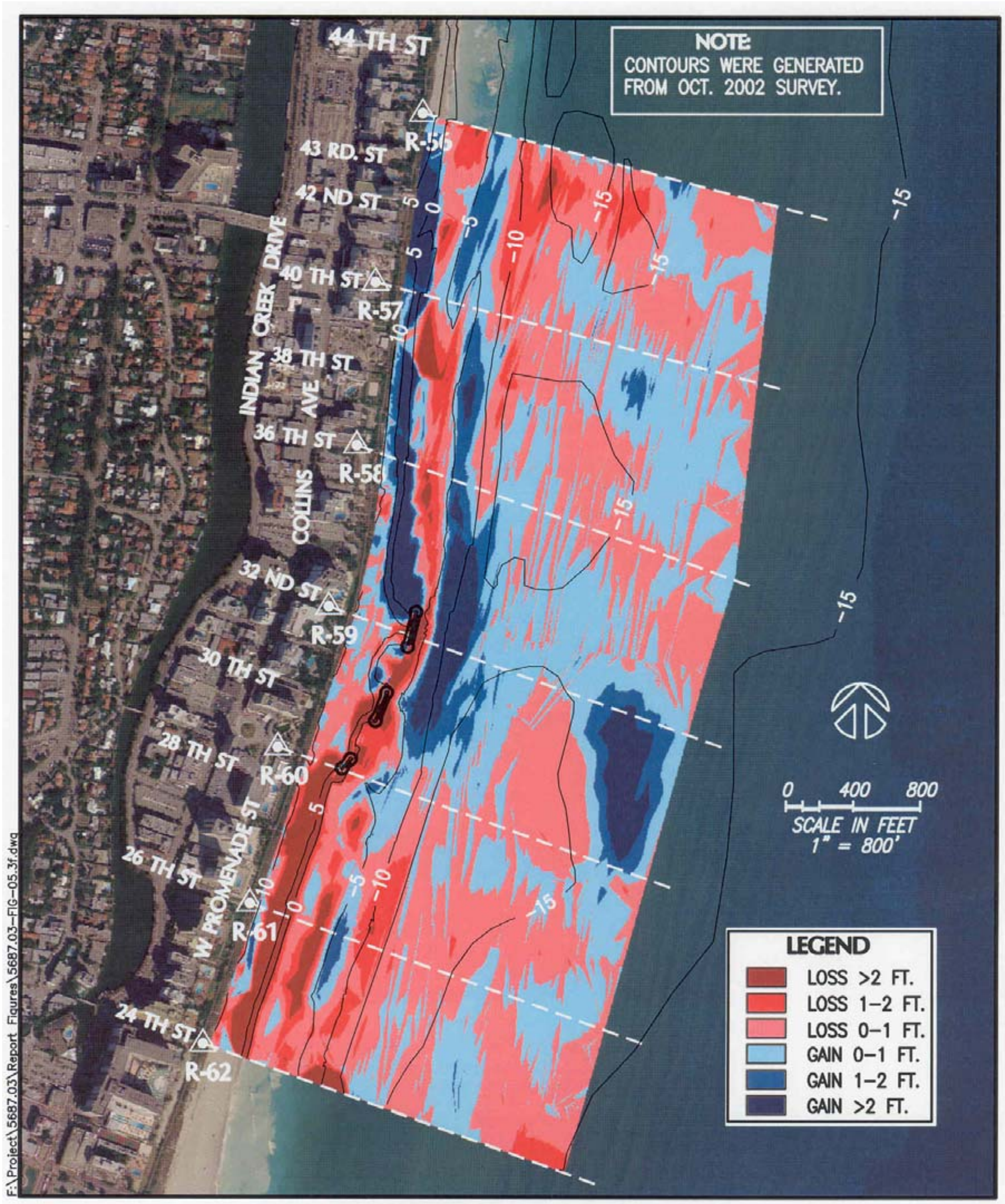


FIGURE 3 F

Morphological Changes at the 32nd Street Breakwaters from Oct. 02 – Dec. 04

February 2004 Survey:
The February 2004 survey revealed an extensive sandbar system forming east and northeast of the northern breakwater as illustrated in Figure 3D. This new bar serves as a "sediment bridge" transporting the material around the breakwaters. The bar system grew significantly from October 2003 reflected in a larger blue area. Furthermore, the bar is almost continuously around and south of the breakwaters. Material continued impounding the area north of the breakwaters from R-59 to R-56, as was the case at the previously fall and winter surveys. Specially, the area from R-56 and R-58 accreted significantly.

The eroded area south of the breakwaters increased in size. At the time of the survey the eroded area was approximately 1,400 feet long and extended almost half way to R-62.

May 2004 Survey:
At the May 2004 survey some of the accreted areas north of the structures observed at the February 2004 survey decreased in size. This followed the pattern observed at the July 2003 survey due to a seasonal reverse in the sediment transport direction towards the north.

Significant erosion was still observed south of the breakwaters and despite the summer season of the survey the erosion appeared to have increased.

December 2004 Survey:
At the latest survey in December 2004, the accretion along the shoreline from R-59 to R-56 continued as the breakwaters trapped material as illustrated in Figure 3F. Furthermore, the bar system seaward of the breakwaters observed at the February 2004 survey, increased in size. While the northern part of the bar system seems to have adjusted, the southern part appears not to be fully developed, and is expected to grow further. Offshore of the breakwaters in water depth of approximately 15 feet, a large area of accretion was observed. This area was also observed at the May 2004 survey, but was more pronounced at this survey.

South of the breakwaters, the eroded area observed at the previous surveys continued to increase in size, demonstrated by the dark red area from R-60 to R-62. This area was approximately 2,000 feet long. The area was nourished in April 2005 with approximately 35,000 cy of material from upland sources to offset the observed erosion.

Based on the morphological analysis described in the preceding paragraphs above, three significant morphological changes were observed: 1) material impounded in the area north of the breakwaters, 2) a bar system developed seaward of the breakwater, and 3) erosion was observed down-drift of the breakwaters. In the following paragraphs each of these mechanisms are discussed.

Material Impoundment

At the time of construction, the breakwaters protruded from the existing shoreline. The impoundment of sand occurs as the breakwaters trap the sediment transported south. The northern breakwater serves as an anchor point for the shoreline, and the impoundment will continue until this area is fully impounded and stabilized. As this area stabilizes, the amount of material bypassing the structures will increase. The December 2004 survey indicated that the area from R-59 to R-56, or approximately 3,000 feet of shoreline has benefited from the construction of the breakwater as material deposited and stabilized the shoreline.

Nearshore Bar

As material deposits north of the breakwaters and the shoreline is moved seaward, the near-shore sandbar is moved seaward as well. The bar system serves as a "sediment bridge" allowing sediment to bypass. The breakwaters were constructed generally where the pre-construction sandbar was located. Therefore, following the construction, a sandbar did not exist in front of the structures and the bypassing rate was reduced. As material was transported to this area, it deposited in front of the breakwaters and a sandbar developed as Figure 3A through 3F illustrates. The bar system is expected to continue growing further south until connecting with the existing bar. As the sandbar grows, the amount of material bypassing the structures will increase, and the erosion observed south of the breakwater should decrease.

Downdrift Erosion

Due to the accretion north of the breakwaters as well as sediment depositing in the sandbar, the littoral transport bypassing the structures will be reduced. Once the northern area is fully impounded and the bar system is fully developed, the bypassing rate will increase and the actual long-term down-drift effects can be determined. Therefore, at this stage it is premature to define the down-drift effects, as the area has not adjusted.

Evaluation of Performance

Several nourishment projects have been performed over the years without stabilizing the 32nd Street area. As the aerial photo from 1996 illustrates in Figure 2, the area needed further stabilization. Figure 4 illustrates a photo of the area in 2004. The difference between the pre- and post conditions are evident as the beach at and north of the breakwaters are significantly wider.

The area expected influenced by the breakwaters extends approximately 5,000 feet north and 3,000 feet south of the breakwaters. This area lost an average of -19,000 cy/yr of material for the period 1980-2000, and -38,000 cy/yr of material for the period 1996-2000. For the period October 2003 to December 2004, this same area experienced no net erosion indicating that area has stabilized. This observation is based on a short time period, however it is a significant reduction. Some down-drift erosion was experienced, but this was offset in April 2005 by placing approximately 35,000 cy of beach fill. This volume is small compared to the annual pre-construction erosion rates for the area between –19,000 cy/yr to –38,000 cy/yr. Furthermore, these down-drift effects are expected to decrease as the area adjusts and reaches equilibrium. This adjustment is expected to occur in the next 4 to 5 years.

FIGURE 4
2004 Aerial of the 32nd Street Breakwaters

The monitoring results indicate, the project has performed well, and has provided much needed stabilization for a highly erosional area. The ongoing monitoring will continue to provide valuable project performance data for analysis of this unique demonstration project. This data can be utilized in the design of future projects at other coastal locations.

Future nourishment may be required, but the overall erosion has decreased and the area has become more manageable. Future nourishment projects should be conducted utilizing sand recycled from the accretional areas further south by installing a permanent pipeline. This method will reduce the maintenance cost even further.

As the sources of offshore beach compatible sand for beach nourishment are diminishing, hot spot management like the 32nd Street Breakwater Project becomes an increasingly important component of county-wide beach management as these areas often dictate the beach nourishment frequency.

Managing erosional hot spots is a method to improve performance of beach nourishment projects.

Conclusion

A study of the morphological changes at 32nd Street Breakwaters located in Miami-Dade County was conducted. The volumetric changes were calculated 3-dimensionaly compared to 2-dimensionly in previous studies. The 3-dimensionally analysis allowed morphological changes to be analyzed. Based on the analysis, three significant morphological changes were observed in the breakwater vicinity: material impounded the area north of the breakwaters, a bar system developed seaward of the breakwater, and significant erosion was observed down-drift of the breakwaters. The analysis indicated that the area is still adjusting to the structures. It is expected that the impoundment of the area north of the breakwaters will continue, thus benefiting an area extending approximately 5,000 feet north of the breakwaters. The sandbar that developed in front of the breakwaters is expected to continue to grow until merging with the existing bar south of the breakwaters. The sandbar serves as a "sediment bridge" allowing material to bypass the breakwaters, thus as the sandbar develops, the bypassing rates will increase. Therefore, the erosion rates experienced south of the breakwaters is expected to decrease as the region adjusts, which may take another 4-5 years. The volumetric analysis showed that during the short period of time, the breakwaters have been installed, the overall erosion for the area has decreased and provided much needed stabilization. As a result, the average annual maintenance costs have been reduced and the area has become more manageable. The diminishing sources of offshore beach compatible sand for beach nourishment make hot spot management like the 32nd Street Breakwater Project an increasingly important component of county-wide beach management.

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