Mitigation Plan for Broward County
Beach Erosion Control Project
Broward County, Florida

United States Army Corps of Engineers
Permit # 199905545 (IP-DSG)

Florida Department of Environmental Protection
Permit # 0163435-001-JC

January 5, 2005

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I Project Background

Most of Broward County's shoreline are in a state of chronic erosion. The State of Florida has estimated that 21 of the 24 miles of Broward's beaches are critically eroded, and in some areas there is little beach left at high tide. To combat this situation, Broward County has been engaged in shore protection, beach restoration, and beach sand management since the early 1960's.

In 1970, the first beach restoration project was conducted in Pompano Beach, followed by similar projects at John U. Lloyd Beach State Recreation Area (1977 and 1989); Hollywood and Hallandale (1979 and 1991); and Pompano Beach and Lauderdale-By-The-Sea (1983). The projects, cost-shared by the U.S. Army Corps of Engineers, the State of Florida, Broward County, and the affected municipalities, involved dredging sand from offshore "borrow sites" and pumping the sand onto the target beaches.

The current Broward County Beach Management Program is a comprehensive plan to replace beach sand where it is needed, to stabilize the most eroded stretches of beach, and, by means of inlet sand bypassing, to "feed" those beaches which are eroding because of the presence of stabilized inlets. Current projections call for approximately 2.5 million cubic yards of sand to be placed on about 11.8 miles of shoreline. The beach in the nourished areas will be 50 to 100 feet wider after the project, and sand by-passing at Port Everglades is predicted to contribute a minimum of 44,000 cubic yards of sand into the Segment III beach system (Coastal Systems International, 1997).

The project is not expected to adversely impact offshore coral reefs, adjacent to borrow areas. The approximately twelve miles of widened beaches are predicted to bury approximately 13.5 acres of nearshore hardbottom during equilibration of the beach fill. This represents the gross area of impact within which only 10.1 acres is actually hardbottom. The remainder is sand bottom. The hardbottom substrate supports various combinations and complexities of benthic and fish communities, and are located in shallow, wave-dominated environments. In some cases, the habitats are subject to periodic covering and uncovering by beach material moved by storms or by previous beach nourishment projects. The County is endeavoring to minimize impacts to these habitats and intends to fully mitigate for unavoidable impacts. This net mitigation planned is 11.9 acres (net) within a 13.5-acre footprint.

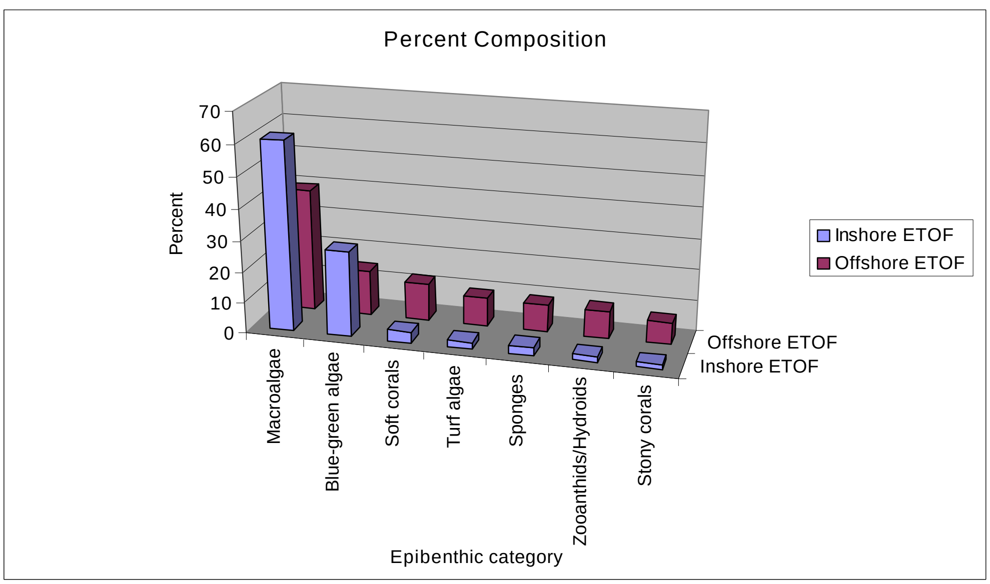
II Comparison of Impacted to Not-impacted Nearshore Reef Communities

The nearshore reef is generally characterized by low topographic relief with a biological community structure controlled by physical oceanographic conditions. These conditions include wave energy, turbidity, temperature extremes, and suspended sediment stresses. As a result, the hardbottom communities closest to the shore are of lower biological diversity and abundance than deeper water areas. Table 1 shows a comparison of hardbottom projected to be impacted by beach nourishment to those offshore of the estimated equilibrium toe of fill. Figure 1 compares the relative composition of the floral and faunal groups at the two areas. A detailed analysis of the biological data from the nearshore hardbottom areas is presented in the project EIS.

Table 1. Comparison of biological characteristics of hardbottom communities inshore (impacted by beach nourishment) to those offshore (not impacted) of the projected equilibrium toe of fill (ETOF).

Biological Characteristic	Inshore ETOF	Offshore ETOF
Average density of the dominant faunal species (#/m^2)	1.00	1.30
Number of stony coral species	6	7
Number of faunal species	10.25 Segment II 4.00 Segment III	19.60 Segment II 13.8 Segment III
Faunal diversity (Shannon Weaver)	1.66 Segment II 0.66 Segment III	2.42 Segment II 1.90 Segment III
Faunal density (#/m^2)	3.80 Segment II 1.23 Segment III	5.82 Segment II 5.66 Segment III

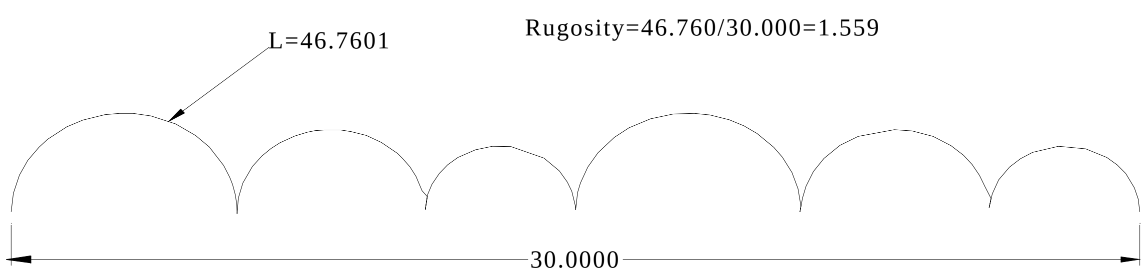
Figure 1. Comparison of the relative composition of the major floral and faunal groups between impacted (Inshore ETOF) and not impacted (Offshore ETOF) nearshore hardbottom areas.



III Mitigation Plan

The mitigation plan for the Broward County Beach Restoration project is based on a 1.2:1 mitigation ratio, providing 11.9 acres of substrate within a 13.5-acre footprint. Construction will take place in two phases, Segment III Mitigation (10.1 acres, gross; 8.9 acres, net) and Segment II (3.4 acres, gross; 3.0 acres, net). Each phase is contingent on receipt of all permits necessary for that phase's beach nourishment. A total of 36.9 acres of suitable sites have been identified to allow some flexibility in construction (Table 2, Figures 2-6). Burial of nearshore reef will be mitigated for by placement of limestone boulders in nearshore reef sand pockets. The individual boulders will be of large size (4-6 feet, diameter) for stability (Stability Analysis, Attachment 1) and placed in a single layer to avoid wave refraction that may affect natural sediment transport processes on the adjacent beach (Shoreline Change Analysis, Attachment 2). Boulders will be placed on shallow sediments (less than 3 feet thick) so that sand scouring does not result in total burial of the rocks. Partial settling will increase stability by anchoring the boulders in place. The criteria for selection and configuration of mitigation sites are 1) inshore of the nearshore hardbottom, 2) offshore of the predicted equilibrium toe of fill, 3) no shallower than the 15-foot depth contour, and 4) with a 50-foot buffer from all significant nearshore hardbottom.

The topography of the limestone boulder reefs will be of greater complexity than the natural impacted hardbottom which is typically low relief limestone pavement interrupted with pockets of higher complexity. The rugosity of the nearshore hardbottom to be impacted was measured by Dr. Richard Spieler, Nova Southeastern University, using the chain method. He found an average of 1.08 (n=199) (Dodge, 2002). Rugosity for the proposed mitigation was determined analytically by drawing an even distribution of 4', 5', and 6' diameter boulders (touching at their midpoints) in AutoCad and draping a polyline over the boulders. This is illustrated in the following figure.



Even distribution of 6', 5', and 4' boulders in profile

The result is a rugosity estimate of 1.56. This represents a 44% increase in rugosity of mitigation reef over the natural nearshore hardbottom. Texturally, limestone is a natural material and will provide a suitable replacement for the impacted nearshore reef substrate. It is anticipated that this plan will provide perpetual reef habitat that will be colonized by organisms similar to those found on the impacted natural reef.

The proposed time frame for construction of the boulder reefs is to begin deployments for Segment III Mitigation in Spring, 2003. Deployment will be carried out from April 1 through September 30. Areas not completed in 2003 will be completed in 2004, but it is anticipated that all deployments for Segment III Mitigation will be completed in the first year. Table 3 compares estimated time of nearshore reef impact to mitigation construction, illustrating that mitigation reefs will be functioning before impacts occur. Observations on artificial reefs constructed in Broward County indicate that juvenile fishes begin to settle on to reefs within days after construction.

Table 2. Locations and area of proposed sites suitable for mitigation.

Mitigation Area	Center Coordinates XY (NAD83)	Center Coordinates Lat/Long	Beach Segment	Reef Area (acres)
1	954611 683600	N 26 12.6884' W 80 05.3846'	II	1.83
2	954480 680863	N 26 12.2368' W 80 05.4121'	II	4.25
3	952181 664712	N 26 09.6066' W 80 05.8530'	II	3.00
4	951954 663363	N 26 09.3512' W 80 05.8965'	II	0.37
5	951037 655841	N 26 08.1107' W 80 06.0737'	II	0.48
6	950683 650626	N 26 07.2503' W 80 06.1450'	II	0.32
7	948333 624147	N 26 02.8823' W 80 06.6078'	III	2.97
7-8	948347 623621	N 26 02.7955' W 80 06.6059'	III	0.94
8	948310 623407	N 26 02.7602' W 80 06.6129'	III	0.67
9	948190 622604	N 26 02.6278' W 80 06.6358'	III	0.33
10	946923 601989	N 25 59.2265' W 80 06.8929'	III	1.86
11	946883 600302	N 25 58.9481' W 80 06.9023'	III	5.70
11b north	947084 600667	N 25 59.0081' W 80 06.8651'	III	2.25
11b south	946952 599834	N 25 58.8707' W 80 06.8902'	III	1.84
12	950551 643120	N 26 06.0115' W 80 06.1786'	II	10.11

Table 3. Projected time line of mitigation function and nearshore reef impacts from beach nourishment of Segment III.[1]

Activity and Time from Beginning of Project: Months	Activity	Area of Reef Impact[2] (acres)	Area of Functioning Mitigation (acres)
0	mitigation construction begins	0	0
6	beach construction begins	0	0

Months	Activity and Time from Beginning of Project Activity	Area of Reef Impact[2] (acres)	Area of Functioning Mitigation (acres)
21	Hollywood/Hallandale impacts begin (Segment III)	2.5	10.1
22	JUL impacts begin (Segment III)	5.0	

[1]Schedule for Segment II Mitigation to be determined after permits are issued
[2] Assumptions: reef impact begins with equilibration of fill, approximately 1 year after placement
Beach construction begins Nov., 2003; mitigation construction April, 2003
Areas are for gross impacts and mitigation area

Artificial Reef Material

Limestone boulders of 4-6 feet diameter will be used for all construction. A minimum density of 131 lbs/cubic foot (pcf) gives a weight range of 2.2 to 7.4 tons per boulder. The estimated quantity of rock needed, assuming an even mix of 4, 5, and 6-foot boulders, is 6,525 tons/acre or 65,900 tons for 10.1 acres. Rocks will be placed in a single layer with no greater than 7 feet of spacing between the individual rocks.

Artificial Reef Construction

Several challenges are inherent in building artificial reefs in shallow waters around natural reefs. These include depth clearance for barge navigability, sensitivity to sea state, and barge anchoring. The magnitude of the project adds the problem of material supply and delivery to the deployment site. In addition, these factors can compound as in the case of sea state and water depth where wave height must be subtracted from the water depth to calculate minimum draft clearances. To allow some flexibility in construction a total of 36.9 acres of suitable sites have been identified (Figures 2-6 at end of document).

Minimum water depth at the proposed mitigation sites is 15 feet, which in calm weather conditions will allow a 600-ton barge to operate (7 feet, loaded draft). The shallow water depths will prohibit construction in any but calm weather conditions. Therefore, all construction will take place during the summer months.

Barges will be anchored during deployment with permanent moorings to allow for 4-point moorings for precise horizontal positioning. The challenge of anchoring is two-fold. Nearby hardbottom restricts anchor placement locations and shallow sediment depths create poor holding ground for anchors. As a result a 50-foot buffer will provide some westward anchoring areas shoreward of the nearshore reef. The buffer will also minimize the risk of accidental damage to natural hardbottom by misplacement of rocks. The permanent moorings (Figure 7) will be installed on sandy substrate and will consist of steel pilings driven into the bottom. The pilings will be cut-off approximately 2 ft above the sand surface and will be left in place after the project is completed.

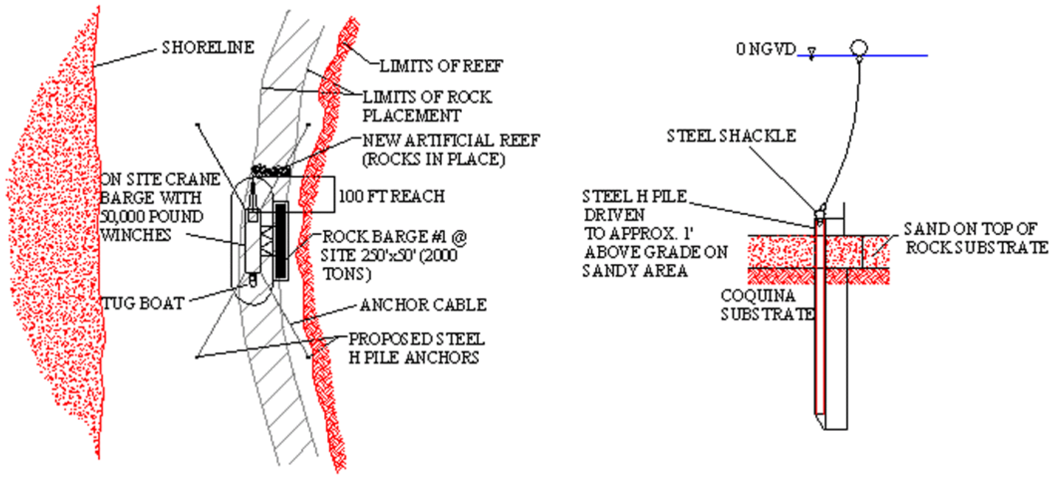


Figure 7. Permanent mooring system for rock deployment barge. Moorings will only be placed in sandy substrate.

Quality Assurance

1. No lines, cables or chain will be allowed to pass over hardbottom areas. If this proves necessary (for reef or existing mitigation) buoyant lines or floats will be used to prevent scraping the reef. Permanent moorings may be used for barges. These will be steel pilings driven into sand covered bottom. No anchors or moorings will be placed on hardbottom.

2. Rocks will be in a single layer but allowance is made for rocks landing in crevices between existing rocks as long as the vertical relief does not exceed 6 feet above the existing grade. A maximum spacing of 7 feet between some boulders is permitted, but the frequency of occurrence of this will not exceed 40%.

3. Limestone boulders will be clean and free of excessive soil or plant material.

4. Barges and tugs loaded drafts will not exceed 10 feet, and vessels will not operate in water depths less than 15 feet.

5. The County will be notified within 24 hours if reef damage occurs, and all construction operations shall cease until an assessment of damage is made.

6. Deployment operations will cease if seas exceed 4 feet, and all vessels must be released from moorings and relocated to deeper waters.

7. Deployment operations will take place between April 1 and September 30 unless approved by Broward County.

8. Transit corridors for barges will be identified to ensure adequate draft is available. The corridors will be located over sandy bottom to the greatest extent possible.

Transplantation of Stony Corals and Macroalgae

Stony corals will be relocated from nearshore impact areas to the mitigation reefs to avoid mortality from burial during equilibration of the beach fill. It is anticipated that 1000 to 2000 colonies of 15 cm diameter or greater will be transplanted onto approximately 5 acres of Mitigation. It is intended to move corals directly from the impact areas onto the mitigation reefs. However, unforeseen circumstances, such as delay of mitigation construction, may make this unfeasible in which case corals will be relocated to a cache site near the intended receiver site. At the earliest opportunity the corals will be moved from the cache site to the final transplant location.

The nearshore hardbottom areas offshore of Broward County Segment II are utilized by sea turtles as foraging grounds for macroalgae. One of the goals of mitigating for impacts to these areas is to provide suitable substrate for colonization by macroalgae. If monitoring of the mitigation for Segment II one year after construction shows that algal cover does not meet the goals established by the Florida Department of Environmental Protection, transplantation of macroalgae will be undertaken. It is intended that fragments of substrate with attached macroalgae will be transplanted to Mitigation Area 5 (0.48 acres, Figure 4 at end of document) in an experiment to see if this accelerates recruitment of macroalgae. The species that will be transplanted are those favored by foraging sea turtles.

IV Background of Reef Related Projects Carried Out by Broward County

Broward County has a relatively long history in the construction of artificial reefs. The goals of the program have been to restore depleted fish stocks by habitat creation and to relieve some of the user pressure (divers and fishers) on the natural reefs. In order to evaluate the success of previous reef constructions and to improve future methods we began the first steps in understanding the fundamental processes to control fish assemblages on reefs by establishing a long term research program. The Following (Table 4) is a list of studies that are completed or ongoing and a summary of results:

Table 4. Broward County Department of Environmental Protection reef research projects (Broward County, 2000; Sherman et al., 2002; and Spieler, 2000).

Year	Study Description	Results
1993-1995	Potential for using tire chips as aggregate in concrete artificial reefs	Tire aggregate is an appropriate material for reef construction
1995-1997	Fish assemblages and recruitment at shallow versus deep-water sites	found greater biomass and diversity of Juvenile fishes at deeper reefs suggesting that recruitment reefs should be placed in deeper water

Year	Study Description	Results
1997-1999	Attractants for settlement on artificial reefs	attractants (floating lines) did not enhance recruitment to reefs
1997-1999	Complexity versus void space in small artificial reefs	high complexity is more important than extensive void space for high fish diversity and biomass
1997-1999	Complexity and refuge size	shelter size is an important aspect of artificial reef design
1997-2001	Fish population assemblages on natural and artificial reefs in Broward County	ongoing; compares population and trophic structure on natural and artificial reefs/vessels
2000-2001	A socioeconomic study of the reef resources of southeast Florida and the Florida Keys	analyzes the economic value of artificial and natural reefs to local and state economies

V Expected Outcomes of Mitigation Project

Preserving natural habitat is preferred to imposing any impacts from human activities. However, when impacts are unavoidable it is necessary to consider all available scientific data to design an optimized, yet economical, mitigation strategy. Based on studies carried out in Broward County waters over the past 20 years it is anticipated that the construction of artificial reef in the nearshore region will provide habitat that is both complex for fish recruitment and provides a substrate that is suitable for colonization by benthic invertebrates. The fact that the artificial reef will be more complex than the natural impacted substrate may result in an effective mitigation ratio greater than the actual proposed 1.2:1. Summaries of monitoring of mitigation projects are found following the references below and support the use of limestone boulders as mitigation for nearshore hardbottom impacts.

VI References

Broward County Department of Planning and Environmental Protection, 2000. *Artificial Reef Research in Broward County 1993-2000: A Summary Report*, Technical Report 01-05, Fort Lauderdale, Florida, unpaginated.

Coastal Systems International, Inc., 1997. *Port Everglades Inlet Management Plan Addendum,* prepared for Department of Natural Resource Protection, Broward County, Florida, 56p.

Dodge, R., 2002. HEA approach for calculating Broward County nearshore mitigation amount, white paper, draft, Saturday, October 5, 2002. Nova Southeastern University Oceanographic Center.

Sherman, R.L., D.S. Gilliam and R.E. Spieler, 2002. Effects of refuge size and complexity on recruitment and fish assemblage formation on small artificial reefs. *Proceedings of the Fifty-Third Annual Gulf and Caribbean Fisheries Institute,* Biloxi, Mississippi, USA, in press.

Spieler, R.E., 2000. *Effects of Module Spacing on the Formation and Maintenance of Fish Assemblages on Artificial Reefs*, Florida Fish and Wildlife Conservation Commission Grant Agreement OFMAS-132, Executive Summary, submitted to Broward County Department of Planning and Environmental Protection, 1p.

VII Summaries of Results of Similar Mitigation Projects

Cummings, S. L., 1994. *The Boca Raton mitigative artificial reef-5 ½ years later*. Proceedings of the 1994 National Conference on Beach Preservation Technology, Tampa, Florida, February 9-11, 252-284.

> A 5 ½ yr study of limestone boulder reefs (for mitigation of a beach renourishment project) in a depth of 2-m off Boca Raton, Florida found that the reefs provided suitable mitigation for nearshore, low relief hard bottom habitat lost as a result of the 1998 Boca Beach Restoration Project. Compared to a nearby natural nearshore rock formation (Red Reef Rock), the Boca Raton artificial reef provided enhanced habitats for fishes and macroinvertebrates. In addition, the shore-detached groin and artificial reef provided a suitable replacement habitat for a majority of the algae found at the nearby natural hard bottom habitat. Cummings stated that the, "..higher relief provided more shelter and greater surface area for the attachment of sessile organisms. Additionally, the higher relief exhibited by the mitigation structures made them less prone to coverage by sand movements, thereby providing a more permanent habitat for marine organism." She also stated that the limestone used to construct the mitigation structures simulated the texture and calcareous nature of the natural nearshore hard bottom formations, whereas, the increased complexity provided increased surface area for colonization.

Miller, M.W. and Barimo, J., 2001. Assessment of juvenile coral populations at two reef restoration sites in the Florida Keys National Marine Sanctuary: indicators of success. *Bulletin of Marine Science*, 69(2): 396-405.

> Mitigation for the groundings of two vessels, the Elpis and Maitland, in the Florida Keys was carried out using limestone boulders and concrete armor structures/limestone, respectively. This assessment on recruitment of stony corals to the mitigation structures indicates that "...coral recruits preferentially occurred on limerock substrates..."

Palm Beach County ERM, 2000. *Evaluation of mitigation reef constructed to offset impacts of Jupiter/Carlin shore protection project.* Interim Report, July 26, 2000, 20p.

> A Mitigation reef was constructed of limestone boulders and one of concrete rubble; depth=17-25'; average relief 2-3', max 5-6'. The monitoring study compared the mitigation reef to the impacted nearshore reef. After 18 months, worm rock encrusted a large proportion of the limestone boulders. The mean coverage by invertebrates and algal taxa on limestone was 60% and the concrete reef 40% (showed little signs of colonization by worm

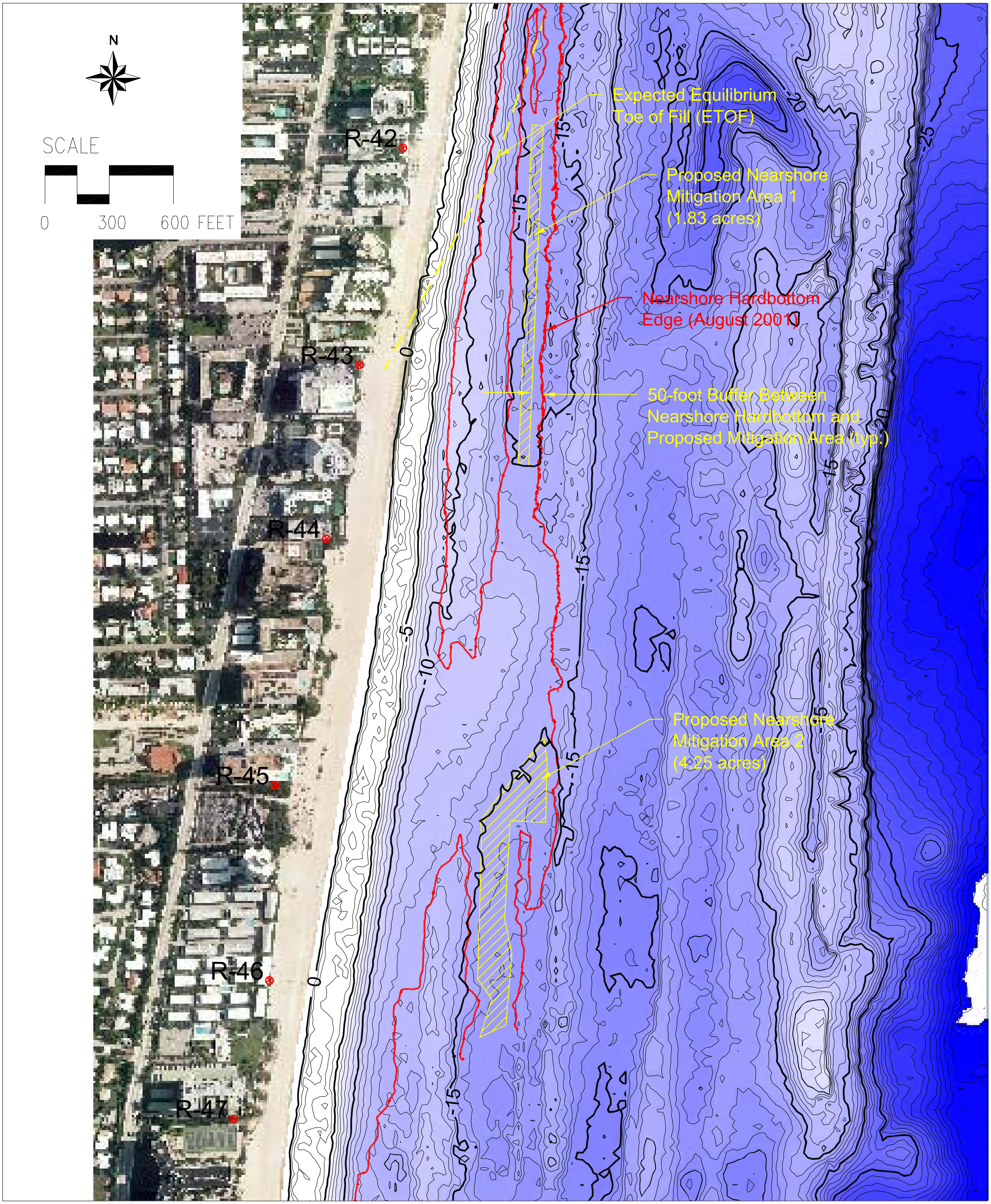
rock). Fish species increased from 26 to 37 on impacted nearshore reef, 35 to 56 on the limestone reef, and 25-57 on the concrete reef. Juvenile fishes were more abundant on the limestone reef than the concrete reef. Numbers of juveniles on rock and concrete sections of reefs were as great as, or greater than numbers on the adjacent natural reef. The authors concluded that the mitigation reefs adjacent to the shore protection project are presently providing suitable habitats for reef fish, invertebrates and algae. The rapid colonization of these structures by benthic inverts and algae indicates that they are placed within hydrodynamic and bathymetric regimes which are conducive to larval settlement and growth. The colonization of the mitigation reef by certain key nearshore reef indicator species such as worm rock and hairy blenny can be considered at least one measure of success. The appearance of a diverse fish fauna indicates that these habitats provide adequate shelter and food to support a healthy fish community. This fauna includes a large proportion of species commonly associated with nearshore reefs, as well as juvenile representatives of many species. The limestone boulder material appears to be particularly preferred by juvenile fishes, and was also colonized by invertebrates more rapidly than the concrete. This may be due in part to the shallower depth of the boulder section, which may favor the growth of worm rock, but is probably also a function of the affinity of many marine organisms for a limestone based substrate.

Spieler, R. E., 2000. *Biological assessment of artificial reef materials: concrete aggregates and quarry stone*. Contract #199.6915.000343, 2000 Annual Report, submitted to the City of Miami Beach.

This study compared fish and invertebrate assemblages on artificial reefs constructed of quarry rock (limestone boulders), gravel-concrete aggregate and tire-concrete aggregate structures over a 2-year period. The reefs were deployed in 7-m water offshore Miami Beach, Florida. They found no significant differences in fish fauna among the reef types, but there were more hard corals found on limestone boulder reefs than concrete materials.

Spieler, R. E., personal communication, 11/29/00. Nova Southeastern University Oceanographic Center

A comparison of fish richness and density of fishes found by Lindeman and Snyder (1998) with Nova Southeastern University's Miami Beach mitigation project study found: Lindeman: nearshore reef; 6-7 species, 38-40 individuals/30 sq meter = 0.2 species/sq m, 1.3 individuals/sq m Miami Beach: limestone boulders; 20 species, 750 individuals/64 sq meter = 0.3 species/sq m, 11.7 individuals/sq m



Broward County Federal Shore Protection Project
Proposed Nearshore Mitigation Areas
Segment II

Figure 2

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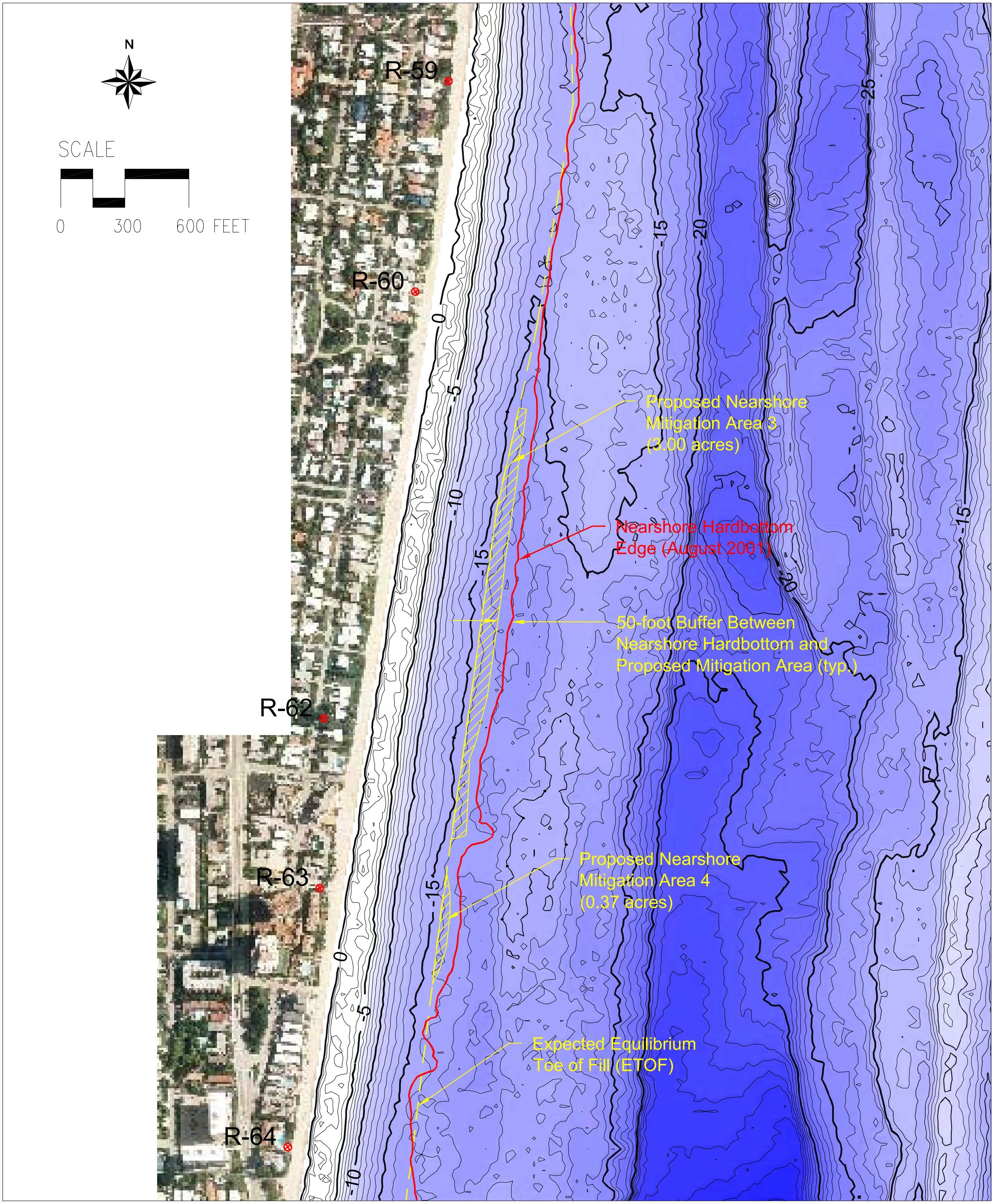

Broward County Federal Shore Protection Project
Proposed Nearshore Mitigation Areas
Segment II

Figure 3

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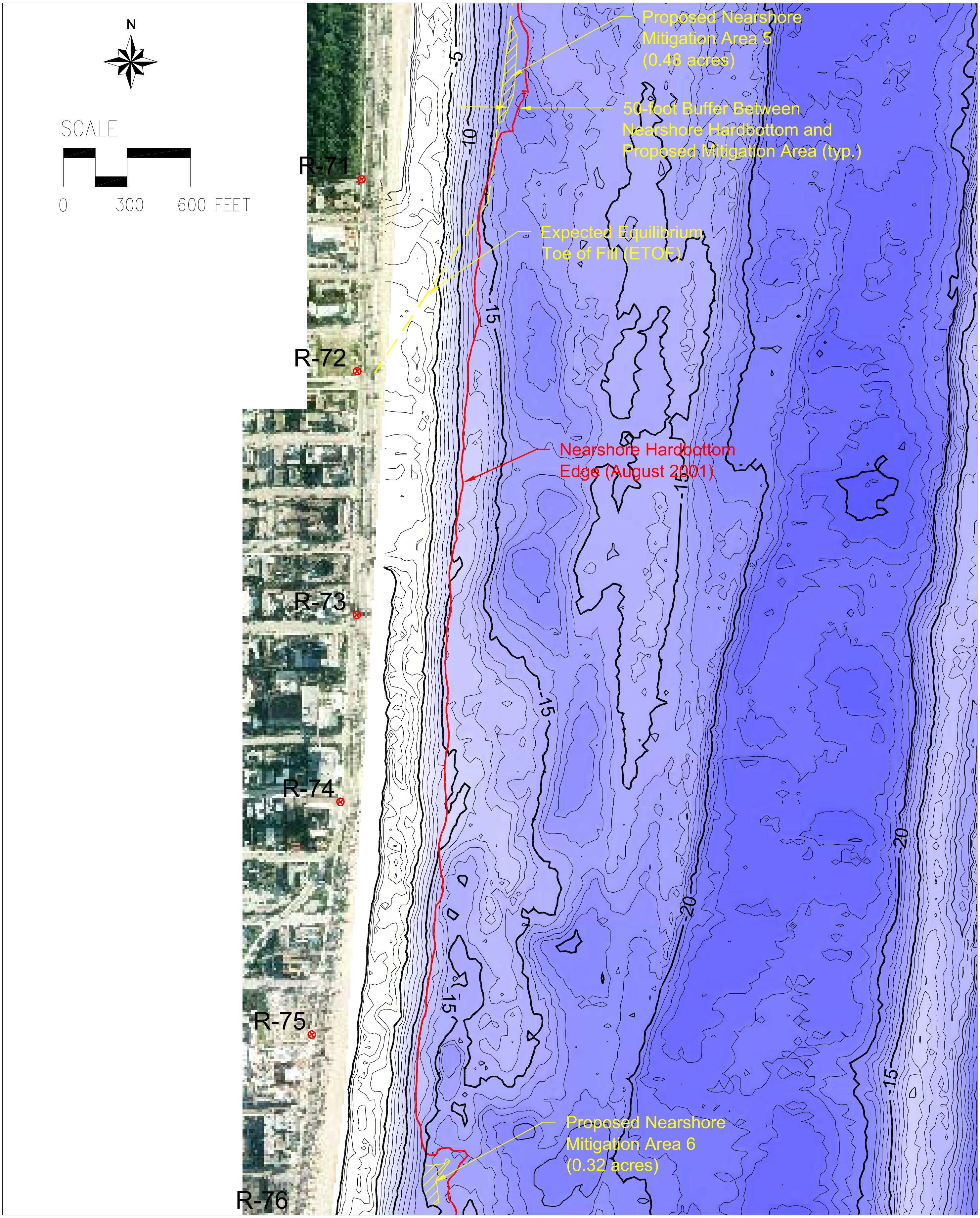

Broward County Federal Shore Protection Project
Proposed Nearshore Mitigation Areas
Segment II

Figure 4

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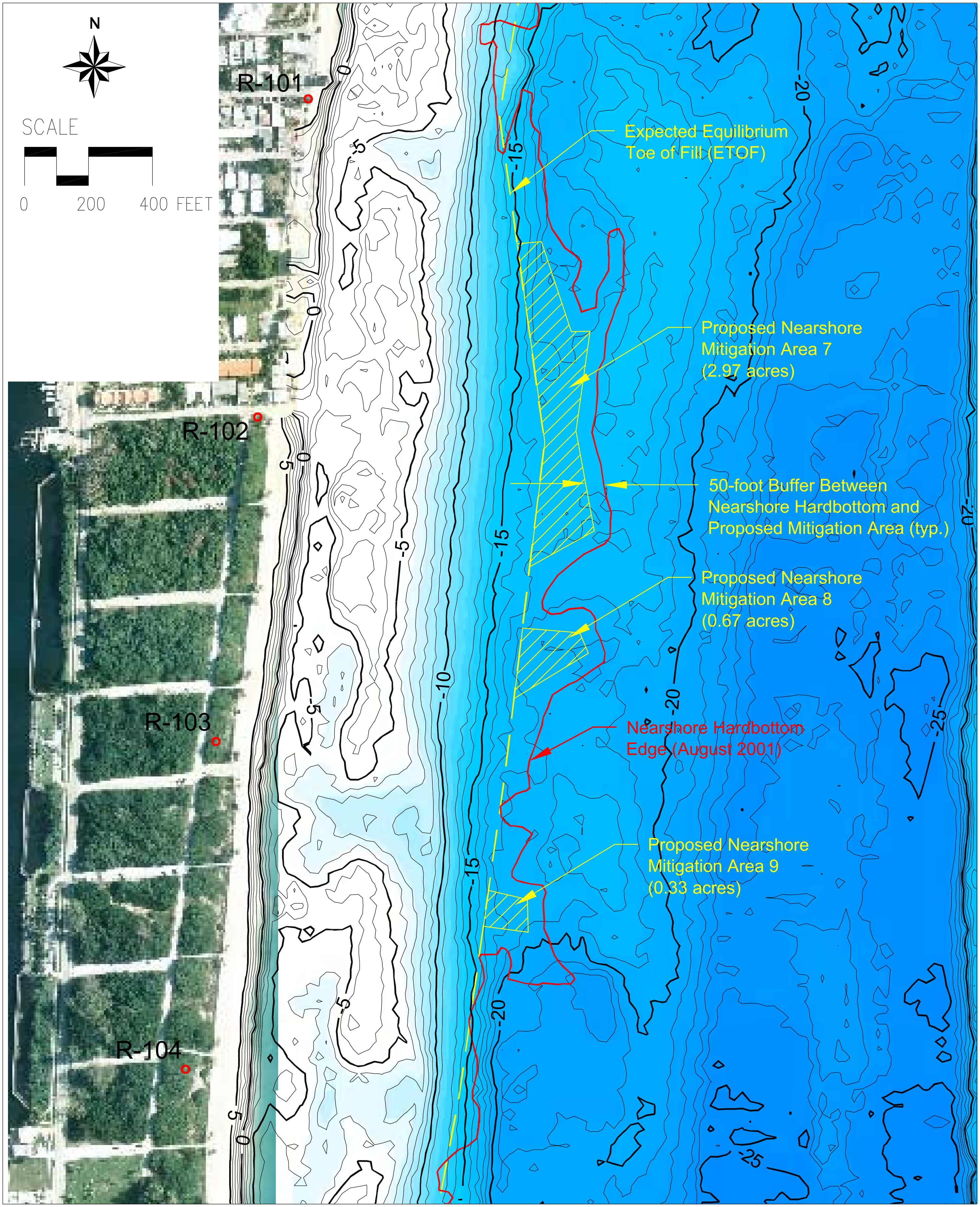

Broward County Federal Shore Protection Project
Proposed Nearshore Mitigation Areas
Segment III

Figure 5

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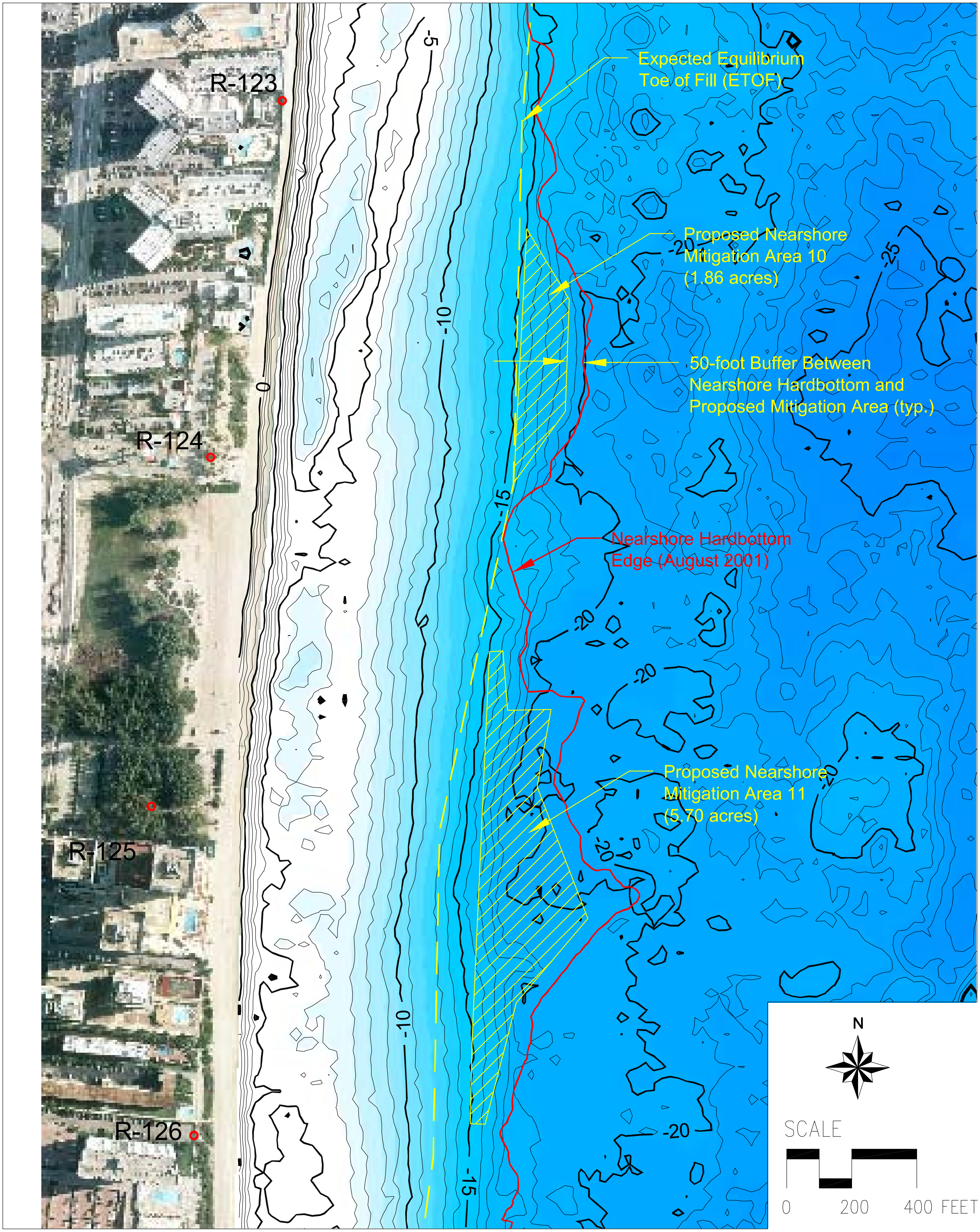

Broward County Federal Shore Protection Project
Proposed Nearshore Mitigation Areas
Segment III

Figure 6

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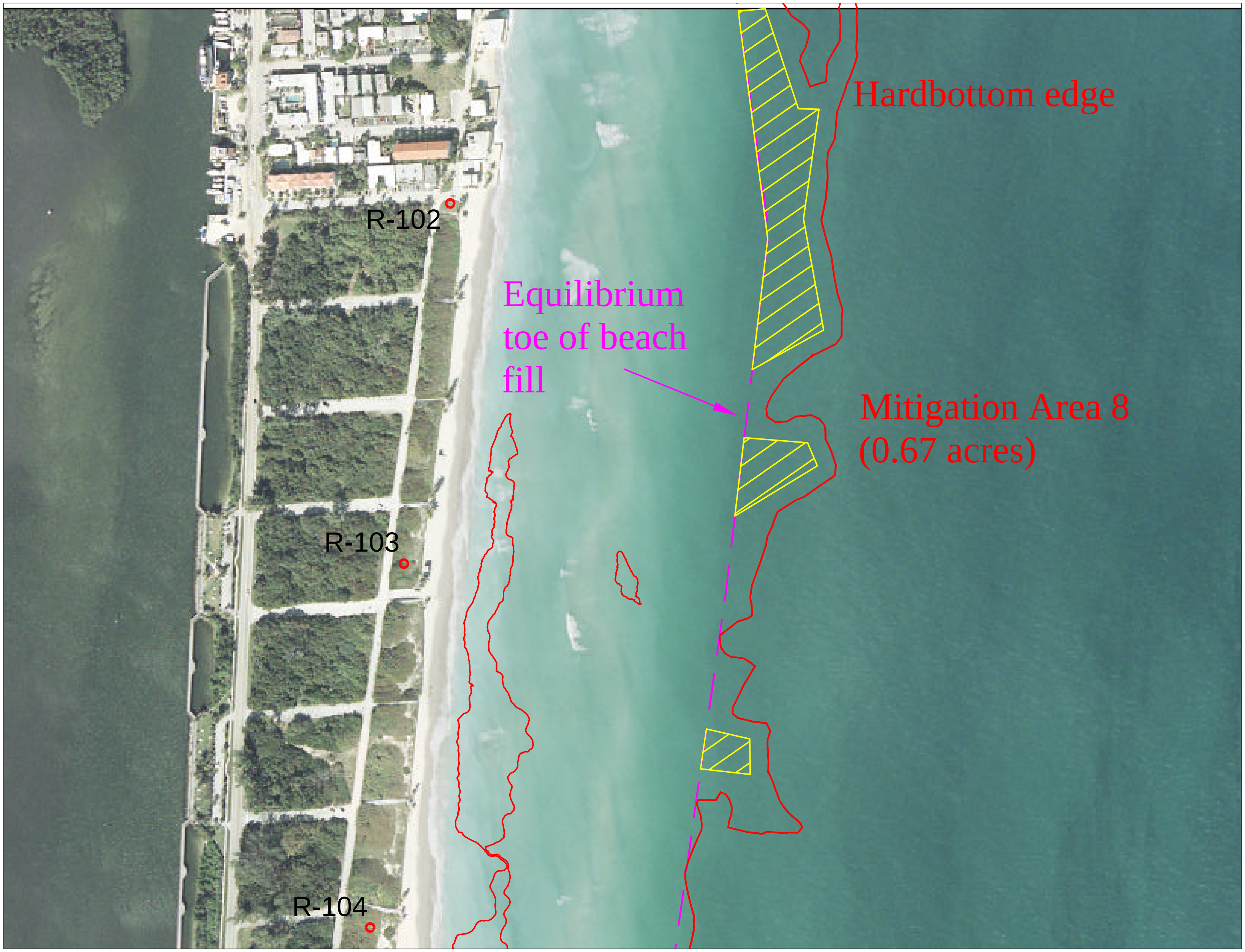

Figure 8. Mitigation Area 8 (0.67 acres) will be used as a site to receive 1000-2000 stony coral transplants taken from hardbottom impact areas.

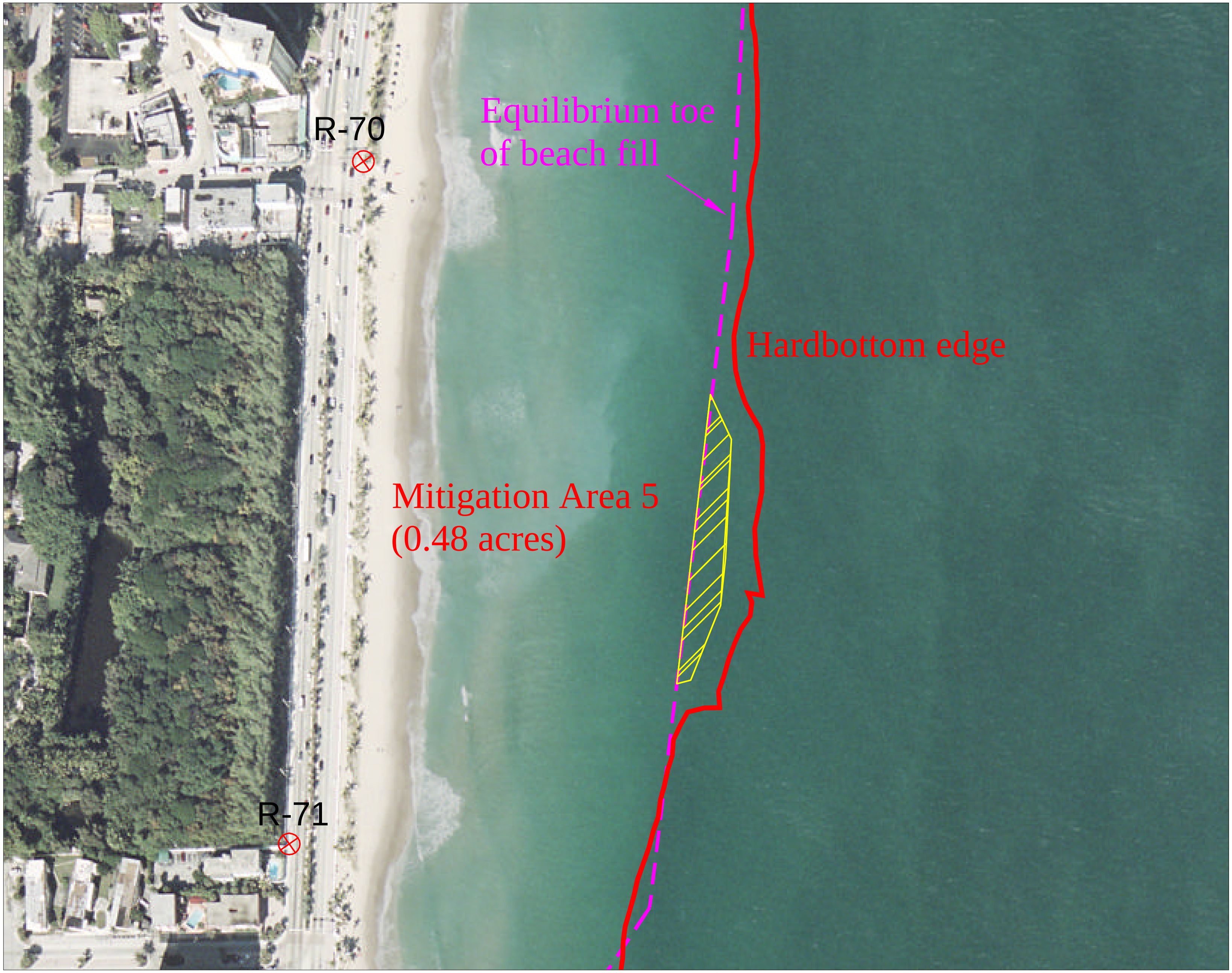

Figure 9. Mitigation Area 5 (0.48 acres) will be used as a site to receive macroalgae transplants if natural recruitment to mitigation reefs does not meet permit goals.

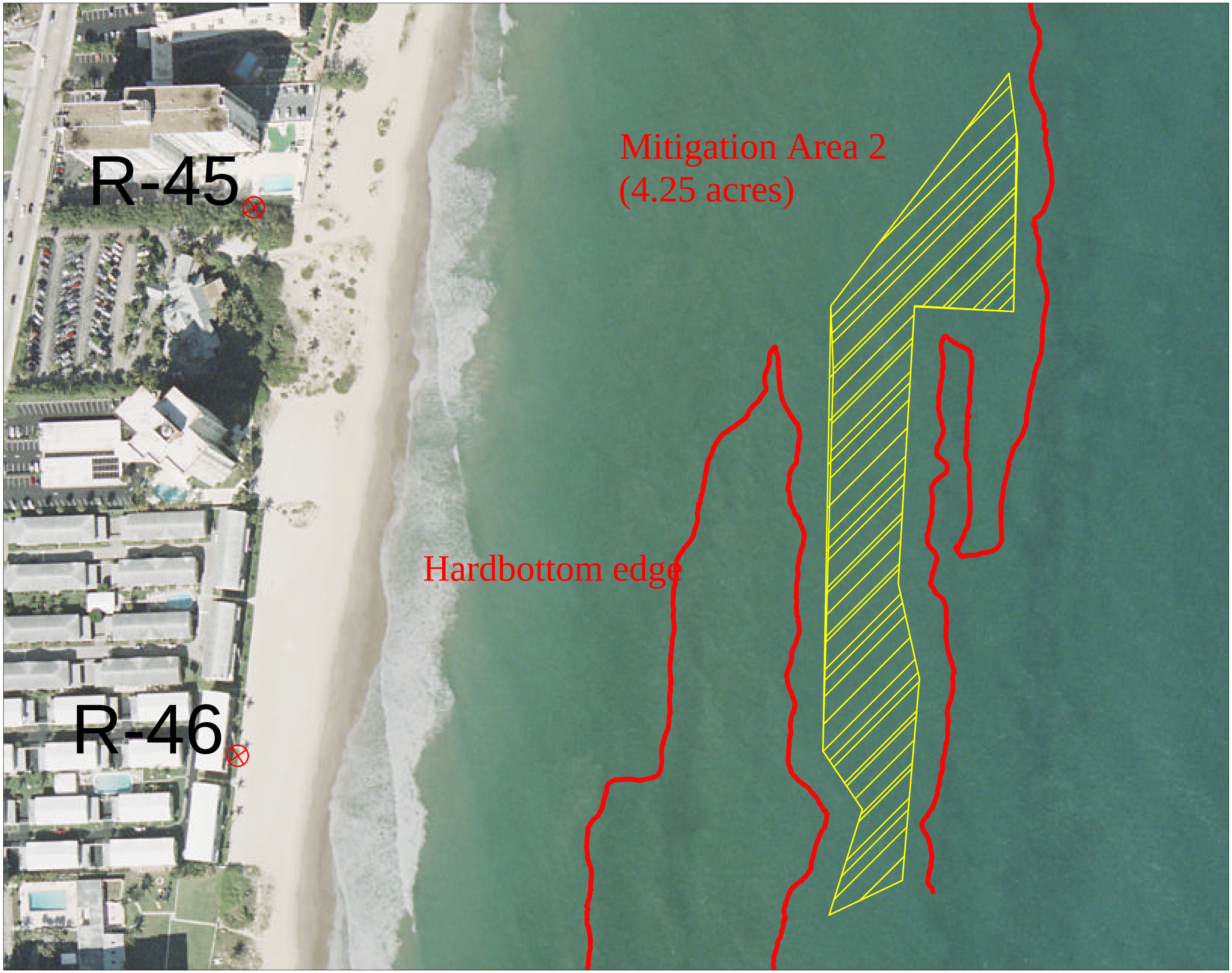

Figure 10. Mitigation Area 2 (4.25 acres) will be used as a site to receive coral transplants in Segment II.