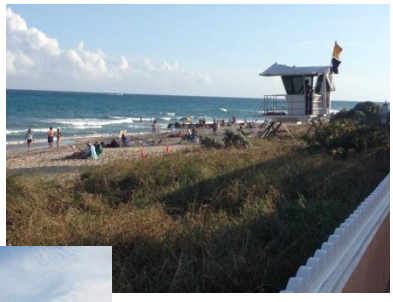
FINAL

Town of Palm Beach
Technical Review of Proposed Coastal Management Program



Prepared For:
Town of Palm Beach
Mayor and Town Council
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EXECUTIVE SUMMARY

Woods Hole Group was contracted by the Town of Palm Beach in April 2012 to perform a technical review of the Palm Beach Comprehensive Coastal Management Program. The primary purpose of the review is to provide Town Council objective technical recommendations regarding next steps for the Town's coastal program and specific projects.

The main report is organized in order of increasing detail to facilitate Town Council review:

- Section 1 Introduction establishes the overall purpose, expectations, and framework.
- Section 2 provides an Overall Perspective on the Palm Beach Coastal Program and Projects.
- Section 3 focuses on Island-wide Considerations applying to more than one Reach. A general overview of Island-wide coastal processes sets the context for how processes affect project performance, and helps identify data gaps that need to be filled to improve the overall program.
- Section 4 includes a preliminary Shore Protection Alternatives Value Assessment related to construction methods, sand source, grain size, and project design.
- Section 5 provides Recommendations and Next Steps for inlet management, each reach, and for the Island as a whole.

The scope provided to Woods Hole Group by Town Council specifically requested two main points to be addressed:

- Conduct a comparative analysis of activities since the 1998 CCMP review
- Consider all projects contemplated between the 2009 SPB Plan and the FY 2013 SPB recommended program

Additional general guidance on the scope of work was offered by Council at a March 14, 2012 meeting:

- Truly unbiased analysis of the SPB recommendations with a focus on feasibility (what is feasible and not feasible), and what the Town should be doing, or not doing.
- Consideration of cost-effectiveness, costs and benefits, and value of recommendations in the SPB plan. Town Council utilized the terms Value Engineering and Cost-Benefit Analysis; however, it was agreed that the Woods Hole Group analysis, while focused on cost-effectiveness, cost realities, and relative costs and benefits associated with certain decisions, would not include a formal Value Engineering study or traditional Cost-Benefit analysis.
- Focus on suitability of Bahamian sand or aragonite for Palm Beach, specifically as related to whether it is permissible within prevailing regulations, likely to provide an increased benefit as compared to traditional sand sources, and whether the incremental benefit would be worth the increased cost.

- Determine whether any other community in the country has been able to successfully eliminate hardbottom concerns.
- Consider groins, and specifically whether groins should or could be installed south of Sloan's Curve or along the entire Island.
- Make a wish list of coastal items with associated permitting limitations and cost realities.

Woods Hole Group also sought and received support from Town Council via an August 14, 2012 meeting to address the following areas:

- Lake Worth Inlet sediment management/bypassing
- Sand sources/alternatives
- Design criteria/expectations
- Island-wide coastal processes
- Monitoring data
- Adaptive management opportunities

The Draft Report was published in February 2013, and comments on the Draft were offered by Council at a public meeting on March 14, 2013. This Final Report addresses the Council comments, as well as comments from the Shore Protection Board during a March 28, 2013 meeting. Specific comments to be addressed in the Final were documented in a Woods Hole Group letter, dated April 25, 2013. Comments are addressed where applicable in the Final Report, and Appendix C provides a summary response to comments. A key addition to the Final Report is a Recommended Plan including budget estimates, provided at the end of the Executive Summary.

Reference materials included more than 400 individual documents totaling more than 10,000 pages. Stakeholder consultations were an essential part of the review process, including phone calls, meetings, and a public workshop hosted by Town Council on December 10, 2012. Woods Hole Group did not view the consultations as a formal peer review, nor did Woods Hole Group execute technical studies to verify the accuracy of work products by others. Instead, information offered by others was utilized to help formulate recommendations. All stakeholders were open, forthcoming with information, and accommodating to Woods Hole Group requests. Town consultants were professional, cooperative, unguarded with their time, and thoughtful in their responses. The stakeholders were genuinely interested in achieving the best results for the Town.

The Woods Hole Group review team included four (4) primary Woods Hole Group personnel with diverse, complementary backgrounds, who have been with the organization since at least 1997: Robert P. Hamilton, Jr., M.C.E., Project Manager and Civil/Coastal Engineer; Kirk F. Bosma, P.E./M.C.E., Coastal Engineer/Modeler; M. Leslie Fields, M.S., Coastal Geologist; and Lee L. Weishar, Ph.D./P.W.S., Senior Coastal Scientist/Engineer.

ES.1 Overall Perspective

The overall perspective establishes the framework for the island-wide and reach-specific recommendations. How and/or whether to proceed with certain recommendations depends upon the Town's overall perspective regarding: goals and expectations for the coastal management program and project performance; vulnerability and risk tolerance; appropriate and affordable level of investment; planning horizon; and stakeholder relations.

The Town has a proactive vision for the coastal management program with a strong community commitment and substantial investment that leaves the coastline as a whole better today than it was 15+ years ago (although some specific areas are suffering). Few exposed coastal communities share this result.

There have been a number of high profile accomplishments, including:

- Sand transfer plant upgrades and operation
- Improved inlet management, including cooperative relations with USACE
- Mid-Town and Phipps Park beach nourishment projects
- Partnering with state and federal agencies for funding support
- Collection of high quality monitoring data
- Sand search investigations revealing local beach-compatible sources
- Participation in the Palm Beach Island Beach Management Agreement (BMA) process
- Appointment of two Shore Protection Boards (SPB), retention of key Town Staff and appointment of a Coastal Coordinator to promote consistency in the program, that have resulted in identification and achievement of objectives.

In addition to the substantial accomplishments, the Town recognizes areas for improvement, and refinements are continuously underway.

Woods Hole Group emphasizes the necessity for compromise and incremental progress in the coastal management plan. Facing the realities of sometimes conflicting resources and stakeholder interests, projects must sometimes proceed incrementally to generate short-term action and inertia, and provide a basis for longer-term refinements. An example is the Phipps Park project. A difficult decision was made in 2006 to proceed with the modified project rather than await an uncertain/unlikely regulatory approval for the full design. Although the consequences of the decision could have been more widely understood by the community, a decision was made to proceed, and provide much-needed sand to supplement the historically starved environment and protect a public resource. Analysis suggests the nourishment would perform better with an expanded template to the north and perhaps even with coastal structures, yet today's regulatory climate indicates another sand-only project with dunes north of the Park will likely be required before pursuing modifications. Seven (7) years removed from the 2006 project, and considering storms impacting the region since construction, one must consider what the condition of Phipps Park and the adjacent beaches would be without the project. Further, using the Reach 8 DOAH case as a model for immobility and valuable time lost, the decision to

proceed with the modified Phipps Park project, despite its reduced performance, resulted in much-needed protection.

The coastal program demonstrated the vision to understand compromise, and that a long-term commitment is necessary for positive change. There are stringent natural resource protection laws for all projects to first avoid impacts, and then minimize them. Only when no better alternative can be demonstrated are unavoidable impacts permissible, which require mitigation. An applicant cannot choose to impact a protected resource and simply propose or negotiate mitigation. This mandated avoid, minimize, and mitigate standard requires sometimes incremental progress and even failure. For this example, Phipps Park may eventually include an expanded nourishment template perhaps with stabilizing coastal structures, but not until lesser impact alternatives have been attempted, monitored, and considered in good faith. With the long-term commitment to the coast, an incremental benefit can be realized with a supplemented sediment supply and moderation of the over-steepened beach profile in the Reach 7 area. The same incremental strategic approach is recommended for Reach 8.

As with all coastal communities, a degree of vulnerability always exists for assets on the coast. FEMA maps indicate areas of the Island are susceptible to erosion from a severe storm today. Future sea level rise has the potential to cause more flooding. Beach nourishment projects have a defined design criteria that can be exceeded (e.g., a project designed to withstand a 25-year storm has a 1 in 25 (or 4% chance) of being exceeded in any given year). Coastal engineering is also based on limited data, which introduces uncertainty. Uncertainty leads to risk, and risk introduces vulnerability. Town decisions, therefore, require an assessment of risk tolerance and a balance of investment to reduce uncertainty. Portions of the Island will always be exposed no matter the level of investment. Recommendations and preliminary analyses in this report will help guide actions to reduce risk. Through the Town Staff and consultants, the information and technical capability exists to design resilient projects, but the ultimate value-based decision is local, based on what's best for the community.

It is also essential that the Town's coastal protection objectives are clear to the community. For the purposes of this technical review, a prevailing goal of 15-year storm protection through use of sand nourishment primarily (including beaches and repetitive dunes) was assumed. The planning horizon also needs to be considered carefully. For the purposes of this technical review, focus was placed on a 10-year planning horizon; however, key areas of concern that benefit from a longer-term view are identified for Town consideration, should the planning horizon be extended.

Lastly for perspective, a directive to Woods Hole Group was to make recommendations on what is perceived to be *feasible*. For the purposes of this review, *feasible* is interpreted to include endeavors that can be completed in a cooperative good faith manner within the foreseeable planning horizon (~10 years). Other, more aggressive, measures can be pursued with the understanding that greater conflicting stakeholder interactions would be inevitable, with uncertain and perhaps costly outcome.

ES.2 Island-Wide Considerations

Recommendations applicable to Palm Beach as a whole, or at least to multiple Reaches, are presented based on evaluations of inlet sediment dynamics, regional coastal processes, available

sediment sources, and other physical characteristics. Recommendations that apply regionally are related to:

- Inlet management: Specific recommendations are itemized with a focus on sand transfer plant upgrades, USACE cooperation, and placement of inlet sand on dry beaches beyond the currently approved footprint in Reaches 1 and 2.
- Regional coastal processes and feeder beach strategies: Overall coastal processes are reviewed as the basis for understanding project performance and uncertainties. Supplemental analysis of historical data is presented along with suggestions for additional analysis to reduce uncertainty and improve the basis for future decision-making and adaptive management. Key findings show: substantial sand transport offshore at least to a depth of -40 feet NAVD; limited evidence of sand disposed within 2,500 ft of the inlet benefitting beaches to the south; a stabilizing effect of the Reach 3 nourishment on the southern end of Reach 2 as well as a stabilizing effect of the Reach 4 nourishment on Reach 5; formation of an offshore sand bar from Reaches 4/5 that does not connect back to shore within Town limits; little to no sand transported onto Reach 7 beaches from the north; evidence that Reach 7 nourishment sand is moving offshore and to the south; and uncertainty regarding the transport of sand on the dry beach around/through the Lake Worth Pier. Specific recommendations are offered for supplemental data analysis, possible modeling, and refined annual data presentations in the Town-wide monitoring reports.
- Beach nourishment project performance: The Mid-Town and Phipps Park beach nourishment projects were reviewed. Mid-Town nourishment sand was removed from the project area relatively steadily over a ~6 year period. Nearly 40% of the Phipps nourishment sand was eroded in the first 2 years, but since then the majority of the sand remains in the project area. The Phipps material was transported offshore and south, and leaves little storm protection benefits at the north end, which eroded rapidly.
- Sand source alternatives: Five (5) sand sources were reviewed including Lake Worth Inlet, local offshore borrow sites, upland sand from Ortona, imported aragonite, and regional offshore sand sources. Key findings included:
    - Inlet sand is the highest priority and should be used throughout Town when possible, not only within Reaches 1 and 2.
    - Ortona sand has the coarsest grain size, and will likely perform significantly better than offshore sand sources.
    - Offshore sand sources with a mean grain size of 0.25 mm or greater, made up of finer sand mixed with shell pockets, has been identified as an improvement over the finer gray sand used previously for beach nourishment. However, the incremental gain in performance with the mixed sediment size is uncertain.
    - Depending upon actual performance of the coarser mixed sand from the nearshore borrow sites, balanced by environmental constraints and potential resource impacts, consideration of using the more common sand farther offshore should be reserved for the future as sand sources are depleted.
    - The Town must place a priority on participating actively in the SAND Availability and Needs Determination study as a community with defined needs for beach compatible material. Future requirements are inevitable.

- Aragonite is not feasible currently due to cost, import uncertainties, environmental concerns, and unknown performance in an active energy zone. Since it is aesthetically pleasing, abundant in supply, and has a coarse grain size (assuming it is durable), it is a possible future source. However, as long as it is more expensive than Ortona sand, it is not worth the extra cost. The economic market should be used to define the feasibility of aragonite.
- Nearshore sand bars should not be mined for purposes of beach nourishment as the bars provide natural shore protection, and are within the active profile. Sand placed on the beaches has the potential to rapidly erode back offshore. The sand bar is an active part of the beach. The beach includes the dune, the dry beach, and the sand immediately below the water line. Seasonal conditions cause adjustments in the cross-section profile of the active beach-dune system. The geometry of the active beach area is reflective of the forces acting upon it. In the spring and summer, longer periods of smaller waves transport sand from the bars back onto the beach. In the fall and winter, larger and more energetic waves and more frequent storms transport sand from the dry beach back into the sea and form sand bars. Mining sand from this active section of the beach would disrupt the natural movement of sand and negatively influence the overall beach by allowing waves to propagate to the shoreline without being dissipated by a healthy sand bar. Effectively transporting and operating equipment close to shore in shallow water at reasonable cost also is a limiting factor.

- Coastal structures: Seawalls represent a critical component of the Palm Beach infrastructure and many upland properties depend upon seawall integrity. A Town-wide program for residents to monitor and maintain seawalls is essential. Existing groins provide stability to beaches, primarily in Reaches 2, 4, and 5, and should be maintained. There is not a single effective Town-wide groin design, nor are groins recommended throughout Town. Although composite T-head groins or breakwaters may be effective at certain locations, stakeholder interviews and experience suggest the feasibility of introducing shore parallel, rubble mound structures in Palm Beach is limited in the present regulatory and stakeholder climate.
- Hardbottom resources: Ephemeral and persistent hardbottom resources serve important ecological functions and values. It is not feasible to pursue projects including widespread coverage of habitat, since impacts must first be avoided, then minimized, and then mitigated. One cannot choose to impact and mitigate, without first demonstrating that other alternative with fewer impacts have been tried and proven inadequate. Projects must be planned with a strong consideration for hardbottom impacts and consequences.
- Dunes: Dunes are most effective when combined with beach nourishment, vegetated and maintained. Repetitive sacrificial dunes can also be used to achieve CCMP objectives, but, this approach represents an expensive strategy as compared to beach nourishment. Dunes generally should not be vegetated unless combined with a fronting beach berm.
- Vulnerability assessment and sea level rise planning: Since significant portions of the Island are presently vulnerable to storm damage and flooding, and rates of sea level rise are expected to increase in the future, the Town should initiate a planning process for adaptation to coastal climate change. The plan should identify flood pathways and

vulnerabilities, develop conceptual alternatives and solutions to minimize risk, and establish timeframes for implementation.

ES.3 Life Cycle Project Performance and Cost Considerations

A selection of shore protection alternatives were evaluated pertaining to relative performance and value to help formulate recommendations. Simplified calculations were made for planning purposes, but are not suitable for design, a formal cost-benefit analysis, or for value engineering. Results showed:

- The STP is a cost-effective method for moving sand to Palm Beach Island. More than 2,600,000 cy of sand have been bypassed by the STP over the past 18 years at a total cost of approximately $7.6M for an average of less than $3/cy on the beach. This is the most cost-efficient method of providing high quality, beach-compatible sand to the Island, and supports the recommendation for continued operation of the STP.
- The STP discharge extension has the possibility to require substantial investment estimated up to $10M for construction, plus mitigation, operation, routine maintenance and damage repairs. The USACE currently has $2M allocated for construction, which can potentially be increased but would require legislative action. Other methods of transporting sand south to the proposed location of the extended STP pipe are available in the short-term at lower cost, including USACE maintenance dredging (no cost to the Town), and mechanical forepassing via trucks for approximately $6/cy. The analysis supports the recommendation to reserve options to extend the STP pipe for the future.

  The influence of sand grain size on nourishment performance was evaluated along with the relative cost of sand from different sources. Using the Phipps nourishment project as an example over a 50-year time horizon, the total cost (present value) using offshore borrow sites with a median grain size of 0.25 mm would be on the order of $80M. Moving to a lower quality borrow site on the order of 0.2 mm would increase the 50-year life cycle cost to $100M. By comparison, if a sufficient quantity of inlet sand could be obtained with a median grain size of 0.33 m, life cycle costs could potentially be reduced by $7M. Based on current cost estimates associated with Ortona and aragonite (and assuming a sufficient quantity and production rate could be achieved), the life cycle costs would exceed the 0.25 mm offshore borrow site by some $78M and $150+M, respectively. The analysis shows the 0.25 mm offshore borrow site is preferred, but supplementing the project maintenance cycle with inlet sand has potential benefits.
- Assessment of alternatives to expand the Mid-Town project footprint north into Reach 2 demonstrated project performance improvements. From a value perspective, extending the Mid-Town project 1,000 ft into Reach 2 would increase the construction cost (assuming no mitigation) by $1.4M, but would be recouped over a 50-year life cycle. A similar analysis examined the addition of beach nourishment south of the Pier in Reach 8, together with the Phipps project extended to the Town limits. Results showed significant improvements to beach nourishment performance in both Reaches 7 and 8. The analysis supported the recommendation to pursue expanding the footprint of these two nourishment projects.

- The potential influence of dredging nearshore borrow sites on beach nourishment project performance was assessed. Results showed the potential wave energy increase associated with dredging nearshore, shallow borrow sites can offset the increased project performance gained by using the coarser grain size.

  For instance, a nourishment project of the same dimensions using 0.25 mm sand dredged from nearshore shallow water is not expected to perform better than a nourishment project using 0.2 mm sand dredged from deeper water where waves are not affected. Consequently, there is not a meaningful cost savings associated with using the higher quality 0.25 mm sand if dredged in shallow water offshore from the nourishment area. Simplified life cycle cost calculations indicate using nearshore 0.25 mm sand might actually increase the 50-year cost of a project like Phipps Park on the order of $8M if wave energy is increased by 25%. This analysis led to the recommendation to be cautious with using nearshore borrow sites, especially offshore areas not currently eligible for nourishment, and to adjust the nourishment template for projects landward of nearshore borrow sites to account for the increased wave energy. Using the nearshore 0.25 mm borrow sites should be considered to be more of an environmental benefit than for beach nourishment performance gains.

ES.4 Recommendations

Section 5 of the main report includes summary tables of recommendations supported by priorities and maps. Several recommendations are related to primary decision points facing Town Council that Woods Hole Group was asked directly to offer an opinion, including:

Sand Transfer Pipeline Extension: Although a commitment from the USACE to cost-share the project should be secured, implementation of the pipeline extension should be postponed indefinitely. There is a need to utilize inlet sand on beaches farther south and leverage the USACE commitment of funding for the pipeline extension, but it is not clear the extension to Angler Avenue will produce benefits to justify the cost. The potential cost to the Town for the project is substantial, and there are alternatives to place sand farther south. Should the alternative discharge location be moved farther south in the future and the USACE secure substantially more funds for construction; the project could be implemented at a later date.

Project Enhancements in Reaches 7 and 8: Two (2) key areas of concern are at the north end of Reach 7 from Phipps Park to Sloans Curve, and Reach 8 south of the Pier. Both areas have more narrow beaches than desired by residents, and solutions have been limited as a result of nearshore ephemeral hardbottom. Town and SoS consultants contemplated more aggressive engineering concepts involving larger volumes of coarser sand, perhaps with coastal structures, that would certainly help maintain wider beaches and improve storm damage protection. In spite of potential coastal engineering and economic merits, implementation of ideal coastal engineering solutions in the short-term is not feasible. Hardbottom considerations are limiting, and must be approached incrementally first via avoiding impacts, then by minimizing impacts, and finally by mitigating unavoidable impacts. Therefore, improved sand only projects are recommended as a next step in Reaches 7 and 8, as part of a long-term incremental, adaptive management approach to shore protection. Implementation of demonstration projects are encouraged in cooperation with the range of stakeholders involved. This is admittedly not the ideal solution from an engineering and economic perspective, but represents a balance of

interests following a more feasible approach. Forcing aggressive short-term solutions will likely result in significant delays and added costs, potentially adding to the long-term sand deficit; the primary source of erosion. The incremental approach should not be utilized as a means to continually expand a project assuming any less stringent environmental review. Future project modifications and regulatory approvals will require a clear demonstration that prior projects either did not perform as intended and/or that environmental impacts were less than anticipated, thereby warranting further action.

At the request of Council, after reviewing and discussing the Draft Report at the March 14, 2013 Council Meeting, Woods Hole Group further prioritized the recommendations presented in the Draft Report. Table ES-1 outlines the recommended plan with clear next steps, including planning level cost estimates. As requested by Council, a 10-year program is recommended. The FY2014 plan is recommended for immediate implementation; however, the degree of confidence decreases over time. Out-year cost estimates and requirements, particularly from 2017 forward will require refinements over time. For instance, the Recommended Plan includes sequential Phipps and Mid-Town renourishments in 2021 and 2022. The actual timing and scope of these projects will depend heavily upon project performance, permitting activities, and storm activity. Woods Hole Group also did not include factors for cost escalation, market fluctuations, or inflation, which are deferred to the Town financial planners.

One dozen (12) Priority 1 items are recommended for immediate action along with other essential elements of the Town Plan. These recommendations include:

- CCMP Supplement; one-time data analysis; and annual Town-wide monitoring supplement, which collectively will provide the basis for documenting project performance and adaptive management decision-making.
- Establishing a coastal structures program related to seawalls and groins
- Repairing the North Ocean Boulevard Seawall
- Establishing a communications program
- Proactive dune vegetation maintenance
- Forepassing sand south from the inlet
- Mid-Town project improvements and renourishment
- Phipps project improvements and renourishment
- Reach 8 (south of Lake Worth Pier) EIS

Three (3) of the Priority 1 items are included in the recommended plan, but have more uncertainty than the others. The first nine (9) Priority 1 items can generally proceed now, whereas the last three (3) items have uncertainty associated with permitting or other agreements. The recommended plan includes all the Priority 1 items since they are strongly recommended assuming appropriate approvals are in-place; thus, we are recommending they be included as part of the financial plan. The uncertain Priority 1 items include:

- Maintenance of Town-owned structures is uncertain since it is not know which structures may require attention.
- Maintenance of nourishments (Mid-Town, Phipps, and future Reach 8) with inlet sand is uncertain since the ability to obtain inlet sand depends upon availability, nourishment project maintenance requirements, and cooperative contracting arrangements with USACE not yet resolved. The plan is based on the assumption that approximately 20% of dredged inlet sand will be transferred by hopper dredge to other beaches on the Island.[1] No particular cost item is attached to these activities since it is not known to what extent the Town will need to cost-share USACE operations, whether the opportunity will actually arise, or whether the project(s) could be funded by diverting a portion of the budgets already allocated for nourishment. Using inlet sand to maintain the nourishment projects may also reduce overall cost by extending the design life for the next large-scale renourishment. If there are additional emergency hopper dredge operations that Town could cost-share, there may be a need to appropriate additional funds not in the plan.
- Reach 8 Phase 1 feeder beach is uncertain since it depends upon the outcome of the Reach 8 EIS.

Five (5) Priority 2 and five (5) Priority 3 items also are included, subject to financial constraints and necessity. An adaptive management approach is recommended to help determine the need. Notes are provided on table ES-1 for each item in the plan to guide when/whether a particular item will be required.

The remaining recommendations offered in Section 5 also are included on Table ES-1. These management strategies will help guide the overall adaptive management approach, but do not necessarily have a direct cost impact for financial planning purposes. The one exception is the sand transfer plant repair fund, which has a cost implication, but we understand is funded separately through a "risk fund."

The Priority 1, 2, and 3 items are recommendations that have a direct cost implication. Cost estimates were developed independently to validate budget items in the Town plan. Woods Hole Group budget forecasts were then compared with Town estimates to derive a consensus for Council review, including a specific FY2014 plan and budget for Town Council consideration.

Assuming the plan or elements thereof are approved by Council, we recommend immediate action on the Priority 1 recommendations and essential Town items. To help manage the volume of information in this report and focus next steps of Town staff and consultants charged with implementing a plan approved by Council that includes recommendations in this report, the key elements required for next steps include:

- Table ES-1 outlining the recommended actions and management strategies
- Tables 5-1, 5-2, and 5-3 providing more details supporting ES-1, and

[1] Assumes the Town will cooperate with a USACE hopper dredge operation three times over the 10-year period securing 100,000 c.y. each event for a total of 300,000 c.y. If the STP produces an average of 75,000 c.y. per year, and the Corps dredges the inlet 5 times at 150,000 c.y. per event, then there would be a total of 1,500,000 c.y. removed from the inlet over the 10-year planning period, of which the 300,000 c.y. placed elsewhere represents 20%.

- Chapters 3 and 5, which provide the rationale for the recommendations.

Table ES-1. Recommended Plan and Priorities

	Description	WHG Item(s)	Pri	10-Year Plan 2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL	Notes
Priority 1	CCMP Supplement; One-time supplemental analysis of data; and Annual Town-wide monitoring report supplement	O-1.1, O-1.2, O-1.3, O-1.4, O-1.5, O-1.6, I-7, 1-2 & 1-3	1	$ 115,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 340,000	Includes: 1) Supplement to existing CCMP, not a full re-do; Town staff take lead with consultant support as needed through general coastal engineering account. Includes design criteria for Reach 1 to identify impounded sand. 2) Expand historic data analysis; document coastal processes implications; provide sample plots and direction for annual reports; decide whether model(s) are needed. 3) Annual supplement to Town-wide monitoring report; data presentation; summary of project performance compared to design expectations; revisit CCMP and identify needs for modifications. Incorporate data from updrift Singer Island and Riviera Beaches. Model annual reports after recommendations from CCMP supplement and one-time supplemental data analysis above.
	Coastal structures program	O-2, O-3, 2-1, 2-3, 3-1, 4-1, 5-1, 6-1, 7-1 & 8-1	1	$ 160,000	$ 200,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 160,000	$ 20,000	$ 20,000	$ 20,000	$ 660,000	Document as part of CCMP supplement. For seawalls, initially: map and classify seawalls/revetments/bulkheads; assess condition; clarify/inventory ownership; ID vulnerable areas; and ID inspection/maintenance needs. For groins, initially task consultants to consolidate recommendations for specific groins based on existing reports; and inventory/clarify ownership. Assume Town take the lead on identifying ownership and providing residents direction on how/where to act (e.g., which ones to repair to advance overall CCMP goals; where inspections needed; guidance for inspections by qualified engineers; general advice through process). Budget estimate assumes Town not responsible for actual project design, permitting, or construction - owners will fund this work for private structures. Recommend Town have a defined advisory or review capacity to ensure structural modifications are consistent with CCMP objectives (consistent with the 1931 ordinance). May include new Town policy for coastal program review of structural modifications or new structures, and enforcement for maintenance/mitigation. Assumes structure assessments will be updated every 5 years.
	North Ocean Boulevard Seawall		1	$ 5,600,000										$ 5,600,000	Critical Town infrastructure already in the plan.
	Communications program	O-5, 7-2 & 8-2	1	$ 25,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 160,000	Website and/or social media updates; 2x or quarterly informational meetings; print materials. Specifically educate public on realistic expectations for beach nourishment projects, including possible need for incremental approach in Reaches 7 and 8.
	Dune vegetation maintenance	O-6	1	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 100,000	Needed to maintain healthy dune plantings.
	Permitting and trial forepassing sand from Reach 1	1-4	1	$ 145,000		$ 120,000								$ 265,000	Implement during years when USACE not pumping sand on the beach in Reach 2. Monitor to determine whether sand placed in northern portion of Reach 2 is benefitting downdrift beaches. A less expensive alternative to test potential utility of STP pipeline extension. Assume trucking 20,000 c.y. at $6/c.y. Assumes monitoring shows "impounded" Reach 1 sand. If recently placed USACE sand shows promise, try two times, and then make adaptive management decision.
	Mid-Town nourishment project	3-2.1, 3-2.3, 3-3, 4-2.1, 4-2.2, 4-4 & 4-2.1	1	$ 11,600,000								$ 14,300,000		$ 25,900,000	Renourish Mid-Town in 2014 (assuming $2M mobilization, 800,000 c.y. at $12/c.y., and truck haul additional 150,000 c.y. to hotspots at Phipps and Reach 8 for $18/c.y.). Assumes 100k c.y. to Phipps and 50k c.y. to Reach 8 dunes, with costs distributed in FY2014 below. Seek permits for northern extension into Reach 2, and possible modification of template due to offshore borrow sites. Assumes permitting completed in 2013 and 2014 project. Assumes full renourishment on 8-year interval in 2022. Additional 150,000 c.y. truck haul for 2022 project kept in Mid-Town budget since location for disposal is TBD.
	Phipps renourishment	7-3.1, 7-3.2, 7.3-6 & 7-3.8	1	$ 1,800,000		$ 14,000,000					$ 14,000,000			$ 29,800,000	Renourish Phipps with widened and extended profile; assumes 2016 construction so can combine with Reach 8 Phase 1. Assumes 1,000,000 c.y. at $12 plus $2M mobilization and 5-year cycle. Also includes 100,000 c.y. in 2014 from Mid-Town truck haul.
	Reach 8 EIS	8-3 with 8-3.1, 8-3.2 and 8-3.4	1	$ 1,000,000										$ 1,000,000	Realistically will take a few years to achieve a desireable project and plan.
	Maintain Town structures		1		$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 13,500,000	Accumulate budget for repairing other Town-owned coastal structures (TBD) including seawalls and groins. Could do as bonded future capital items. Does not include Town-funded repairs to private structures, which has potential to add substantial costs not included herein. Recommended but uncertain since structures requiring repairs TBD.
	Maintain nourishment(s) with inlet sand	3-2.2, 4-2.3, 7-3.2, 7-3.7 & 8-3.3	1	$ 50,000										$ 50,000	Secure permissions and cooperative agreements to obtain inlet sand via hopper dredge to maintain Mid-Town, Phipps and/or Reach 8. Incorporate into project permits and BMA. Assumes 2 events at 100,000 c.y. each at average $15-incremental cost to USACE base, which would cost $1,500,000 each. No specific incremental cost item added, though, since uncertain opportunity, has potential to be funded with nourishment allocation, and perhaps reduces cost by extending life of nourishment. Additional funding may be required if USACE performs emergency inlet hopper dredge and Town desires a cost-share to maintain nourishment at Mid-Town, Phipps, or Reach 8. $50,000 specified in FY2014 is for work to coordinate effort to implement as needed/available.
	Reach 8 Phase 1 feeder beach	8-3.3	1	$ 900,000		$ 1,620,000					$ 1,620,000			$ 4,140,000	Assumes first phase of Reach 8 in FY2016 will be 65,000 c.y. feeder beach south of Pier plus 25,000 c.y. in dunes combined with Phipps renourishment for truck-haul of 90,000 at $18/c.y. ($12 to pump and $6 to truck). Alternative is to use Orotona sand at $40/c.y. Subsequent maintenance from inlet hopper and/or truck haul from Mid-Town or Phipps nourishment projects, or even Reach 1 impounded sand. Strongly recommended but uncertain design and outcome from Reach 8 EIS. Also includes 50k c.y. in FY2014 from Mid-Town truck haul.
	Priority 1 Subtotals			**$ 21,405,000**	**$ 1,750,000**	**$ 17,310,000**	**$ 1,570,000**	**$ 1,570,000**	**$ 1,570,000**	**$ 1,710,000**	**$ 17,190,000**	**$ 15,870,000**	**$ 1,570,000**	**$ 81,515,000**	
	Other essential Town items			$ 1,510,000	$ 1,380,000	$ 1,590,000	$ 1,440,000	$ 1,440,000	$ 1,440,000	$ 1,440,000	$ 1,598,000	$ 1,440,000	$ 1,440,000	$ 14,718,000	Essential Town items include physical monitoring and reporting, sea turtle monitoring, beach tilling, escarpment removal, biological monitoring, beach nourishment construction mitigation, STP operating, coastal program operating, general coastal engineering, and regional sand needs study.
	Recommended Plan			**$ 22,915,000**	**$ 3,130,000**	**$ 18,900,000**	**$ 3,010,000**	**$ 3,010,000**	**$ 3,010,000**	**$ 3,150,000**	**$ 18,788,000**	**$ 17,310,000**	**$ 3,010,000**	**$ 96,233,000**	

Table ES-1. Recommended Plan and Priorities (continued)

	Description	WHG Item(s)	Pri	10-Year Plan 2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL	Notes
Priority 2	EIS/permits for explanded inlet sand placement	I-3.5, I-3.6, 2-2 & 3-4	2		$ 1,000,000									$ 1,000,000	Includes expanded placement south of Angler Avenue and south through Reach 2 into northern end of Reach 3/Mid-Town project. Obtain approvals for USACE project(s) in 2017 and beyond; could target next project by 2015, but there are higher priorities in short-term.
	Tri-party inlet dredge permitting	I-8	2			$ 150,000								$ 150,000	Implement if USACE fails to dredge or Town not satisfied with location of dredge material placement. Town continue to work with other parties to understand relative roles, liabilities, overall interest, and process should the Town choose to pursue in future. Note, there is no specific program item to fund the actual dredging and placement of sand from the inlet.
	Vulnerability assessment	O-4	2	$ 100,000										$ 100,000	Focus on existing and future vulnerability of Town infrastructure to extreme storms and sea level rise. Results would help plan future seawall/bulkhead upgrade requirements.
	Ongoing forepassing of sand from Reach 1 south	1-4	2					$ 120,000		$ 120,000		$ 120,000		$ 360,000	Continue forepassing if trial proves beneficial.
	Gulfstream groin	4-3	2									$ 1,700,000		$ 1,700,000	Construct only if consistent need arises after next nourishment project.
	Priority 2 Subtotals			$ 100,000	$ 1,000,000	$ 150,000	$ -	$ 120,000	$ -	$ 120,000	$ -	$ 1,820,000	$ -	$ 3,310,000	
Priority 3	STP pipeline extension	I-3.7 & I-4	3											$ 8,000,000	Not recommended at this time; perhaps consider in future should other plans for moving inlet sand farther south prove not possible or ineffective. Cost assumes $5M construction and $3-$5M for mitigation with $2M USACE cost-share.
	Permits to dispose finer dredged sand in dune system	I-6	3											$ 100,000	Would gain flexibility to use fine material on dry beach in dunes; however, not presently recommended since monitoring of the recent USACE sand may show intertidal placement is preferred instead.
	Island-wide modeling	O-1.7	3											$ 200,000	Depends upon results of supplemental data analysis in O-1.3; only do regional modeling if will be part of future annual updates/adaptive management analysis. Assumes $100k initial application and $25k every other year for design modifications/refinements.
	Phipps improvements	7-4	3											$ 6,390,000	Will depend upon performance of next project. Assumes next project will be expanded (more sand/maybe structures) requiring at least EIS supplement (500k). Assumes $6M in additional sand (2,100 ft at 75 c.y./ft and $12/c.y.), structures (4 at $500k each), and mitigation ($2M), but highly uncertain; hence, Priority 3 status.
	Reach 8 improvements	8-3.3 Next phases	3											$ 11,000,000	Important but very difficult to predict at this time; may be required if feeder beach south of Pier is permitted but proves inadequate to maintain the Reach. Assumes additional $1M in supplemental EIS/permitting. Solution(s) perhaps would involve more sand (5,000 at 50 c.y./ft at $18/c.y. trucked from Phipps stockpiled or from inlet), structure(s) (5 at $500k); mitigation ($3M); hence, Priority 3 status.
	Priority 3 Subtotals*													$ 25,690,000	*** Priority 3 items are too uncertain to attach a timeline**

Table ES-1. Recommended Plan and Priorities (continued)

	Description	WHG Item(s)	Pri	10-Year Plan 2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL	Notes
Other Management Strategies	**Recommendations that offer guidance or policy but don't have a direct cost**														
	Repair sand transfer plant and reserve funds for future repairs	I-1													Short-term repair cost (~$500,000 and annual accumulation of ~$100,000) accounted separately through Risk Fund.
	Continue to place STP sand to stabilized north end, but seek alternatives	I-2 & 1-1													Status quo until can gain flexibility to place sand elsewhere.
	USACE cooperative agreement	I-3.1, I-3.2, I-3.3, I-3.4													Continue working with USACE to have Town participation in bid process, have input on construction method to ensure placement on Town dry beaches and intertidal zone (even if USACE needs emergency dredging with hopper dredge), and coordinate permits.
	Prioritize sand placement in southern portion of approved template	I-3.8													Improves potential for sand to move south beyond the inlet.
	SAND participation	O-9													It is essential for Town staff to actively participate in the regional Sand Availability And Needs Determination (SAND) investigation since the Town will require regional sand sources in the future.
	Maintain Reach 5 primarily via Mid-Town project	5-2													Continue current practices, while gaining flexibility to directly nourish certain areas via Item 5-5 if erosion occurs.
	Take caution with using southern portion of South Borrow Area 1	5-4													Has the potential to alter transport in Reach 5, which has been otherwise stable.
	Take caution with using South Borrow Area 2 and do not use southern portion fronting Reach 7	6-3 & 7-3.3													Use seaward portion since landward portion is possibly within the active transport zone. Do not use portion offshore Sloans Curve offshore Reach 7 erosional hotspot.
	Vegetate dunes in Phipps project only with full beach nourishment	7-3.4													Without full beach nourishment template, dune vegetation will not have sufficient time to establish.
	Construct Phipps project from south to north	7-3.5													Construct full width template at the north end of the project last, just prior to demobilizing equipment. Will ensure full template at north end upon completion of construction where project is most vulnerable.
	Maintain Reach 5 groins, including Monster Groin	5-3													Groins help stabilize Reach 5 and possibly minimize hardbottom impacts in Reach 6.
	Permits for Reach 5 maintenance	5-5													Obtain permits to maintain minimum beach in Reach 5 directly if needs arise; include flexibility for sand from upland and inlet in addition to traditional offshore sources. Perhaps add to Mid-Town permits for truck haul to Reach 5 if needed. Expected to be included in BMA.
	Establish Reach 6 as area to maximize hardbottom coverage	6-2													Has potential to offer flexibility for hardbottom impacts in other areas via BMA regional approach.
	Federal regional permit for BMA	O-7													If BMA is approved at State/Town level, Town staff then work with Federal regulatory staff to consider and pursue regional permit.
	ToY exceptions in permits	O-8													Town staff seek provision in project permits and/or BMA for exceptions to standard ToY windows for nourishment if erosion is severe, eliminating habitat (e.g., sea turtle nesting) absent beach nourishment.

1.0 INTRODUCTION

Woods Hole Group was contracted by the Town of Palm Beach in April 2012 to perform a technical review of the Palm Beach Comprehensive Coastal Management Program. The primary purpose of the project is to provide Town Council objective technical recommendations regarding next steps for the Town's coastal program and specific projects. Reporting directly to Town Council differs from the typical coastal engineering consultant assignment, which reports to Town Staff. In this case, Town Staff provided technical support, but did not direct the work. Woods Hole Group is conducting this work as an approved Town consultant from the 2009 selection process. Woods Hole Group also presented to the Shore Protection Board in 2009, and performed a prior Peer Review of the Comprehensive Coastal Management Program (CCMP) Update in 1998.

As the decision-making authority, Town Council decides on the coastal program projects and capital expenditures. The need for this objective technical review arises from the substantial investment involved, and sometimes differing opinions communicated to Council by the public. These differing opinions exist in part because coastal management is a multi-disciplinary field with a level of uncertainty, but also because stakeholders are passionate about the coast and their community, and coastal management requires substantial investment. Varying opinions also may not always be consistent with stated CCMP objectives. Primary documents for Council deliberations are put forth by the Shore Protection Board (SPB) and Town staff. Annually, recommended projects and associated budgets for a 10-year planning horizon (most recently for FY 2013 and a FY 2013-2022 forecast) are provided to Town Council for decision by the SPB and Town Staff. The plan is consolidated from a combination of town consultant reports and dedicated outreach to the public, including the coastal engineering and environmental communities, as well as a diverse group of interested and active stakeholders. Council also receives input and recommendations directly from stakeholders, through individual citizens, organized associations, and consultants. Neighboring communities, not-for-profit associations, environmental professionals/policy-makers, and other professionals in the field also contribute information and materials for Council consideration. It is Woods Hole Group's intention through this report to provide Council information to support its decision-making process.

1.1 Report Contents

The report is organized in order of increasing detail to facilitate Town Council review.

- The **Executive Summary** offers the key points and recommendations from the report.
- Section 1 **Introduction** is intended to establish the overall purpose, expectations, and framework for the project.
- Section 2 provides an **Overall Perspective** on the Palm Beach Coastal Program and Projects, including big picture achievements and areas for improvement.
- Section 3 is focused on **Island-Wide Considerations**, and identifies key issues and recommendations that apply to more than one Reach, and generally to the community as a whole. Also included is a general overview of Island-wide coastal processes as apparent to Woods Hole Group using only the available information (which has some

identified limitations). The purpose of the review of coastal processes is to set the technical context for how the processes affect project planning and performance expectations. Evaluating coastal processes also helped the team determine whether there are key uncertainties or data gaps that need to be filled to improve the overall program.

- Section 4 provides a **Shore Protection Alternatives Value Assessment** for a subset of projects related to factors such as construction method, sand source, grain size, and project design.
- Section 5 provides **Recommendations and Next Steps** for inlet management, each reach, and for the Island as a whole.

1.2 Scope of Work

The scope document provided to Woods Hole Group by the Town is provided in Appendix A. Town Council specifically requested that two main points be addressed:

- Conduct a comparative analysis of activities since the 1998 CCMP review
- Consider all projects contemplated between the 2009 SPB Plan and the FY 2013 SPB recommended program

Additional general guidance on the scope of work was offered by Council at a March 14, 2012 meeting and requested:

- Truly unbiased analysis of the SPB recommendation with a focus on feasibility (what is feasible and not feasible), and what the Town should be doing (or not doing).
- Consideration of cost-effectiveness, costs and benefits, and value of recommendations in the SPB plan. (Town Council utilized terms Value Engineering and Cost-Benefit Analysis; however, it was agreed that the Woods Hole Group analysis, while focused on cost-effectiveness, cost realities, and relative costs and benefits associated with certain decisions, would not include a formal Value Engineering evaluation or traditional Cost-Benefit analysis.)
- Focus on suitability of Bahamian sand or aragonite for Palm Beach, specifically as related to whether it is permissible within prevailing regulations, likely to provide an increased benefit as compared to traditional sand sources, and whether the incremental benefit would be worth the increased cost.
- Determine whether any other community in the country has been able to successfully eliminate hardbottom concerns.
- Consider groins, and specifically whether groins should or could be installed south of Sloan's Curve or along the entire Island.
- Make a wish list of coastal items as compared to permitting limitations and cost realities.

Woods Hole Group also sought and received support from Town Council via an August 14, 2012 meeting to address the following areas identified in Phase 1:

- Lake Worth Inlet sediment management/bypassing

- Sand sources/alternatives
- Design criteria/expectations
- Island-wide coastal processes
- Monitoring data
- Adaptive management opportunities

In response to the Town Council request, Woods Hole Group proposed a phased approach that formed the basis of the contract:

- Phase 1 included **Task 1 - Obtain and Review Materials**. An extensive library of existing information was compiled and reviewed. Materials reviewed are summarized in section 1.2 below. Although materials were continually referenced and reviewed throughout the course of the project, the Phase 1 review was intended to gain a working knowledge of the issues, identify data gaps, and define key areas of focus for the Woods Hole Group review and recommendations. Phase 1 also included a decision point to determine whether the approach for the remainder of the project required refinement. During Phase 1, one refinement expanded the amount of information reviewed, and included an increase in the initial time estimated for stakeholder interaction in Task 2. Phase 1 also included an onsite meeting and updated inspection of the local beaches in June 2012.
- Phase 2 included **Task 2 - Stakeholder Consultations**, a **Task 3 - Recommendations Report**, and **Task 4 - Management and Coordination**.
    - Task 2 Stakeholder Consultations was a focus of the work, and included correspondence and interviews with individual Town Council members, individual members of the Shore Protection Board, citizens, associations and their consultants, members of the research community, Town consultants, state agency/regulatory personnel, and Town staff. Task 2 also included participation in a public work shop held by Town Council on December 10, 2012, as well as additional onsite shoreline inspections in December 2012.
    - The scope for Task 3 included Draft and Final Recommendations Reports. Woods Hole Group was afforded tremendous flexibility in performing this work and preparing project deliverables. However, due to prevailing rules and policies related to sharing public documents, the need to preserve objectivity, and Woods Hole Group's direction to report directly to Town Council, it was not appropriate to share preliminary documents such as preliminary drafts of this report prior to publishing and submitting the Draft Report to Town Council. Although essential to assure objectivity, the process inherently introduced the opportunity for the Draft Report to lack certain information of interest to Council. Given the breadth of information reviewed, extensive local knowledge amongst stakeholders, long history of shore protection in the Town, and the likelihood that data and reports

not reviewed by Woods Hole Group exist, the process also introduced the opportunity for Woods Hole Group to present mis-informed or incomplete information. Therefore, having the opportunity to refine the draft to address matters not originally included, and incorporate information not previously known or understood was essential to the process. Certain initial recommendations or findings in the Draft were refined for the Final Report, as anticipated.

- Task 4 Management and Coordination included a full range of correspondence, technical resource coordination, progress reports to the Town, and general project administrative duties to comply with the contractual requirements.

- OPTIONAL Phase 3 **Supplemental Technical Analyses** was reserved for filling data/information gaps possibly requiring attention to execute the technical review or formulate recommendations. Possibilities included: monitoring data analysis; wave/sediment transport analyses or sediment budget updates; habitat delineations; environmental/risk assessment enhancements; financial analyses; or other supplemental work identified through the course of the technical review. It was not appropriate to define a need or scope of work for these items prior to performing the Technical Review, so these items were defined as Optional and not included in the contract. Certain data gaps were identified and supplemental analyses are recommended in this report; however, an essential need for Woods Hole Group to conduct these analyses was not recommended as part of the technical review process. How and whether the recommended analyses are implemented remains to be determined as a follow-up to this Technical Review.

The Draft Report was published in February 2013, and comments on the Draft were offered by Council at a public meeting on March 14, 2013. This Final Report addresses the Council comments, as well as comments from the Shore Protection Board during a March 28, 2013 meeting. Specific comments to be addressed in the Final were documented in a Woods Hole Group letter, dated April 25, 2013. Comments are addressed where applicable in the Final Report, and Appendix C provides a summary response to comments. A key addition to the Final Report is a Recommended Plan including budget estimates, provided at the end of the Executive Summary.

1.3 Materials Reviewed

An original list of reference materials was recommended by Town Council with support from Town staff that included:

- Shore Protection Board-Related Items: The specific FY 2013 SPB Plan recommended to Town Council (Appendix B), as well as extensive sets of meeting agendas, notes, support materials, and related presentations and reports from January 2009 through March 2012. These items included extensive correspondence between Town staff and Erickson Consulting Engineers (ECE) on behalf of Town residents.
- State of Florida Department of Environmental Protection (FDEP) Reports: Specifically including Strategic Beach Management Plan, Critical Erosion Areas Report, Offshore Sand Search Guidelines, and the Lake Worth Inlet Management Plan.

- Feasibility Studies for Reaches 2, 5, and 8.
- Permitting Submittals as related to the Sand Transfer Plant (STP) modification and Reach 8 Joint Coastal Permit applications and related materials.
- Legal Documents pertaining to the DOAH case and Town of Palm Beach versus USA Civil Action.
- Coastal Structure Reports, including groin and armoring inventory, overall coastal structures plan, and Phipps Park design document.
- Physical Monitoring Reports since 2004 including various pre- and post-project monitoring surveys related to the Mid-Town and Phipps 2006 beach nourishment projects, Town-wide monitoring surveys, and post-storm survey reports.
- Biological Reports related to the Phipps Park and Mid-Town Beach Nourishment projects.
- Geotechnical Reports summarizing the 1999, 2007 and 2011 sand search studies.

In addition to the library originally recommended, a series of subsequent, supplemental materials were made available:

- Wave studies related to potential borrow site impacts
- Coastal management history document
- Peer review of coastal structures plan
- Updated inlet sediment budget
- FDEP documents related to the Beach Management Agreement (BMA) and coastal armoring policy
- Reach 7 and 8 plans by ECE
- Peer review of Reach 7 design document
- Sand transfer plant (STP) data
- Hardbottom maps
- 1998 CCMP and peer review
- Sand grain size and durability research
- Wave and water level data from public sources (e.g., USACE and NOAA)
- Southeast Florida Sand and Needs Determination (SAND) initiative preliminary information

In the course of conducting its work, Woods Hole Group was informed of useful complementary reference materials during the stakeholder consultations, and requested additional information from Town staff. The project team also conducted independent research and compiled information via internet and library searches, through talking with knowledgeable stakeholders in other communities/agencies, and made full use of the in-house reference materials and resources.

More than 400 individual documents spanning more than 10,000 pages of information were compiled.

1.4 Stakeholder Consultations

Stakeholder consultations were an essential part of the review process. Although Woods Hole Group's objectivity was essential for Town Council, the team's separation from day-to-day, local activities introduced an inherent learning curve that was supplemented through stakeholder consultations. The collective value and decades of local stakeholder experience were invaluable, and a critical element for Town plans moving forward. Stakeholder consultants were conducted in a cooperative, teaming approach. Woods Hole Group viewed these interactions as an opportunity to better understand and gain technical information to help guide Town decisions. Woods Hole Group did not view the consultations as a formal peer review, nor did Woods Hole Group execute technical studies to verify the accuracy of work products by others. Instead, information offered by others was utilized to help formulate recommendations. Stakeholder consultations included informal and extensive telephone calls, electronic correspondence, and personal interviews. Discussions were open, forthright and held in confidence with the Woods Hole Group team. No recordings or documentation became available as a result of the discussions. All stakeholders were open, forthcoming with information, and accommodating to Woods Hole Group requests. Town consultants were remarkably professional, cooperative, unguarded with their time, and thoughtful in their responses. It was clear that the stakeholders were genuinely interested in achieving the best results for the Town. The Woods Hole Group team respected the commitments extended and valued the opportunity to exchange ideas with all stakeholders involved.

Specific stakeholders consulted included:

- Individual Town Council Members, including: Mayor Gail L. Coniglio; David A. Rosow, President; Robert N. Wildrick, President Pro Tem; William J. Diamond; Richard M. Kleid; and Michael J. Pucillo
- Comments received at a December 10, 2012 Town Council public workshop
- Individual Shore Protection Board Members, including: E. LLwyd Ecclestone, Chairperson; Gerald Frank, Vice-Chairperson; Kane Baker; J. Patterson Cooper; Lee David Goldstein; and Lewis Katz
- Palm Beach Civic Association c/o Mr. Garrison duP Lickle (President of original SPB)
- Citizens' Association of Palm Beach c/o Chairman Lew Crampton
- The Coalition to Save our Shoreline c/o Mr. Richard Hunegs, Esq. (Leadership), Ms. Madelyn Greenberg, and Erickson Consulting Engineers c/o Karyn Erickson and Doug Dusini
- Individual citizens including Bobbie Lindsay-Buck (former SPB Member), Gene Fuse, and Dr. Sanford Kuvin
- Surfrider Foundation Palm Beach County Chapter c/o Chairman Todd Remmel and Stakeholder Liason Tom Warnke

- Dr. Harold Wanless, University of Miami
- Town Consultants, including specifically: Applied Technology & Management (ATM) c/o Mike Jenkins; Coastal Eco-Group c/o Cheryl Miller; Coastal Planning & Engineering (CP&E) c/o Tom Pierro; Coastal Systems International (CSI) c/o Penny Cutt; Coastal Technology Corporation (CTC) c/o Michael Walther and Tem Fontaine; Humiston & Moore Engineers (H&M) c/o Mohamed Dabees; and Tetra Tech c/o Craig Kruempel
- Florida Department of Environmental Protection (FDEP) c/o Danielle Fondren, Bob Brantley, Lainie Edwards, and Marty Seeling
- US Army Corps of Engineers (USACE) Jacksonville District c/o Tim Murphy in Planning and Leah Oberlin of Regulatory in the South Florida Area Office
- Town Staff Members, including Town Manager Peter B. Elwell, Public Works Director H. Paul Brazil, Town Engineer James Bowser, and Coastal Coordinator Robert Weber

Woods Hole Group also consulted with colleagues and contacts in other municipalities with similar experiences, as well as USACE contacts in other regions to gain useful perspective for Palm Beach. The process also included Public meetings on December 10, 2012 and March 14, 2013.

1.5 Meet the Team

The review team included four (4) primary Woods Hole Group personnel with diverse, complementary backgrounds, and who have been with the organization since at least 1997:

- Robert P. Hamilton, Jr., M.C.E., Project Manager and Civil/Coastal Engineer
- Kirk F. Bosma, P.E./M.C.E., Coastal Engineer/Modeler
- M. Leslie Fields, M.S., Coastal Geologist
- Lee L. Weishar, Ph.D./P.W.S., Senior Coastal Scientist/Engineer

Additional technical and administrative support to the project was provided by Ms. Elise Leduc (Environmental Scientist and GIS Specialist), Mr. John Brawley (Coastal Systems Ecologist), Dr. Leonid Ivanov (Physical Oceanographer), and Ms. Nadine Sweeney (Project Administration).

Mr. Hamilton is a Civil/Coastal Engineer and Vice President for Business Development at the Woods Hole Group. He is the Project Manager for the technical review of the Palm Beach Shore Protection Plan, providing a consistent point of contact with the Town and stakeholders, and leading the Woods Hole Group team. He is primary author of the deliverables, and also was the Project Manager for the 1998 Peer Review of the Comprehensive Coastal Management Plan Update, performed by Woods Hole Group (then Aubrey Consulting, Inc.).

He's been with the Woods Hole Group since 1994, and has previously served as Coastal Engineer, Business Unit Director, and V.P. for Scientific Operations. He earned a B.S. in Civil

Engineering from Lehigh University, and a M.S. from the University of Delaware Center for Applied Coastal Research. He is focused on development of business relationships and multi-disciplinary project and client management. His extensive market and contracting experience includes government agencies, architectural/engineering partners, offshore oil and gas producers, private owners/developers, power utilities, and manufacturing industries. He has strong technical, analytical, and problem-solving skills combined with an effective leadership, communication, negotiation, and personnel management approach.

His technical expertise is on solving problems related to shoreline erosion, coastal structures, water quality, environmental permitting, and the transport and dilution of thermal discharges and contaminants released into the marine environment. He also has multi-jurisdictional regulatory experience, including preparing EIS documents under NEPA, and has served as an expert witness. Mr. Hamilton's technical skills include numerical modeling and analyses of nearshore wave refraction, diffraction and breaking, sediment transport and shoreline change, and two- and three-dimensional hydrodynamic processes, including plume dispersion and mixing zones. His field skills include site assessments, wave and tide data collection, bathymetry data collection, beach profile surveying, and scientific SCUBA diving. Recent types of coastal projects in which Mr. Hamilton has participated are related to beach nourishment, salt marsh restoration, dredging and dredged material disposal, and environmental resource impact assessment and management planning.

Mr. Kirk Bosma is the Team Leader for the Coastal Sciences, Engineering & Planning group at Woods Hole Group, and has been with the company since 1997. His role on the Palm Beach shore protection plan technical review is to provide a coastal engineering perspective with a focus on coastal processes, project performance, and life cycle cost and performance considerations. He is a registered Professional Engineer (P.E.), with expertise is in the areas of numerical modeling of coastal and estuarine processes, coastal engineering design for shore protection, wave propagation and transformation, sediment transport and littoral processes, hydraulics for marsh restoration, and data collection and implementation of coastal engineering projects. Mr. Bosma earned his Masters in Coastal Engineering from the University of Delaware in 1997 and his B.S. in Civil Engineering in 1994. He has extensive experience in the analysis of nearshore wave conditions and the impacts of waves on coastal erosion, and evaluating hydrodynamics of estuarine systems. Mr. Bosma has implemented technically advanced data analysis techniques to assess the estuarine, coastal, and oceanographic environment, including wave, tide, current, sediment, and particle transport processes. Mr. Bosma also has extensive experience developing and employing numerical models for marsh restoration, sediment transport, nearshore spectral wave transformation, particle transport, bathymetric evolution, two- and three-dimensional hydrodynamic processes, and then being able to interpret and analyze the results. He is experienced in utilization of UNIX- and PC-based software packages and programming languages to present, analyze, and solve engineering and scientific problems. Mr. Bosma has designed a number of coastal engineering structures and erosion mitigation solutions.

Recent types of coastal projects Mr. Bosma has managed include: beach nourishment, dune restoration, wave, current, and sediment transport modeling, marsh restoration projects, soft and

hard solution coastal engineering design, construction oversight, and borrow site impact assessment. Mr. Bosma has been the project manager for both large coastal restoration and marsh restoration projects that have included evaluation of a variety of restoration alternatives and included the implementation of a comprehensive data collection and physical processes modeling programs.

Ms. M. Leslie Fields is a Coastal Geologist with more than 25 years of experience in the areas of coastal geology and coastal process evaluation. She provides a geomorphology and geology perspective to the Palm Beach team, and focused on identifying overall coastal processes trends as specifically related to past beach nourishment project performance and how processes may affect planning of future projects. She joined Woods Hole Group in 1989, and specializes in analyses of shoreline change, geomorphic evolution of coastal systems, coastal hazard evaluation and mitigation, GIS development, coastal wetland delineation, sediment transport analyses, and permitting (local, state, and federal). Ms. Fields is experienced with all facets of environmental impact analyses, ranging from the design and collection of field data to alternative analyses, and design for mitigation. She has strong written, communication, and organizational skills. Further, Ms. Fields has extensive experience in the use of GIS technology to display and analyze spatially-related data for coastal and marine projects. She routinely uses ESRI's suite of ArcGIS products to analyze, evaluate, and present information for Woods Hole Group projects. She has combined her familiarity with GIS software, database management, coastal processes, and cartography to effectively manage and present a wide range of coastal and marine issues.

Over the past 16 years, Ms. Fields has been responsible for managing and conducting numerous projects involving the evaluation of coastal processes and shoreline response, as well as planning and permitting projects for construction. She has performed numerous shoreline change studies along the eastern US. These studies examined issues including impacts from inlet stabilization, installation of shore protection structures (groins, revetments), inlet formation, and dredging. Where possible these studies developed information on historical shoreline change, incorporating data on regional geomorphic evolution. In many cases, information from the shoreline change analyses were coupled with numerical model results for wave transformation and sediment transport to help evaluate impacts of shore protection alternatives.

Dr. Lee Weishar has more than 30 years of experience in the fields of oceanography, coastal engineering, sediment transport, and nearshore processes. He is a Senior Scientist and Engineer at Woods Hole Group, a Professional Wetland Scientist, and joined the company in 1989. He focuses on coastal engineering and wetland/marsh restoration. Complementary to his work at Woods Hole Group, he actively publishes and participates in the Estuary Research Foundation, Restore Americas Estuaries, and Society of Wetland Scientists. He also is on the Board of Directors and Executive Board for the American Shore and Beach Preservation Association (ASBPA). Dr. Weishar specializes in the integration of biological, ecological, and hydraulic data to develop wetland restoration designs and to ensure that the design will meet the restoration objectives. Additionally, Dr. Weishar has

extensive experience in evaluating the potential impacts of proposed restoration projects on existing wetlands and adjacent transitional, buffer, and upland areas. In order to implement these projects, Dr. Weishar has permitted a wide variety of projects that include beach nourishment, revetments, and wetland restoration.

Dr. Weishar's current work involves the restoration of both large and small-scale salt marshes and beaches. He has been involved in the design, permitting and construction phases of restoration projects for more than a decade. During the design phases of large-scale projects, Dr. Weishar spearheads the preliminary hydraulic design and hydrodynamic analyses that prove to the client that a large-scale restoration is feasible. Dr. Weishar has worked to perform critical examinations of the marsh and beach restoration performance through frequent on-site visits and analytical analyses. Dr. Weishar helped pioneer the applications of Ecological Engineering and Adaptive Management in the fields of marsh restoration and coastal engineering.

2.0 OVERALL PERSPECTIVE

Over the past two decades the Town of Palm Beach has made positive strides in managing its shoreline, and there remain opportunities to refine and improve the program. The overall perspective establishes the framework for the more specific island-wide and reach-specific recommendations and analyses that follow. How/whether to proceed with certain recommendations will depend upon the Town's overall perspective regarding: goals and expectations for the coastal management program and project performance; vulnerability and risk tolerance; appropriate and affordable level of investment; planning horizon; and stakeholder relations.

2.1 A Proactive Vision

Coastal management in the Town of Palm Beach is advanced compared to most communities. Having the CCMP and updated annual plans with a 10-year planning horizon, which include a vision and specific priorities, is commendable. Hiring knowledgeable and committed Town staff to ensure professionalism and consistency is an essential part of a successful coastal management program the Town has embraced. The community also clearly recognizes the importance of the coastline and there is a shared passion amongst the citizenry, where organizations are formed specifically to address beach and shore protection matters year-round. It is not uncommon for residents to be discussing the beaches and beach management issues casually and in a spirited manner. At the highest levels of municipal government including the Mayor and Town Council, there is an educated set of priorities that address shore protection. This is a rare environment for a coastal community, particularly for one with a seasonal population. In many communities (including many highly tourist-driven economies along the Atlantic seaboard), merely gaining decision-making recognition of beach erosion issues is an accomplishment. In Palm Beach, there is recognition of the issues, and also a strong investment in the coastal management program. That there are sometimes conflicting opinions on the matter is a sign of guardianship, which can be embraced, in that it spurs action.

Since 1993, the Town has invested $70.6M in the coastal management program, and, in no uncertain terms, the commitment has directly benefitted certain beaches, indirectly benefitted other beaches, and enhanced the community. As one example, when first visiting Mid-Town Palm Beach in 1995, Woods Hole Group personnel observed a highly eroded shoreline with waves breaking consistently on the base of the seawall and little to no dry beach. For instance, the top photo on Figure 2-1 shows a portion of the Mid-Town beach in the early 1990s during the PEP reef construction when water levels met the base of the seawall. The bottom left photo shows the Mid-Town beach prior to the 1995-1996 nourishment project with on a narrow beach. In December 2012, even following Hurricane Sandy, healthy beaches prevail at Mid-Town (Figure 2-1 bottom right).

Long-term benefits of the Town's coastal management program are illustrated by Figure 2-2. Cumulative sand volume change along Palm Beach above the -25 ft depth NAVD contour is shown for three time horizons: 1990-1997, 1997 to 2012, and 2008 to 2012. Distance along the shoreline from north to south is represented by the horizontal axis, and volume change is shown on the vertical. An upward slope indicates accumulation of sand, whereas a downward slope indicates erosion of sand. Up to 1997, which included the Mid-Town project of 1996, there was an overall loss of sediment along Palm Beach of nearly 200,000 cubic yards per year (cy/yr).

Since 1997, implementation of the shore protection plan has accumulated sand exceeding 250,000 cy/yr. Gains since 2008 have been lower, on the order of 150,000 cy/yr; however this more recent period included only one major dune restoration project. Although certain areas have benefitted more than others, the program has reversed the trend. Portions of the Town's coastline are better off today than 15+ years ago. Few exposed coastal communities can make this claim.

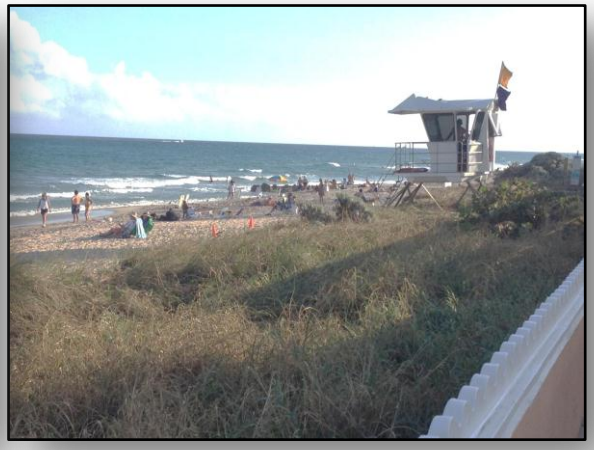


Figure 2-1. Mid-Town beaches in early 1990s during PEP reef construction prior to 1995 beach nourishment (top photo courtesy Town of Palm Beach). Typical eroded profile (bottom left) at Mid-Town prior to beach nourishment in 1995-1996 (photo courtesy of FDEP) and health Mid-Town dunes (bottom right) following Hurricane Sandy on December 9, 2012.

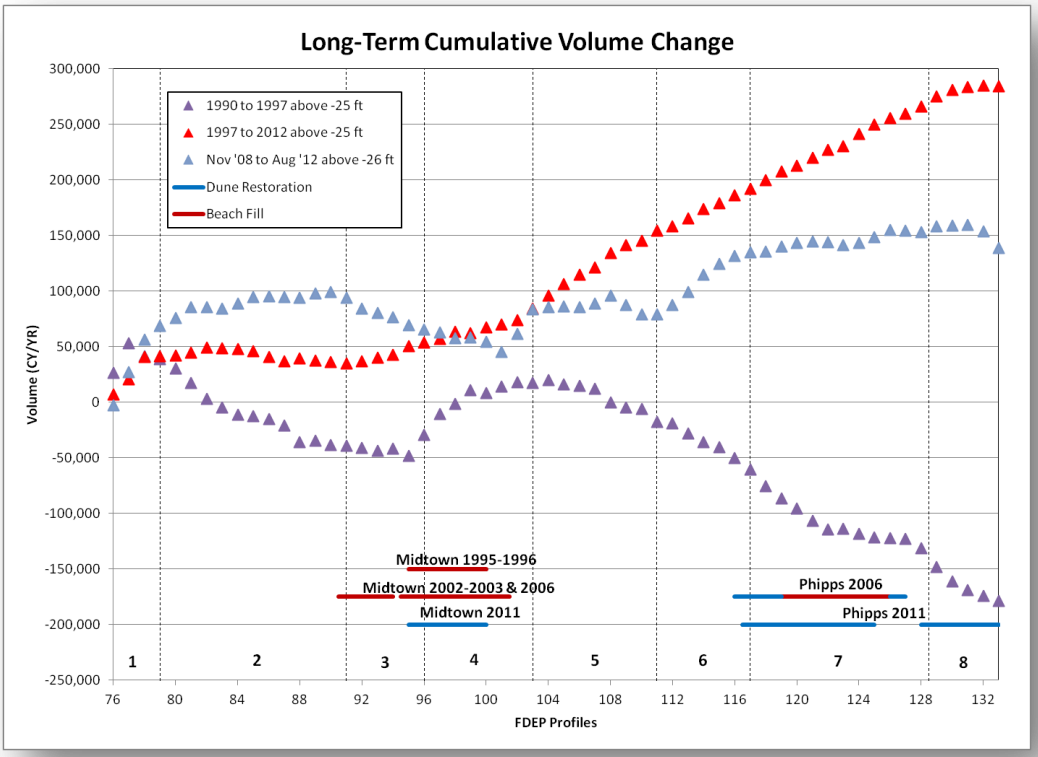


Figure 2-2. Long term cumulative sand volume change above ~25 ft NAVD depth since 1990.

2.2 High Profile Coastal Program Accomplishments

- The STP (Figure 2-3) was originally activated in 1958 and recently upgraded in 2009. The plant has provided some 2,624,000 c.y. of coarse-grained, beach compatible sediment directly to the Island beaches since 1996. During its first 28 years of operation the STP bypassed 1,500,000 cy of sand to the South Beach (Dean, 2008). Wide, healthy beaches and dunes, and the stability of Reach 1 near the inlet are directly attributed to the STP (Figure 2-4).
- An evolving cooperative relationship with the US Army Corps of Engineers (USACE) has helped add sand to the littoral system, including a path forward to place high quality sand dredged from the inlet directly on the dry beach and immediate nearshore area south of the inlet. Prior 1986, the USACE dredged and disposed some 5.2 million cy of sand offshore (Dean, 2008). The 2013 USACE dredging project added over 400,000 cy of beach-compatible sand to the dry beach. The improved project design with expanded settling basin introduces the cutterhead dredge as the least cost alternative, and sets plans for dry beach placement of maintenance dredge material approximately every other year for the foreseeable future (personal communication, USACE).

Figure 2-3. Sand transfer plant (STP) at Lake Worth Inlet.

Figure 2-4. Wide healthy beach and dune system characteristic of Reach 1.

- Mid-Town received 3,125,100 c.y. of sand, including an expanded nourishment template throughout Reaches 3 and 4, and construction of 13 groins. Establishment of healthy dunes in portions of Reach 4 (Figure 2-1, right photo) indicate a more natural beach profile, and there is evidence the Mid-Town project provides supplemental downdrift benefits to beach width and volume for Reach 5 (CPE, 2009).
- Nearly 1,284,800 million c.y. of sand were added to Reach 7 as part of the Phipps Park beach nourishment and dune construction project and subsequent FEMA-funded repairs in 2011. Supplementing the sand supply to this starved coastal system was an essential first step to mitigating erosion there. Securing permits for the project and successfully constructing mitigation reefs also were substantial accomplishments.
- When available, state and federal government funding has been secured to supplement shore protection costs. More than $14.5M in state funding has been secured since 1993, and nearly $7.25M of FEMA aid was issued to Palm Beach to restore beaches after Hurricanes Frances and Jeanne (2004) and Tropical Storm Fay (2008). Having certified "engineered" beaches is critical to securing these funds, and the Town has the experience necessary to maintain eligibility and participation in these types of programs.
- High quality monitoring data have been collected related to beach profile change, sea turtle nesting, and hardbottom resources. The substantial investment in these data provides a solid basis to understand coastal processes and project performance, while also gathering information about the sensitive ecological resources, functions and values. This type of information is essential for future projects, both in an adaptive management sense to plan and improve performance, and also to avoid and minimize future resource impacts.
- Geotechnical investigations revealed the quality and quantity of offshore sand resources, including an abundance of natural regional gray fine sand. Recently, nearly 8 million cy of sand/shell composite sand was identified between six (6) offshore borrow areas (ATM, 2011 and 2012), and three sites were subsequently authorized by DEP in the

Draft BMA (DEP, 2013). Beach-compatible sand is the single most important scarce resource affecting the coastal program.

Accomplishments have been made towards restoring the littoral transport system, identifying offshore sand resources, and establishing the Town of Palm Beach as a leader in coastal management.

- Participation in the FDEP Palm Beach Island Beach Management Agreement (BMA) Pilot Project ensures the Town has forged a leadership role regarding future cutting-edge management policies for beach communities.
- As of April 8, 2013, the entire Town of Palm Beach shoreline including Reach 8 south of the Lake Worth Pier, is designated by FDEP as critically-eroded.
- Appointment of two (2) Shore Protection Boards, retention of key Town staff with extensive knowledge of coastal issues, and hiring of a Coastal Coordinator all add leadership and consistency to the program. Selecting and contracting the services of qualified Coastal Engineering and Environmental Consultants also contributes to the professional cooperative vision for the coastline. On November 12, 1998, the first Shore Protection Board provided twelve (12) conclusions, recommendations and comments. All items were either implemented, advanced, or continue to apply today. Similarly, the second Shore Protection Board developed a set of eight (8) goals, also all of which are being implemented or remain today. The clarity of the program demonstrates the ability to set and achieve goals, and maintain consistency for the long-term.

2.3 Refinements are Underway

Accomplishments aside, the coastal program overall (including SPB, Town Staff, Mayor and Town Council) has proactively recognized areas for improvement and taken action:

- At the inlet, dredged and bypassed sand needs to be placed farther south to more efficiently supplement the littoral system. Cooperative efforts are in progress with the USACE and others to pursue improvements via an extended STP pipeline and expanded disposal templates.
- The northern end of the Mid-Town and particularly the Phipps Park beach nourishment projects erode rapidly, leaving areas more vulnerable. Design initiatives are progressing to improve project performance.
- At Mid-Town there were unanticipated impacts to sensitive hardbottom communities following nourishment. Appropriate mitigation measures are proactively being addressed in cooperation with the resource agencies.
- Dunes have shown varying levels of success. From strictly a storm damage protection perspective, repetitive dune projects can achieve the CCMP objective of providing protection from the 15-year storm, which is estimated to erode 17 cy/ft in non-seawall backed beach profile locations (ATM, 1998). Repeatedly adding sand to maintain the minimum dune can provide storm protection; however, dunes alone without beach nourishment are not perceived as adequate to residents in areas such as the northern end of Reach 7 and in Reach 8. Repetitive dune projects also can be more costly than large-

scale beach nourishment. Consequently, refined designs, more comprehensive environmental assessments (e.g., EIS proceedings), and monitoring/analysis of prior project performance are being pursued.

- Dune vegetation has proven effective when combined with beach nourishment; however, invasive vegetation maintenance has been required, and vegetation without fronting beach nourishment in eroding areas does not have adequate time to establish because the dunes provide only short-term protection and erode rapidly during severe storms. Program refinements have been implemented to address these matters; however, a budgetary line item is needed to continue the vegetation maintenance.
- Groins have varying levels of influence on the shoreline, and the long history of groins in Palm Beach leaves uncertainties regarding their position, condition and performance. Consequently, a structures inventory and a structures plan were completed as the basis for future decisions on groin removal, maintenance, improvements, and new construction.
- Through the DOAH case, the Reach 8 project suffered a setback in terms of identifying opportunities for projects that provide protection, ensure a healthy littoral system and conserve sensitive habitats. Yet, the case provided a learning experience, a deeper understanding of stakeholder values, and set a course of action to regroup. This provides an opportunity to work more cooperatively with stakeholders for future projects. Consequent cooperative joint efforts with neighboring communities and the County are afoot to develop regional solutions to achieve the multiple objectives of the varied stakeholders. Reach 8 has also subsequently been designated as critically-eroded, which can introduce opportunities for more proactive shore protection.
- Areas lacking a direct or limited coastal program activity, including Reaches 2, 5 and 8 specifically, have been the subject of detailed feasibility studies to identify and evaluate alternatives.

2.4 Incremental Progress and Compromises

Conflicting interests necessitate compromise; however, incremental benefits can be realized through a long-term commitment to the coast.

Facing the realities of sometimes conflicting resources and stakeholder interests, projects proceed incrementally in some cases when the ideal project is not feasible in the short-term. Incremental progress and monitoring generates short-term action and inertia, and can provide a basis for longer-term refinements. An example is the Phipps Park project where the initial design was compromised when the northern section was removed from the beach nourishment design template. A difficult decision was made to proceed with the 2006 modified project rather than await an uncertain/unlikely regulatory approval for the full design. Although the consequences of the decision could have been more widely understood by the community, a decision was made to proceed, and provide much-needed sand to supplement the historically starved littoral system and protect a public resource. Analysis suggests the nourishment would perform better with an expanded template to the north and perhaps even with coastal structures, yet today's regulatory climate indicates another sand-only project with dunes north of the Park is required (and is acknowledged in the Draft BMA (DEP, 2012)) before pursuing modifications. Seven (7) years removed from the 2006 project, and considering storms

impacting the region since construction, one must consider what the condition of Phipps Park and the adjacent beaches would be without the project. Further, using the Reach 8 DOAH case as a model for immobility and valuable time lost, the decision to proceed with the modified Phipps Park project, despite its reduced performance, resulted in much-needed protection.

The coastal program has the vision that a long-term commitment is necessary for positive change. There are stringent natural resource protection laws for a project to first avoid impacts, and then minimize them. Only when no better alternative can be demonstrated are unavoidable impacts permissible, which require mitigation. An applicant cannot choose to impact a protected resource and simply propose or negotiate mitigation. This mandated avoid, minimize, and mitigate standard requires sometimes incremental progress and even failure. For this example, Phipps Park may eventually include an expanded nourishment template perhaps with stabilizing coastal structures, but not until lesser impact alternatives have been attempted, monitored, and considered in good faith. With the long-term commitment to the coast, an incremental benefit can be realized with a supplemented sediment supply and moderation of the over-steepened beach profile in the Reach 7 area. The same incremental strategic adaptive management approach applies also to Reach 8.

2.5 Vulnerability

With all the progress and successes resulting from the management plan, as with all coastal communities, a degree of vulnerability always exists:

- The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) show the potential for flooding and wave-induced storm damage of the Palm Beach barrier island during a 100-year storm event. Because of its direct exposure to the Atlantic Ocean, the entire oceanfront is mapped within a FEMA velocity zone with risks from flooding and wave damage. Vulnerability on the ocean side of the Island is highly dependent on the integrity of the existing seawalls and shore protection structures. Increased water levels in Lake Worth during storm events also pose a risk of flooding to extensive areas of the Island from the west side. Figure 2-5 shows a portion of the FEMA FIRM for the Reach 2 area where gray shaded areas represent flooding during a 100-year storm. Low ground elevations between El Pueblo Way and Eden Rd. allow flooding from the west side of the Island with water depths between 2 and 5 feet. This vulnerability exist along much of the west side of the Island where low-lying areas allow inland flooding
- A decision was made long ago to develop Palm Beach as a barrier island, which introduces the inherent risks of having assets on the coast. Given the investment involved, retreat is not a feasible option, which places assets at risk that require investment to protect. Even natural coastal systems, such as the National Seashore along the east coast of Cape Cod and Assateague Island are at risk of ongoing erosion and storm damage. Fixing a line behind which development needs to be protected inherently increases risk.
- In addition to the current vulnerabilities demonstrated by FEMA, sea level is rising (NOAA, 2012 and Boon, 2012), and there is potential for increased storm frequency and

intensity. These combined effects create short-term and increasing long-term exposure for Island assets.

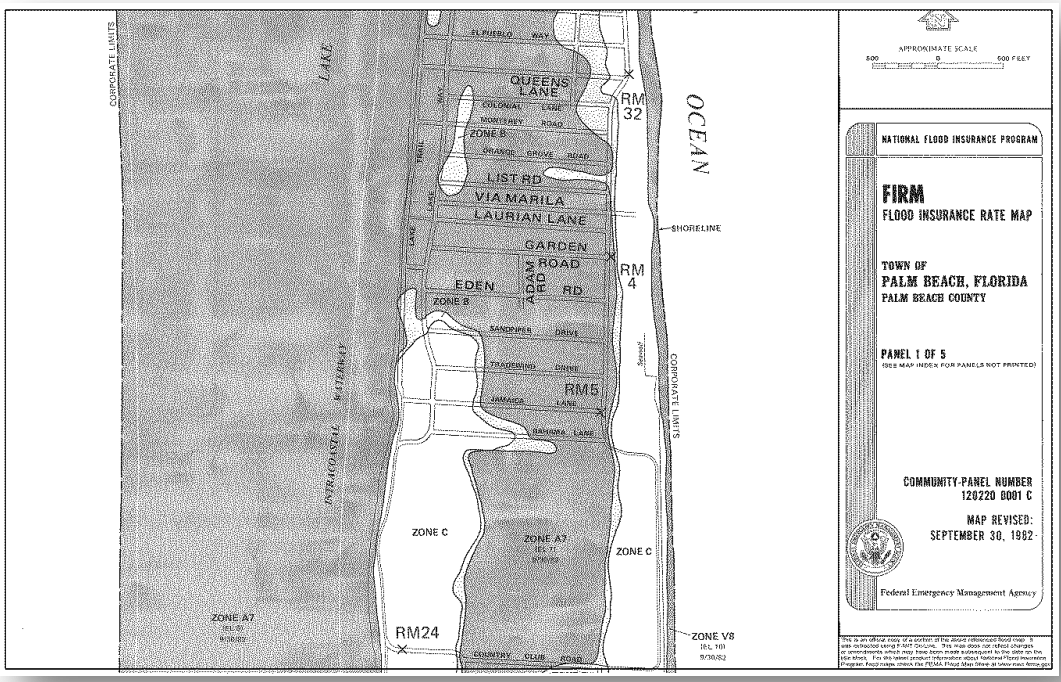


Figure 2-5. Portion of FEMA FIRM for Reach 2 showing areas vulnerable to flooding and wave-induced storm damage during a 100-year storm event.

- Even if all the CCMP projects are constructed, the projects and adjacent infrastructure are vulnerable to storm damage (i.e., FEMA repairs after Tropical Storm Fay) because there is always a chance that a future storm that will exceed design criteria. For instance, the CCMP protection standard is the 15-year storm. To add a measure of conservatism, beach nourishment projects are designed for the 25-year storm, which ideally means there is a beach berm width and height to protect against damage during a 25-year storm. The 25-year project design is not expected to last 25 years. Rather, a 25-year design is a pure statistical quantity with a 1 in 25, or 4% chance of being exceeded in any given year based on past storm activity. There is no assurance that future storm patterns will mimic history, and there is a chance that multiple storms exceeding the 25-year standard could occur in a single or consecutive calendar years. Additionally, periods of increased storm frequency and storms of extended duration can reduce the protection afforded by the projects even if the storms do not exceed the 25-year design criteria. Figure 2-6 for instance illustrates the number of storms with offshore wave heights greater than 9.8 ft (3 m) impacting the Palm Beach coastline between 1998 and 2012. Increased storm frequencies are shown in 2001, 2005, 2007 to 2008, and 2011. While the 25-year storm wave height is considerably higher than 9.8 ft, back-to-back storms with moderate wave heights decrease the ability of the nourishment projects to provide the desired level of

protection. A recommendation is offered to clarify project design criteria, which needs to be more specific than the 25-year storm. Design parameters related to storm surge elevation, storm wave conditions, and storm duration all need to be outlined clearly as the basis for design, and to allow a definitive evaluation of project performance in response to subsequent storms.

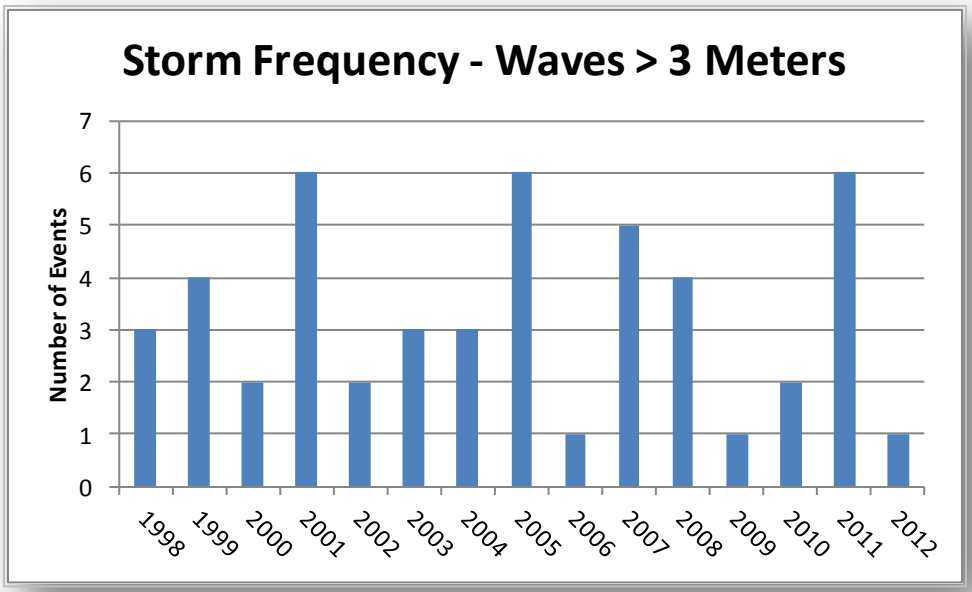


Figure 2-6. Frequency of high energy wave events offshore of Palm Beach for the period 1998 to 2012.

Storms with extended duration also increase vulnerability in the project areas. Figure 2-7 shows the duration of wave events greater than 9.8 ft for the period 1998 to 2012, with specific storms known to be particularly destructive to Palm Beach highlighted separately. Nearly 60% of the high energy storms lasted longer than 24 hrs, and 16% lasted longer than 48 hours. Even though wave heights during these storms did not exceed the 25-year criteria, many of them caused significant beach erosion, notably Tropical Storms Andrea and Fay and Hurricane Sandy.

- As a last line of defense, particularly for long stretches of Reach 2, all of Reach 6, the northern portion of Reach 7, and increasing sections of Reach 8, protection of upland infrastructure depends upon trusting the integrity of pile foundations and existing seawalls. Some seawalls are aged, have not been inspected, and in some cases are buried and of uncertain design, location, and condition. Buildings constructed after 1984 should generally conform to a pile-supported construction method, which can provide robust protection (even better than a seawall in some cases) in the event of massive beach/barrier erosion as long as the piles are properly designed to withstand ocean wave and current forces.

- Project designs also are made more vulnerable when environmental constraints compromise the engineering design. Beach nourishment design cross-sections are adjusted to accommodate required distances from natural resources such as hardbottom; thus, reducing the projects ability to meet the desired storm protection criteria.

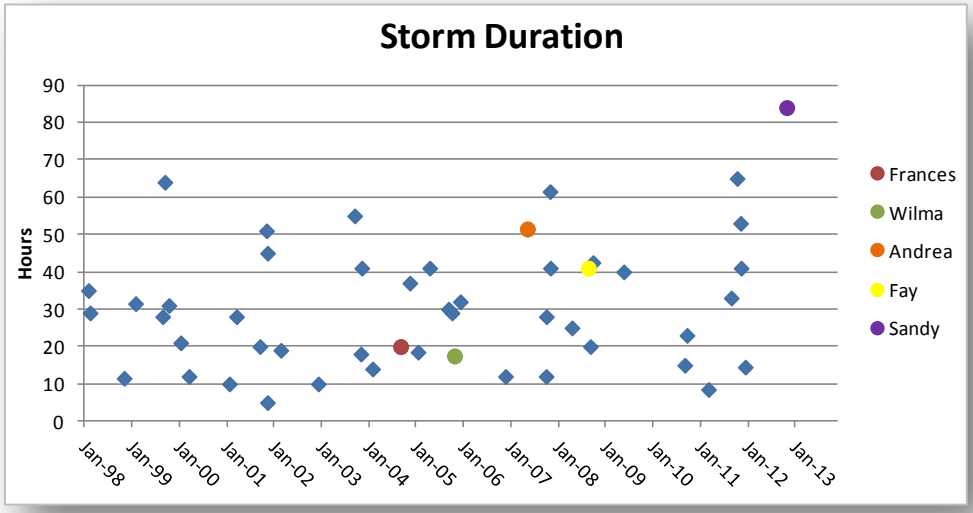


Figure 2-7. Duration of high energy wave events greater than 3 m offshore of Palm Beach for the period 1998 to 2012.

- Coastal engineering is based on scientific assumptions, limited data, and engineering judgment. Substantial assumptions are inherent to the complex physics of coastal processes, frequency and intensity of future coastal storms, forecasting impacts of identified storms, actual quality of sand borrowed based on sparse geotechnical information, and predicting project response to the dynamic coastal wave.

Uncertainty leads to risk and risk introduces vulnerability. Town decisions, therefore, require an assessment of risk tolerance and a balance of investment to reduce uncertainty. Portions of the Island will always be exposed no matter what level of investment is made. Recommendations and preliminary analyses in this report will help guide actions. Through the Town Staff and consultants, the information and technical knowhow has been established to design resilient projects, but the ultimate value-based decision is local based on what's best for the community.

2.6 Goals and Planning Horizons

The objective of the coastal management program emphasized to Woods Hole Group is storm protection. The 1998 CCMP focuses on effectively managing the shoreline and inlets to ensure proper storm protection, and states specifically, "The targeted level of storm protection for all beach restoration projects on the Island should enable any individually considered shoreline restoration segment to incur damages from a 15-year return interval storm at any time between the initial restoration (first time sand is placed on the shoreline) and subsequent renourishments (regular maintenance interval of sand placement to restore the shoreline to its initial restoration position)." The recent Shore Protection Board was created (Ordinance No. 1-08, July 2008) to "act in an advisory capacity to the Town Council and shall make recommendations to the Town

Council on all matters relating to shore protection in the Town of Palm Beach." Thus, we understand the primary objective is protecting the entire coast at minimum against a 15-year storm using primarily sand, supplemented by coastal structures where sand placement is limited due to environmental constraints.

However, there are indications that the goals of the community may be broader. Although a combination of repetitive dunes, seawalls and/or pile foundations can provide the 15-year protection specified for the coastal management program, citizens desire wider beaches in certain locations. The CCMP also acknowledged and attempted to quantify benefits related to property values, storm protection benefits, recreational benefits and public access. A recent consultant report (CTC, 2011) included an analysis of alternatives for coastal structures, and stated the Town objectives include: a minimum "walk-able" beach width of 20 ft along the beach within the groin-field (width assumed from the +5 foot contour to the existing upland dune or seawall); and avoiding impacts to nearshore hardbottom. *Beaches* specifically also have been identified as "the greatest natural asset in the Town of Palm Beach" (e.g., FY2012 Proposed Coastal Management Program Budget). Beach nourishment projects also have been focused on publicly accessible stretches of coastline that offer complementary benefits. When queried through the stakeholder consultation process for this project, the prevailing theme was shore protection, but various other benefits of beaches were of clear import.

The goals of the CCMP must be clearly communicated and the planning horizons should be evaluated to ensure adequate lead time to address key issues.

There is a need to be very clear on the goals of the coastal management program. Storm protection alone, for instance, may be achieved through robust hard structures, such as seawalls, pile foundations, or modifications to upland structures. However, a focus on hard structural protection would result in a different focus for the 10-year plan, which currently depends heavily upon beach nourishment and repetitive dune replacement/construction to provide at least 15-year protection. Achieving a desired level of storm protection primarily through maintenance of healthy beaches, alternatively introduces a range of other values: a healthy littoral system for Palm Beach and adjacent communities; ecological values (e.g., sea turtle nesting); recreation; aesthetics; and economic benefits associated with recreational use and property value perception. For the purposes of this technical review, a prevailing goal of 15-year storm protection through use of sand nourishment primarily (including beaches and repetitive dunes) was assumed.

In addition to the goals for the coastal management program, there is a need to consider the planning horizon duration. Although the 1998 CCMP considered intervals up to 50-years, 10-years has been the operating planning horizon for budgetary purposes, which has the potential to reduce focus on longer-term considerations. For instance, sand supply for beach nourishment will be of great concern in the future. Since there currently appears to be an adequate supply for a 10-year horizon, though, there is less focus on identifying future sources in the existing CCMP.

Sea-level rise also is not of tremendous concern over the next 10-years, but has the potential to alter the risk profile and storm protection strategy in the future. Planning for longer term sea level rise may heighten the need for adaptive engineering works related to coastal structures as a last line of defense, larger scale shoreline modifications (e.g., such as establishing headland type formations), and perhaps road relocation and/or managed retreat in certain high risk areas.

Furthermore, and as demonstrated through the Mid-Town project, recurring beach nourishment projects can be required to offset historic erosion and oversteepening of the beach profile. With a nourishment cycle of 6-8 years, a 10-year planning horizon considers one nourishment cycle at a time. The most cost-effective approach for one nourishment project in the short-term may be different than the most cost-effective approach in the long-term (i.e., perhaps costs can be saved over a decadal time scale by investing more in the short-term). For the purposes of this technical review, focus was placed on a 10-year planning horizon; however, key areas of concern that benefit from a longer-term view are identified for Town consideration.

2.7 Stakeholder Relations and Policies

There are a multitude of stakeholders and prevailing policies associated with Town beaches, with which the Town and its citizens engage at various levels within the context of the CCMP. State and federal environmental policies shape activities consistent with ecological functions and values, yet are not always aligned with storm protection objectives. For example, USACE has responsibility to implement the least cost safe navigation maintenance of Lake Worth Inlet; not always consistent with restoring sediment to Palm Beach Island. Adjacent communities and port facilities have local requirements not always aligned with what is best for Palm Beach (e.g., opposition to beach nourishment in the City of Lake Worth). Stakeholders for sunbathing, surfing, diving, boating, fishing, and ecological preservation also have a recognizable voice in the management of the public trust that is the coastline. Citizens within Palm Beach can have substantially different priorities for the beach. Acknowledging the diversity and legitimacy of conflicting stakeholder interests and the prevailing laws is essential for progress. As stated previously, cooperation and compromise can be required to make incremental progress. The Town needs to be upfront on its intentions with stakeholders, and make decisions accordingly. All stakeholders should understand the uncertainty and risk involved with individual projects, and that expectations are not the same in all areas. Unexpected performance or setbacks in one particular area should not constitute the basis for invalidating the plan as a whole. Consultants and staff engaged by the Town should also be viewed as stakeholders, with whom a level of trust can be established as the basis for implementing the plan.

Successful implementation of the CCMP involves the cooperation of a wide range of well informed stakeholders.

A directive to Woods Hole Group is to make recommendations on what is perceived to be *feasible*. For the purposes of this review, *feasible* is interpreted to include endeavors that can be completed in a cooperative good faith manner within the foreseeable planning horizon (~10 years). Other more aggressive measures can be pursued with the understanding that greater conflicting stakeholder interactions would be inevitable, and with uncertain and perhaps costly outcome.

3.0 ISLAND-WIDE CONSIDERATIONS

Certain considerations apply to Palm Beach as a whole, or are at least applicable to multiple Reaches. This section discussions Island-wide considerations, and presents recommendations that apply regionally related to:

- Inlet management
- Regional coastal processes and feeder beach strategies
- Beach nourishment project performance
- Sand source alternatives
- Coastal structures
- Hardbottom resources
- Dunes
- Sea-level rise and climate change planning and adaptations

Some Island-wide considerations also provide a basis for Reach-specific recommendations in section 5.

3.1 Inlet Management

Although all developed coastal communities are at risk due to sediment supply deficits, impacts of coastal storms, and sea level rise, Palm Beach Island has heightened vulnerability due to the long-term impacts of Lake Worth Inlet. As summarized by Dean (2008), there was a net deficit of sand to Palm Beach Island of more than 3.8 million cy between 1883 and 2007. The CCMP (ATM, 1998) referenced annual sediment losses of 260,000 cy/yr in spite of some 39,525, 122,305, and 133,156 cy/yr added to the Island from the STP, channel maintenance dredging, and the 1996 Mid-Town beach nourishment project, respectively. A sediment budget update by Coastal Tech (2000) indicated Town beaches suffer a longshore sediment transport deficit of 202,000 cy/yr due to the inlet. More recently, the 2011 Town-Wide Physical Monitoring Report (ATM, 2012) indicated at net loss of 251,000 c.y. between October 2010 and November 2011 above -26.5 ft NAVD and a net loss of 278,700 c.y. between -26.5 and -40 ft NAVD in the same time period. Based on the 2011 monitoring data, absent the ongoing beach nourishment projects (which added 203,600 cy/yr), there is a residual net volumetric sand deficit to the Island of 66,500 cy/yr. This indicates the ongoing contributions from the STP and inlet maintenance dredging projects help prevent and minimize additional shoreline losses attributed to the presence of the inlet, but more sand is needed to mitigate the sand deficit to the Island. To remedy historical losses, there is a need for beach nourishment equal to or greater than recent history, and a need to add more sand to the beaches from sand transfer and inlet maintenance. Ongoing efforts at the inlet are helping, but are not sufficient. Although beach nourishment projects are helping to gain back historical losses (at a rate of approximately 137,100 cy/yr since 1990 according to the 2011 data), the long-term impacts from the inlet require either a tremendous amount of sand in the short-term, or a long-term commitment to adding sand to the system. Single beach nourishment projects should not be expected to mitigate the long-term damage.

The most important aspect of the Lake Worth Inlet Maintenance Plan is to maximize placement of sand on the dry beach, and avoid traditional offshore placement of dredged material. Placement of sand directly on the beach berm, within the dunes, or at least within the active nearshore zone (wading depth or less) is essential. Given the new inlet configuration with the expanded settling basin, the preferred least cost dredging method is now a cutterhead pipeline dredge, which is needed to access the depth-limited settling basin. The cutterhead dredge then allows for direct pumping of sand onto the beach. For example, the 2013 USACE dredging project added more than 400,000 cy of sand to the Reach 1 and 2 beaches and shallow surf zone region extending 2,500 ft south from the inlet. Future expectations are for dry beach placement to provide direct storm protection, or nearshore placement immediately below mean low water (MLW) every other year that will help stabilize the beach by widening the profile and mitigating equilibration losses. Interim hopper dredge maintenance may occur in the alternate years, including offshore disposal within the ~17 ft NAVD contour. The Town should use this sand as well, including payment of incremental cost, if necessary, to pump sand directly on Town beaches other than Reach 1 and the northern part of Reach 2.

Although this is a significant improvement over past practices with hopper dredges that placed material offshore in water depths of 15 ft or more, placing all the sand at the north end of the Island is not the ideal solution. The current inlet management practices result in impounded sand in Reach 1, while storm protection benefits beyond Reach 1 and the northern ~1,000 ft of Reach 2 are limited. Reach 1 is historically stable and not in need of additional nourishment, particularly considering that it also benefits directly from the STP. There are lost opportunities associated with current inlet management practices that can be realized by placing inlet sand on dry beaches beyond 2,500 ft south of the inlet. Sand dredged from the inlet should be placed farther south to directly provide storm protection on the dry beach within the remaining portions of Reach 2, and/or to maintain the Mid-Town (Reaches 3 and 4), Phipps (Reach 7), or other future projects in other Reaches (e.g., Reach 5 or 8). Given the finite offshore sand resources, marginal quality, and cost of upland sand sources, inlet sand should be assigned the highest priority for nourishment and maintenance of Palm Beach.

Expansion of the disposal area to include the entirety of Reach 2 also would be preferred over placement in Reach 1. Although more detailed study of sand transport would be required, placing sand on the dry beach at the southern end of Reach 2 or directly within the Mid-Town nourishment footprint in Reach 3 has the potential to maintain the northern section of the Mid-Town project, improve longevity with a coarser grain size from the inlet (as compared to traditional offshore sources), reduce environmental impacts, and reduce dependence on scarce and potentially more costly offshore borrow sites. It is feasible to directly pump the material to Reach 3 during inlet dredging operations. In the alternate years when the hopper dredge may be used by USACE, it also is feasible to transport and pumpout the sand to other beaches throughout the Island.

Specific recommendations include:

- Repair the STP with cost-sharing from the County. Consider establishing reserve funds for future repairs given inevitable damages to expedite the process with subsequent reimbursement by others if cost-sharing is imminent (e.g., County). From a financial planning perspective, though, the Town should recognize that sand will continue to

accumulate at the STP and within the inlet project; therefore, more pressing coastal management requirements elsewhere can take priority.

- Continue present practice of placing STP sand and USACE dredged sand on Reach 1 and the northern part of Reach 2, but recognize this is not the ideal placement area and pursue alternatives below.
- Secure agreement with USACE for inlet management and maintenance, including:
    - Allow Town participation in bid specifications for dredging projects.
    - Primarily define cutterhead pipeline dredge method as least cost alternative (considering shallow draft needed for expanded settling basin) with direct placement on dry beach berm or within a shallow wading depth.
    - Reserve opportunity to utilize pumpout hopper dredge in certain circumstances, with Town option to pay incremental cost increase to transport and pump sand directly on the dry beach.
    - Utilize permits so that USACE projects can place sand within beach nourishment footprints secured by Town (e.g., Mid-Town, Phipps, and others TBD).
    - Pursue EIS and permits for expanded footprint of dry beach placement, including a narrow Reach 2 beach. Ideally, there would be flexibility for all of Reach 2, but any advances beyond the current 1,000 ft section would benefit Reach 2. USACE should exercise flexibility in making this improvement, realizing that incremental progress, is preferable to an "all-or-nothing" philosophy.
        - Provided there is a possibility to build a narrow beach of constant elevation through Reach 2, pursue permits for a pipeline corridor from the inlet through Reach 2 for direct nourishment at the north end of the Reach 3 Mid-Town footprint.
        - Recognize there are substantial limiting factors associated with these advancements to Reach 2, including tens of acres of hardbottom resources, private property access/easements, variable condition and elevation of groins, undulating beach elevation and statutes requiring placement of inlet material directly downdrift.
    - Cost-share possible future construction of an extended STP discharge pipeline extension.
    - Prioritize sand placement within the southern portions of the template when feasible.
    - Pursue opportunity to dispose finer material (but still beach compatible) within Reach 1 back-beach and dune system.
    - Pursue future expansion of the inlet settling basin to allow dredging flexibility based on sedimentation patterns.
- Postpone implementation of pipeline extension indefinitely, pending resolution of effective alternatives to achieve objectives (e.g., direct placement by cutterhead dredge in southern portions of template, southern extension of template, mechanical forepassing).

- Ensure placement on Town Beaches is defined as the preferred disposal alternative for clean, beach-compatible sand should navigation interests drive future expansion of the federal channel at Lake Worth Inlet.
- Closely monitor sediment transport on updrift Singer Island beaches and sand quantities at the STP, expanded settling basin, and inlet for future trends indicating reduced supply of sand for bypassing. There is potential for updrift activities to affect long-term sand supply.
- Pursue permits to dredge the inlet via the Tri-Party effort or independently, if the Town can be comfortable that dredging the inlet does not compromise its position regarding USACE and port responsibility for downdrift impacts to Palm Beach associated with inlet maintenance.

The overall inlet management strategy should include a comprehensive program to operate the STP consistently, and work with USACE to ensure all sand dredged from the inlet is placed on the dry beaches, and not limited to the current Reach 1 and 2 disposal area.

3.2 Regional Coastal Processes and Feeder Beach Strategy

The coastal processes along the Island of Palm Beach vary from north to south, and this causes changes in sediment transport trends and pathways. These variations are due to a number of factors such as large-scale morphology changes or undulations along the Island, extent and location of hardbottom resources, coastal structures, and unique offshore bathymetry. As incoming waves interact with these features the wave energy is altered and sediment transport rates and pathways are affected. An in-depth understanding of these processes is critical as the CCMP implements projects to protect the coastline of Palm Beach by restoring the natural functions of the littoral transport system.

The project specific and Town-wide physical monitoring programs have generated a valuable long-term dataset documenting response of the coastline and nearshore areas to the dominant coastal processes. Data for shoreline and beach volume change are compiled on an annual basis, and sometimes more frequently (e.g., after storms), and used to compare with previous monitoring surveys. When viewed on a regional basis, the data can be used to evaluate trends in littoral transport and impacts of significant storm events for the entire Island. Patterns of cross-shore sediment transport can also be evaluated, and when viewed on a reach-by-reach basis, the data provide insight on the extent of transport between adjacent reaches; lending insight to evaluate feeder beach strategies and establish cells for improved coastal management.

Long-term physical monitoring data from 1990 to 2012 show the benefits of the CCMP activities over the past two decades. Cumulative sand volume change along the Palm Beach shoreline above the -25 ft NAVD depth contour is shown in Figure 3-1 for the time periods 1990 to 1997 and 1997 to 2012. Negative slopes indicate erosion and positive slopes indicate accretion. The earlier time period, which only includes the 1995-1996 Mid-Town nourishment project, shows a cumulative loss of sediment along the entire coastline of approximately 200,000 cy/yr. The more recent time period, which includes two renourishment projects at Mid-Town, the initial Phipps Park beach/dune nourishment, post-storm dune restoration in 2011, and a concerted effort to reintroduce inlet sand to the northern portion of the Island, shows an accumulation of sand just over 250,000 cy/yr. The earlier trend, which reflected a long-term deficit of sand, was reversed

by improved management practices aimed at restoring the natural functions of the longshore transport system. Although the nearshore response varies from one reach to the next, the long-term data illustrate the dominant north to south littoral transport and the importance of maintaining a healthy flow of sediment.

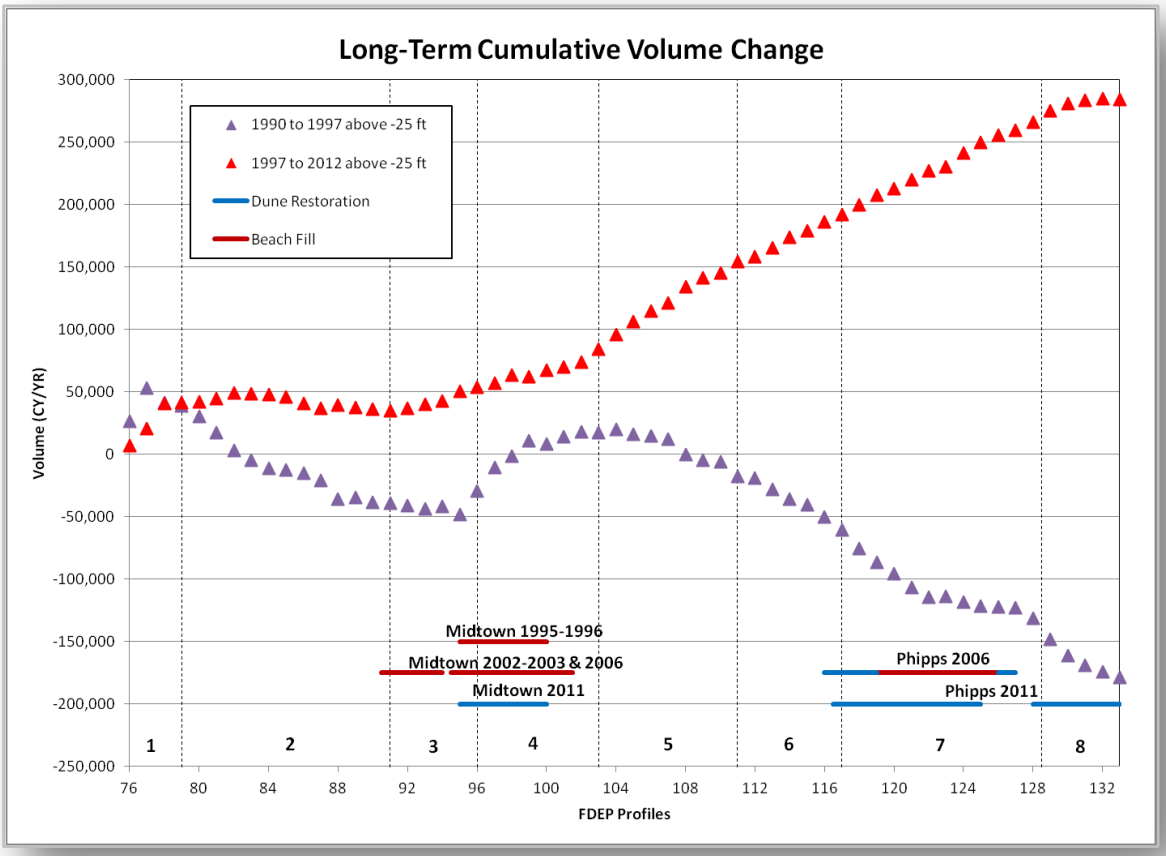


Figure 3-1. Long term cumulative sand volume change above ~25 ft NAVD between 1990 and 2012.

In addition to the movement of sediment along the coastline, there is evidence of significant cross-shore sediment transport. Previous estimates of the depth of closure, the point beyond which there is little sediment movement, are between the -21.5 to -26.5 ft NAVD depth contour. However, volume changes from the physical monitoring data show there is active transport at least out to the -40 ft NAVD depth contour. Figure 3-2 illustrates cumulative volume change between April 2008 and November 2008 for three cross-shore zones: above 0 NAVD; 0 to -26.5 ft NAVD; and -26.5 to -40 ft NAVD. The beach area above 0 NAVD and the offshore area between -26.5 and -40 ft NAVD both show a cumulative loss of sediment along the entire coastline of 90,000 and 390,000 cy/yr, respectively. Over the same time period, the intermediate depth zone between 0 and -26.5 ft NAVD shows a cumulative gain of approximately 200,000 cy/yr. Similar findings of active sediment transport out to the -40 ft NAVD depth contour are found in the other monitoring data. This suggests earlier estimates for the depth of closure may

be shallow, and considerations should be given to adjusting the depth to the -40 ft NAVD contour to account for a wider zone of active sediment transport.

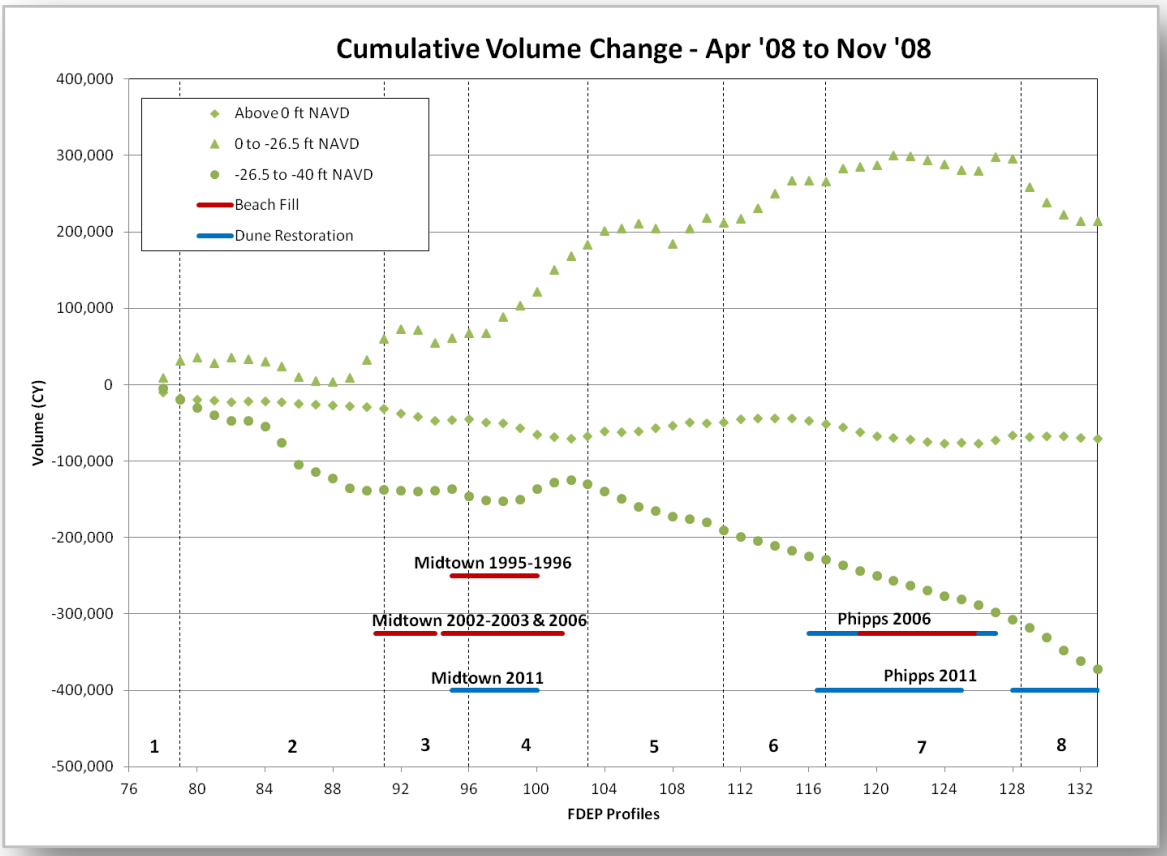


Figure 3-2. Short-term cumulative volume change between Apr. 2008 and Nov. 2008 for three cross-shore depth zones.

Volume changes along the dry beach above MHW can also be evaluated using the physical monitoring data. Figure 3-3 shows the cumulative volume change for the beach above MHW using data collected between April 2008 and December 2012. With the exception of two time periods (November 2008 to September 2009; October 2010 to November 2011), all other data show cumulative beach erosion. This regional loss of sediment is consistent with background erosion rates of 2.0 cy/ft/yr reported by ATM, 2010. Higher losses were measured between August 2012 and December 2012; however, this time period includes Hurricane Sandy. Cumulative gains during the November 2008 to September 2009 period are the result of large quantities of sand bypassed/dredged from the inlet to Reach 1, as well as downdrift and nearshore spreading of the 2006 Phipps Park nourishment project into Reach 8. Gains during the October 2010 to November 2011 time period are primarily in the Mid-Town and Phipps Park areas where dunes were reconstructed to mitigate storm damage from Tropical Storm Fay. That the portion if the shoreline above MHW necessary for storm protection is continuously eroding, suggests the south to north longshore transport is not consistently building the dry beach throughout Town.

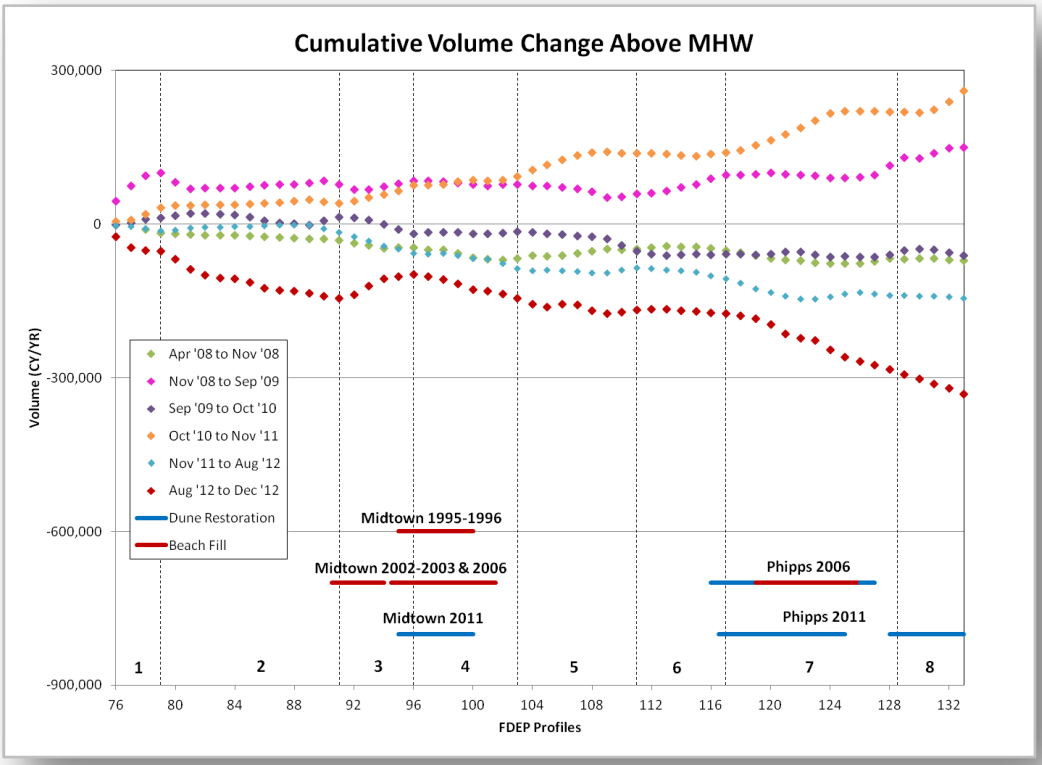


Figure 3-3. Cumulative sand volume change above MHW between 1990 and 2012.

An improved understanding of sediment transport between adjacent reaches is important for ongoing management of the beach, and can be used to influence decisions on adjustments to nourishment designs to improve performance and storm damage protection, and potentially maximize cost efficiencies. Figure 3-4 illustrates cumulative volume changes by reach for the period November 2008 to August 2012, where changes on the dry beach above MHW are distinguished from those between MHW and -40 ft NAVD. These data help identify transport pathways along the coastline and suggest grouping the reaches into management cells for a coordinated set of recommendations.

Reaches 1-2-3: Significant gains in Reach 1, especially in the nearshore zone out to -40 ft NAVD, reflect the management of inlet sand through STP bypassing and USACE dredge placement. Waves and winds from the south and southeast also cause sediment to accumulate against the jetty. A shadow zone is formed by the jetty during northeast wave approaches slowing transport of sand out of Reach 1. The sharp drop in cumulative sand volume between Reaches 1 Reach 2 indicates that inlet sand placed in Reach 1 and the north end of Reach 2 is not consistently moving south beyond the placement area. Although seawalls exist in this area, the beach width is narrow, and there is a need to provide additional sand in front of the seawalls to ensure adequate levels of storm damage protection. Section 5 offers recommendations to move impounded sand from Reach 1 further south into Reach 2 and beyond.

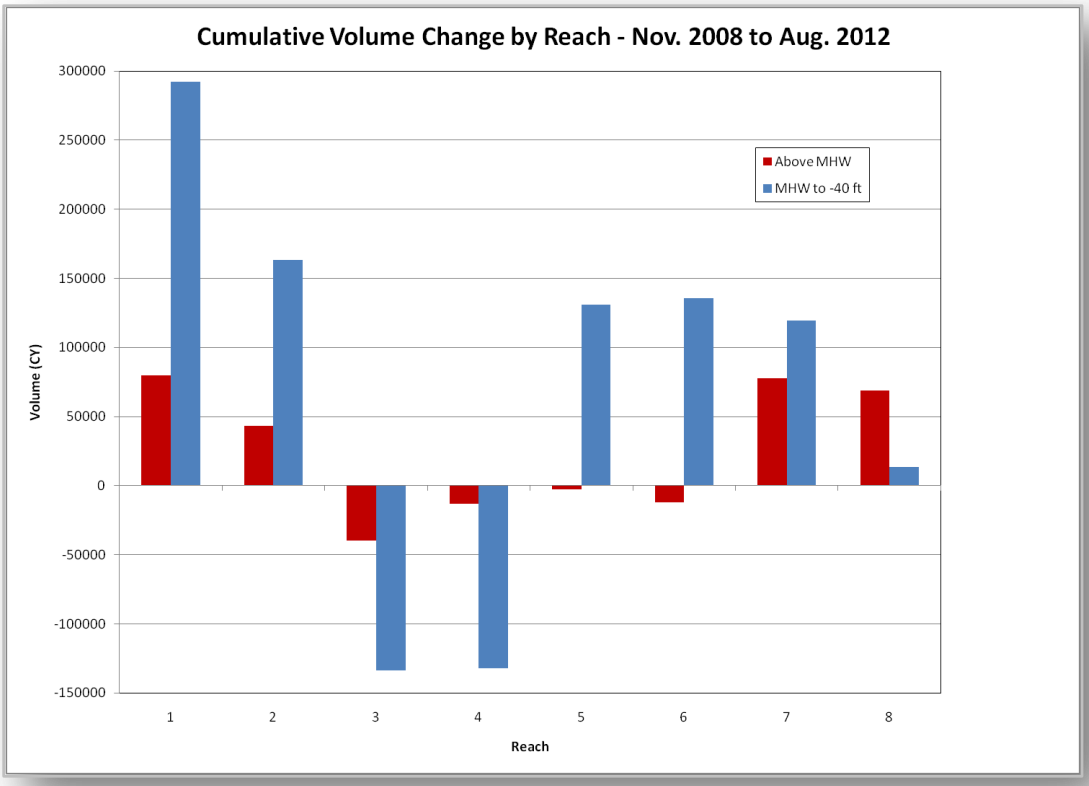


Figure 3-4. Cumulative volume change by reach between Nov. 2008 and Aug. 2012.

The loss of sand shown in Figure 3-4 from Reaches 3 and 4 is a result of erosion of the Mid-Town nourishment project constructed in 2006. Beach losses are greatest in Reach 3 because sediment eroded from this area moves south and helps to feed Reach 4, and because there is little sediment from Reach 2 to naturally replenish Reach 3. In addition, there is evidence from the shoreline monitoring data that sediment placed at the northern end of Reach 3 is transported into the adjacent portion of Reach 2. Sediment is moving out of Reach 3 into Reaches 2 and 4, and there is little opportunity for sediment to feed Reach 3 naturally from the adjacent beaches. To address this issue, Reaches 1, 2, and 3 have been grouped together as a management cell, with recommendations geared towards moving the inlet sand further south to manage the sediment deficits in Reaches 2 and 3.

Reaches 4-5: Cumulative losses on the dry beach (above MHW) gradually decrease from Reach 3 to Reach 5 (Figure 3-4). This reflects the southerly spreading of sediment placed as part of the 2006 Mid-Town project from Reach 4 into Reach 5. In the nearshore zone between MHW and the -40 ft NAVD contour, much of the Mid-Town nourishment sand is transported out of the Reach 4 area and moved south to the nearshore areas of Reaches 5 and 6. The Reach 4 Mid-Town project is acting as a feeder beach for Reach 5, and contributing to the relative stability of the Reach 5 shoreline. The majority of sand accumulates offshore of MHW, though. Existing groins in Reach 5, including the "Monster Groin", also contribute to the stability of this Reach, providing a measure of storm protection.

Reach 6: Cumulative losses on the dry beach in Reach 6 (Figure 3-4) are relatively small due to the fact that the existing state revetment anchors the shoreline and prevents further erosion. Wave interaction with the structure also tends to create higher energy conditions not conducive to beach accretion. There is little evidence that the beaches in Reach 6 are fed by the adjacent Reach 5 beaches to the north. However, in the nearshore zone between MHW and the -40 ft NAVD contour, cumulative accretion suggests southerly transport of the Mid-Town nourishment placed in 2006 along a shore parallel offshore bar. Deflection of this material into the nearshore zone may be caused by the undulation of the shoreline, which bends more to the west in the southern part of Reach 5 and northern part of Reach 6. Shore protection in Reach 6 is managed exclusively with the state revetment, and given the conditions there is little reason to expect that a beach could be maintained in this area. The lack of a Reach 6 dry beach and the transport of material along an offshore sand bar, indicates limited opportunities for north to south transport to beaches in Reach 7. Hence, no significant feeder beach should be expected for Reach 7 from the north.

Reaches 7-8: Volume changes in Figure 3-4 for Reaches 7 and 8 show a net gain in both the dry beach area and the nearshore zone out to -40 ft NAVD. The increased beach volume is a result of the 2011 dune restoration project, which added approximately 81,000 cy of sand to the upper portion of the beach (56,000 cy in Reach 7 between R-116.5 and T-125; and 25,000 cy in Reach 8 south of the Pier between R-128 + 974 and R-134). The data also indicate spreading of the Phipps Park nourishment project from Reach 7 toward the Pier, as well as cross-shore movement from the upper beach face to the nearshore zone. Shoreline change data following the 2006 Phipps Park project indicate the northern end of the project area, between FDEP profiles 116 and approximately 124, serves as a feeder beach for the southern end of Reach 7. The Phipps Park project at the northern end of Reach 7 is vulnerable to erosion because of its proximity to the state revetment, lack of sediment supply from Reach 6, and reduced project footprint which excludes beach nourishment in lieu of dunes only. While the physical monitoring data indicate that material from Reach 7 moves to the south, it is still unclear how much material is transported south along the beach versus in the nearshore zone, and what the influence of the Lake Worth pier is on the transport patterns. Consequently, recommendations have been developed for supplementing sand to the Reach 8 area.

Further evaluation of sediment transport pathways for the Island was conducted using data analyses presented by Humiston & Moore Engineers. Figures 3-5 and 3-6 show contour maps of elevation change along the coastline for key time periods. Changes between 2001 and 2006 (Figure 3-5) illustrate response of the beach and nearshore zone following placement of the 2006 Mid-Town and Phipps Park nourishment projects. Areas of sediment accretion are shown in red and yellow; areas of erosion are shown in blue. Sand placed in the Mid-Town project area between FDEP profiles 90.5 and 101.5 is evident; however, south of profile 98 in Reach 4, the beach sand appears to have been eroded. Whether this material moved seaward to form a nearshore bar, or dispersed further south into Reach 5 is not certain. The change in shoreline orientation at profile 98 also impacts the transport pathways, with a tendency for sediment placed in Reach 3 and 4 to be diverted away from the shoreline into a nearshore bar. Further south in the Phipps Park area, nourishment placed in 2006 is evident between FDEP Profiles 116 and 127. The broad width of the accumulation zone reflects a rapid cross-shore spreading of the nourishment material following initial placement. The cross-shore movement of the Phipps

nourishment is indicative of the over-steepened profile that resulted from the long-term sand deficit.

Nearshore response during the 3-yr period following the 2006 Mid-Town and Phipps Park projects is shown in Figure 3-6. Sediment losses in the Mid-Town project area reflect erosion and spreading of the nourishment sand. Beach and nearshore accretion between FDEP profiles 102 at the south end of Reach 4 and 113 at the north end of Reach 6, support the conclusion that the Mid-Town project serves as a feeder beach for Reach 5. The contour data also show an offshore deflection of sand into a nearshore bar starting around FDEP profile 110 located at the boundary between Reaches 5 and 6. The deflection may be caused by the change in shoreline orientation, which causes the bar to remain offshore beyond the south end of Reach 8. If this sediment transport pathway can be shown to be persistent through time, it would suggest little possibility of feeding the dry beaches in Reaches 6, 7, and 8 with sand from the Mid-Town project. Elevation changes in the Phipps Park area support the conclusion that Reach 7 acts as a feeder beach for beaches toward the Pier. Additional contour maps of elevation change over time, similar to the Humiston & Moore figures are recommended to further analyze the sediment transport pathways in key areas of uncertainty.

While the existing physical monitoring data have been used to evaluate sediment transport pathways and to identify management cells, additional insight into the remaining uncertainties could be gained by modifying the data presentation in the annual Town-wide monitoring reports. For example, the annual beach profiles in the Mid-Town and Phipps Park areas are not compared with the design templates for the nourishment projects, so the project performance and levels of protection remaining are not readily apparent. Additionally, the three cross-shore depth zones chosen to present the volume change data allow little flexibility in analyzing longshore and cross-shore transport pathways. The current data presentation makes it difficult to identify the influence of smaller scale features like nearshore bars, hardbottom, and groins on the shoreline and nearshore response. Recommendations are presented herein to modify the data presentation to facilitate a greater understanding of the shoreline evolution.

Specific recommendations include:

- Establish cells for coastal management that include groups of Reaches that can be managed together:
    - North Cell: Reaches 1, 2, and 3
    - Central Cell: Reaches 4 and 5
    - FDOT Cell: Reach 6
    - South Cell: Reaches 7 and 8

- Pursue opportunities to move inlet sand and impounded sediment from Reach 1 to sediment starved areas in Reach 2, and potentially further south into the northern end of Reach 3.

- Continue to maintain the Mid-Town project in Reaches 3 and 4, which acts as a feeder beach for Reach 5. Maintain the existing groins in Reach 5, including the “Monster Groin”, recognizing the stabilizing effect on the beach.

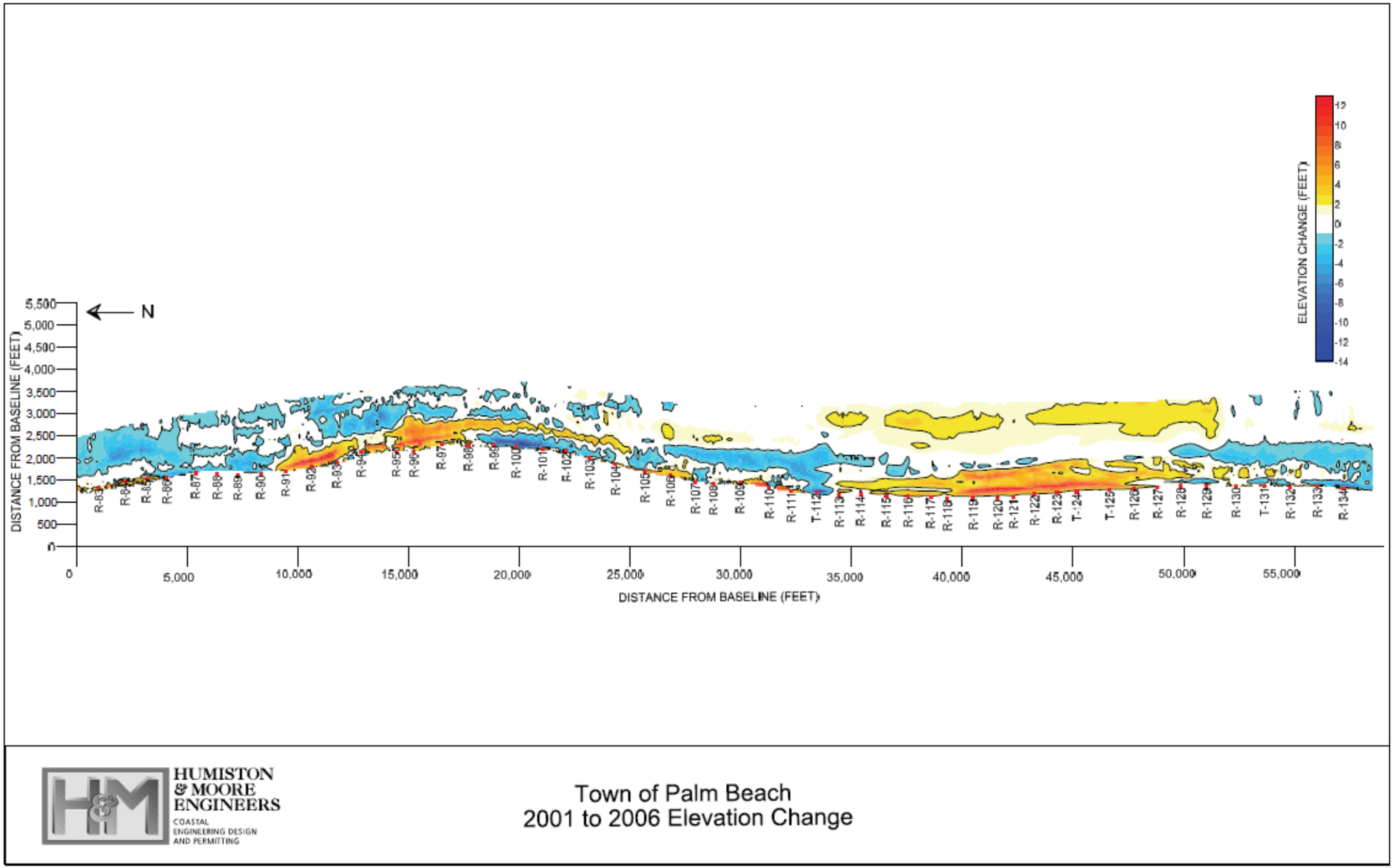


Figure 3-5. Contours of elevation change along the Palm Beach shoreline between 2001 and 2006 (from Humiston & Moore Engineers)

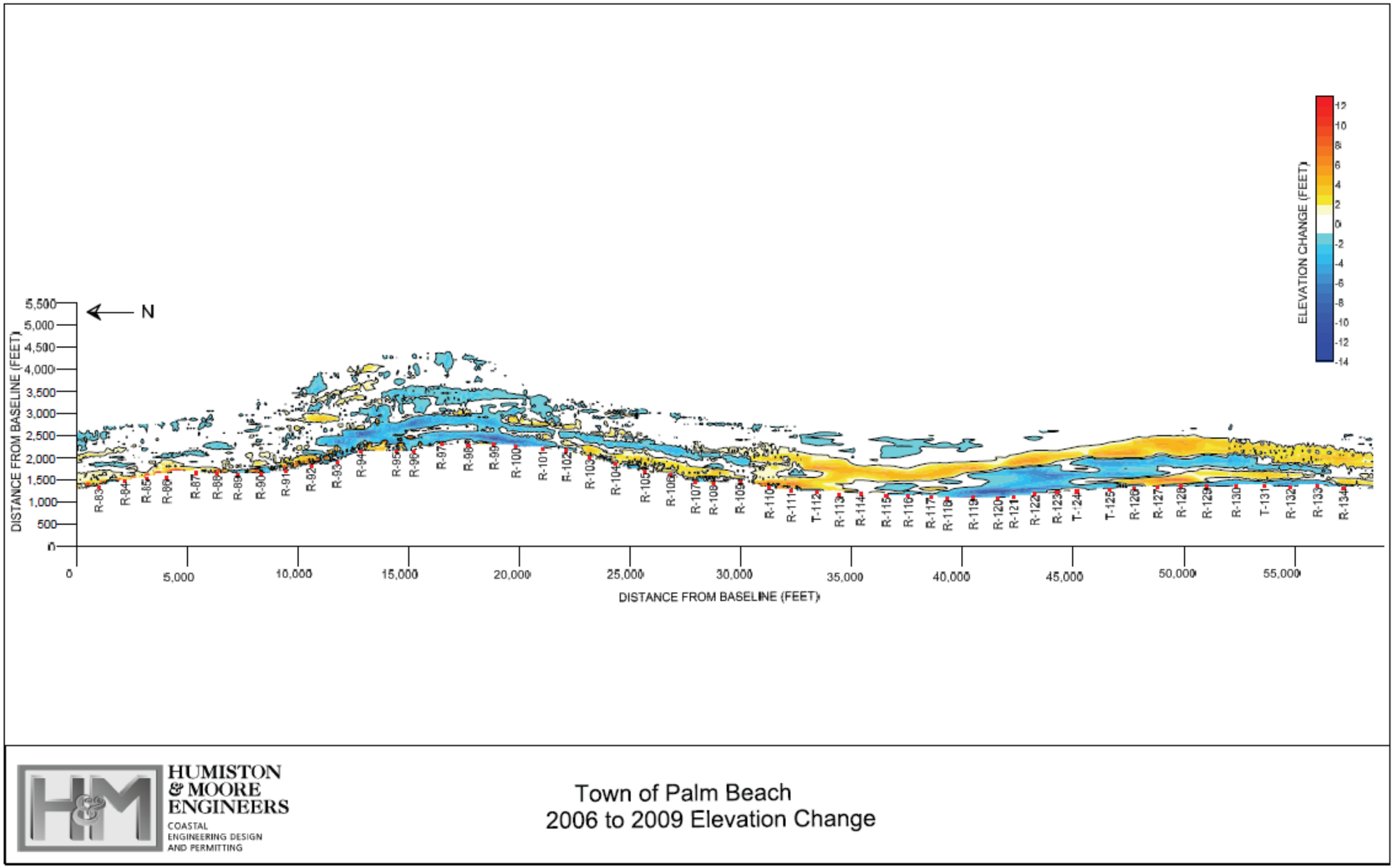


Figure 3-6. Contours of elevation change along the Palm Beach shoreline between 2006 and 2009 (from Humiston & Moore Engineers)

- Establish Reach 6 as an area to maximize hard bottom coverage to advance the regional objectives of the BMA.
- Pursue opportunities to maximize sand placement at the northern end of Reach 7 and supplement sand to the Reach 8 area, particularly considering its relatively new critically-eroded designation.
- Modify presentation of data in annual Town-wide monitoring reports:
    - Annually plot design beach cross-section to achieve desired level of protection along with monitoring profiles.
    - Annually plot post-construction profiles for most recent beach nourishment projects along with monitoring profiles.
    - Annually map portions of the Island satisfying and not satisfying design level of protection in the plan.
    - Annually plot geomorphological change by contouring topographic and bathymetric change.
    - Provide more spatial resolution in the cross-shore direction for volume change along the profile (as compared to the current practice based on MHW, -13.1, -26.2, and -40 ft). A finer breakdown, combined with geomorphic change contours would help understand volume changes on the offshore bars, for instance.
    - Use modified data presentation to conduct a more in-depth evaluation of sediment transport pathways with a goal of refining sediment management in the four (4) cells.
- Identify and track project performance near erosional hotspots. Prioritize adaptive management actions around hotspot areas so as not to compromise overall project performance (e.g., maintain sand nourishment more frequently and/or pursue supplemental structural measures in erosional hotspots to extend overall project design life). Based upon consultations with Town staff, there are different types of erosional hotspots observed in Town. Some are persistent, and some are believed to move down the beach. The persistent hotspots tend to be influenced by neighboring shoreline irregularities and/or exist within areas where nourishment cannot be currently permitted (e.g., north end of Reach 7). Some of these persistent areas also likely result from focusing of wave energy and gradients in the longshore sediment transport rate. Hotspots can be mitigated through localized over-nourishment or more frequent sand nourishment in hotspot areas, as well as with strategic placement of coastal engineering structures. Longer beach nourishment projects with consistent coarse-grained sand also help manage erosional hotspots. Localized erosional hotspots can compromise an overall nourishment project design life, though, so understanding the location and causes for erosional hotspots is an important aspect of beach nourishment design. The Recommended Plan in the Executive Summary includes a provision for truck hauled sand associated with each major nourishment project to provide flexibility to over nourish erosional hotspots and/or maintain erosional hotspots in other areas throughout Town. These variables are taken into consideration with the adaptive management of both the Mid-Town and Phipps / Reach 7 projects (as identified in the BMA). FDEP recommends that hot spots be addressed with soft sand solutions before hard structural solutions are considered (i.e., perform another beach nourishment project in Reach 7 with a modified template and

monitor before considering groins).

- Update wave and physics-based sediment transport modeling to understand rates and variability of transport as basis for improved project design and clarifying feeder beach expectations. This activity should only be conducted if major uncertainties still exist after the more in-depth study of the physical monitoring data. The model also can be applied to understand coastal processes forcing mechanisms contributing to erosional hotspots. For instance, applying the model to understand whether observed erosional hotspots are resulting from focused wave energy and/or alongshore sediment transport gradients would help reveal the root cause, and provide a basis for improved coastal engineering design.

3.3 Beach Nourishment Project Performance

A long-term commitment to maintaining the existing beach nourishment projects in the Mid-Town and Phipps Park areas is important for continued shore protection, both in the immediate project areas and adjacent beaches that benefit. The stated goals for the Mid-Town and Phipps Park project areas are to protect against the 15-year storm, and renourishment intervals of 6 to 8 years have been projected to maintain this level of storm damage protection. Since the CCMP allocates resources to maintain these projects, it is helpful to evaluate past project performance against the projected renourishment interval to support future planning efforts. This can be accomplished by using monitoring data to track nourishment material remaining in the project area(s) during the years following construction, and then comparing the results against the projected 6 to 8 year design life. However, based on information currently available, it is not clear what the design criteria are for how much sand needs to remain in the project area to provide the 15-year storm protection. Clear criteria for project performance need to be established so past projects can be evaluated and stakeholder expectations clarified.

Data available through Town-wide and project specific monitoring programs have been used to track the amount of nourishment material remaining in the Mid-Town and Phipps Park project areas during the years following construction. Although the amount of sand needed to provide the 15-year storm protection is not clearly understood and project performance cannot be directly assessed, analyses are presented below to illustrate sand loss from the project area over the 6-year design life.

Percentages of fill remaining in the Mid-Town project area following the 1996 and 2006 projects are shown in Figure 3-7. For the 1996 project, data were available to compute the percent of fill remaining above two different depth horizons: MHW; and the -15 ft NAVD contour. The -15 ft NAVD contour shows a greater percentage of nourishment remaining over time than the MHW horizon. Approximately 3.5 years after initial construction, 80% of fill was remaining above the -15 ft NAVD contour and 46% was remaining above MHW. Data at the end of the 6-yr design life were not available for this report; however, approximately 60% of fill would be remaining above the -15 ft NAVD contour and 30% remaining above MHW for trends projected out 6 years.

For the 2006 Mid-Town project, Figure 3-7 shows the percent fill remaining above the depth of closure, assumed to be the -26 ft NAVD contour. These data show approximately 20% of fill remaining above the depth of closure after 6 years. In comparison, sediment losses from the

2006 project were significantly greater than the 1996 project, likely the result of increased storm frequency during the period following the 2006 nourishment. Storms are an important force in moving sediment away from the project areas, as seen by the losses caused by Hurricane Sandy in late 2012.

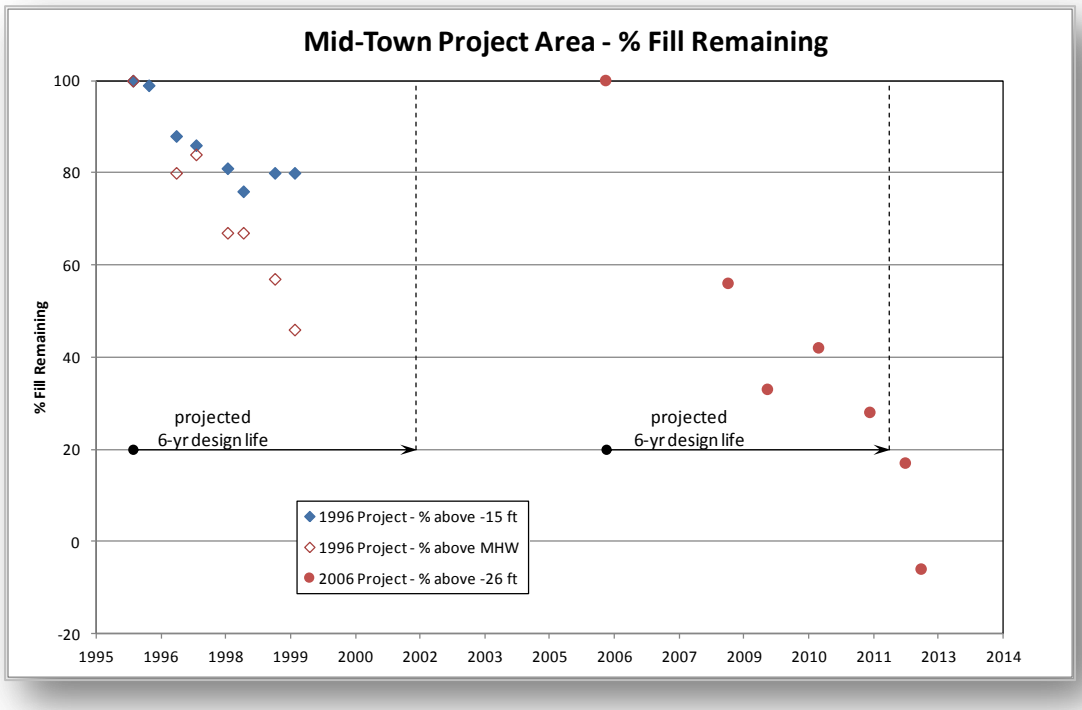


Figure 3-7. Loss of sediment from the 1996 and 2006 Mid-Town nourishment projects over the projected 6-year design life.

Monitoring data from the Phipps Park project were used to compute the percent of fill remaining above the depth of closure (-26 ft NAVD) following the 2006 nourishment project (Figure 3-8). These data show a loss of nearly 40% of the fill material within 2 years after project completion, followed by a gradual accumulation of sediment. At the end of the projected 6-yr design life, approximately 70% of fill remained in the project area above the -26 ft contour.

Although much of the nourishment material was retained in the project area, the available volume data do not identify sand remaining on the dry beach where it provides storm damage protection. For this type of analysis, monitoring data were used that show changes in the mean high water shoreline were utilized. Figure 3-9 shows the shoreline positions in the Phipps Park area between FDEP monuments 113 and 129 over the period February 2006 to December 2012. The shoreline positions are shown relative to the pre-project conditions. Positive numbers represent a wider beach than the February 2006 pre-project conditions, and negative numbers represent a narrower beach. The data show greatest losses of fill at the northern end of the nourishment project, between FDEP monuments 119 and 124. Although the beach in 2012 was still wider than it was prior to the 2006 project, there was a significant redistribution of material

from north to south. At the northern end of the project area where dunes were the only form of protection (monuments 116 to 119), the beach is actually narrower now than before the 2006 project including additional dune sand placed for FEMA repairs. Although the percent of fill remaining above the -26 ft NGVD contour suggests that the project is performing well (Figure 3-8), the beach at the northern end of the project has lost considerable sand, even including repetitive dune efforts to maintain the desired 15-year storm protection.

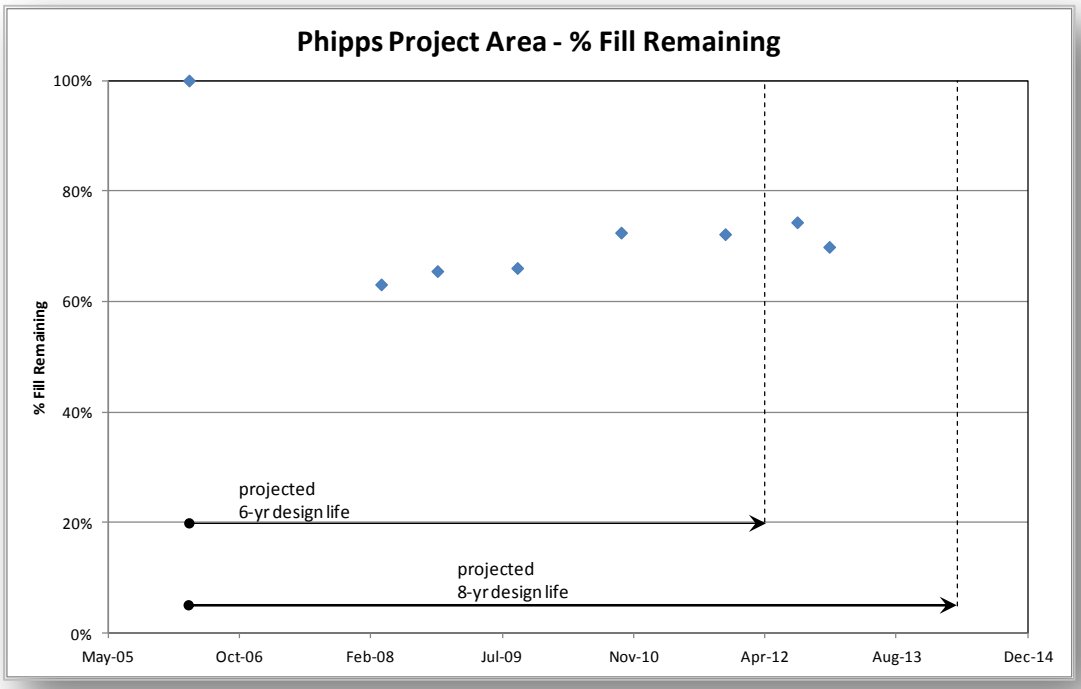


Figure 3-8. Loss of sediment from the 2006 Phipps Park nourishment project over the projected 6 to 8-year design life.

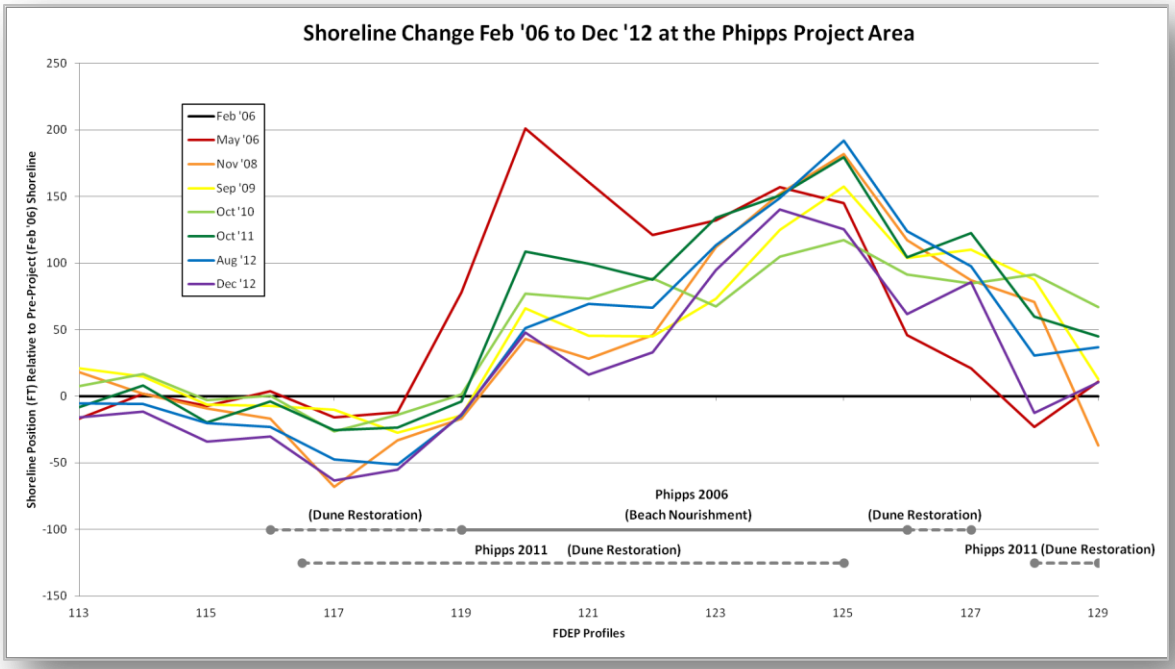


Figure 3-9. Shoreline change in the Phipps Park project area relative to the pre-project (February 2006) shoreline.

Long-term monitoring data are extremely valuable in measuring loss of sediment from the nourishment projects, as well as localized areas of erosion and accretion; however, performance of the projects can only be assessed when specific criteria are clearly defined. Specific recommendations for evaluating performance of the nourishment projects include:

- Clearly define the goals for the nourishment projects (e.g., protection against a 15-yr storm for 6 to 8 years).
- Clearly define the criteria for successful performance of the projects (e.g., define the percentage of fill anticipated to provide protection for a 15-yr storm, and identify where on the profile the sediment must be to provide the desired level of protection).
- Collect/present the monitoring data in a manner that allows project performance to be easily quantified (e.g., calculate volume changes over 1 to 2 ft depth intervals or within the original project footprint).

3.4 Sand Source Alternatives

Access to a sufficient quantity of high-quality, beach-compatible sand is of critical importance to the future of the Palm Beach coastal management program. With beach nourishment and dune restoration as the primary alternatives for shore protection and typical beach nourishment projects requiring on the order of one million cubic yards of sand, vast quantities of sand are required to serve short- and long-term needs. Estimated sand needs for the coastal program over the next 50 years are expected to exceed 13 million c.y. Most recent sand searches revealed 8 million c.y. of what is considered to be beach-compatible sand throughout 6 different sites.

Identified offshore beach-compatible sand sources are, then, currently believed to harbor enough sand for a time period on the order of 20 years if nourishment continues at a similar rate as the recent past. Although Palm Beach has access to more sand than some other communities in southeast Florida, the supply is not adequate for the long-term assuming large-scale beach nourishment will remain an integral part of the coastal management program. The most recent BMA Draft also did not endorse all 6 recently discovered borrow sites, suggesting the identified local sources may be exhausted more quickly than 20 years.

Sand is therefore a scarce resource, and there is a need to consider various alternatives and secure access to a long-term, high quality, and affordable sand supply, including:

- Lake Worth Inlet sand
- Local offshore borrow sites
- Upland sand
- Imported aragonite
- Regional offshore sand sources

A summary of sand source alternatives follows, including information related to relative quality, available quantity, production rates, environmental considerations, and cost. Recommended priorities for sand sources are provided as the basis for project and Reach-specific recommendations.

3.4.1 Lake Worth Inlet sand

The best source of sand for the dune and beach restoration projects is sand from Lake Worth Inlet. This sand would normally reach the beaches downdrift of the tidal inlet if the harbor jetties were not there. Absent jetties and dredging, natural bypassing tends to be episodic via various ebb shoal formation, migration, detachment, and welding processes. Based upon a preliminary review of USACE geotechnical information including grain size data from the inlet (Parris, A., P., et. al., 2012), the particle size of the Lake Worth Inlet sand is variable. The coarsest sand is derived from the updrift beaches near the sand transfer plant (Figure 3-10) and from the main outer navigation channel, where the average grain size is reported to be greater than 0.3 mm. Sand dredged from the inlet proper and the updrift settling basin is anticipated to be of similarly high quality. This sand transfer plant and outer inlet dredged sand is ideal for beach nourishment. Finer sand is typically dredged from the inner navigation channel and turning basin. Sand grain size is expected to be variable in the improvement dredging footprint of the

Figure 3-10. Sand in Reach 1 representative of sand transfer plant material.

updrift settling basin. Rock fragments were observed at most locations, and may represent a fraction of the material, but these are not required to be dredged.

Historically sand from Lake Worth Inlet has been bypassed to Palm Beach via the STP, and placed either on the beach or offshore via dredging operations. Annual quantities placed on the beach from the STP range from 56,000 c.y. in 1998 up to 255,000 in 2001 for a total of more than 2.6 million c.y. since 1996 (annual average of over 150,000 c.y.). Reports from the USACE indicate the typical annual quantity dredged from the inlet exceeds 100,000 c.y. The estimated quantity dredged in 2013, including improvement of the settling basin, exceeded 400,000 c.y. This project was constructed using a cutterhead pipeline dredge; therefore, the majority of sand in 2013 was placed directly on the dry beach or just offshore. The USACE also has authority to place the more variable quality sand from the inner channel directly in the nearshore zone in wading depths and shallower using the pipeline dredge. Personal communication with USACE indicates intentions to utilize this pipeline cutterhead method every other year, which is a marked improvement over past practices of placing the sand from a hopper in water depths of 15 ft or more. Hopper disposal in intermediate depths provides limited storm protection compared to direct beach and swash zone placement.

Rough calculations for planning purposes show the average cost per cubic yard of bypassed sand is less than $3/cy (Section 4.1). USACE sand is at no cost to the Town, provided it is placed as part of the USACE least cost alternative, which has traditionally been the case. Should the Town pursue options to place the sand at a different location than the USACE least cost alternative, the Town would have to pay the incremental cost increase for placement, which would be variable depending upon method, location, and market conditions. For planning purposes in this document, an incremental cost for placement at other locations is assumed to be $10 - $20/cy.

The quantity of sand from the inlet exceeds the volume for stabilizing Reach 1, and provides an opportunity for nourishment and maintenance of other beaches throughout Town using cost-effective, relatively coarse-grained sand. Recommendations for inlet sand management in this report strongly encourage placement of Lake Worth Inlet sand at locations other than the Reach 1/northern Reach 2 USACE disposal area. Methods for extended placement may include longer pipeline cutterhead operations, and utilizing pumpout hopper dredges.

3.4.2 Local offshore borrow sites

One of the most cost effective methods for building beaches is to borrow sand from nearshore areas using a hopper (for distant sites or energetic ocean conditions) or cutterhead pipeline dredge (for nearby sites in relatively quiescent ocean conditions). Placing sand on the beach using a dredge minimizes re-handling and reduces cost. The Town has a history of using nearshore borrow sites, including for Mid-Town and Phipps beach nourishment projects. Geotechnical studies and project experience using borrow sites offshore Palm Beach shows the quality is variable. Gray sand with a median grain size of around 0.2 mm is ubiquitous; however, areas with the coarser material are sparse. Some borrow sites have been depleted of the coarser fraction of material, and other previously identified borrow sites proved patchy in grain size with a combination of fine sand, weathered shell, and rock fragments. The BMA sets a standard of 0.25 mm for the median grain size for beach nourishment, which constrains the suitable areas. Whether this standard can be retained for the long-term is uncertain as the coarser material borrow sites are depleted.

Recently, six (6) borrow areas harboring some 8 million cy (ATM 2011 and ATM 2012) were identified for Palm Beach consisting of a variable mix of the typical gray sand with weathered shell producing a composite grain size generally meeting the 0.25 mm standard.

The first report (ATM, 2011) identified 3 borrow sites for use in the north end of Town. Two of the borrow sites (NBA1 and NBA2) were located north of Lake Worth Inlet and contained the coarsest material. The third borrow site is located nearshore and immediately south of the inlet. NBA1 is located between Transects R-65 and R-70, comprises approximately 122 acres with a mean grain size of 0.276 mm that varies between 0.23 and 0.32 mm, and is expected to produce approximately 2.8 million cy of sand. NBA2 is located between Transects R-73 and R-75, also north of Lake Worth Inlet. The borrow site is approximately 20 acres, has a mean grain size of 0.25 mm that varies between 0.24 and 0.25 mm, and harbors approximately 0.567 million cy of sand. The third borrow site (NBA3) is located south of the inlet and in the lee of the southern jetty. This area has been used by the USACE for nearshore dredge disposal. The borrow site spans approximately 24 acres in size, is located between Transects R-76 and R-77, has a mean grain size of .225 mm that varies between 0.22 and 0.23 mm, and can produce approximately 0.6 million cy of sand. The sand within NBA3 is reported to be finer than the two northern borrow sites but still suitable for beach nourishment. NBA3 also is closest to shore (~525 ft), and has greatest potential for wave energy and surfing impacts. NBA1 is endorsed in the latest Draft BMA.

A second report (ATM, 2012) identified suitable sand sources for the south end of Town. The report identified three potential borrow sites SBA1, SBA2, and SBA3. SBA1 is located offshore of Reaches 4 and 5 (R-98 through R-104). The mean grain size is 0.253 mm, and recommended sections for use range from 0.20 to 0.31 mm (other areas within the rectangular footprint not recommended for use have mean grain size of 0.17 mm). There is a concern that rock fragments may be deposited on the beach when sand is dredged from this borrow area. The second southern borrow site (SBA2) is located north of Phipps Park in Reaches 6 and 7 between Transects R-110 and R-120. The site is approximately 268 acres, and is expected to yield 1.68 million cy of sand with a mean grain size of 0.295 mm from recommended sections (ranging from 0.21 to 0.36 mm). Other samples within the borrow site not recommended for use had a mean grain size as low as 0.15 mm. The southernmost borrow site (SBA3) is located offshore Reach 8 south of the Lake Worth Pier approximately midway between R-128 and extending south to R-135. The borrow site is approximately 122 acres, is expected to yield 1.83 million cy of sand, and has a mean grain size of 0.254 mm ranging from 0.17 to 0.33 mm. SBA 2 and SBA 3 are endorsed in the latest Draft BMA.

All three southern borrow sites have layers of fine sand and coarse shell. The reported average grain size is derived from a composite of the sediment core. The sediment core is sub-sampled to obtain a representative fraction from each layer. The composite grain size is then reported and used for calculating overfill ratios and beach fill performance. The dredging process combines the sand and produces a mixture of grain sizes believed to approximate the composite grain size from the core sub-samples.

Although the sand and shell will be mixed through the dredging and placement process, it is uncertain whether there will be a meaningful improvement in performance as compared to the ubiquitous 0.2 mm gray sand. Based upon information provided, the shell fraction in these

borrow sites represents a weathered structure with similar density as sand, and less subject to breakdown as compared to skeletal shell materials derived in other geographies. Shell fragments are more angular than sand, though, which can lead to a reduced settling velocity with potentially more transport. There also is potential for durability problems over time, but there is no strong evidence of this. Although the shell fraction in these samples is not of great concern with regard to performance, it comprises the coarsest material in the borrow site and only represents a fraction of the total volume. There also are substantial quantities of finer sediment within these borrow areas (less than 0.2 mm), and the characterization is subject to resolution of the samples collected for the studies. The number and spacing of core samples meets standard practice; however, there is always uncertainty involved with areas not sampled. There also will be a natural sediment gradation as the dredge moves through the borrow site dredging successive layers of coarse shell and fine sand. The material deposited on the beach will not always be homogenously mixed. As a result, there will be pockets of shell and gray sand placed on the beach. After placement, sediments will be naturally worked by the incident waves. Coarser material typically migrates down the beach into the swash and upper low tide beach. A field-scale research experiment could be conducted to investigate the effects of the dredging process and long-term wave action on the shell fraction should the Town wish to reduce this uncertainty.

The new sites also are relatively close to shore, particularly the south borrow sites, which can be as close as ~525 ft and as shallow as 4 ft NGVD (NBA 3). Aside from NBA-3, which is by far the closest and shallowest site, the other sites are typically more than 1,100 ft from shore in water depths greater than -18 ft, NGVD but still well within the active profile and in water depths that can affect wave energy. The proximity to the shoreline and relatively shallow depth introduces the potential for cross-shore losses from the beach back into the borrow area, interruption of longshore transport (particularly sand bars offshore Reaches 6, 7, and 8 identified in Section 4.2), and wave energy focusing as the incoming waves respond to the new bathymetry (deeper water transmits more wave energy). Nearshore sand bars specifically should not be mined for purposes of beach nourishment since the bars help reduce wave energy impacting the shoreline, and are within the active profile; therefore, sand placed on the beach from nearshore sand bars potentially will be transported back to the sand bar area.

Wave studies by ATM indicate potential for wave energy modifications that affect longshore transport rates and gradients, as well as surfing conditions. The greatest impact is anticipated with NBA 3 where longshore sediment transport rates may be increased by 40-60%, and surfing conditions would be fundamentally changed and reduced. Other areas revealed the potential for changes in longshore sediment transport rates generally less than 10%, and approaching 20% for NBA 2, where surfing conditions also are valued. Prior work by Woods Hole Group for the Town of Jupiter Island showed that historic nearshore borrow sites contributed to formation of erosional hotspots. Alternatively, reports for beach response landward of relatively shallow borrow sites in Broward County do not indicate adverse impacts. Woods Hole Group also evaluated potential wave energy impacts associated with sand mining in federal waters offshore Alabama, North Carolina and New Jersey, and anticipated influences associated with sand mining 3 or more miles offshore. The need to recognize and compensate for wave energy and sediment transport modifications, has been factored into the recommendations set forth later in this report.

Further, some of the borrow sites are offshore areas not currently eligible for beach nourishment, potentially exacerbating erosional pressures on areas the Town is not able to remedy. Overall, it is difficult to quantify whether beach nourishment projects will perform better using the new borrow sites with 0.25 mm sand versus more readily available offshore sources with 0.2 mm sand. This is an uncertainty the Town should recognize that is explored further in Section 4.

Aside from sediment site, the primary advantage of the nearshore borrow sites is cost, assuming the project entails a large enough quantity to substantiate the upfront mobilization cost that can approach $2M for a pipeline cutterhead dredge. Once the dredge is onsite, there are no major production constraints other than the capacity of the borrow site and weather. A large hopper dredge can typically place more than 10,000 cy/day on the beach, and pipeline dredges can place more than 25,000 cy/day on the beach under favorable conditions. The ATM geotechnical studies anticipated costs for using the North Borrow Sites to range from $9.44 to $10.73 per cy at Mid-Town, and $12.93 to $14.30 at Phipps (using an assumed pumping cost of $6 and variable unit cost of $0.75/mile). Costs for using South Borrow Sites were estimated to be between $6.40 and $11.50 per cy (using an assumed pumping cost of $5.50 and variable unit cost of $1.50/mile). These cost estimates do not include mobilization, which is typically $2 to $2.5M, adding another $2 to $2.5 per cy for a large 1,000,000 cy beach nourishment project. These estimates are reasonable based on recent history; however, they are subject to market fluctuations.

By comparison to other sources explored below, nearshore borrow site sand is relatively inexpensive. Additional sand can also be stockpiled during a beach nourishment project and truck hauled to a nearby location. The estimated incremental cost (in addition to the dredging cost) for a local truck haul is $6/c.y. It also has the potential for reducing turbidity (assuming the shell fraction is weathered and not subject to breakdown in the construction process and subsequent wave abrasion), and for improving suitability for sea turtle nesting habitat. The Town should reserve the opportunity to carefully evaluate the relative pros and cons of these sites, and reconsider use of more traditional gray sand borrow sites in the future as more monitoring data become available and the coarser material is depleted.

3.4.3 Upland sand

An upland source of sand from Ortona has been used for dune construction at Mid-Town, and within Reaches 7 and 8. Following Tropical Storm Fay, Ortona sand was used for an emergency repair project (with FEMA support). Although a large number of trucks were utilized to construct this project (totaled 133,000 cy), the quantity was not sufficient to justify the cost of mobilizing a dredge. When appropriately washed of the fine fraction, Ortona sand is reported to have a mean grain size of 0.57 mm; the largest grain size of any sand source available to the Town.

The available quantity at Ortona is vast; however, there are several challenges for using the Ortona source of sand. First, sand must be trucked to the site putting a large number of trucks on the roads, introducing traffic and air quality impacts, interrupting local beach use, and requiring truck access to the beach. Trucking also limits the production rate. Assuming 80 trucks per day, each carrying 15 cy, the daily production rate for planning purposes is approximately 1,200 cy/day with a maximum of less than 2,000 cy/day. This represents a fraction of the rate from an

offshore dredge. Quality must also be ensured, and inspection of each truckload is recommended prior to placement on the beach.

Cost is also a constraint, as the unit cost for planning purposes is $37 to $40/cy, more than triple the cost for dredging offshore sand. Environmentally, provided the sand is washed, turbidity is limited and sea turtle nesting is reported to occur within areas nourished with Ortona sand.

All things considered, Ortona sand remains a viable source of dune and beach nourishment sand when a larger grain size results in a favorable project life cycle cost benefit ratios, or when hydraulic placement of sand is a concern or prohibited due to offshore resource considerations. Large-scale construction using Ortona also would have to be phased over several seasons due to limited production rates. In addition to repetitive dune construction, Ortona sand may also provide a suitable source for maintenance of larger-scale projects (e.g., annual maintenance to supplement periodic re-dredging using offshore sand). Section 4.3 presents relative costs and benefits for defined scenarios as the basis for planning purposes and for the Reach-specific recommendations in Section 4.

3.4.4 Imported aragonite

Aragonite sand is an oolitic calcium carbonate compound that forms from a change in seawater pH produced through either a biogenic chemical or an inorganic process. Most of the Bahama Banks topography is aragonite, comprising billions of tons in reserve with millions of new tons reported produced each year. Oolitic aragonite particles have an oblong shape (Figure 3-11), and are reported to have a mean grain size of 0.42 mm or greater.

Widespread experience with aragonite constructed beaches is limited. It was used for a small scale beach nourishment project at Fishers Island, NY, where the wave climate was moderate. This project was in a semi-sheltered location downdrift of a harbor jetty, utilized only approximately 600 cubic meters of material, and was not directly comparable to Palm Beach in size or exposure. The littoral system was controlled by the harbor jetty and a downdrift groin. Additionally, the project was partially sheltered from incident waves by the harbor jetty. Another difficulty in assessing how aragonite performed in this project is the lack of long-term monitoring data.

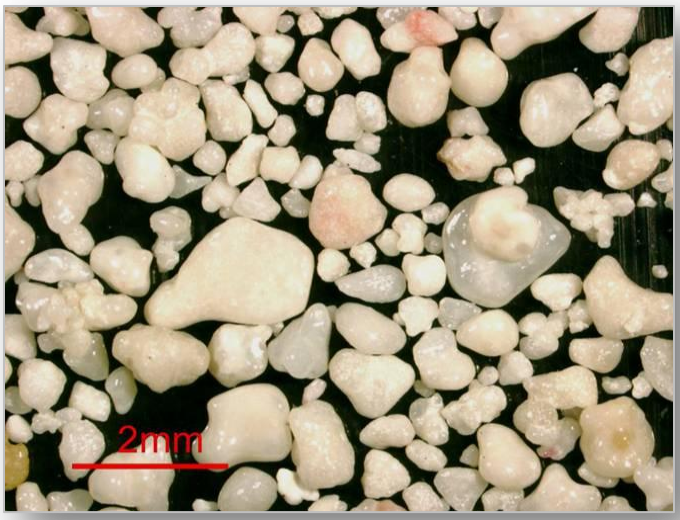


Figure 3-11. Representative Bahamian aragonite sand, courtesy of Sara Beth Kopczynski (Lehigh University)

It is unclear, therefore, how aragonite will perform as beach nourishment under more energetic incident wave conditions at Palm Beach. Some literature suggests aragonite can

perform as well as quartz sand. A comparison of the sieve and settling tube (fall velocity) analyses suggests that aragonite actually has hydraulic properties of a grain size larger than 0.42 mm. However, the durability and shape of aragonite particles introduces an uncertainty related to weathering and breakdown of the individual particles (Wanless and Maier, 2007).

Environmental considerations associated with aragonite also are uncertain, considering the potential for breakdown and associated turbidity. Imported materials also have the potential to introduce foreign organisms; therefore, the aragonite needs to be dried to eradicate local organisms before placement on the beach. Federal laws prohibit importation; however, this is not a constraint at Palm Beach since the beach nourishment projects are not federally-funded. Depending upon the source from Bahamas, Turks and Caicos, or other, there may also be local resistance to exporting the material, which is attractive to beachgoers.

The cost of aragonite is not certain, but is reported to be in the range of $45 to $55 per cy. Production rates would be depend upon the method used to import and deliver the material. Highest production rates may be achieved using pumpout hopper barges, but no aragonite project of this magnitude has been constructed in FL. Given the uncertainties regarding performance, environmental impacts, and high cost, aragonite does not offer a short-term feasible sand source alternative.

Woods Hole Group recommends the Town allow the commercial export and transportation markets to establish the product as a viable commodity. As long as Ortona sand is substantially cheaper, there is limited motivation to pursue aragonite. For long-term planning purposes, should the Town wish to take leadership role in pursuing aragonite, some basic research may be conducted to evaluate durability and performance in the lab and perhaps further evaluate the potential environmental impacts while the business aspects and market conditions evolve (which we envision as a market driven process and the responsibilities of the local exporting governments and commercial transportation/import authorities). All factors considered, it would not be surprising if aragonite was a future viable source, but there are too many uncertainties presently.

3.4.5 Regional offshore sand sources

If the grain size standard for offshore borrow sites remains at least 0.25 mm, then there will be a shortage of local offshore borrow site sand for beach nourishment. Other potential sources of sand may be found in the region. North of Palm Beach where the continental shelf widens, there are larger potential offshore borrow sites. State resources typically extend 3 miles offshore, beyond which sand and gravel become federal resources. Federal sands are managed by the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly the Minerals Management Service (MMS). The division that controls offshore energy and minerals is the Bureau of Ocean Energy Management (BOEM). BOEM is tasked with finding and developing energy and non-energy resources such as sand and gravel for beach nourishment and other construction projects. Legislation allowing BOEM to issue negotiated leases for Outer Continental Shelf (OCS) sand and gravel was enacted in 1994. This legislation allows the Bureau to convey, on a noncompetitive basis, the rights to OCS sand, gravel, or shell resources funded in whole, part, or authorized by the Federal Government. In 1992, the Bureau began working cooperatively with coastal states to locate and evaluate sand deposits in Federal waters with potential for use in beach nourishment projects. To date there have been 22 leases for

offshore sand eight of theses leases have been with the state of Florida. BOEM is anticipating an increase in requests for OCS sand since sand in state waters continues to be depleted.

In addition to the BOEM effort, there is an ongoing FDEP and USACE initiative to identify regional offshore sand sources for communities located along the southeastern Florida coastline. The initiative, termed the Southeast Florida Sediment Assessment and Needs Determination (SAND) study has compiled information on sand requirements over the next 50 years in the five (5) counties of St. Lucie, Martin, Palm Beach, Broward, and Dade. Field data collection is currently underway to identify potential offshore borrow sites with beach compatible sand, and recommendations are being developed for regional sediment management planning that would serve the needs of the five counties included in the study. FDEP and USACE are working to finalize the study with a report to be issued this year. Since there will be a need for the Town of Palm Beach to secure additional sand sources for shore protection projects once the existing nearshore borrow sites are depleted, it is important that the Town actively participate in the SAND Availability and Needs Determination effort through coordination with the sponsoring agencies and an understanding of the study process.

3.4.6 Sand source alternatives summary

The review of sand source alternatives provides the basis for future prioritization and for Reach-specific recommendations presented later in this report. The overall recommended approach includes the following elements:

- Utilize the inlet sand as much as possible, not only to maintain the current disposal area in Reaches 1 and 2, but take action to utilize inlet sand at other locations recognizing there is impounded sand within Reaches 1 and 2. Utilizing inlet sand throughout Town presents an opportunity to reduce dependence on offshore borrow sites, more frequently maintain beach nourishment projects thereby extending the renourishment period, and distribute coarser grained material throughout Town beaches:
    - Expanding the approved disposal area further into Reach 2 will allow for direct placement on the beach during inlet dredging operations.
    - Expanding the approved disposal area throughout all of Reach 2 creates an opportunity to establish a narrow beach connecting Reaches 1 and 3, thereby allowing direct pumping of inlet sand to maintain the Reach 3 portion of the Mid-Town project.
    - Working cooperatively with USACE, the Town can pursue incremental improvements to the inlet dredging project when hopper dredges are used to haul and pumpout the material to help maintain the Mid-Town, Phipps or other future beach nourishment projects.
    - Advancing the initiative to obtain separate permits (via Tri-Party effort or other means) will provide the Town flexibility to obtain high quality inlet sand independently and perhaps more cost-effectively for use throughout Town.

- Minimize dependence and use of local nearshore borrow site sand considering scarcity, potential impacts associated with close proximity to shore, and variable grain size including substantial finer sand fraction. Recognize necessity and cost benefits

associated with using local borrow sites for beach nourishment construction, but utilize other measures (e.g., inlet sand and Ortona sand) to extend renourishment periods.

- Utilize Ortona sand for dune construction and incremental beach nourishment maintenance in emergency situations; otherwise, truck hauling of stockpiled offshore sand during nourishment projects is recommended to reduce the cost of dune and/or erosional hotspot maintenance.
- Actively participate and secure access to regional offshore sources via the SAND program given inevitable needs.
- Monitor market-driven feasibility of aragonite; however, do not consider it to be a viable source in the short-term due to high cost and uncertainties related to performance, environmental impacts, and supply considerations.

Key conclusions include:

- Inlet sand is the highest priority. The Town should take action to ensure every last grain of sand possible is placed on Town beaches, ideally throughout Town and not only within Reaches 1 and 2.
- Ortona sand has the coarsest grain size, and will likely perform significantly better than offshore sand sources.
- New offshore sand sources have more coarse grains due to shell pockets; however, the incremental gain in performance is uncertain. A significant fraction is much like the ubiquitous gray sand, and there are uncertainties associated with the proximity to the shoreline in terms of intersecting the active profile, interrupting offshore bar transport, inability to nourish landward of borrow areas to mitigate potential effects, and impacts associated with wave energy focusing, sediment transport and surfing conditions. Nearshore sand bars should not be mined for beach nourishment.
- Depending upon actual performance of sand from the nearshore borrow sites, balanced by environmental constraints and potential resource impacts, consideration of using the more common gray sand from farther offshore should be reserved as a future option.
- The Town must place a priority on participating actively in the SAND study not only for interest, but as a community with defined needs. Future requirements are inevitable, and access to coarser grain material farther offshore would be desirable even in the short-term.
- Aragonite is not feasible currently due to cost, import uncertainties, environmental concerns, and unknown performance in an active energy zone. However, as sand resources are depleted, more is learned about its performance, and the market and delivery methods are clarified, aragonite may become a legitimate future possibility. It is aesthetically pleasing, abundant in supply, and has a coarse grain size (assuming it is durable). At this time, aragonite is not an affordable option, but it is recommended to let the market define the feasibility of aragonite.
- Should the Town be interested to advance the science associated with borrow site alternative uncertainties, two possible studies could be pursued, perhaps in cooperation with a University:

Depending upon the level of interest to prepare for future sand deficits, the Town may elect to participate in a lab-scale or small pilot scale research endeavor to help define future feasibility of aragonite. The purpose would be to provide scientific data to help understand aragonite performance and environmental impacts should the market create an affordable scenario in the future. A higher priority should be placed, though, on securing improved access to Lake Worth Inlet and regional federal sand resources, which have less uncertainty and would likely be lower cost alternatives.

- Another suggestion would be to participate in a study of the response of shell particles from offshore borrow sites to determine if they are durable throughout the dredging and wave action processes. The project could be as simple as taking a series of discrete cross-shore sediment samples along a series of transects. These sediments could be analyzed using both conventional sieve analyses and a Rapid Sediment Analyzer (fall velocity/settling tube). The results of the study could provide data on how the grain size across the beach changes over time and how the average grain size of the beach (or regions) changes as the beach fill ages. It would be helpful to obtain sediment samples before, during, and immediately after the beach nourishment project is completed, and at several time intervals throughout the project design life. The purpose would be to determine whether the shell fraction in the nearshore borrow sites retains its integrity over time, and whether the effective grain size remains coarser than the more common gray sand offshore.

3.5 Coastal Structures

Two primary types of coastal structures were evaluated:

- Structures intended to provide a last line of defense against severe storms, such as seawalls and revetments
- Structures intended to help stabilize the beach, such as groins.

Properly designed seawalls and revetments can effectively protect upland properties. If the goal of the coastal management program was strictly protection of upland property, seawalls and other measures may be effective. However, last line of defense strategies typically do not help maintain beaches, and can have adverse impacts on beach stability. Effective seawalls eliminate upland sources of sediment from eroding that would otherwise naturally replenish the coastal system. When exposed directly to waves and currents, seawalls can intensify energy causing localized scour and beach erosion. Properly designed rubble mound, rock revetment structures can help dissipate wave energy and locally accumulate sand; however, they often include relatively shallow slopes and occupy large footprints of beach that provide valuable habitat including for nesting sea turtles. The decision to have a concrete seawall, rock revetment, and/or composite structure is site-specific, and no general recommendations can be offered. As with seawalls, rock revetments inhibit the natural functioning of the beach and dune system and are often not approved by FDEP unless an emergency has been declared or demonstrated. A seawall-protective revetment may extend the life of a seawall, such as the one constructed along North Ocean Boulevard in Reach 2 in 2007 following a Town Council issued emergency, but will not eliminate the need for replacement. Placing new revetment on the beach-dune system is

typically not accepted or recommended by the State and Federal regulatory and advisory agencies because it eliminates sea turtle nesting habitat.

Having properly designed, inspected, and maintained seawalls landward of a healthy, maintained beach and dune system is an effective composite strategy for shore protection (e.g., Mid-Town Palm Beach). Given the potential impacts to upland assets from severe coastal storms that exceed beach nourishment design criteria, rising sea levels, and potential for future intense storms, seawalls are an essential component of long-term protection. It is possible there are properties without seawalls that may become eligible in the future. Buildings constructed prior to 1985 (i.e., non-conforming structures) at risk of damage from a 15-year storm may be eligible; therefore, it is recommended to inventory properties potentially eligible for future seawalls and establish a monitoring protocol to determine when eligibility is achieved so the property owners can be proactive if desired.

As a comment on the Draft Report, Woods Hole Group was asked by Town Council to review the Palm Beach Country Club seawall. There are reports of overtopping on a regular basis, including during typical seasonal storms (i.e., not extreme storms), as well as visible dead grass landward of the seawall. Consultations with Town staff indicated the wall is not overtopped by waves on a regular basis, but that salt spray often blows over the wall particular during northeast storms with winds from the east. The dead grass is not believed to result from seawall deficiencies, and may be mitigated through improved onsite irrigation and maintenance. Experience in other areas suggests grass can be damaged by salt spray, requiring regular maintenance. Although not within the scope of this review, a coastal structures program is recommended to inventory seawalls on the Island, and identify candidate structures for maintenance. One element of the seawall program would be to establish design guidelines (including recommended crest elevation necessary to provide adequate storm protection). Should the observed landward impacts continue, The Palm Beach Country Club seawall is a candidate for review. Raising the seawall is not recommended, however, unless the design is found to be inadequate for storm protection purposes. Some overtopping during severe storms and salt spray during moderate storms with onshore winds is to be expected.

Alternate last lines of defense also include modifications to infrastructure, such as pile foundations. Although there are exceptions, buildings constructed after 1984 are not eligible for seawalls; however, they incorporate other measures, such as pile-supported foundations for conformance. In Palm Beach, it is believed that structures in the south part of Town conform to this policy, and effectively are protected from severe coastal flooding and erosion events provided the pile foundations are driven deep enough, and are designed to withstand dynamic wave and current force loadings. An engineering inspection, including field verification, is recommended if uncertainty exists regarding the integrity of the foundations. A preliminary study by the Town identified approximately 40 properties in Reaches 7 and 8, and all either had a seawall or were on piles if no seawall was present (e.g., Balleria). The study was preliminary and did not include field verifications.

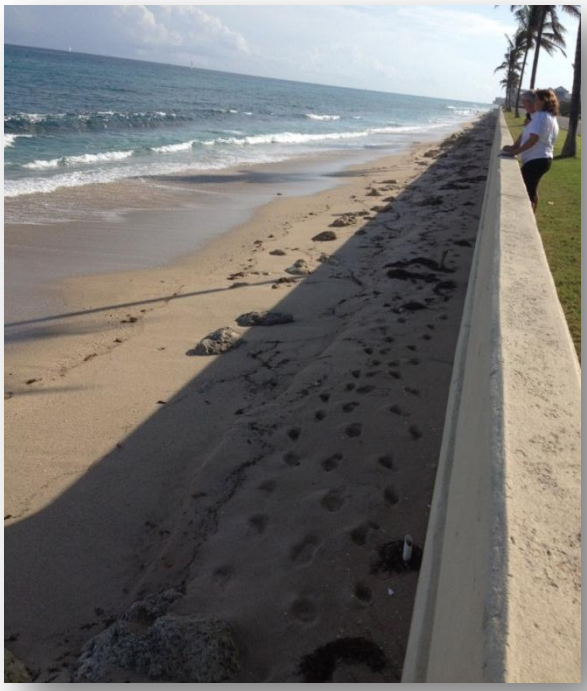


Figure 3-12. North Ocean Boulevard Town seawall (December, 2012).

Groins can effectively stabilize the shoreline where there is an adequate supply of sand. When used in series and/or as a terminal structure along with beach nourishment, groins can help manage longshore transport and associated beach erosion. Groins also can be used to help maintain a minimum beach profile (or *template* of the beach) for more modest storm protection, seawall toe protection, and recreational use. Short groins can help reduce the beach nourishment footprint, and are potentially beneficial where there are sensitive nearshore resources, such as hardbottom. Groins do not create sand, though. Lacking a sufficient sediment supply, groins can cause downdrift erosion. Groins are also not certain to function effectively, and warrant site-specific experience, designs, and applications. Properly designed and located groins can help control longshore transport of sand; however, groins may not function as intended where cross-shore sand transport and losses are substantial, for instance. Materials must be carefully selected for the local conditions, and groins can be relatively expensive to construct. In some cases, the incremental cost of groin construction can exceed similar benefits gained through expanded localized beach nourishment.

Based on the general characteristics of coastal structures, the following general guidelines are offered for Palm Beach as the basis for Reach-specific recommendations related to coastal structures:

- Seawalls in Palm Beach offer a critical last line of defense; however, there are substantial uncertainties related to the design criteria, current condition, need for maintenance, and in some cases the actual location and condition of seawalls and/or pile foundations is not field-confirmed. That a significant number of seawalls are privately or state owned introduces challenges for the Town's coastal management program to take a leadership role in ensuring the integrity of this essential last line of defense. Recommendations are provided for private owners to take a more proactive role in maintaining seawalls.
    - The North Ocean Boulevard seawall should be repaired since it provides protection for critical Town infrastructure (Figure 3-12).
    - Beach front owners along Reach 2 (Figure 3-13), northern part of Reach 7, and southern part of Reach 8 (Figure 3-14) are particularly dependent upon seawalls and other last line of defense strategies, and should prioritize seawall and/or foundation inspections including field confirmations.

- The State revetment along Reach 6 protects critical infrastructure, and the Town should retain personnel to ensure the wall is proactively inspected and maintained.
- Lake front owners within areas mapped in FEMA flood hazard zones are subject to seawall/bulkhead overtopping and flooding. These owners should maintain/repair their structures to ensure continued protection.

Figure 3-13. Representative Reach 2 seawall protection (December, 2012).

Figure 3-14. Representative Reach 8 seawall protection (December, 2012).

- Groin design, current condition, and functionality vary substantially; however, the majority of groins in Palm Beach are functioning and providing stability to the beaches at some level. Reports by Isiminger, Coastal Technology Corporation, and Coastal Planning & Engineering offer detailed information related to the location, condition and recommendations for individual groins, both privately and publicly owned. Information in these reports forms the basis for next steps. Because of the site-specific nature of groin performance and design, there is no groin design that can be applied uniformly, and groins are not recommended for the entirety of Palm Beach. Although several existing structures may need maintenance or reconstruction, large-scale construction of new groins is not recommended primarily to avoid interruption of regional sediment transport patterns.
    - Consultant opinions for groins are generally aligned. Where there are differences of opinion, we recommend the Town task the consultants with collaborating to present uniform recommendations. Their local knowledge of the individual structures, building materials, contractor capabilities, access, etc. is essential.
    - Groins in Reach 2 are functioning and offer beach stability and modest storm protection, at least in helping to maintain the toe of the seawalls. The analysis by Coastal Technology Corporation indicates substantial cost benefits associated with maintaining these structures with regard to stabilizing a minimum beach. The combination of groins with potential expansion of the USACE disposal footprint has the potential to improve beaches in Reach 2.

- The newly proposed groin in Reach 4 can help manage the localized hotspot erosion, but should not be expected to improve the overall Mid-Town project performance. The substantial expenses associated with this groin should only be incurred if the landward seawall and/or road are threatened, and if the groin is constructed together with beach nourishment to fill the structure to entrapment and minimize potential for downdrift impacts (considering benefits of the Mid-Town project for downdrift beaches in Reach 5).
- The groin at the boundary between Reaches 5 and 6, known as the "Monster Groin", helps stabilize Reach 5, and removal is not recommended. It is uncertain whether an adequate supply of sand would be transported to provide any meaningful storm protection to Reach 6, and removal may adversely affect hardbottom resources in Reach 6 including the 3.1 acre mitigation reef.
- Caution should be exercised before introducing new groins to Reaches 7 and 8. Although certain areas at the northern portion of Reach 7 and southern portion of Reach 8 may benefit from groins in the future, it is not certain whether the incremental expense of introducing groins to these sediment starved areas will result in intended benefits. An incremental approach is recommended to further restore sediment to these areas, and monitor performance, prior to installing coastal structures.

- There remains uncertainty regarding ownership of coastal structures in Town. As a comment on the Draft Report, Town Council requested a necessity to identify coastal structure (particularly groins) ownership as a basis for determining responsibility for costs to perform repairs. A review of property ownership was not within the scope for this Final Report; however, is recommended as part of the coastal structures program.
  - Town staff conducted preliminary research and revealed the Public Works Department is in possession of a long scroll map that provides plan and cross-section views of bulkhead and groin work completed in Town between 1926 and 1931. At that time, private property owners would request "permit approval" from Town Council to construct groins. Based on the limited information located during the initial search, these structures were often built by "Town forces." It was a different time in history when contractors were not readily available, and Town services were available at a cost to residents. Town staff believes the cost of services were assessed to the private property owner who maintained liability for downdrift influences. The document indicates that 24 groins were constructed between 1926 and 1930 in this manner along the shoreline now referred to as Reaches 2 and 3. On December 5, 1931, Town Council approved an ordinance adopting an "Official Bulkhead and Groyne Plat for the Town of Palm Beach" in order for continued private improvements to be made along the shoreline using contractors, rather than Town forces. The work was done under the supervision of the Town. The ordinance included standards and specifications for which both bulkheads and groins would be sited and dimensioned. The coastal structures program included in the Recommended Plan extends the spirit of this 1931 ordinance to ensure new structures or modifications to existing structures are consistent with the CCMP.
  - A program to repair Town-owned structures is recommended; however, a program for the Town to assume responsibility for repairing and improving

privately owned structures would incur substantial investment. At a minimum, Town staff should provide advice to owners and review proposed modifications to coastal structures to ensure consistency with the coastal program objectives.

Other types of coastal structures, such as T-head groins and breakwaters, have potential to help extend the design life of beach nourishment projects. From a coastal engineering design perspective, beaches that are severely eroded, over-steepened, or exposed to intensified wave/current energy may benefit from such structures. Shore parallel or composite structures with shore-perpendicular trunks can dissipate more wave energy and provide a physical obstacle limiting offshore sand transport, as evidenced by the apparent effectiveness of the composite structures at the Breakers for instance.

However, there is strong opposition to shore parallel structures both from within regulatory agencies (state and federal) and from other active stakeholders. Voiced concerns are related to bottom coverage, interference with sea turtle nesting activities, introduction of habitat for predators, damages to surf break quality, potential for downdrift impacts, as well as other recreational and aesthetic considerations. The opposition is strong enough to render the short-term pursuit of such structures to be infeasible. Offshore structures also can be expensive since the footprint and height necessary to be effective tend to be relatively large; therefore, benefits should be well established.

Breakwaters or similar composite structures are not recommended within the near term or next renourishment interval. Although there is limited existing evidence to support the potential environmental benefits of offshore structures, Woods Hole Group suggests groins and/or breakwaters can be used to serve a dual purpose of shore protection and habitat restoration/mitigation. Should consecutive sand nourishment projects alone prove inadequate for certain locations, a pilot demonstration project including structures and nourishment, with a design purpose also to restore or mitigate habitat should be considered.

3.6 Hardbottom Resources

There is a long history of hardbottom and reef resources offshore Palm Beach. The coastal zone harbors extensive hardbottom resources, including low relief nearshore ephemeral habitat, as well as more persistent higher relief habitat farther offshore. Along with sea turtle nesting habitat, the hardbottom resources provides some of the highest value and functional natural resources in the coastal zone. Hardbottom provides structure for cover and colonization, substrate for food sources and foraging, and the shallow transition ecotones offer opportunities for biodiversity.

From a coastal engineering and shore protection perspective, hardbottom introduces challenges. Nearshore ephemeral hardbottom especially is challenging since many resources would not be exposed but for the very erosion problem that beach nourishment and other shore protection activities are intended to address. There is the proverbial Catch 22 situation in that nourishing beaches has potential for adverse impacts to hardbottom, whereas not nourishing has the potential to expose more hardbottom further limiting opportunities to nourish and protect the shoreline. Not nourishing also exacerbates the sediment starved environment, threatening habitat qualities associated with the nearshore littoral zone and dune systems including nesting habitat for listed species of sea turtles. Long-term sediment starvation also can create an environment

devoid of beach habitat whereby seawalls and other coastal structures are in direct contact with the ocean as the last line of defense, effectively eliminating the natural beach system. Therefore, a balance is necessary between achieving healthy littoral systems, beach habitats (including for sea turtle nesting), and healthy hardbottom habitats, while also protecting coastal infrastructure.

The state of Florida recognizes the need for this balance and has proactively commissioned studies to investigate and monitor hardbottom habitat as the basis for making management decisions in the coastal zone. In 2009 DEP commissioned CSA to prepare a literature synthesis on the Ecological Functions of Nearshore Hardbottom Habitats in East Florida, and DEP followed with a Project Management Plan related to nearshore hardbottom habitats. The purpose of the program is to conduct a study to assist applicants in the appropriate design and siting of hardbottom or reef mitigation, and to assist in resolving technical differences between hardbottom or reef mitigation requirements of the State and the Corps. Balance also has been demonstrated in Palm Beach, resulting in approval for unavoidable impacts with the Phipps nourishment project through substantial mitigation. Impacts also resulted from the Mid-Town project, and steps are being taken towards an equitable solution for mitigation. The BMA also suggests flexibility on managing hardbottom resource impacts by monitoring and assessing impacts on a regional basis, potentially affording more flexibility for impacts in certain locales provided the resource as a whole is conserved within the BMA area.

Town Council posed the question of whether there are other communities that have eliminated hardbottom concerns. Although there are projects resulting in substantial impacts to hardbottom, there is no substantive evidence that a community in Florida can proceed with shore protection projects without strong constraints by hardbottom resources where they exist. Examples where substantial impacts result are generally associated with projects with limited upfront analysis and/or poor construction controls and processes, as well as regions of the world where environmental policies are either non-existent, less developed, or where there is a different standard for determining the necessity for "unavoidable" impacts. Ephemeral and persistent hardbottom resources serve important ecological functions and values. It is not feasible to pursue projects that include widespread coverage of habitat, since impacts must first be avoided, then minimized, and then mitigated. Mitigation occurs when impacts are determined to be unavoidable, which is a rigorous standard by Florida and United States regulatory standards. One cannot choose to impact and mitigate, without first demonstrating that other alternatives with fewer impacts have been tried and found to fail. Projects must continue to be planned with a strong consideration for hardbottom impacts and consequences. Recommendations are presented in this report for incremental adaptive management approaches including a long-term commitment and upfront cooperation with resource agencies.

3.7 Dunes

Coastal dunes provide shore protection and habitat value. Dunes are most effective when incorporated as natural, vegetated features backing a wide healthy natural or renourished beach. With a higher elevation than the beach berm, dunes provide additional protection against severe events with higher water levels and energetic wave runup. Dunes also provide a supplemental volume of sand that can be eroded during severe events to help maintain a healthy coastal system. Reports documented certain areas of the New Jersey coastline benefitted during Hurricane Sandy as a result of healthy dune systems (e.g., Hutchins and Augenstein, 2012).

Dunes within coastal systems where beaches are wide and sand is plentiful also can build during typically less energetic ocean conditions as winds transport sand that accumulates within dunes. Vegetation helps accumulate additional sand, and well-established root systems within dunes add stability during erosional periods. Dunes in Reach 1 and Reach 4 in Palm Beach are examples of healthy dunes that provide both storm protection and habitat value.

Lacking a fronting beach, dunes are difficult to maintain when regularly exposed to ocean tide and wave activity. Sand can be scarped rapidly from exposed dunes, leaving a steep face subject to slumping and further erosion. In cases where dunes are regularly exposed to ocean energy, they should be considered sacrificial for the purposes of providing temporary shore protection and supplementing the local sediment supply. Since multiple growing seasons are typically required to establish robust vegetation, investment in dune plantings is typically not recommended for sacrificial dune projects.

Figure 3-15. Example of a geotextile tube dune core courtesy of Apollo Environmental (Apollo, 2012).

When dunes are used in shore protection applications providing a last line of defense, certain measures can be taken to stabilize the dune. Sometimes called dune cores, typical methods include burying sand-filled geotextile tubes (Figure 3-15), sand bags, biodegradable coir, and even hard materials (e.g., rock or concrete) within the dune. To maintain consistency with regulatory policy and fulfill coastal resource functionality, dune cores often require uncertain and potentially costly conditions to keep them covered with sand.

Per Chapter 62B-56, Florida Administrative Code, FDEP permits the use of sand-filled geotextile containers used as the core of a reconstructed dune. Perpetual maintenance is required as long as the container is located within the dune. Once a container becomes exposed, the responsible entity has 14 days to provide a corrective action report. Corrective actions include the replacement of sand to maintain at least three feet of sand and stabilized with native beach-dune vegetation. Due to the narrow shoreline in several reaches in Town where beach nourishment is not currently performed, and the frequency of higher-energy waves along the east coast of Florida, it is cost prohibitive to obligate such a perpetual sand placement effort. The unpredictable liability associated with maintaining and covering dune cores makes them difficult to incorporate into a municipal program (i.e., uncertain budgetary requirement for public funds). Private owners may wish pursue them as a supplement to dune restoration activities assuming the owner(s) are willing to assume the financial liability to maintain the dune cores in accordance with State Code. Preliminary information from DEP indicated that perhaps only a handful of these permits have been issued since the Code was adopted, and all were small scale, private property installations.

The repetitive dune projects in certain areas of Reach 7 and Reach 8 are examples of sacrificial dunes for more temporary shore protection value. For Palm Beach, ideally all beaches would

include a natural cross-section that includes a wide, healthy beach backed by higher, vegetated dunes. This scenario would utilize vast quantities of sand, as well as substantial coverage of nearshore hardbottom resources. The Town's practice of incorporating dunes behind the beach nourishment projects should be continued and expanded where possible. For eroding areas currently absent beach nourishment due to hardbottom or other constraints, repetitive dunes can serve to provide the 15-year storm protection specified in the CCMP. Dune projects should include a sand quantity of at least the minimum 17 cy/ft, which is estimated to erode during a 15-year storm (for properties without seawalls), and ideally significantly more as sacrificial sand that will erode prior to exposure to a 15-year event. When combined with properties that have seawalls, pile foundations, or other structural protection measures, dunes can also serve to provide toe protection for the landward infrastructure.

It should be recognized that exposure of repetitive sacrificial dunes even to modest normal high tide and storm activity will erode the dunes, and dunes can be largely eroded and distributed across the beach in a relatively thin veneer within short time periods. Considering the cost per cubic yard of a truck haul operation from Ortona is ~$40 for planning purposes, and the cost per cubic yard for a typical beach nourishment project using offshore dredged sand is ~$12 for there are financial incentives to pursue wider beach nourishment projects where repetitive dunes are currently in-place. Although a beach nourishment project utilizes a larger volume of sand, the greater upfront investment in beach nourishment can reduce long-term costs. For instance, a beach nourishment project with a template of ~80 cy/ft nominally costs $1,000/ft to construct. By comparison a truck haul repetitive dune project with a template of 25 cy/ft costs approximately the same $1,000/ft to construct. The expected design life of the beach nourishment project is substantially longer, though, thereby providing a higher level of protection for a longer period of time with similar investment. Feasibility of obtaining environmental approvals and costs for environmental impact assessment work, as well as potential mitigation for hardbottom coverage associated with beach nourishment are not accounted for in this simplified analysis, which simply demonstrates the incentive to pursue beach nourishment from the singular financial perspective.

Overall, dunes should be incorporated at the landward portion of beach nourishment profiles wherever practicable, and can be used to achieve the CCMP objectives in certain locations where beach nourishment is not currently permitted.

3.8 Vulnerability Assessment and Engineering Adaptations

Extreme storms pose an immediate risk to coastal communities. Areas of Palm Beach are at risk of flooding presently, particularly on the Lake side. As shown in Section 2.5, FEMA maps indicate vulnerability to flooding during a 100-year storm, resulting in a need to consider upgrading bulkheads in certain areas particularly on the west side of the Island.

Increasing sea levels pose a foreseeable risk to developed coastal areas and to the ecological and economic resources of many coastal systems. Sea level rise is an increase in the mean sea level, measured as the average of tide levels over a specific time period. Since 1900, global average sea level has risen approximately 1.7 mm per year. Moving forward, the historical rate of sea level rise may accelerate as a result of thermal expansion of seawater, melting of land-based ice, and changing of the ocean dynamics. Consequently, the topic of accelerated sea level rise in the 21st century and beyond has been the subject of much discussion in the scientific community.

The Intergovernmental Panel on Climate Change (IPCC) advanced the current state of knowledge of past and future changes in sea level in relation to climate change. Taking this information, numerous federal agencies, including the USACE and the National Oceanic and Atmospheric Administration (NOAA), have developed sea level rise scenarios (Parris, et. al, 2012) and guidance for sea-level rise planning into civil works programs (USACE, 2011). Historic sea-level rise rates for the Palm Beach region based on long-term water level measurements are approximately 2.4 mm per year (0.1 inches per year). Projections for accelerated rates of sea-level rise indicate that an increase of up to 1.5 meters (4.9 ft) is possible by 2100.

In June 2012, a Sea Level Rise Summit was hosted by the Florida Center for Environmental Studies focused on Risk and Response and the Future of the Florida Coast. Seven (7) sessions were held focused on Florida-specific sea level rise estimates, challenges, and possible adaptations that can be pursued. Key findings showed 2.4 million of the 4.9 million people in the US living below an elevation of 4 ft are in Florida, and there are more than 100 Towns in Florida where half or more of the residents live below an elevation of 4 ft. Given the unique local challenges, conference sessions also addressed implications on insurance, economics, built environments, urban planning, and public engagement. A full report is expected in the Fall, and updates will be posted at: http://www.ces.fau.edu/SLR2012.

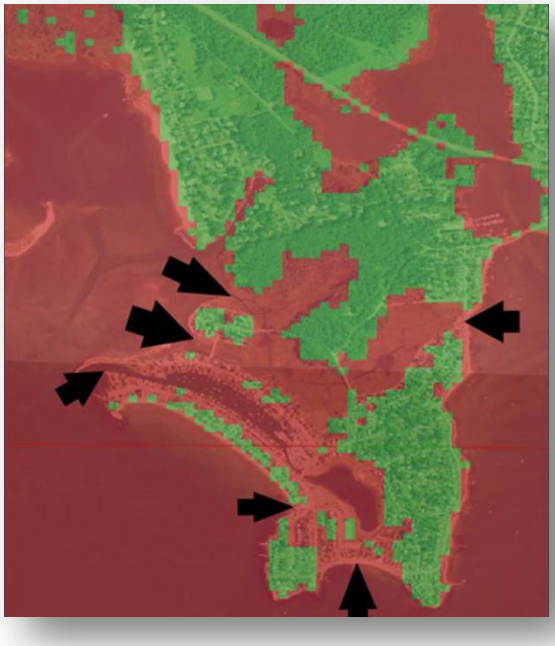


Figure 3-16. Example flow pathways identified for Groton, CT under combined sea-level rise and storm surge scenario.

The Town of Palm Beach is implementing the CCMP for current erosion of the coastline; however, with expected sea-level rise, the Town should also be planning with a vision towards the future. This is especially true given the already existing vulnerability to storm-induced flooding from the western side of the Island. The vulnerability will only increase with accelerated rates of sea-level rise. Special consideration should be given to engineering adaptations, and design elements should consider the effects of changing sea levels and storm intensity.

Numerous coastal communities have developed, or started to develop, Vulnerability Assessments and Coastal Climate Adaptation Plans that integrate projected sea-level rise and storm damage influences into their planning process. These plans typically assess the ability of coastal and other structural engineering alternatives (specifically modular and adaptable solutions) to function in response to potential future sea-level rise and/or storm surge events. Conceptual engineering alternatives typically include site-specific solutions and more regional approaches. Solutions include engineering alternatives that address vulnerable pathways of flood waters to intercept flooding before it reaches vulnerable infrastructure (Figure 3-16). Coastal

protection and flood management alternatives include, but are not limited to, structural alternatives, adaptable and modular engineering concepts, flood proofing, bioengineered technology, managed retreat/relocation, elevating, flow control structures, and evacuation plans.

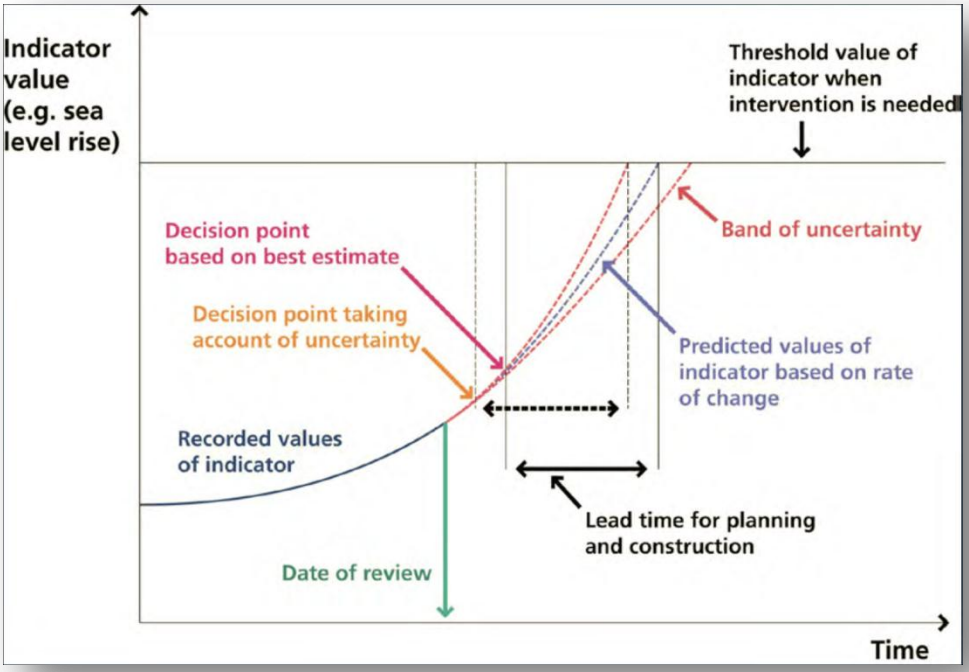


Figure 3-17. Time horizon planning components for adaptation to sea-level rise (courtesy of Simm, 2010).

Many solutions are focused on alternatives that are adaptable with time. For example, adjustable modular seawalls can be installed (increase or decrease crest, modify thickness, etc.) as sea levels change. These concepts provide alternatives and planning approaches to mitigate, minimize, or adapt to effects of sea level rise and storm events. Pros and cons of the potential adaptation options and alternatives should be evaluated, along with approximate construction and maintenance costs for planning purposes. Due to the inherent uncertainty in sea-level rise predictions, the planning should be supplemented with ongoing observations to help guide the selection, design, and implementation timeframe for potential solutions. Certain adaptations or engineering solutions may not be essential at the present time, but may become more critical in the future.

These adaptation timeframes will allow for appropriate planning, definition of potential trigger decision points for implementation, and provide a basis to monitor climate changes (e.g., measured sea level rise) prior to investing significant capital in potential solutions (Figure 3-17).

Specific recommendations include long-term planning for sea-level rise to include a Coastal Climate Adaptation Plan that would:

- Identify areas presently vulnerable to storms

- Assess ranges of future vulnerability due to storms with sea level rise
- Develop maps showing vulnerable properties and pathways
- Identify possible adaptations (phased) that the Town and residents can pursue

4.0 SHORE PROTECTION ALTERNATIVES-VALUE ASSESSMENT

This section evaluates a selection of shore protection alternatives relative to performance and value. Preliminary evaluations of project performance and potential cost savings are included. Results provide basic confirmation for some recommendations, based on first-order technical analyses that evaluate the relative performance and cost implications for various shore protection actions. The analyses are not detailed assessments typically performed for engineering analysis or design, and include basic assumptions and simplifications. Rather, the analyses are geared towards providing a preliminary estimate of value for planning purposes, focused primarily on the performance and cost effectiveness of a selected alternative or action. The analyses are intended to be an initial screening tool. More detailed assessments would be required for design or more formal cost-benefit or value engineering study.

4.1 Value of the Sand Transfer Plant

The Town of Palm Beach invests significant effort and expense to maintain and operate the sand transfer plant (STP) at the Lake Worth Inlet (Figure 4-1). The STP, built in 1937, transfers sand from Singer Island to Palm Beach by bypassing Lake Worth Inlet. The STP is considered to be a critical component of the overall coastal management plan for transferring sand that would have naturally been transported to Palm Beach absent the inlet. From a practical perspective, it makes sense to continue to operate and maintain the STP; however, the STP consumes a relatively significant expenditure to operate and maintain. Over the last 18 years, the STP has cost approximately $7.6 million (averaging $425,000 per year), including operational costs as well as upgrade and repair costs. Although it appears to be practical and functional, a natural question is whether the benefits of the STP warrant these annual expenditures, or could an improved benefit be realized by applying these expenditures to another

Figure 4-1. The sand transfer plant on the north side of Lake Worth Inlet (photo courtesy of http://portofpalmbeachpost.com).

shore protection option? For example, by not operating the STP, would more material be available for dredging at a lower cost to the Town?

From a cost perspective, the amount of sediment bypassed by the STP over the last 18 years was approximately 2,600,000 cubic yards. This equates to a sediment cost of approximately $2.92 per cubic yard via the STP bypassing. Compared to other sand sources (e.g., offshore and upland sources), which cost anywhere from 3 to 15 times as much, the STP sand source represents a significantly cheaper source of sediment. This inlet sediment is also the native sediment that would naturally be transported to Palm Beach in lieu of the Lake Worth Inlet and its associated structures. As such, despite the potential uncertainty associated with the fate and transport of the bypassed sediment, the cost of the sediment alone likely warrants the continued cost associated with the STP.

Based on monitoring data between 1997 and 2010 (ATM, 2011), the area between Florida Department of Environmental Protection (FDEP) monuments R-76 and R-79 (encompassing Reach 1 and the northern end of Reach 2) has experienced a net volumetric increase of approximately 755,000 cubic yards (+58,000 cubic yards per year) from the shoreline to the -26.5 foot contour. This increase is approximately 37% of the total volume bypassed via the STP over the same timeframe. It is likely that some of the accretion in this area is also due to other sources (e.g., USACE dredge disposal in the nearshore zone). Therefore, at most, approximately 37% of the sediment bypassed has remained in this area and roughly indicates that a significant portion of the bypassed sediment is being transported out of the Reach 1 area. However, it is unclear exactly where to, or on what timescale, this sediment is being moved. For example, the nearshore zone just to the south of this accretion area (FDEP monuments R-79 to R-82) has lost approximately 87,000 cubic yards (-6,700 cubic yards per year). Although it may be expected that the bypassed sediment would also result in some level of accretion in downdrift areas, perhaps an influx of bypassed sediment has simply reduced the erosion rate in this section. A portion of the bypasses sand also has likely moved offshore.

Compared to other sand sources, which cost anywhere from 3 to 15 times as much, the STP sand source represents a significantly cheaper source of sediment (less than $3 per cubic yard).

Therefore, based on the information available, the continued operation of the STP is warranted to maintain the health of the Reach 1 and Northern Reach 2 shorelines, as well as some potential benefits to the system as a whole. Given the STP operation comprises a relatively significant portion of the overall coastal management plan budget, and benefits to downdrift beaches are uncertain, recommendations are provided to utilize sand from the inlet at other locations in Town.

4.2 Cost Considerations for STP Discharge Extension

One alternative explored by the Town is the an installation of a second discharge for the STP located approximately 3,000 feet south of the current discharge. The intentions of this discharge extension are:

- to place bypassed sediment farther south in the littoral system to encourage downdrift transport; and
- to allow for multiple discharge locations from the STP for more adaptive management ability of the bypassed material

Implementation of this project would most likely include drilling a pipeline extension along with a booster pump and other appurtenances. The extension would include two discharge points. The cost for this extension could approach $10 million, and there is substantial uncertainty with this estimate pending geophysical borings. The USACE currently has allocated $2M for the project. Additional federal funding may be secured for construction, but would require legislative action that is uncertain given the prevailing federal economic climate. This represents a significant expenditure for the USACE and perhaps Town.

Due to the cost and other factors, other options of forepassing sediment from the current STP discharge location were considered and compared to the discharge extension option. For example, a mechanical forepassing program (via trucking or a land-based mobile dredge system) could be established, implemented, and monitored to identify the potential benefits and impacts of placing a portion of the bypassed sand further to the south. This approach would eliminate the present day capital cost associated with installing a discharge extension, while providing the ability to monitor the performance and behavior of sediment placed further south along the coastline. The cost associated with a manual forepassing (trucking) operation of sand from Reach 1 to the proposed extended discharge point would be on the order of $6/cy. Assuming an incremental $5M construction cost would be borne by the Town, 50,000 cubic yards per year of sediment could be transported and graded for more than 15 years for the equivalent capital cost of the discharge extension. All of the STP bypassed sediment (approximately 150,000 cubic yards per year) could be forepassed and graded for ~5 years for the equivalent capital cost of the discharge extension. This does not include other possible costs to the Town associated with environmental mitigation for possible hardbottom impacts, as well as operation, maintenance, and repairs that could add millions to the Town cost for the project.

Mechanical forepassing of sediment allows a cheaper short-term option for getting sediment from STP bypassing further south in the system and allows for performance monitoring without a costly pipeline extension.

Since the southern limit of the USACE inlet dredging/beach nourishment project is also in the vicinity of the proposed discharge pipe extension, Woods Hole Group recommends observing the performance of the 2013 dredging project to determine whether sand placed at that location provides meaningful benefits to the shoreline. It is also recommended that the Town obtain permits to allow mechanical forepassing of impounded Reach 1 sand and/or a portion of the STP bypassed sand to areas to the south. These methodologies can be applied and monitored first to determine the effects of placing sediment at the proposed extended discharge location prior to proceeding with the STP upgrade project.

4.3 Influence of Grain Size on Beach Nourishment Performance

Beach nourishment projects within the Town of Palm Beach (Mid-Town and Phipps) could potentially utilize a number of alternative sand sources (Section 3.6) of various grain size sediments that can affect performance. This analysis compares the expected performance of the Phipps Nourishment project based on utilizing different sources of sediment for relative performance comparison. The basic conclusions from this assessment could also be applied to Mid-Town or other future nourishment projects. The sand sources evaluated include:

- Lake Worth Inlet sand with an average grain size of 0.33mm
- An ideal, local offshore borrow site with an average grain size of 0.25mm
- An upland sand source (Ortona Sand) with an average grain size of 0.57mm
- Imported aragonite sand with an average grain size of 0.42mm
- A common offshore sediment with an average grain size of 0.20mm primarily analyzed for comparison purposes

A first-order analysis of beach nourishment performance using the various sand sources was conducted. At this preliminary level, the analysis assumes that constructing the beach from each of these sources is logistically feasible, and the necessary volume of sediment is readily available. Although, this assumption may be invalid for certain sources (e.g., it is unlikely that the entire Mid-Town project could be constructed in one season using an upland sand source or maintenance sand dredged from the inlet), the objective of the analysis is a relative comparison between the various sources for future planning. The analysis is a simplified approach focused on providing relative comparisons to assist planning. The analysis is not based on a detailed assessment of the coastal processes, nor should it be used to provide design lifetimes.

A brief analysis, which combines the conservation of sediment equation with the linearized transport equation, was conducted to determine the performance of the various sand sources. The *Pelnard-Considére* (1956) equation is used to obtain theoretical results to establish design and performance standards for the Phipps nourishment. The *Pelnard-Considére* equation can be applied to determine the performance of a beach nourishment project. A more detailed description of the derivation of the equations and their applications can be found in Dean (2002).

For this analysis, the Wave Information Study (WIS) time series of wave and wind data, developed by the United States Army Corps of Engineers, were used to describe the wave climate offshore of Palm Beach. A representative two-dimensional spectrum was generated for each approach direction to create a 20-year evaluation of wave impacts at the shoreline. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000), and identifies all potential approach directions, including those that may occur only a small percentage of time during a typical year, but potentially have significant impact on sediment transport. Values of alongshore diffusivity were computed for each directional bin and used for modeling beach nourishment performance.

Since the material spreads over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. Subsequently, nourishment alternatives and varying sand sources can be compared based on longevity. For this analysis,

service life of the beach nourishment is defined as the percent of the initial beach nourishment left within the boundary of the initial fill. The percentage remaining decreases with time, but the material is not necessarily lost from the system. Sediment may have been transported offshore or along the beach. Although the sediment no longer falls within the initial nourishment template, it has not completely disappeared from the system.

Figure 4-2 presents the projected performance of the Phipps project for the various sediment sources. The performance is expressed in terms of the percent of initial material remaining along the vertical axis, with time in years along the horizontal axis. Beach nourishment performance results are presented for a beach nourishment constructed from Lake Worth Inlet sand (black line), Ortona sand (red line), Aragonite (green line), an offshore site with 0.25mm sediment (purple line), and an offshore site with 0.20mm sediment (blue line). For example, after 7 years, approximately 40% of the initial fill volume is remaining in the template area if utilizing the offshore borrow site (0.25mm sediment), or approximately 480,000 cubic yards of an initial 1.2 million cubic yard nourishment at Phipps. A total of approximately 720,000 cubic yards would be required in a periodic nourishment to return the nourishment template to the design after 7 years.

Figure 4-2 compares nourishment performance for various sediment sources. Table 4-1 shows the percent of nourishment remaining in the template area after 5 years for each sediment source. Increased performance is predicted for coarser sediment. For example, Ortona (upland) sediment performs better than the offshore sediment. After 5 years, a nourishment project constructed with Ortona sand has 62% remaining, approximately 20% more (240,000 cubic yards) than a project constructed with offshore sand (0.20mm).

Table 4-1. 5 year performance at Phipps for various sediment sources.

Sediment Source	Percent Remaining after 5 years
Lake Worth Inlet	51%
Ortona	62%
Aragonite	55%
Offshore (0.25mm)	48%
Offshore (0.20mm)	42%

Although coarser sediment performs better, it is not necessarily the most cost-effective. Results of the performance analysis (Figure 4-2) were combined with cost estimates for various sediment sources (section 3.6) to develop a life cycle cost assessment over a 50-year time horizon.

This first-order analysis of cost implications is presented in Figure 4-3, which presents the total cost of maintaining a beach nourishment project at Phipps over a 50-year time horizon. The total cost is presented on the vertical axis, and comparisons are made to a base Phipps project assumed to be constructed using offshore sediment with an average grain size of 0.25mm. Table 4-2 presents the Phipps cost differences (compared to 0.25 mm sand) over a 50-year time horizon when utilizing various sand sources.

Although Aragonite and Ortona (upland) sand perform significantly better than finer grain material, the increased cost associated with this material renders them far less cost effective.

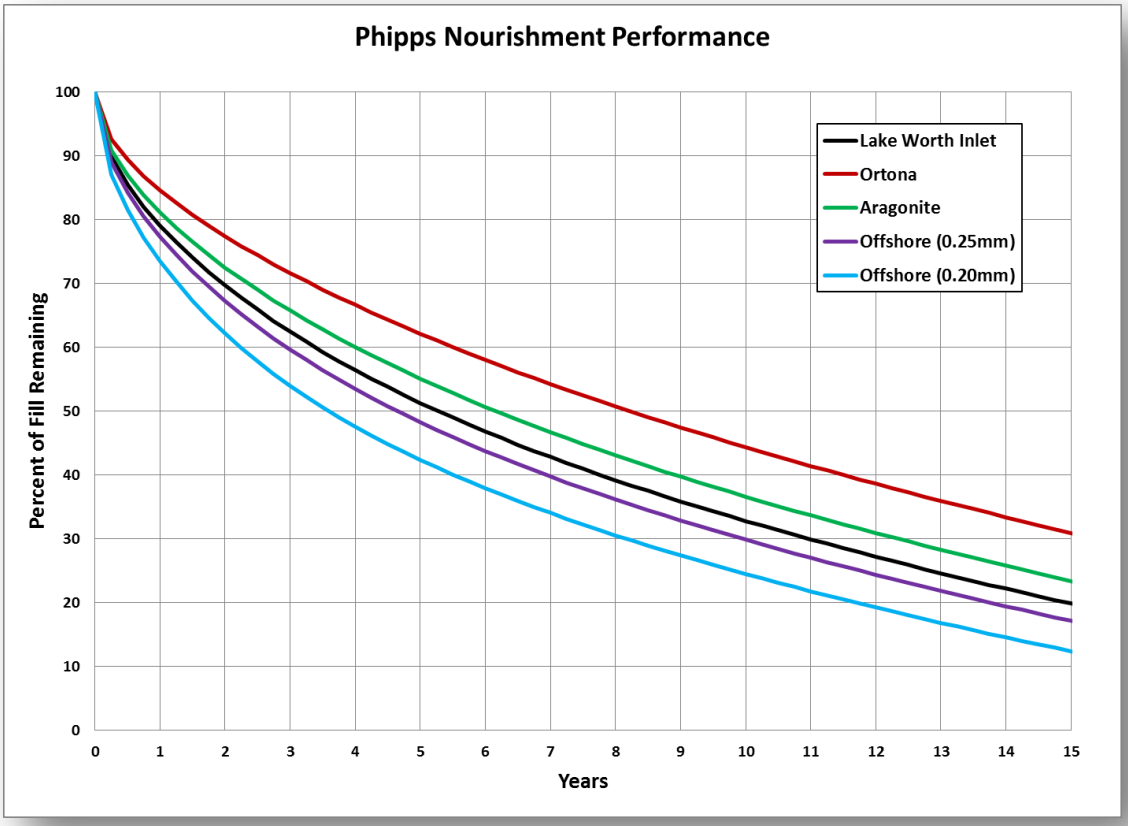


Figure 4-2. Estimated beach nourishment performance for the Phipps project using various sediment sources.

Figure 4-3 summarizes the total cost of maintaining a beach nourishment project at Phipps over a 50-year time horizon. Total cost is presented on the vertical axis, and comparisons are made to a base Phipps project constructed using offshore sediment with an average grain size of 0.25mm.

Results indicate the most cost effective material is the Lake Worth Inlet dredged sediment (and bypassed material), which should be prioritized as a sediment source, not only for disposal at Reach 1 and 2, but also for all projects throughout Palm Beach. However, it is unlikely that the total required volume for initial construction of a project at Phipps or Mid-Town would be available solely from the inlet. Inlet sand does provide a viable source for maintaining projects constructed first with offshore borrow site sand to extend the lifetime and reduce long-term costs. The analysis also indicates that although coarser grain material is expected to perform

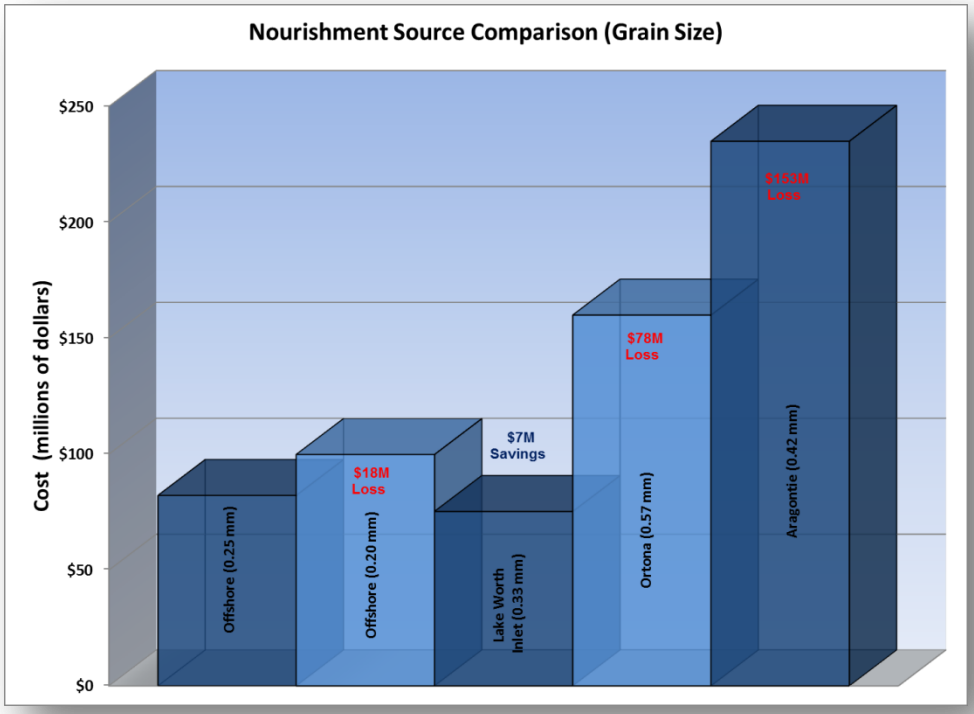


Figure 4-3. Estimated costs over a 50-year time horizon using various sediment sources to construct the Phipps nourishment project.

more effectively, the increased cost of acquiring and placing this material does not make it nearly as cost effective as more frequent nourishments using finer grain offshore sediments. Finally, this analysis indicates the proposed approach of using the offshore sediment with an average grain size of 0.25mm appears to be the correct approach for initial construction of projects. This sediment represents the second most cost-effective source. Sufficient quantities are currently readily available as a nourishment source, and construction methods have suitable production rates for a project of this magnitude. Subsequent periodic nourishments, completed on a scheduled and more frequent time scale, should target Lake Worth Inlet sediment as a source for these maintenance projects.

Sediment from Lake Worth Inlet represents the most cost-effective source of sediment for beach nourishment projects at Palm Beach due to the combination of reasonable cost with improved performance.

Table 4-2. Total cost and cost differences (compared to 0.25 mm sand) over a 50-year time horizon when utilizing various sand sources to construct the Phipps nourishment project.

Sediment Source	Approximate Total Cost (millions)	Cost Difference (millions)
Lake Worth Inlet	$75	$7
Ortona	$160	-($78)
Aragonite	$235	-($153)
Offshore (0.25mm)	$82	$0
Offshore (0.20mm)	$100	-($18)

4.4 Northward Expansion of Mid-Town Nourishment

This strategy considers the potential benefits of expanding the current Mid-Town project from its current length of approximately 12,700 feet by adding 1,050 feet to the northern end of the template into the southernmost portion of Reach 2. The intent of this expansion would be to enhance updrift spreading of the Mid-Town project into Reach 2, providing additional sediment to the narrow beach there while also bolstering the overall performance of the Mid-Town project. The relatively modest increased length would be focused on avoiding direct impacts to the hardbottom in Reach 2.

A modest expansion in the Mid-Town project length to the north has appreciable benefits to the Reach 2 area.

Figure 4-4 provides plan view of the Palm Beach shoreline in the vicinity of the Mid-Town project area. The horizontal axis represents distance alongshore, and also provides FDEP monuments for reference. The vertical axis shows the approximate beach berm width in feet. The blue lines represent the approximate berm width increases relative to existing shoreline position (zero) following the placement of nourishment at Mid-Town. The solid blue line shows the idealized shoreline planform immediately after the current template project has been constructed, while the other blue lines show the idealized dispersion of the beach after 5 years (double line), 10 years (dashed line), and 20 years (dotted line). The green lines represent the approximate berm width increase for an expanded template project. The subsequent green lines indicate the expected dispersion of the berm width as a function of time (years following the expanded nourishment). The analysis is similar to the methodology presented in Section 4.3 and includes a background erosion rate.

Results indicate that even the relatively modest increase in project length (approximately 1,050 feet of additional length north) has potentially appreciable benefits to Reach 2. The increased project footprint provides increased project longevity in Reach 2 and in the northern portion of Reach 3. The expanded template also improves sediment supply to the southern portion of Reach 2 and provides sediment to an area (over 1,000 feet) that would not have benefited from the Mid-Town project dispersion under the current template configuration. From a value standpoint, the extended project requires additional upfront construction investment on the order of $1.4M (assuming no mitigation). Due to the incremental improved performance of the project as a whole, though, the life cycle cost would break even to maintain the additional 1,050 section.

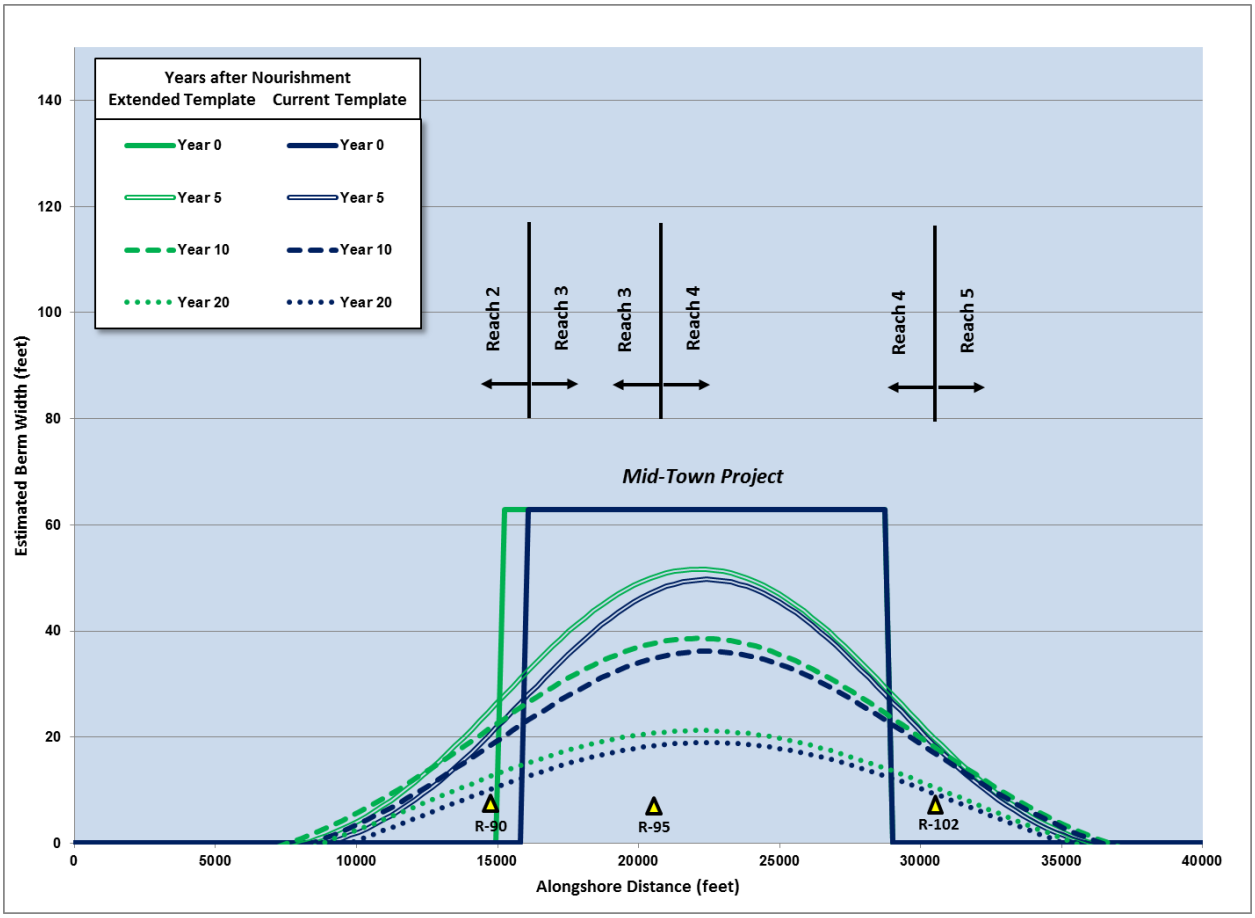


Figure 4-4. Plan view of nourishment dispersion at Mid-Town for existing project template (blue lines) and an expanded project template (green lines).

4.5 Impacts of Nearshore Borrow Sites on Nourishment Performance

The sand search investigations conducted by ATM for the Town of Palm Beach during 2011 and 2012 identified six (6) potential offshore borrow sites for use in future beach nourishment projects. Detailed geophysical investigations were used to delineate the new borrow sites and to identify beach compatible sand with mean grain sizes between 0.23 mm and 0.29 mm. To obtain the coarser sediment sizes, the new borrow areas had to be sited in the nearshore zone, generally closer to the coastline than the 0.20 mm borrow sites. Additionally, two of the south area borrow sites (SBA1 and SBA2) were located offshore of portions of the shore protection projects at Mid-Town and Phipps Park, and the third south area borrow site (SBA3) was located offshore of a potential future nourishment project in Reach 8. Due to the nearshore location of the south area borrow sites, and proximity to the beach nourishment projects, consideration should be given to potential changes in nearshore wave energy that could impact nourishment project performance.

To illustrate potential impacts of dredging nearshore borrow sites on project performance, a first-order evaluation of nourishment performance at the Phipps Park project area was completed. The evaluation compared the expected performance using finer sand size of 0.20 mm with an average size of 0.25 mm from the new borrow sites. Potential impacts from changes in wave energy caused by the proximity of the nearshore borrow sites to the shoreline were also factored

in to the analysis. Using information from a borrow area wave modeling report prepared by ATM (2012) for the northern sites, and preliminary modeling results for the southern sites (ATM, 2011), a 25% increase in wave energy along the shoreline behind the borrow sites was assumed for this analysis. ATM indicated that changes of up to 30% could occur to the alongshore sediment transport rate, and also found that shallower cuts in the borrow areas, for example a -10 ft cut, cause smaller increases in wave energy and changes to the alongshore sediment transport rate.

Figure 4-5 shows the expected performance curves for the Phipps Park nourishment project constructed with 0.20 mm and 0.25 mm sized sand, as well as the potential influence of dredging the nearshore borrow site on performance of the 0.25 mm project. The solid orange and purple lines show percent of fill remaining for the 0.20 and 0.25 mm projects, respectively, with no influence of the borrow sites. The dashed purple line shows the reduced performance of the 0.25 mm project behind an excavated nearshore borrow site causing a 25% increase in wave energy along the shoreline. As expected, the analysis shows improved performance with the coarser grain size. For example, after 6 years approximately 7% more fill is left in the project area when the 0.25 mm sand is used. However, when the potential impacts of the nearshore borrow site are taken into consideration, the percent of fill remaining for the coarser sediment is actually lower than for the 0.20 mm sediment. This reduction in project performance also would impact the long-term costs of the project. For example, in this scenario over a 50-year time horizon, the added cost would be $26 million to maintain the Phipps project with 0.25 mm sediment influenced by increased wave energy at a nearshore borrow site. This would be $8 million dollars more than to maintain the same project with 0.20 mm sediment from an offshore borrow site that did not influence the project area.

Potential improvements to project performance gained from acquiring larger grain size at nearshore borrow sites may be offset by increased wave energy at the project site.

Results from this evaluation underscore the importance of wave model studies to quantify the potential impacts of the nearshore borrow sites on wave energy focusing and sediment transport along the shoreline. This is especially true in areas where the borrow sites are directly offshore of existing beach nourishment projects, and expected levels of performance may be impacted by the changes in wave energy. Where impacts are identified, results from site-specific model studies should be used to update the beach nourishment templates and/or design lifetimes. In other areas of the coastline where beach nourishment is not currently permitted, use of the borrow sites should be managed carefully, (e.g., shallow cuts, use of seaward portion) to ensure no adverse impacts to the beaches. For borrow sites where transport pathways cause reduced sediment supply to the beach, and no landward project is currently authorized for nourishment, consideration should be given to eliminating the nearshore borrow site. This preliminary evaluation suggests the incremental improvements to project performance resulting from the coarser grain size may not be as perceived.

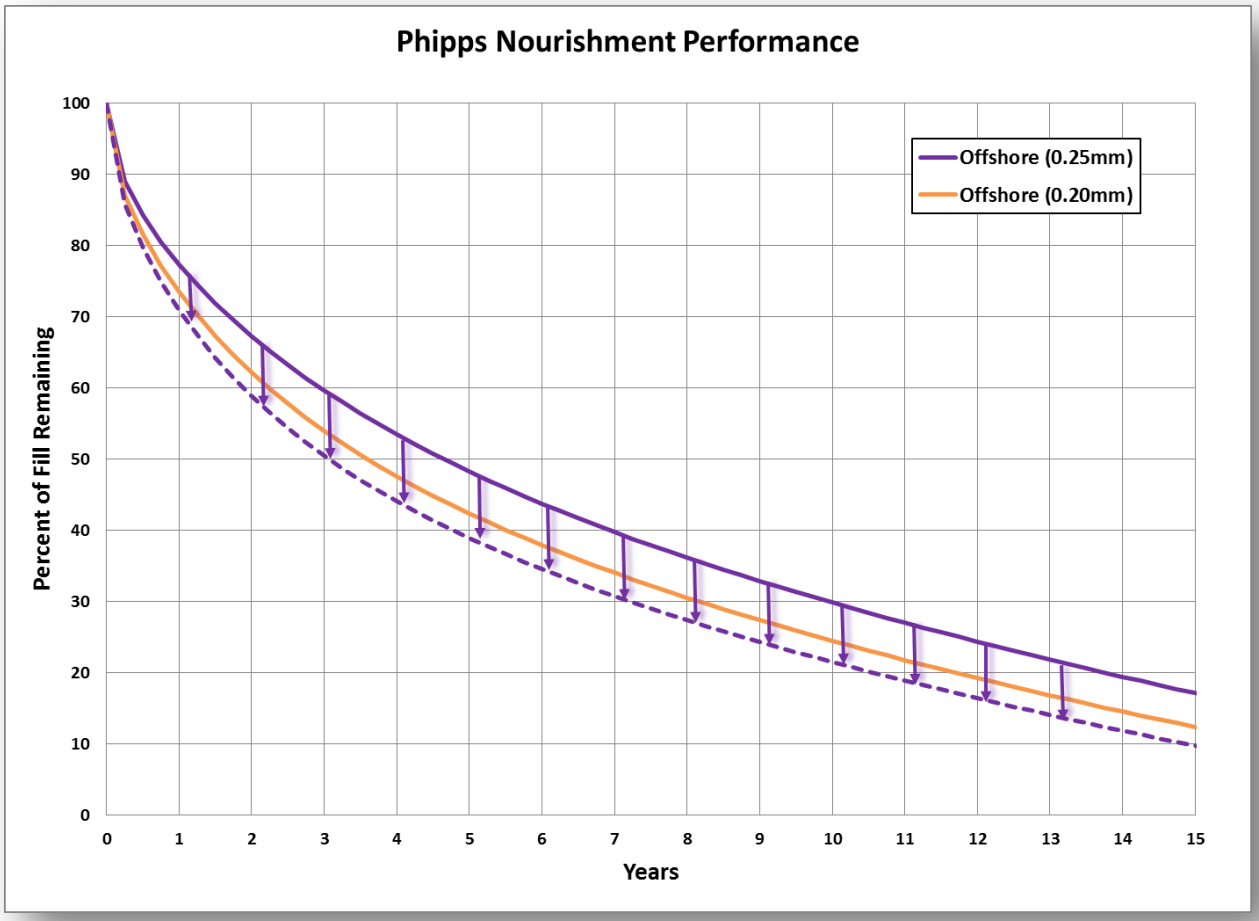


Figure 4-5. Projected impacts of wave energy changes from nearshore borrow sites on performance of the Phipps Park nourishment project

4.6 Reach 7 and Reach 8 Nourishment Project Expansion

This analysis considers the potential benefits of expanding the current Phipps project from its current length of approximately 7,400 feet by adding a 2,000 foot nourishment just south of the City Lake Worth Municipal Beach. The intent of this expansion would be to enhance the spreading of the Phipps project into Reach 8, while also bolstering the overall performance of the Phipps project. This additional nourishment component would need to be part of an EIS, and there are considerations related to potential hardbottom impacts.

Figure 4-6 shows a plan view representing the Palm Beach shoreline in the vicinity of the Phipps project area. The horizontal axis represents distance alongshore, and also provides FDEP monuments for reference. The vertical axis shows the approximate beach berm width in feet. The green lines represent the approximate berm width increases relative to existing shoreline position (zero) following the placement of nourishment at Mid-Town. The solid green line shows the idealized shoreline planform immediately after the current template project has been constructed, while the other blue lines show the idealized dispersion of the beach after 1 year (double line), 5 years (dashed line), and 10 years (dotted line). The solid blue line represents the approximate planform increase for an expanded template project. The subsequent blue lines indicate the expected dispersion of the berm width as a function of time (years following the expanded nourishment). The analysis is similar to the methodology presented in Section 4.3 and Section 4.4 and also includes a background erosion rate.

A simplified analysis was applied that does not account for site-specific physics and influence of the Pier; however, results are instructive for planning purposes. Results indicate the additional Reach 8 nourishment, although relatively small, provides a significant benefit to the downdrift shorelines in Reach 8, while also improving the overall performance of the Phipps project north of the Pier. From a value perspective, there is not a cost savings to achieve since substantial additional investment is required for the additional nourishment south of the Pier. However, Reach 8 would benefit directly, and the nourishment in Reach 7 would last longer. Uncertainties associated with sediment transport from Phipps to the dry beach in Reach 8 also would be reduced with direct placement of sand on Reach 8 beaches south of the Pier. There is potential for impacts to hardbottom resources south of the Pier, which would have to be evaluated. A refined design and cost analysis would be required, based on site-specific wave and sediment transport models that include the local physics and influence of the Pier. It is possible the sheltering effect of the Pier will reduce the potential for transport and hardbottom impacts. The geometry of the nourishment south of the Pier would also be refined to minimize impacts.

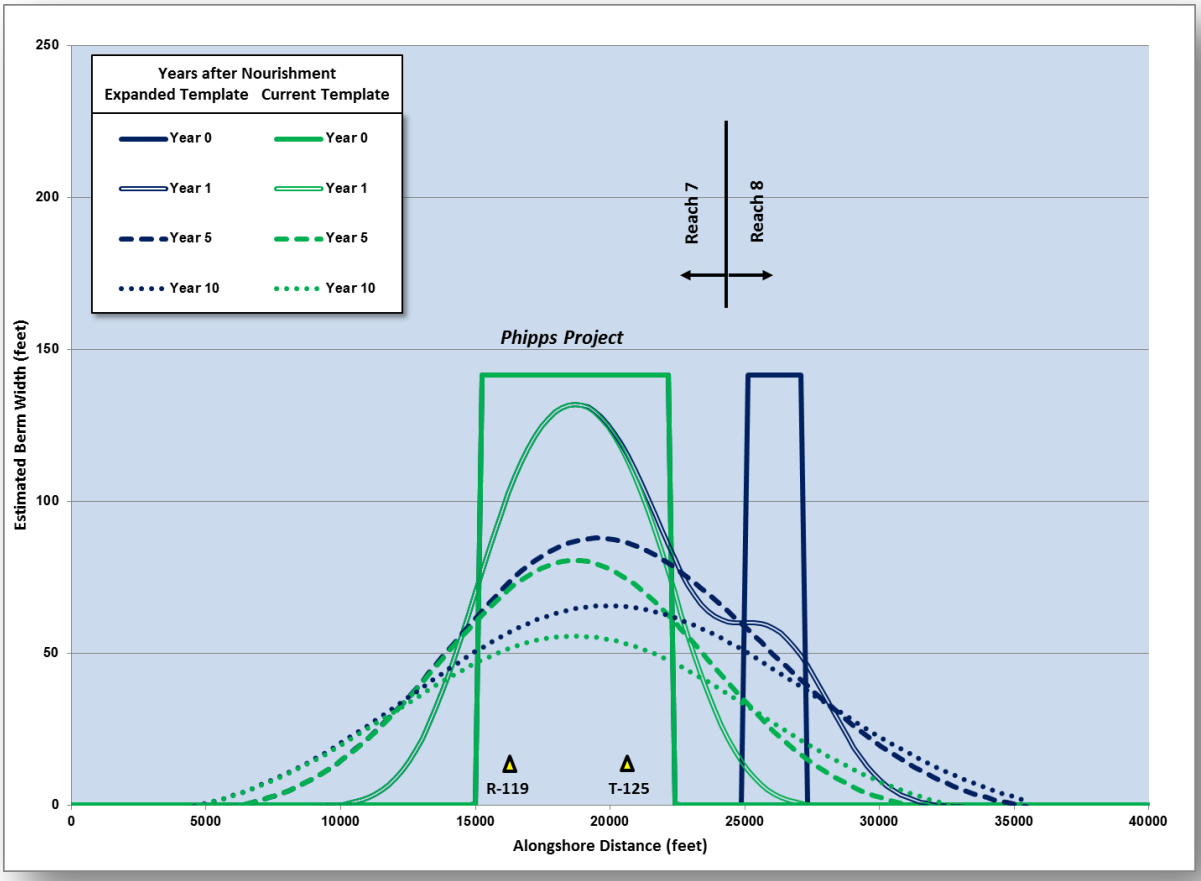


Figure 4-6. Plan view of nourishment dispersion at Phipps for existing project template (green lines) and an expanded project template (blue lines) that adds a small nourishment in Reach 8.

5.0 RECOMMENDATIONS AND NEXT STEPS

This section provides itemized recommendations in Tables 5-1 through 5-3, supported by a rationale and assigned a priority level:

- Priority 1. Activities recommended immediately
- Priority 2. Items to implement after Priority 1 as funds are made available
- Priority 3. Items to consider for the future

The tables also indicate whether the recommendation is included in the FY 2013 Coastal Management Program Plan, and if the project or activity is included in the Draft BMA. Overall Recommendations in Table 5-1 apply to the Island as a whole, or at least to multiple Reaches. The Overall Recommendations include additional data collection and analysis that lend greater insight, improve project design, and aid future decision-making. Table 5-2 provides Inlet Management Recommendations, which also have the potential to affect the Island as a whole or multiple Reaches. Reach-specific recommendations are provided in Table 5-3, along with maps indicating where recommendations apply.

Recommendations are comprehensive, reflecting the need to take action and continue the substantial investment to maintain the Palm Beaches. Each recommendation is assigned a number. An "O" nomenclature applies to Overall Recommendations, and an "I" applies to Inlet Recommendations (e.g., O-1, O-2, O-3, etc. for Overall Recommendations; I-1, I-2, etc. for Inlet Recommendations). Reach-Specific recommendations are numbered by Reach (e.g., 1-1, 2-1, and 3-1 for Reaches 1, 2, and 3, respectively).

This section also addresses select primary decision points requested specifically by Town Council members during stakeholder interviews (Section 5.1), suggests pilot projects (Section 5.2), and suggests next steps for completing the project (Section 5.3).

5.1 Primary Decision Points

Several recommendations are related to primary decision points facing Town Council on which Woods Hole Group was asked directly to offer an opinion. A more in-depth rationale for these recommendations follows:

Sand Transfer Pipeline Extension: Although finalization of a commitment from the USACE for the project is strongly recommended, implementation of the pipeline extension should not be pursued at this time and should be reserved for the future. There is a certain need and strong recommendations throughout this report to better utilize inlet sand on beaches farther south from the inlet. There also is a desire to leverage the USACE commitment of substantial funding for the pipeline extension.

However, reality is the pipeline extension will not place sand any farther south than currently possible through the maintenance dredging project. There also is no certainty that placement of more material at this location will benefit downdrift beaches other than in the near vicinity of the placement location. There are other methods that should be implemented first before committing to the pipeline extension, including direct dry beach placement by the USACE using the new

lowest cost cutterhead pipeline dredging method, as well as mechanical forepassing of sand by the Town from the current STP discharge location. If these projects prove the new discharge location is beneficial, then proceeding with the extension may be more attractive provided there is an ability to increase the USACE currently available budget of $2M to fund complete construction of the upgraded facility, which requires legislation expected to be challenging in these economic conditions.

Another factor leading to the recommendation not to proceed with the STP extension in the short-term is the likely requirement for substantial Town funds to cost-share the project above the USACE commitment, including: design and recommended upgrades beyond what the USACE can fund; hardbottom mitigation; and future operation and maintenance including repairs for damages to a more substantial pump and pipeline system, which are likely given history of operation of the current STP. Actual project costs could approach $10M, which with the current $2M USACE cost-share could incur up to $8M in Town investment. The project also is controversial amongst residents, which alone should not force a decision, but should factor in respectfully considering uncertain benefits and costs to the Town. The funds would be better utilized in the short-term for more direct placement of inlet sand on beaches farther south in Town.

Reaches 7 and 8 Project Enhancements: Two (2) key areas of concern are at the north end of Reach 7 from Phipps Park to Sloans Curve, and the south end of Reach 8. Both of these areas have more narrow beaches than desired by residents, are subject to storm damage, and solutions to date are limited as a result of natural resource considerations primarily related to nearshore ephemeral hardbottom. Although there is a need for more data and engineering analysis to substantiate the conceptual designs put forth by Town and SoS consultants, more aggressive engineering solutions involving larger volumes of coarser sand with coastal structures would help maintain wider beaches and improve storm damage protection locally. Based on the information reviewed, Woods Hole Group also is of the opinion that more aggressive measures might eventually be included at these locations to achieve a 6+ year design life, which is not possible using repetitive dunes only in a cost-effective manner.

However, implementation of ideal coastal engineering solutions in the short-term may not be feasible (to be determined through the EIS process). Hardbottom considerations are substantial, and must be approached incrementally first via avoiding impacts, then by minimizing impacts, and finally by mitigating unavoidable impacts. Necessity for unavoidable impacts has not yet been proven to the resource protection authorities, particularly at the federal level. Project performance also is not fully proven, and will necessitate monitoring of a full renourishment template prior to gaining permits for more aggressive solutions. Repetitive dunes combined with the presence of seawalls and pile supported conforming structures are advancing the 15-year protection goal set forth by the Town's CCMP, but at considerable expense. The goals are not fully achieved, which is understandably frustrating to residents. It is not clear also whether the CCMP objectives align with resident preferences for wider beaches. In this regard, these areas are not unlike Reaches 2 and 6 where little beach resource exists, but protection is afforded through coastal structures.

However, advancements have been made, and from a resource protection perspective there are less aggressive measures to be approached incrementally with a long-term view. For these

combined reasons, Woods Hole Group is recommending enhanced sand only projects for the next round of Reach 7 and 8 projects as part of a long-term incremental, adaptive management approach to these areas. Although not guaranteed approval particularly for Reach 8 south of the Pier, sand only projects are the natural next step. As of April 8, 2013, the entire Town of Palm Beach shoreline, including Reach 8 south of the Lake Worth Pier, is designated by FDEP as critically-eroded, which will hopefully introduce more flexibility in the regulatory process to demonstrate the project need. Implementation of pilot demonstration projects also is encouraged in cooperation with the range of stakeholder involved. This is admittedly not the ideal solution from an engineering and economic perspective, but represents a balance of interests in a more feasible manner.

From the Town's perspective of achieving the CCMP goals, the primary driver for advancing solutions beyond repetitive dunes is cost-effectiveness. Simplified analysis shows that one beach nourishment project using local offshore sand borrow areas results in a similar cost per foot of a truck haul dune project with a certain shorter design life. Therefore, there is incentive to advance a more robust solution.

Forcing aggressive short-term solutions, though, will likely result in significant delays and added costs, meanwhile delaying supplementing the long-term sand deficit, which is a primary source of the erosion problem in the first place. The incremental approach should not be utilized as a means to continually expand a project assuming any less stringent environmental review. Future project modifications and regulatory approvals will require a clear demonstration that the prior projects either did not perform as intended and/or that environmental impacts were different than anticipated thereby warranting further action. Merely proposing a more aggressive solution within the same context will result in a similar ruling by prevailing regulatory authorities. Therefore, clear definition of project performance expectations and resource impacts is essential along with careful monitoring. The adaptive management approach should be discussed in good faith with the regulatory authorities in the initial application process to ensure expectations are clearly established.

The recommended plan for Reaches 7 and 8 includes the following elements, specifically identified with cost estimates in the Recommended Plan in the Executive Summary:

- Short-term berm and dune protection coordinated with the next Mid-Town renourishment in FY 2014. Up to 150,000 cubic yards of additional sand is recommended to be stockpiled and truck hauled to Reaches 7 and 8 during the next Mid-Town project. The exact location for placement shall be specified by the project design engineer.
- The intent of the short-term truck haul coordinated with the Mid-Town project, then, is to offer interim protection while the Reach 8 EIS progresses, hopefully allowing a larger-scale feeder beach south of the Pier in Reach 8 concurrently with the next full Phipps renourishment in FY2016.
- Full Phipps Park renourishment in FY2016, combined with nourishment of a Reach 8 feeder beach south of the Pier. The Phipps project should also be improved to include a wider beach fronting Phipps Park, and a full beach nourishment template extending farther south. Consultations with Town staff indicate the Phipps nourishment quantity is

assumed to be 1,000,000 cubic yards; exact quantities required to fill the template will be specified by the design engineer.

- The Reach 8 feeder beach design will be resolved as part of the EIS process, and is assumed to include up to 90,000 cubic yards truck hauled from Phipps during the nourishment project. This is an assumption for planning purposes only, as the project specifics will be determined through the engineering design and Reach 8 EIS process.
- After the short-term truck haul project along with the Mid-Town project, it is strongly recommended to nourish the full Phipps template to provide the best opportunity for lasting performance. Although it is possible the future Phipps project will include sand nourishment up to Sloans Curve (not just dunes), and perhaps structures, it is not feasible from a regulatory perspective at this time. Building and monitoring the full project performance will be an essential requirement to help prove whether an expanded template is needed to the north. Based on the compromises and public perception associated with the first Phipps project, it also is essential to build the full project with high quality sand, and objectively gauge its performance.
- Even with the expanded full Phipps template, the design engineer should re-evaluate the project design life. For planning purposes, Woods Hole Group assumed the design life for the next project will be 5 years, which may be extended in the future as more sand is added to the system (e.g., dredged from the inlet and/or truck hauled from Mid-Town) and if project improvements are made for subsequent renourishment(s) (e.g., wider profile up to Sloans Curve and perhaps structures).
- The scope and timing of subsequent renourishment projects in Reaches 7 and 8 will be determined through an adaptive management approach. For planning purposes only, it was assumed that Phipps project improvements may include an additional 75 cubic yards of sand per foot along the 2,100 ft of beach between Sloans Curve and Phipps Park, up to 4 structures, and mitigation. Also for planning purposes, the Reach 8 project improvements were assumed to include an additional 250,000 cubic yards of sand, up to 5 structures, and mitigation. There is tremendous uncertainty associated with these potential Reach 7 and 8 project improvements that would only be pursued if the next-phase of sand only projects proves inadequate. Actual designs would be resolved through subsequent engineering and EIS activities. The timeframe for the Environmental Impact Statement (EIS) process is dictated largely by the U.S. Army Corps of Engineers checklist timeline for specific process milestones required by the National Environmental Policy Act (NEPA). Project costs for Reach 8 will be dependent on the type of project ranging from sand placement only, sand placement and the inclusion of shore-perpendicular groins, sand placement and the inclusion of shore parallel breakwaters, or sand placement with a combination of groins and breakwaters. Mitigation, at an estimated cost of $1 million per acre, will be a contingency on the footprint of the project and the secondary influences of the project. Due to the cost of sand, rock materials, and mitigation, a project in Reach 8 south of the Lake Worth Pier could top $20 million in initial construction. It is premature to include a project of this magnitude in the budgetary estimate or Recommended Plan at this time; however, the 10-year plan will require updates upon completion of the Reach 8 EIS.

- As part of the overall adaptive management approach, maintenance of Reaches 7 and 8 also should be pursued using inlet sand to potentially introduce more coarse sand, gain permitting flexibility, and extend the nourishment design life.

Table 5-1. Recommendations for Inlet Management Activities

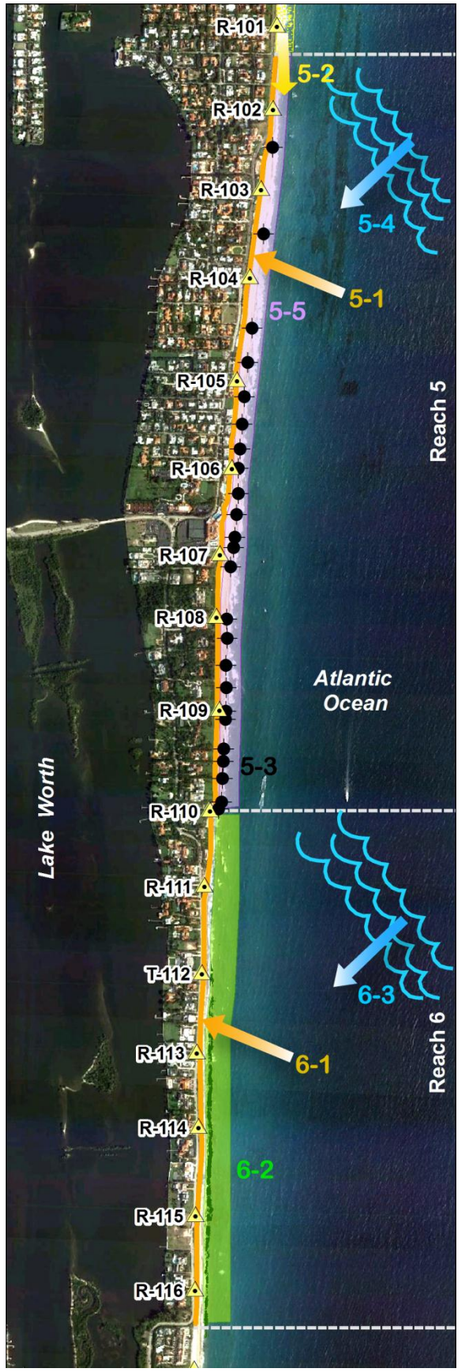
Recommendations	SPB Item	Priority	In BMA	Rationale
INLET				
I-1. Repair the sand transfer plant and establish reserve funds for future repairs given inevitable damages	67	1		Town consider providing source of cash flow to expedite repairs with subsequent reimbursement by others (e.g., County). Recognize, though, that sand will continue to accumulate for later transport if funds are needed for higher priority activities.
I-2. Continue to place sand transfer plant and dredged material on Reach 1 until flexibility can be gained for placing material elsewhere	67	1		Pursuing various options in this report for placing inlet sand in other areas is strongly recommended.
I-3. Seek a cooperative agreement with USACE related to dredging projects. Specifically achieve commitment from USACE to:	5,17, 12,18	1		
I-3.1 Allow Town participation in bid specifications for dredging projects		1		The Town needs to be involved early in the process (6+ months prior to construction) to ensure sand is placed on beaches in most need. This is particularly true for hopper dredge projects that will require arrangements to secure a pumpout hopper, determine appropriate cost-sharing, and select highest priority beaches in need of inlet sand outside of Reaches 1 and 2.
I-3.2 Primarily define cutterhead pipeline dredge method as least cost alternative		1		Cutterhead dredge is essential for dry beach placement, and is necessary considering shallow draft needed for dredging the expanded settling basin.
I-3.3 Reserve opportunity to utilize pumpout hopper dredge and establish emergency funds for rapid access when short-term USACE dredge projects arise		1		Recommend Town prepare to pay cost increment to transport and pump sand directly on the dry beach where most needed. Projects can arise quickly when navigation is threatened; therefore, access to finances in short-term is essential. The cost increment may not always be affordable depending upon quantity of sand to be dredged and location to be pumped; however, having the flexibility to take advantage is critical.
I-3.4 Coordinate permits		1		Need flexibility for USACE to place sand in beach nourishment footprints secured by Town (e.g., Mid-Town, Phipps, others TBD).
I-3.5 Pursue EIS and permits for expanded footprint for dry beach placement as per Item 2-2		2		Ideally gain permission to dispose throughout Reach 2, even for a narrow beach as per Item 2-2.
I-3.6 Pursue a pipeline corridor through Reach 2 for nourishment of Reach 3 as per Item 3-4		2		Idealistic opportunity as per Item 3-4.
I-3.7 Cost-share possible future construction of an extended sand transfer plant discharge pipeline extension		3		Although not recommended at this time since there are potentially better ways to transport the sand farther south, having USACE commitment to cost-share a future project is essential for the project to ever move forward.
I-3.8 Prioritize sand placement within the southern portions of the template		1		Data do not reveal reliable storm protection benefits south of where the material is placed in Reach 2; therefore, placement as far south as possible is required including in a future expanded footprint.
I-4. Reserve implementation of pipeline extension for future	12, 13, 14	3	Y	Pipeline extension not recommended at this time pending resolution of effective alternatives to achieve similar objectives (e.g., direct placement by cutterhead dredge in southern portions of template, southern extension of template, mechanical forepassing of sediments immediately adjacent to the inlet via truck, placement in other areas outside of Reaches 1/2).
I-5. Ensure placement on Town Beaches is preferred disposal alternative for clean, beach-compatible sand should navigation interests drive future expansion of Lake Worth Inlet		3		Although navigation interests are outside of the scope, there are ongoing activities related to future inlet improvements that will potentially produce substantial quantities of beach-compatible sand that need to be placed on dry beaches in Palm Beach, ideally not in the existing Reach 1/2 footprint.
I-6. Pursue permits to utilize finer fraction material (still beach-compatible) within backbeach and dune system in Reach 1.		3		Current practice of nearshore placement is better than prior offshore disposal; however, dune construction with the clean and beach-compatible material will provide more direct storm protection benefits.
I-7. Closely monitor sediment transport on updrift Singer Island beaches and sand quantities at sand transfer plant, expanded settling basin, and inlet		1		Need to proactively identify future trends indicating any reduced supply of inlet sand for bypassing, which will affect long-term sand needs from other sources.
I-8. Pursue tri-party inlet dredge permitting	16	2		The Town should have flexibility to obtain coarse sand from the inlet for beach nourishment throughout the Island. Inlet sand potentially offers the highest quality, most cost-effective sand for beach nourishment construction and maintenance. Should USACE funding be compromised, the Lake Worth Inlet federal navigation project be de-authorized, and/or policy prevent future placement on Town beaches, having independent permits to dredge the inlet will prove beneficial. It also is possible the Town can obtain cost-effective commercial bids to utilize inlet sand for general project maintenance and construction. Town should ensure, however, that independent inlet dredging does not compromise USACE and Port responsibilities for downdrift erosion.

Table 5-2. Recommendations for Reach Specific Management Activities

Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 1				
1-1. Renourish beach with the STP and inlet dredged sand.		1		STP and dredging activities provide more than an adequate supply of sand to maintain Reach 1. Continue present practice with understanding that beach width and sand supply exceed CCMP storm protection requirements. Alternative disposal locations for inlet sand should be pursued as a high priority.
1-2. Establish design storm protection berm with advanced nourishment.		1		A design storm protection berm meeting or exceeding CCMP goals will provide a basis for comparison to profile data to quantify whether there is impounded material in Reach 1, providing an adaptive approach for placing inlet sand elsewhere. The specific design storm protection berm required in Reach 1 should be specified as part of the recommended CCMP update.
1-3. Monitor Reach 1 profiles and compare to design berm to quantify impounded sand.		1		When the profile exceeds the design berm, there is a basis for utilizing STP or dredged inlet sand in other Reaches and/or forepassing impounded Reach 1 sand to other Reaches.
1-4. Obtain permits for mechanical forepassing of impounded Reach 1 sand to southern portion of Reach 1, Reach 2, or other future approved areas (e.g., USACE template extension).	21	1		Mechanical forepassing (via trucking) can be a cost-effective alternative for transferring impounded Reach 1 sand to downdrift beaches. Permitting process may be expedited for activities (e.g., trucking) perhaps requiring only a coastal construction control line permit.
REACH 2				
2-1. Work with citizens on field-verification of seawall condition as per overall last line of defense program (O-2).	27	1		Walls are aged and of uncertain condition, including design standard, toe protection, and deterioration. Residents need to have the condition and level of protection field-verified to determine requirements for maintenance and improvements since Reach 2 depends heavily on seawall resiliency.
2-2. Pursue with USACE flexibility to extend the disposal site and nourish a minimum dry beach width along Reach 2 as part of inlet maintenance and perhaps via forepassing from Reach 1.	21	2		Data do not show consistent natural transport of bypassed sand into Reach 2 (other than within the placement template at north end and immediate vicinity). Any southern expansion would be helpful, even including a narrow beach for toe protection or a portion of Reach 2 to Merrain Rd where there is additional public access. Transport into Reach 2 is a key uncertainty that can be quantified with more detailed monitoring data analysis and perhaps modeling.
2-3. Work with citizens on individual groin repairs, as per overall groin program (O-3).	2,3	1		Reach 2 has numerous groins of varying design and condition that collectively help stabilize the beach. Groins can help template the minimum beach required to protect seawall toes, maintain sand in the littoral system, and perhaps provide sea turtle nesting habitat. Available data do not reveal Reach 2 is consistently providing sand to Reach 3, so anticipated downdrift impacts are limited, providing the opportunity to repair groins with limited anticipated consequences. The Coastal Tech report economic analysis demonstrated a substantial cost savings to maintain a narrow beach in Reach 2 with groins in-place. Supplemental sand to maintain groin fillets could be provided via expanded inlet dredge disposal footprint and/or mechanical forepassing from Reach 1. Repairs to specific groins can be resolved cooperatively between consultants based on extensive prior work.

Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 3				
3-1. Work with citizens on field-verifying seawall condition as per overall last line of defense program (O-2).		1		Walls are aged and of uncertain condition, including design standard, toe protection, and deterioration. There may be properties currently lacking protection or with under-designed protection eligible for future seawalls or other last line of defense measures. Potentially eligible properties should be identified and monitored for proactive planning.
3-2. Maintain Reach 3 part of Mid-Town project.	30, 21	1	Y	Data do not show sand transport from Reaches 1 and 2 onto the storm protective beach berm in Reach 3. Transport into Reach 3 is a key uncertainty that can be quantified with more detailed monitoring data analysis and perhaps modeling.
3-2.1 Construct concurrently with remainder of Mid-Town in Reach 4 whenever possible.		1		The longer project has the potential for a longer renourishment interval.
3-2.2 Utilize inlet sand for maintenance with pumpout hopper dredge when possible.		1		Inlet sand is of higher quality, reduces dependence on offshore sources, and allows for potentially more frequent maintenance (when coordinated with inlet maintenance dredging) to extend renourishment intervals. Will require coordination with USACE and perhaps cost-share for incremental cost increase.
3-2.3 Ensure full construction of northern template to help stabilize Reach 2.		1		Data indicate stabilization of the southern end of Reach 2 as a result of beach nourishment in Reach 3.
3-3. Pursue expansion of Mid-Town nourishment footprint into southern portion of Reach 2.		1		An expanded nourishment will last longer and benefit more of the southern end of Reach 2.
3-4. Pursue flexibility (perhaps with USACE) to place a pipeline for direct dry beach nourishment of Reach 3 as part of inlet maintenance dredging.		2		An idealistic opportunity with substantial benefits allowing direct maintenance of Reach 3 nourishment, and also stabilizing the southern end of Reach 2 with high quality inlet sand. Hampered by several obstacles (offshore hardbottom, private property easements, lack of constant dry beach elevation, groins of varying heights and repair along pipeline route in Reach 2). Consider as future endeavor, particularly if a narrow beach can be established along Reach 2 to lay pipe.

Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 4				
4-1. Establish program for inspection and classification of seawalls, as per overall last line of defense program (O-2).		1		Walls are aged and of uncertain condition, including design standard, toe protection, and deterioration.
4-2. Maintain Mid-Town project.	30, 21	1	Y	
4-2.1 Quantify sand volume needs based upon position of monitoring profile compared to design cross section.		1		Renourishment volume needs at Mid-Town may be reduced over time due to accumulated profile and dune system.
4-2.2 Construct concurrently with remainder of Mid-Town in Reach 3 whenever possible.		1		The longer project has the potential for a longer renourishment interval. A key uncertainty is sediment transport between Reaches 3 and 4 as related to the dry beach berm. The properties and structures from the Breakers to Barton Avenue potentially have a significant influence. This is a key uncertainty that can be resolved with more detailed monitoring data analysis and perhaps modeling.
4-2.3 Utilize inlet sand for maintenance with pumpout hopper dredge when possible.		1		Inlet sand is of higher quality, reduces dependence on offshore sources, and allows for potentially more frequent maintenance (when coordinated with inlet maintenance dredging events) to extend renourishment intervals. Will require close coordination with USACE and perhaps cost-share for incremental cost.
4-3. Construct new groin at Gulfstream if necessary to protect critical infrastructure; maintain other groins as per overall groin program (O-3).	30a	2	Y	Only introduce the new groin if the local erosion threatens the seawall and road. Must also concurrently fill the groin to entrapment to minimize initial potential downdrift influence. Repairs to specific groins can be resolved cooperatively between consultants based on extensive prior work.
4-4. Update Mid-Town design (template or design life) to account for potential influence of dredging South Borrow Area 1.		1		Accelerated losses (through increased wave energy and perhaps cross-shore losses within depth of closure) are possible in the lee of the borrow site.

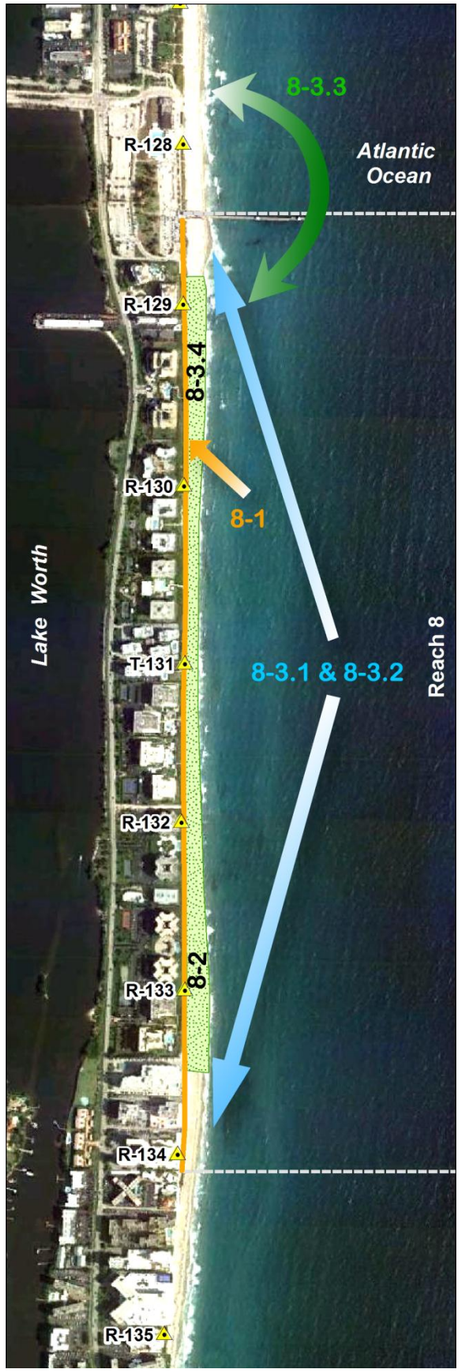


Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 5				
5-1. Establish program for inspection and classification of seawalls, including identification of properties with future potential eligibility for structural protection as last line of defense (O-2).		2		Depending upon future patterns of erosion, some Reach 5 properties may require and may be eligible for a last line of defense. These properties should be identified and monitored for eligibility for future proactive protection.
5-2. Maintain beaches primarily via Mid-Town project and feeder beach approach.		1		Data show relative stability of Reach 5 beaches, including longshore transport of sand along offshore sand bars. A key area of uncertainty remains, regarding rates of transport from Mid-Town and contributions to the Reach 4 dry beach. More detailed monitoring data analysis can help resolve uncertainty. Modeling may be required to understand wave energy forcing and transport pathways for separation of sand transport to offshore bar. Processes appear to be linked to the large-scale geomorphology (e.g., shoreline curvature); however, a more detailed understanding of patterns may lead to alternate recommendations.
5-3. Maintain groins in Reach 5, including "Monster Groin", recognizing stabilizing effect on beach as per overall groin program (O-3).	2,3	2		Reach 5 has numerous groins of varying design and condition that help stabilize the beach. Data show Reach 5 is not providing a source of sand to downdrift beaches in Reach 6 that contributes to storm protection, so anticipated downdrift impacts are limited. Groins at the southern boundary of Reach 5 (including the "Monster Groin") help stabilize Reach 5. It is uncertain whether removal will provide a source of sand that would benefit storm protection in Reach 6; removal may adversely impact hardbottom habitat including the 3.1 acre mitigation reef. Maintenance of the groins is recommended. Repairs to specific groins can be resolved cooperatively between consultants.
5-4. Exercise caution using southern portion of South Borrow Area 1.		1		Dredging SBA-1 has potential to accelerate sediment transport within Reach 5, otherwise relatively stable, but where nourishment not currently permitted to remedy unanticipated impacts.
5-5. Pursue project allowing repairs to maintain a minimum berm width in Reach 5 if needed.		2		With no project in-place for Reach 5 there is little flexibility to respond to emergency repairs after storms. Expansion of the Mid-Town template into Reach 5 (at least landward of SBA-1) should be considered to compensate. A design storm protection berm should be established for Reach 5 and compared against monitoring data to determine vulnerability. Reach 5 should be established as a site for future maintenance if needed via pumpout of inlet sand and/or truck haul.

Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 6				
6-1. Perform independent assessment of state revetment, as per overall last line of defense program (O-2).		1		The state revetment protects critical infrastructure. Need to ensure there is 50-year protection, identify vulnerabilities (e.g., armor size, toe stability, overtopping, other), and make recommendations to the state for proactive maintenance improvements.
6-2. Establish Reach 6 as an area to maximize hard bottom coverage to advance regional objectives of BMA.		2		The Town made a commitment in Reach 6 via the 3.1 acre mitigation reef, and there is little need for a beach with the state revetment in-place. Given the potential future need for additional mitigation for other projects (e.g., north end of Reach 7 and in Reach 8), expanding hardbottom coverage and function in Reach 6 potentially can provide flexibility for beach nourishment in other Reaches in the spirit of the BMA to conserve hardbottom Island-wide.
6-3. Exercise caution using SBA2, and use seaward portion until post-dredge monitoring data can demonstrate if SBA2 interferes with transport.		1		SBA-2 is within the depth of closure and in close proximity to an offshore sand bar that transports sediment along the coast.

Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 7				
7-1. Establish program to ensure condos north and south of Phipps Park have adequate severe storm protection via seawalls or pile foundations as per overall last line of defense program (O-2).		1		Although not preferred by the public and perhaps more expensive to maintain than beach nourishment, the CCMP requires 15-year protection, which can be achieved with structures and repetitive dunes. Structural measures are needed for primary severe storm protection for the foreseeable future. Residents need to have the condition and level of protection field-verified to determine requirements for maintenance and improvements.
7-2. Ensure the public recognizes the Phipps project requires an incremental approach with compromises.		1		Beach nourishment is a long-term commitment and investment. In the case of the Phipps project, adaptive management is required to improve incrementally based upon prior project performance. Expectations for performance of the northern half should be tempered. A 6-8 year design life is not reasonable for the entire project area. Even though the physical performance monitoring data strongly indicate the need to extend the nourishment template north to Sloans Curve (in Woods Hole Group's opinion), the hardbottom is a valuable resource, and federal agency concerns are substantial. Pursuing the full template and/or structures (e.g., groins) would delay and potentially compromise the rest of the project.
7-3. Renourish the Phipps project.		1	Y	Renourish now without pursuing expanded nourishment template to north or adding groins. The project area is vulnerable and requires renourishment. Based on available information, there is conflicting evidence whether introducing groins, which are costly and non-existent in this stretch of beach, will have a meaningful improvement on the project.
7-3.1 Widen the profile at Phipps Park and extend the nourishment template farther south.	43, 44, 21	1	Y	Attempt to extend design life of the project and introduce more sand to the coastal system.
7-3.2 Use the coarsest grain size sand available from offshore sites for construction, and maintain with inlet sand (via pumpout hopper) or Ortona sand.		1		Finer sand used in the prior project potentially exacerbated offshore losses and reduced overall performance. Due to long-term erosion and oversteepening of the profile, continued cross-shore equilibration of this area should be expected regardless of grain size. Beaches at the north end of the project, particularly between Phipps Park and Sloans Curve where the nearshore zone appears to be deep and scoured, will require repeated nourishment and should be expected to erode more quickly.
7-3.3 Do not utilize southern portion of South Borrow Area 2.		1		The southern portion of SBA-2 is offshore the highest eroding area south of Sloans Curve. Dredging there has the opportunity to further exacerbate wave energy and interfere with regional sediment transport patterns. Without the opportunity to build a full nourishment template north of Phipps Park, this portion of the borrow site should not be used.
7-3.4 Vegetate dunes only when constructed together with beach nourishment.		1		Vegetation on emergency dune projects will not have time to establish prior to subsequent storm erosion.
7-3.5 Construct from south to north if feasible.		1		Will ensure full template at the most vulnerable north end upon completion of project construction.
7-3.6 Ensure design engineer updates design expectations.		1		Although a large fraction of the sand remains in the project area (mostly offshore and in the south end of the project), portions of the project maintaining a minimum beach berm for 15-year protection (as per CCMP) were reduced within 2-yrs of the original Phipps project. The modified design with wider Phipps section and extended template to the south also will alter design life expectations.

Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 7 (cont.)				
7-3.7 Establish north end of project for maintenance with inlet sand from pumpout hopper.		1		Allows more flexibility for maintenance of beach profile and/or dunes using high quality inlet sand, perhaps in affordable fashion (as compared to maintenance with Ortona sand) where most erosion is anticipated.
7-3.8 Establish clear performance objectives in project permits as basis for monitoring and determining future improvements.		1		Clearly defined criteria are needed for whether the project achieves its intended level of protection and anticipated environmental impact. Establishing potential needs for expanding the nourishment footprint to north and/or introducing coastal structures in the future will require clear performance criteria. A path forward should be established in the permits, which is essential to success of improvements contemplated in Recommendation 7-4.
7-4. Improve the Phipps Project.	47, 48, 21	3		Although seawalls and/or pile foundations combined with repetitive dunes can achieve the CCMP goal for 15-year protection, there is potential for a more cost-effective solution with fewer maintenance requirements and associated environmental impacts that involves larger scale beach nourishment and perhaps structures. Anticipate Supplemental or Full EIS will be needed to proceed with substantive project modifications. Although expanding the full template north will almost certainly improve performance based on existing data (in Woods Hole Group's opinion), recommend monitoring performance of next Phipps project for at least one year before proceeding with EIS to better constrain alternatives.
7-4.1 Expand understanding of Reach 7 coastal erosional processes.		3		Key uncertainties remain regarding wave and current energy focusing at Reach 7, sediment transport rates and patterns, and shoreline response. More detailed monitoring data analysis and perhaps modeling will provide information to refine Reach 7 designs. Items to resolve include: sand transport rates and pathways at the Reach 6/7 transition; potential for increased wave/current energy at Sloans Curve; sources of sand for the formation of a substantial offshore sandbar at Reach 7; and possible dispersion of sand over the Reach 7 profile with limited storm protection benefit as the profile flattens.
7-4.2 Select and evaluate a full range of non-structural alternatives.		3		Recommended alternatives to evaluate: extension of nourishment template north to Sloans Curve; groin alternatives; dune core between Phipps Park and Sloans Curve (understanding possible maintenance requirements); extension of nourishment template south to Town limits.
7-4.3 Select and evaluate a full range of structural alternatives.		3		Recommended alternatives should include a finite set of structural alternatives consolidated by cooperative Task Force including: Town staff and consultants. Additional Woods Hole Group recommendations include: terminal groin(s) at the north end of Reach 7/Sloans Curve (to stabilize Reach 7 nourishment/dunes, dissipate wave/current energy, and protect Reach 6 hardbottom); and/or a terminal groin south of Phipps Park (to regulate southward longshore transport from the north end of the project). Recognize that groins are costly and not yet certain to be effective here.
7-4.4 Establish incremental approach via EIS with clear decision points and performance criteria.		3		Need to define a clear pathway and performance standards for phasing incremental improvements to the project based on project performance compared to monitoring data. Depending upon physical performance and environmental impacts, future improvements can be implemented. They may require additional Supplemental Environmental Impact analyses, minimization measures, and even mitigation; however, the pathway with clear decision points should be established upfront. Also, pursue phased approach whereby initial projects can proceed while other alternatives are more fully vetted and the initial projects are monitored. Seek to incorporate this type of strategy into the BMA. A demonstration project may be helpful as outlined below.



Recommendations	SPB Item	Priority	In BMA	Rationale
REACH 8				
8-1. Establish program to ensure properties have adequate severe storm protection via seawalls or pile foundations as per overall last line of defense program (O-2).		1		Location, design criteria, and current condition for some structures are not certain and require field verification. Also identify properties that have future potential eligibility for structural protection. Structural measures are needed for primary severe storm protection for the foreseeable future. Residents need to have the condition and level of protection field-verified to determine requirements for maintenance and improvements.
8-2. Ensure public understands that Reach 8 (particularly the south end) is an area where incremental approach with compromises is required.		1		Reach 8 requires a long-term commitment and investment. Adaptive management is required whereby future projects can be improved incrementally based upon prior project performance. Although wide beaches, perhaps with structures, are preferred and would improve protection, the hardbottom is a valuable resource, and state and federal agency concerns are substantial along with other stakeholders. In spite of engineering merits, pursuing a full template with structures like Mid-Town is not feasible in the short-term, and will at least require incremental progress with sand only first. Recommended incremental steps are outlined below. Achieving a 6-8 year design life with the early projects is not likely to be feasible particularly at the southern end of Reach 8.
8-3. Proceed with Regional EIS including Reach 8 with carefully defined alternatives, an incremental approach, and managed expectations.	57,58,59	1		Improvements to the Reach 8 project are at a stalemate without the EIS. Although seawalls and/or pile foundations combined with repetitive dunes can achieve the CCMP goal for 15-year protection, there is potential for a more cost-effective solution with fewer maintenance requirements and associated environmental impacts that involves larger scale beach nourishment and perhaps structures.
8-3.1 Expand understanding of Reach 8 coastal erosional processes.		1		Key uncertainties remain regarding sediment bypassing the Lake Worth Fishing Pier, as well as wave and current energy focusing within Reach 8, sediment transport rates and patterns, and shoreline response. More detailed monitoring data analysis and perhaps modeling will provide information to refine Reach 8 designs. Items to resolve include: sand bypassing rates and pathways across the Lake Worth Pier; transport rates for sand in the northern portion of Reach 8 to provide a feeder beach to the southern portion; potential for increased wave focusing within Reach 8 for existing conditions and in response to dredging SBA-3; and whether/where the sandbar offshore Reach 8 attaches to the shoreline.
8-3.2 Select and evaluate full range of alternatives for Reach 8.		1		Recommended alternatives to pursue include: expedited initial approval of a sand only solution that includes a wider feeder beach south of the Pier and dunes throughout Reach 8 to supplement starved littoral system and toe protection; a modest beach nourishment profile with coarse sand fronting the dunes in the southern portion of Reach 8; and conditional future incorporation of wider beach profile in southern end perhaps combined with groins. The new critically-eroded designation for Reach 8 also provides potential for more proactive projects. Groin alternatives should be specified by design engineer, including consideration of groin configuration recommended by consultants. Recognize that groins are costly and not certain to be effective here.
8-3.3 Construct first phase of project concurrently with Phipps renourishment.		1		A longer project has potential to extend the renourishment interval and optimize potential benefits to Reach 8 from the combined nourishment in Reaches 7 and 8, including an extended southern profile in Reach 7 and potential continued transport of the 1996 Phipps project sand.
8-3.4 Pursue phased approach whereby certain projects can be approved while other alternatives are more fully vetted and monitored.		1		Define a clear pathway and performance standards for phasing incremental improvements to the project based on project performance compared to monitoring data. Depending upon performance and environmental impacts, future improvements can be implemented. May require additional Supplemental Environmental Impact analyses, minimization measures, and even mitigation; however, the pathway with clear decision points should be established upfront. Also, pursue a phased approach whereby initial projects can proceed while other alternatives are more fully vetted and the initial projects are monitored. Seek to incorporate this type of strategy into the BMA. A demonstration project may be helpful as outlined below.

Table 5-3. Recommendations for Island-Wide Overall Management Activities

Recommendations	SPB Item	Priority	In BMA	Rationale
ISLAND WIDE				
O-1. Supplement Coastal Processes Analysis and Update CCMP	65,66	1		
O-1.1 Clearly define updated goals and objectives for Coastal Management Program		1		Specify upfront the primary purpose of the Program including intended level of protection (i.e., 15-year), and methods of protection (i.e., primarily through sand nourishment). Clearly state any secondary objectives related to recreational benefits, priority on public beaches, restoration of sea turtle nesting habitat, conservation of hardbottom habitat, aesthetics, property values, or others as appropriate. Specify role and location of coastal structures included in the Plan, and locations where the Town intends to maintain structures (e.g., North Ocean Boulevard Seawall, Mid-Town groins, others). Clearly identify structures or other resources the Town does not intend to maintain (e.g., state revetment, privately owned seawalls and groins).
O-1.2 Clearly define design criteria for beach nourishment, repetitive dune, and coastal structure projects included in the plan		1		Establish overall design criteria for sand replenishment projects (e.g., 25-year storm with 6-8 year renourishment interval for beach nourishment; 15-year storm for repetitive sacrificial dunes), and structural design criteria (e.g., 50-year storm surge and wave conditions). Design criteria for storm surge elevation, storm wave conditions, and storm duration need to be defined. The design beach template should include minimum storm berm, and advance nourishment required to achieve intended design life. Ensure the project design template achieves the Program objectives, and clearly indicate areas where the design is compromised and performance may be affected (e.g., due to hardbottom or other constraints).
O-1.3 Perform one-time supplemental analysis of historical monitoring data		1		Advancing the analysis included within the scope of this technical review will reveal more detailed information about historical project performance, and sediment transport pathways and rates that can benefit future project design. Key areas of uncertainty need to be explored further including transport pathways and rates: From Reaches 1/2 into 3; Between Reaches 3/4; From Reach 4 into 5; Between Reach 6 and adjacent Reaches; Around the Lake Worth Pier from Reach 7 into Reach 8.
O-1.4 Establish and refine littoral cells for coastal management that include groups of adjacent Reaches		1		Based on available information, Reaches 1, 2, and 3 can be managed together, particularly as the nourishment projects in Reaches 1 and 3 can be expanded into Reach 2 and coastal structures within Reach 2 can be used to enhance protection. Reaches 4 and 5 can be managed together, primarily with Reach 4 feeding Reach 5. Reach 6 stands alone, and can be considered as an area for enhancing hardbottom resources. Reaches 7 and 8 can also be managed together, particularly as the Reach 7 nourishment project is extended south, and at least a feeder beach can be established in the north end of Reach 8 to help address the new critically-eroded designation.
O-1.5 Modify scope and presentation of monitoring data in annual Town-wide report		1		Annually include: Design beach cross section compared to monitoring profiles to determine where the intended level of protection exists and where it does not; Most recent post-construction beach/dune profile compared to monitoring profiles to visually gauge project performance; Plan view of Island showing locations where the design criteria are satisfied and not satisfied; and Geomorphological change contours showing where sand is accumulating and eroding to reveal sediment transport pathways. Results from O-1.3 will provide specific examples as a guideline.
O-1.6 Update above items annually		1		Include a supplement to the annual plan that clearly defines goals, projects and design criteria, which may evolve over time.
O-1.7 Apply and update an Island-wide wave and physics-based sediment transport model		3		Pending further analysis of historical monitoring data, a regional set of models may be required to better understand rates and variability of transport as basis for improved project design and clarifying feeder beach and other project performance expectations. Project specific design criteria can be established based on wave energy focusing, specific influence of offshore borrow site mining can be assessed, and rates/gradients of sediment transport can be refined. The model should only be applied if calibrated against field data (e.g., historical shoreline change, beach profiles, wave measurements), and if it will be updated and maintained as an adaptive management and planning tool.

Recommendations	SPB Item	Priority	In BMA	Rationale
ISLAND WIDE (cont.)				
O-2. Establish last line of defense program and citizen notification/participation, including:		1		Provide residents guidance and encourage inspection and classification of all seawalls and foundations (in the case of conforming structures) in terms of storm protection provided as last line of defense. Identify vulnerable areas without designed seawalls or conforming structures, and monitor areas that may become eligible over time. It is critical to involve property owners since many structures are privately owned and not responsibility of Town.
O-3. Establish groin maintenance and repair program	2,3	1		Obtain consolidated consultant recommendations, and involve citizens since many are privately owned. Key areas are Reach 2 groins for maintaining at least a minimum beach, Reach 4 groins with Mid-Town project, and Reach 5 groins for stabilizing the beach fed primarily by the Mid-Town project. Although certain areas of Reaches 7 and 8 may benefit from future coastal structures, none are recommended at this time, primarily due to environmental resource constraints and regulatory feasibility, and remaining uncertainty regarding performance. There is not an Island-wide groin solution.
O-4. Perform a flooding and climate change/sea level rise vulnerability assessment		2		As a supplement to the CCMP, areas presently at high storm damage and flood risk should be identified along with areas subject to future vulnerability associated with sea level rise. Flooding pathways should be mapped. Possible engineering adaptations (phased) should be explored for the Town and residents to pursue.
O-5. Commit a communications line item		1		Regular website updates are needed related to projects, photos, and current events. Other outreach venues and materials may also be pursued such as social media pages. A dedicated web page and/or brochure should be published to clarify coastal management program objectives, scope, expectations, constraints and remaining vulnerabilities. Other communication materials may be related to the last line of defense seawall/foundation program (O-2), as well as the flooding and climate change/sea level rise vulnerability assessment (O-4), for example.
O-6. Establish budget for dune vegetation maintenance		1		Dune vegetation requires regular maintenance, including removal of invasive, supplemental plantings, and perhaps fertilization to maximize performance benefits.
O-7. Pursue federal regional permit for BMA activities		3		Assuming the BMA process results in a series of projects and conditions endorsed by the Town, there is a need to streamline the federal regulatory review process as well. A federal regional permit for specific activities in the BMA is one vehicle to pursue. Track an upcoming notice from the federal government for a regional permit related to beach renourishment.
O-8. Pursue opportunity for Time of Year exceptions to nourish certain areas	17,18	3		Areas lacking sea turtle nesting habitat may be identified, and a protocol defined for nourishing outside of normal ToY windows (e.g., work with USACE for placement of inlet dredged material in Reach 2 from an emergency navigation maintenance project). Protocol may include a minimum eroded beach profile in certain areas where beach nourishment is already approved.
O-9. Proactively participate in the SAND program		1		High quality and affordable sand sources are a finite and scare resource that will be diminished in the foreseeable future. Establishing the Town of Palm Beach as a recipient for regional offshore sand sources will provide essential future flexibility.

5.2 Demonstration Projects

New technologies and new applications of existing technologies should be considered to advance the phased incremental approach to shoreline management in certain locations. From purely an engineering perspective, more substantial beach nourishment including strategically designed structures would be preferred in certain areas, including the northern part of Reach 7 and the southern portion of Reach 8. Although there are substantial technical gaps in the analysis and uncertainties with how structures will perform in these areas, more aggressive solutions, in the spirit of those proposed both by Town and residents' consultants, would perform better than repetitive dunes alone. Furthermore, while the goals of the CCMP can be satisfied with repetitive dune projects fronting either seawalls or conforming post-1985 structures with pile foundations, simple financial analysis suggests larger scale beach nourishment can also be more cost-effective (not accounting for mitigation costs), while also providing a greater level of protection.

Primary areas of concern in Reach 7 and 8 are fronted by nearshore hardbottom, a highly protected ecological resource. Based on the entirety of information collected by Woods Hole Group and stakeholders consulted through this process, it is not feasible presently to expect wide nourishment templates with structures will be permissible in the short-term. The same logic applies to Reach 2 where similar resources exist. An incremental approach will be required, which should not be considered a defeat or a failure. Rather, it represents progress. Since the coastal system is sand-starved and requires a long-term approach, an incremental approach will help restore the natural system methodically. In parallel, more data can be collected to help refine needs for expanded nourishment templates and/or structures. Open collaboration with regulatory authorities, including clear definition of goals and decision points, will also build a cooperative environment. This approach is consistent with the regulatory mandate to first avoid impacts, then minimize, and then mitigate when impacts are unavoidable.

As part of this incremental approach, we recommend pursuit of new technologies and demonstration project(s) in critical areas. Three opportunities exist for demonstration projects: 1) the northern part of the Reach 7 project from Phipps Park to Sloans curve; 2) the southern portion of Reach 8; and 3) Reach 2 where rehabilitation of existing groins combined with nourishment from the inlet project landward of hardbottom may demonstration effective methods that can be applied elsewhere on the Island. These areas provide opportunities for a demonstration project that is transferrable to other portions of the Island where similar constraints exist. Demonstration projects, if approved, will likely require clear thresholds for performance, and perhaps provisions for removal and/or mitigation.

The opportunity to implement a demonstration project in Reach 7 should be pursued immediately after the next nourishment project if the northern portion of the project erodes rapidly again, as Woods Hole Group anticipates. With two projects in-place and monitored, there will be a strong body of evidence to work with regulatory personnel to advance project improvements. The northern portion of Reach 7 is unique also since it is adversely affected by the extensive adjacent state revetment (reducing the updrift sediment source), and also appears to bear the brunt of intensified wave and current energy (although uncertainties remain). In addition to the alternatives presented by Town and SoS consultant for Reach 7, Woods Hole

Group recommends consideration of a terminal groin at the north end of Reach 7/Sloans Curve to stabilize the Reach 7 nourishment/dunes, dissipate wave/current energy, and protect Reach 6 hardbottom. A terminal groin south of Phipps Park to regulate southward longshore transport from the north end of the project also should be considered.

The opportunity to implement a demonstration project in Reach 8 should be pursued and included as part of the alternatives analysis in the context of the regional EIS; however, reasonable expectations for approval are limited. There will most likely be a need for a more modest sand only alternative including a feeder beach south of the pier (also not at all ensured of regulatory approval) prior to anything more comprehensive. For a later demonstration project in Reach 8, Woods Hole Group recommends consideration of a modest beach nourishment profile with coarse sand fronting the dunes in the southern portion of Reach 8, perhaps combined with groins as conceptualized by ECE. As with Reach 7, the demonstration project could incorporate creative structural designs (e.g., low-profile, notched, or adjustable height groins), different construction materials, and/or multi-purpose structures intended to both stabilize the beach and provide ephemeral hardbottom habitat. Woods Hole Group also recommends considering a permeable and/or notched terminal groin near the south end of Reach 8 to stabilize the beaches to the north while also facilitating transport to southern beaches.

The purpose of the demonstration project(s) would be to address the common problem in Town to maintain a beach landward of nearshore hardbottom habitat. Although the concept is promising for coastal structures to extend the life of the nourishment and also to limit impacts of the nourishment on hardbottom, there is not a strong body of evidence supporting a project of this type; thus, presenting the opportunity for a demonstration project. The demonstration project has potential to guide future projects in Reach 8, as well as Reaches 2 and 7 or other areas within the BMA. Perhaps the most immediate opportunity for a demonstration project is within Reach 2 where groins already exist that could be rehabilitated in conjunction with sand nourishment from the inlet. Should the combination of groins and modest beach nourishment prove effective at maintaining a beach while limiting potential impacts to nearshore hardbottom in Reach 2, there may be evidence to help advance similar future strategies for Reaches 7 and/or 8. A demonstration project should be advanced in good faith as a normal alternative within the context of environmental process (e.g., EIS), and would not receive any less rigorous review.

5.3 Next Steps

Anticipated next steps after submittal of the Final Report include:

- Town Council review of Final Report, including the Recommended Plan in the Executive Summary.
- Presentation and discussion of the Final Report at the Town Council meeting on June 12, 2013.

We recommend the Town proceed with the Recommended Plan, at least for FY2014. The Plan has been coordinated with Town staff, and we understand a program plan is forthcoming from staff consistent with the recommendations in this Final Report for deliberation by Town Council.

Assuming the plan or elements thereof are approved by Council, we recommend immediate action on the Priority 1 recommendations and essential Town items. To help manage the volume of information in this report and focus efforts of Town staff and consultants charged with implementing a plan approved by Council that includes recommendations in this report, the key elements required for next steps include:

- Table ES-1 outlining the recommended actions and management strategies
- Tables 5-1, 5-2, and 5-3 providing more details supporting ES-1, and
- Chapters 3 and 5, which provide the rationale for the recommendations.

6.0 REFERENCES

References listed below represent only a small fraction of the materials consulted for the technical review, and are the documents specifically referenced in the report text. A complete list of reference documents will be provided to Town staff separately.

Apollo Environmental Strategies, Inc. 2012. "Name of Project: Repair of Geotextile Core Dunes at Bolivar Peninsula." Published: June 14, 2012. Accessed: February 28, 2013. <http://apolloenvironmental.com/projects_bolivar_dunes.html>.

ATM. 1998. Comprehensive Coastal Management Plan Update, palm Beach Island, Florida, June 1998.

ATM. 2010. Phipps Ocean Park (Reach 7) Beach Restoration and Dune Construction Project Third Year Post-Construction Physical Monitoring Report, January 2010.

ATM. 2010. Mid-Town Beach Renourishment and Expansion Project Third Year Post-Construction Physical Monitoring Report, January 2010.

ATM. 2011. Town of Palm Beach Town-Wide 2010 Physical Monitoring Report, April 2011.

ATM. 2011. Town of Palm Beach Offshore Sand Search Investigations North Area Summary Report and Attachments, August 2011.

ATM. 2012. Town of Palm Beach Offshore Sand Search Investigations South Area Summary Report and Attachments, April 2012.

Boon, John D. 2012. Evidence of Sea Level Acceleration at U.S. and Canadian Tide Stations, Atlantic Coast, North America. Journal of Coastal Research, 28(6), 1437-1445.

Byrnes, M.R., J.S. Ramsey, R.M. Hammer, and E.A. Wadman. 2000. Assessing Potential Environmental Impacts of Offshore Sand and Gravel Mining. Final Report to the Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Coastal Zone Management, 43 pp.

CPE. 2009. November 2008 Town of Palm Beach Town-Wide Monitoring Report, May 2009.

CTC. 2011. Coastal Structures Plan for the Town of Palm Beach and Appendices, March 2011.

Dean, Robert G. and Robert A. Dalrymple. 2002. Coastal Processes with Engineering Applications. Cambridge University Press.

Dean, Robert G. 2008. Independent Review of the Town of Palm Beach Reach 8 Beach and Dune Restoration Project.

Florida Department of Environmental Protection. 2012. Palm Beach Island Beach Management Agreement.

Hutchins, R. and S. Augenstein. 2012. "N.J. sand dunes protected Shore towns from Hurricane Sandy's wrath." The Star-Ledger. Published: November 6, 2012. Accessed: February 28, 2013. <http://www.nj.com/news/index.ssf/2012/11/nj_sand_dunes_protected_shore.html>.

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R.Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the U.S. National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp

Pelnard-Considere, R. 1956. Essai de Theorie de l'Evolution des Forms de Rivages in Plage de Sable et de Galets, Fourth Jounes de l'Hydralique, les energies de la Mer, Question III, Rapport No. 1, 289-298.

Simm, Jonathan. 2010. Developing SLR adaptation strategy for the Thames Estuary (TE2100). HR Wallingford presentation: http://corpsclimate.us/docs/Dec2010workshop/8_SLR_Adaptation_Strategy_Thames_Simm_2Dec10.pdf.

Wanless, Harold R. and Katherine L. Maier. 2007. An Evaluation of Beach Renourishment Sands Adjacent to Reefal Settings, Southeast Florida.

APPENDIX A. SCOPE OF WORK FROM TOWN

Shore Protection Board's Recommendation to Town Council Regarding Scope and Cost of the Town's Coastal Protection Program
Peer Review by Woods Hole Group Scoping Notes

MAIN POINTS TO ADDRESS:

- Conduct a comparative analysis as to what has been done since the 1998 CCMP review
- Consider all projects under consideration between the 2009 SPB Plan and the FY 2013 SPB recommended program

Some general Town Council comments from March 14, 2012, to help formulate an appropriate scope of work:

- SPB Recommendation bears further analysis. Truly unbiased. Look at entire plan and see what is feasible and what is not feasible. What we should be doing and what we should not be doing.
- Value Engineer the SPB plan: Cost effectiveness
- Cost-Benefit Analysis of projects: Is Aragonite (if even permittable) worth the cost? Will the performance of Aragonite provide an increased benefit which overshadows its higher cost?
- Will Bahamian sand make a difference or will it not?
- Whether or not any community in this country been able to successfully get rid of hardbottom concerns
- Could we get any groins south of Sloan's Curve. Can we install groins along the entire island?
- Wish list coastal items vs. permitting and cost realities

<u>Schedule</u>

- Anticipated Start Date: April 12, 2012
- Anticipated Completion Date: Early August 2012

<u>Correspondence of Woods Hole</u>

To engage with anyone related to this matter, but to use Town staff (myself) as a pass through to each of the appropriate consultants, etc. This will prevent unnecessary budgeting concerns. WHG is to use the information provided within suggested literature to develop a path forward for the SPB and Town Council. All resources are to be available, at the discretion of WHG, to ensure that this piece of work can be appropriately accomplished.

<u>Suggested Literature for Review, 1999 - Present</u>

Shore Protection Board-Related Items

- Various Town staff memorandums to SPB members, January 2009- March 2012
- Report to the Town Council, SPB, November 2009
- FY 2012 Proposed Coastal Management Program Budget & 10-Year Forecast, Town staff, March 2011

- An Independent Review of the Town of Palm Beach Coastal Management Plan, Erickson Consulting Engineers, October 2011
- Response to ECE "An Independent Review of the Town of Palm Beach Coastal Management Plan, October 2011", Town staff, November 2011
- Comments on ECE Review of Town's Beach Management Program, Erickson Consulting Engineers, January 2012
- FY 2013 Proposed Coastal Management Program Budget & 10-Year Forecast, Town staff, February 2012

State of Florida DEP Reports

- Strategic Beach Management Plan, FDEP, May 2008
- Critical Erosion Areas Report, FDEP, June 2011
- Offshore Sand Search Guidelines, FDEP, September 2010

Feasibility Studies

- Draft Feasibility Study of Palm Beach Island Shoreline Reach 2, Applied Technology & Management, August 2002
- Feasibility Study of Palm Beach Island Shoreline Reach 5, Applied Technology & Management, June 2005
- Feasibility Study of Palm Beach Island Shoreline Reach 8, Applied Technology & Management, January 2005
- Independent Review of the Town of Palm Beach Reach 8 Beach and Dune Restoration Project, Robert Dean, July 2008
- Reach 8 Feasibility Study, Coastal Systems International, January 2010

Permitting Submittals (Documents listed below, as well as responses by FDEP, available on State website)

LAKE WORTH INLET

- Sand Transfer Plant Modification Application for JCP, Applied Technology & Management, September 2011

REACH 8

- Reach 8 Joint Coastal Permit Application, Coastal Planning & Engineering, June 2005
- Reach 8 RAI #1, Coastal Planning & Engineering, June 2006
- Reach 8 RAI #2, Coastal Planning & Engineering, March 2007
- Reach 8 Geotechnical Data Submittal, Coastal Planning & Engineering, May 2007
- Reach 8 RAI #3, Coastal Planning & Engineering, July 2007
- Reach 8 RAI #4, Coastal Planning & Engineering, October 2007
- Reach 8 Biological Assessment, Section 7 Consultation, Coastal Planning & Engineering, October 2007
- Reach 8 Supplemental Information, Coastal Planning & Engineering, October 2007

- Application for Joint Coastal Permit Reach 8 Beach Nourishment, September 2010
- Reach 8 Addendum ETOF Report, Coastal Systems International, July 2011
- South End Palm Beach Restoration (Reach 8) Mitigation Design Report, Coastal Systems International, September 2011
- FDEP RAI #1, USACE RAI #2, Reach 8, Coastal Systems International, December 2011

Legal Documents

- Recommended Order, DOAH Case No. 08-1511, Administrative Law Judge Robert Meale, March 2, 2009
- FDEP Consolidated Final Order, OGC Case No. 08-0469, DOAH Case No. 08-1511, Secretary Michael W. Sole, July 15, 2009
- Town of Palm Beach vs. USA, Civil Action No. 09-64L, dated February 4, 2009

Coastal Structures

- Phipps Ocean Park Structures Analysis Report, Taylor Engineering, March 2010
- Town of Palm Beach Groin and Armoring Inventory, Isiminger & Stubbs Engineering, March 2010
- Central Palm Beach County Comprehensive Erosion Control Project Numerical Modeling of Shore Protection Alternatives, for Palm Beach County ERM, Coastal Planning & Engineering, February 2011
- Coastal Structures Plan, Coastal Technology Corporation, March 2011
- Phipps Ocean Park Beach Restoration & Stabilization, Draft Design Document, Coastal Technology Corporation, October 2011

Physical Monitoring

- Post-Hurricane Shoreline Evaluation, PBS&J, February 2005
- Town of Palm Beach 2005 Annual Monitoring Survey, Coastal Planning & Engineering, November 2005
- Town of Palm Beach 2004 Post-Storms' Survey Report, Coastal Planning & Engineering, November 2005
- 2006 Phipps Beach Renourishment Project Pre- and Post-Construction Survey Report, Coastal Planning & Engineering, December 2006
- 2006 Post-Construction Report for Phipps Ocean Park (Reach 7), Coastal Planning & Engineering, June 2007
- 2006 Post-Construction Report for Mid-Town (Reach 3 and 4) Beach Renourishment Hurricane Damage Repair Project, Coastal Planning & Engineering, June 2007
- 2007 Monitoring Report for Phipps Ocean Park (Reach 7), Coastal Planning & Engineering, August 2008
- 2007 Monitoring Report for Mid-Town (Reach 3 and 4) Beach Renourishment Hurricane Damage Repair Report, Coastal Planning & Engineering, August 2008
- Townwide Monitoring Report, Coastal Planning & Engineering, November 2008

- Phipps Ocean Park (Reach 7) Third Year Post Construction Physical Monitoring Report, Applied Technology & Management, January 2010
- Mid-Town Beach Renourishment and Expansion Project (Reach 3 and 4) Third Year Post Construction Physical Monitoring Report, Applied Technology & Management, January 2010
- Townwide Monitoring Report, Coastal Planning & Engineering, May 2009
- Townwide 2009 Physical Monitoring Report, Applied Technology & Management, April 2010
- Phipps Ocean Park (Reach 7) Fourth Year Post Construction Physical Monitoring Report, Applied Technology & Management, January 2011
- Mid-Town Beach Renourishment and Expansion Project (Reach 3 and 4) Fourth Year Post Construction Physical Monitoring Report, Applied Technology & Management, January 2011
- Townwide 2010 Physical Monitoring Report, Applied Technology & Management, April 2011
- Phipps Ocean Park (Reach 7) and Reach 8 Dune Restoration and Partial Nourishment 2011 Pre- and Post-Construction Physical Monitoring Report, Applied Technology & Management, June 2011
- Mid-Town Beach Expansion and Nourishment Project Post-Fay Dune and Berm Repair Construction Physical Monitoring Report, Applied Technology & Management, June 2011

Biological Reports

- Final SEIS, Phipps Ocean Park Beach Restoration Project, Coastal Technology Corporation, February 2004
- Phipps Ocean Park Beach Restoration 2010 Biological Monitoring Report, Tetra Tech and Coastal Eco-Group, January 2011
- Mid-Town Beach Expansion and Nourishment Project, 5th Post-Construction Environmental Monitoring Report FINAL, Tetra Tech and Coastal Eco-Group, January 2011

Geotechnical Reports

- Offshore Sand Source Investigation, Volumes I & II, Coastal Planning & Engineering, March 2000
- Town of Palm Beach Offshore Sand Search Investigations, North Area Summary Report, Applied Technology & Management, August 2011
- Town of Palm Beach Offshore Sand Search Investigations, South Area Summary Report, Applied Technology & Management

(As of 3/22/2012; there may be other documents)

TOWN OF PALM BEACH

Information for Town Council Meeting on: August 14, 2012

To:	Mayor and Town Council
Via:	Peter B. Elwell, Town Manager
From:	H. Paul Brazil, P.E., Director of Public Works
Re:	Update on Woods Hole Group's Comprehensive Review of the Shore Protection Board's Comprehensive Long Term Coastal Management Program
Date:	August 9, 2012

STAFF RECOMMENDATION

Town staff recommends that Town Council [1] review the preliminary report and provide any direction deemed necessary to Woods Hole Group (WHG), [2] to publicly announce a date for a Public Workshop, as indicated within WHG's Town Council approved scope of work, and [3] extend the deadline for the WHG final report and presentation.

GENERAL INFORMATION

Woods Hole Group (WHG) has provided Town staff with the attached letter for distribution to the Town Council members. The letter summarizes the progress made to date, highlights both the materials reviewed and materials still pending, and provides a brief list of key issues identified with the specific intent of receiving feedback from the elected officials. WHG will not be present at the August 14, 2012 meeting. Rather, WHG will be present at an upcoming public workshop.

The final report and recommendations from WHG has been expected to be received in early October. Pending review of upcoming consultant deliverables and the outcome of the public workshop, WHG has expressed concern for adequately reviewing the additional information and getting the final report submitted in early October. WHG has inquired about flexibility in the process and has indicated that a November submittal deadline would allow sufficient time for a complete review and thorough professional work product.

SPECIAL CONSIDERATIONS

One element of WHG's Phase II activities includes a Public Workshop for Town's residents to provide public comment. This event could be held in Town Council Chambers on Monday, August 27; Tuesday, August 28; Thursday, August 30; or Friday, August 31, 2012. Alternatively, the Public Workshop could be held during the week of the September Town Council meetings, as long as Town Council approves extending the final report deadline to November.

Attachment

cc: Shore Protection Board
Robert Weber, Coastal Coordinator
Robert Hamilton, Woods Hole Group

Woods Hole Group 81 Technology Park Drive E. Falmouth, MA 02536 USA TELEPHONE: 508.540.8080 FAX: 508.540.1001 www.woodsholegroup.com

Sent by Electronic Mail

August 9, 2012

Town of Palm Beach
Attn: Town Council
C/o Mr. Robert Weber, Coastal Coordinator
Town of Palm Beach Public Works Department
Post Office Box 2029
Palm Beach, FL 33480-2029
Email: rweber@townofpalmbeach.com

Re: Preliminary Phase I findings – Focal Points for Phase II and Recommended Next Steps

Dear Mr. Weber,
This letter presents a progress report on our Phase I review of the documents and data related to the Palm Beach Shore Protection Plan and activities. This brief update is offered in advance of the August 14 Town Council Meeting to update the Council on ongoing activities and planned direction for our work. A primary purpose of this letter also is to request Town Council direction on next steps, specifically including the four (4) items below. Succinct specific questions for Council on these four (4) items are listed in Attachment A to this letter:

1. **Focal points/key questions for Phase II** – Preliminary focal points are offered in this letter for Council consideration. If Council members have guidance on particular areas of focus (e.g., other areas to emphasize), we request feedback.

2. **Stakeholders with whom to interact in Phase II** – A list of stakeholders is provided in this letter for Council consideration. If Council members prefer an alternative or supplemental list of stakeholders for us to contact, we also request guidance.

3. **Public/stakeholder workshop scheduling** – A critical element for our Phase II work is an opportunity to interact with and gain comments from the public. We believe this workshop should include a brief presentation from Woods Hole Group on our scope of work and a progress report on activities, followed by ample opportunity for the public to offer ideas and comments. Woods Hole Group would offer a draft agenda in advance of the workshop. This workshop should be scheduled relatively soon at the convenience of the Town. We request a workshop either the week of August 27 or September 10, with a preference for a September date if the overall schedule

permits. We anticipate that Town Council will wish to conduct this as a Town Council Workshop, encouraging public participation. We will prepare accordingly unless another format is preferred by Council.

4. **Overall project schedule** – We presently understand there are plans to present and discuss our report on the agenda for the October or November Town Council meeting. There are several factors affecting completion and review of our report. Relevant materials currently are being prepared by Town consultants (not yet available) that will directly factor into our findings (e.g., CP&E and Humiston & Moore reports related to groins/coastal structures; and Tetra Tech analysis of hard bottom resources; among others). We will need to obtain these reports with adequate time to review and incorporate into our work. There also are State of Florida initiatives, such as the Beach Management Agreement (BMA) for Palm Beach Island and the Southeast Florida Sand Availability and Needs Determination (SAND) study, which have scheduled milestones in September and beyond, that can affect the Town's future shore protection plans and may factor in to our findings. There also are scheduling factors related to the Town's budgeting process, the public workshop, and we anticipate Town Council members will want a certain period of time to review our report prior to a presentation at a Town Council meeting. All these factors considered, along with other concerns of the Council that we may not recognize, we request feedback from Town Council on when our Draft Report should be delivered and at what future Town Council meeting we should prepare to present and discuss our findings. If there is a strong preference for the October 9 Council meeting, and if the Draft Report must be submitted to Council with ample time to review before the meeting, there may not be time to incorporate certain information still pending from Town consultants, the state, or the public. We can adjust our plans accordingly with advice from Council on the overall schedule.

Progress Update

A project team has been formed at Woods Hole Group consisting of: Project Manager/Coastal Engineer Bob Hamilton; Coastal Engineer Kirk Bosma, P.E.; Coastal Geologist M. Leslie Fields; and Coastal Engineer/Oceanographer Lee L. Weishar, Ph.D., P.W.S. With substantial support from Mr. Rob Weber, a tremendous volume of materials have been obtained from the Town. The materials initially identified include:

- Various Shore Protection Board documents, Coastal Management Program plans, support technical reports, briefings to Town Council, reviews by Erickson Consulting Engineers (ECE), and responses to reviews
- State of Florida DEP reports
- Project Feasibility Studies
- Permit submittals related to Lake Worth Inlet and Reach 8
- Legal documents
- Coastal structures reports
- Physical monitoring reports and data
- Biological reports and data
- Geotechnical reports and data

Woods Hole Group 81 Technology Park Drive E. Falmouth, MA 02536 USA TELEPHONE: 508.540.8080 FAX: 508.540.1001 www.woodsholegroup.com

In the process of reviewing these documents and ensuing research and discussions with Town staff, a series of other documents were obtained also with support from the Town:

- Supplemental sand search/source-related documents
- Preliminary wave studies related to impacts of offshore borrow sites
- State SAND initiative
- Updated hard bottom maps/aerial photographs/supporting GIS, photos and data
- 50-year sand projected needs
- Correspondence related to critically eroded status for Reach 8
- Reports and correspondence with DEP related to Town Annual Funding Request and projected long-range budget
- Independent research

This wealth of information exceeds expectations, and is under continued review by the project team. Several internal working meetings have been completed after review of certain materials so the project team can exchange ideas and define key issues. Members of the team also conducted a supplemental site visit to Town Beaches, participated in the July 13 BMA work shop, and joined an August 7 SAND conference call. Stakeholder interviews are currently being scheduled, and the Phase I deliverable is underway. The team is looking forward to receipt of reports pending from other consultants specifically related to coastal structures and groins to enhance the performance of beach nourishment projects.

Key Issues/Areas for Phase II Woods Hole Group Review and Recommendations

In the process of reviewing materials to date and conducting team working meetings, a series of key issues and focal points for Phase II were identified. These key focal points are subject to refinement and modification as more materials are obtained and reviewed; however, a preliminary listing is provided below for Town Council consideration. Guidance is requested from Council Members if there are particular areas the Town would prefer we not focus, and if there are key areas of interest to Town Council not listed below. Key issues, identified based on our review of materials and original Town Council direction, are:

- Comparative assessment of project performance since 1998 CCMP review
    - Review of storm protection design standards
- Overall unbiased review of 10-year plan, including feasibility of projects in the 2009 SPB Plan and 2013 SPB Recommended Program; ideas on project prioritization considering realistic permitting and cost concerns
- Lake Worth Inlet Sediment Management/Bypassing
    - Extension of discharge pipeline; selection of discharge location
    - Plans for maintenance dredged sand; priority for placing sand on beach
    - Sand retention basin improvements
- Hard Bottom
    - Monitoring program; place beach nourishment in perspective with other natural ephemeral resources; storm impacts
    - Search for other sites; precedent for impacts and recovery elsewhere

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- Sand Sources/Alternatives
    - Consider whether existing sources are suitable; sufficient; too close to shore
    - Evaluate need and status of federal/BOEMRE/SAND sources for future planning
    - Evaluate suitability/extent of geophysical data
- Aragonite, specifically
    - Performance characteristics; effects of density/shape/durability
    - Environmental characteristics
    - Logistics
- Coastal Structures
    - Evaluate specific designs (e.g., groins south of Sloan's Curve)
    - Review/prioritize areas
    - Evaluate expectations
- Design Criteria/Expectations for overall coastal management plan/projects
    - Clarify design criteria and design basis
    - Clarify overall goals/expectations
    - Realistic limits on what can reasonably be achieved in certain timeframes
- Island-wide coastal processes/sediment budgets
    - Evaluate adequacy of current understanding of island-wide processes
    - Are hotspots, nodal points, and other sediment transport gradients understood
    - Is there a strong basis for sediment budget/incorporation of monitoring data
    - Reach-specific processes/plans; opportunities to manage more on a *regional basis* including combination of certain inter-related Reaches
- Value Engineering
    - Sand value analysis (performance vs. cost of different alternatives such as aragonite)
    - Coastal structure analysis (performance benefits vs. cost)
    - Overfill (performance benefits vs. cost and potential environmental impacts/cost of mitigation)
    - Overall consideration of cost-effectiveness
- Monitoring Data
    - Evaluate overall plan/analysis methods
    - Consider opportunities to optimize value of this investment to support project designs/adaptive management approach
- Adaptive Management Opportunities/Recommendations:
    - Inlet sediment management
    - Beach nourishment priority areas; adjacent benefits
    - Groins/coastal structures; priorities; local and adjacent effects
    - Sand sources; adequacy; alternatives
    - Hard bottom/other resource impacts; opportunities/constraints
    - Monitoring data/enhanced applications thereof
    - Specific Reach activities where more uncertainty on future approach remains (e.g., Reaches 2, 7, and 8)

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Stakeholder Interaction/Discussion

Based on the review of materials, a preliminary list of stakeholders to contact has been assembled including:

- Applied Technology and Management – emphasis on sand source/search information
- Coastal Planning & Engineering – emphasis on shore protection projects and offshore sand resources
- Coastal Systems International – emphasis on the Reach 8 project design
- Coastal Technology Corporation – emphasis on shore protection projects and coastal structure alternatives
- Erickson Consulting Engineers as consultant to SOS and NAPB – emphasis on review of 10-year plan, specific design recommendations, and suitability of aragonite
- FDEP – emphasis on BMA, SAND initiative, and overall perspectives on environmental impacts
- Humiston & Moore Engineers – emphasis on review of groins/coastal structures for Reach 7
- Tetra Tech/Coastal Eco Group – emphasis on hard bottom resources
- USACE – emphasis on federal project reviews as related to environmental impacts

This list is in addition to Town Council Members, Shore Protection Board Members, and the general public, who will have an opportunity to voice opinions and comments at the workshop anticipated during the first week of September or last week of August at the discretion of Town Council as requested in Item 3 on page one of this letter. We request Town Council guidance on other stakeholders specifically recommended for contact who might not otherwise offer input at the public workshop.

Recommended Next Steps and Schedule

Planned activities include continued review of available documents, obtaining and reviewing supplemental documents as they become available, conducting stakeholder discussions, and executing the public workshop. Following these activities, our technical team will coordinate individual findings and observations into a unified set of observations, recommendations, and identification of data gaps/remaining questions. The Draft Report will be prepared for review by Town staff and Town Council as appropriate, and will be presented for discussion at an ensuing Town Council Meeting. As outlined in Item 4 on page two of this letter, guidance is requested from Council on the overall schedule. From a technical perspective, and considering the wealth of information available and likely to be offered by stakeholders, it might be preferred to plan for a November Town Council meeting, particularly if ample time is required for Council review of the Draft Report in advance of the presentation. However, we understand there are other factors affecting the schedule, and will take necessary measures to adhere to the schedule required by Council. Earlier guidance from Council on the overall required schedule is requested so the technical team can plan accordingly.

Woods Hole Group appreciates the opportunity to support the Town on this important project. Please contact me directly if there are questions or requirements for additional information. We look forward to working with you to complete this work.

Sincerely,

The Woods Hole Group, Inc.

Robert P. Hamilton, Jr.
V.P., Business Development/Coastal Engineer

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Attachment A. Questions for Town Council

Below are 4 specific questions for Town Council related to items 1 through 4 in the Woods Hole Group letter, dated August 8, 2012. It is assumed that Council Members will be familiar with the contents of the letter in advance as the basis for answering these questions:

1. The August 8, 2012 Woods Hole Group letter offers a list of key issues/areas for Phase II. Are there additional key issues/areas of focus that Town Council requests be included, and/or are there key issues/areas included on the Woods Hole Group that should be removed or de-emphasized?

2. The August 8, 2012 Woods Hole Group letter offers a list stakeholders to contact in Phase II. Are there additional stakeholders that Town Council requests specifically to be contacted by Woods Hole Group?

3. There is a need to schedule the Phase II public workshop, and the week of August 27 or September 10 are offered as preliminary options. Would Town Council support a workshop during the week of September 10?

4. Woods Hole Group requests guidance on the overall project schedule. Key scheduling items involve the date of the Town Council meeting in October or November when the Draft Report will be presented and discussed, and the time required in advance of the meeting for Town Council to review the materials. Considering various factors affecting the project schedule, would Town Council support discussing the report at the November Council meeting? How much time would Town Council request to review the report in advance of the meeting?

APPENDIX B. FY 2013 10-YEAR PLAN

TOWN OF PALM BEACH

Town Council Meeting on: March 14, 2012

Section of Agenda

Regular Agenda - New Business

Agenda Title

Recommendation to Town Council Regarding the Scope and Cost of the Town's Coastal Program.

Presenter

Peter B. Elwell, Town Manager

Supporting Documents

- Memorandum dated March 6, 2012, from H. Paul Brazil, Director of Public Works
- FY 2013 Proposed Coastal Budget

TOWN OF PALM BEACH

Information for Town Council Meeting on: March 14, 2012

To: Mayor and Town Council

Via: Peter B. Elwell, Town Manager

Via: H. Paul Brazil, Director of Public Works

From: Robert Weber, Coastal Coordinator

Re: Scope and Cost of the Town's Coastal Management Program

Date: March 6, 2012

STAFF RECOMMENDATION

Town staff recommends the following:

- Town Council approval of the Shore Protection Board's recommended FY 2013 Coastal Management Budget for inclusion into the Town's overall FY 2013 proposed budget.
- No action to be taken by the Town Council at this time regarding the long term Coastal Management Program, until the SPB has an opportunity at its March and April 2012 meetings to complete consideration of several significant projects.
- Town Council provide direction concerning a potential peer review of the updated long term Coastal Management Program, including relevant documents prepared by Town staff consultants, or others.

GENERAL INFORMATION

The Shore Protection Board (SPB) has been recommending coastal budgets to the Town Council one year at a time for the past three fiscal years (FY 2009, 2010, and 2011). Staff has recommended to the SPB that coastal protection be included in the Town's 10-year Long Term Financial Plan. On February 23, 2012, the SPB unanimously approved both the FY 2013 coastal program budget and a 10-year plan. However, the 10-year plan being recommended by the SPB may be amended after further consideration of several items that the SPB will address at its March or April 2012 meetings.

The SPB's February 23, 2012, approval has been a result of the lengthy scope and cost discussions held by both the SPB and Town Council since 2009. Below is a timeline of relevant actions:

February 11, 2009 - Town Council directed the Shore Protection Board to provide a long term coastal protection plan of action for Town Council consideration in November 2009.

November 10, 2009 - Following 15 meetings, the SPB provided a plan to Council which

included "Required", "Recommended", and "Under SPB Consideration" items for a 10-year plan from FY 2010 through FY 2019. The plan, which included a SPB recommendation of $83.4 million over 10 years, was accepted by Town Council as a general blueprint for the Town's Coastal Management Program (not as an adopted official plan). Several items, including Groin Rehabilitation (Reaches 2-6), Dune Restoration (Reaches 2, 5, and 6), and Beach Nourishment and Structures in Reach 8, required further consideration by the Board. These "Under SPB Consideration" items, if advanced for implementation, would have increased the cost of the 10-year program to $137.1 million between FY 2010 and FY 2019.

December 14, 2010 – The SPB provided an annual report to the Town Council indicating that the board has continued to analyze "Under SPB Consideration" projects. During development of the FY 2011 coastal program budget, the long term planning document was carried out by the SPB only five (5) years from FY 2011 through FY 2015. The five-year plan recommended by the SPB exceeded $58 million. Adding in the projects "Under SPB Consideration" increased the cost of the 5-year plan to nearly $97 million. Town Council directed the SPB to go through the plan and to re-prioritize the individual items and focus on the most achievable projects and the ability to get them constructed.

January 2011 - Town staff urged the SPB to take action during the FY 2012 budget process regarding the scope, cost, and funding of the Town's Coastal Management Program. Echoing Town Council direction, Town staff suggested the SPB decide on the lowest cost program that would adequately protect the Town. Staff added that if the board did not believe that there was an acceptable Plan B program, the Plan would require a level of funding that the Town citizenry may not support.

February 24, 2011 – The SPB continued the discussion of the scope, cost, and funding of the Town's coastal management program. The SPB requested Town staff revision of the FY 2011 planning document with the most up-to-date variables applied for the FY 2012 budget and 10-year plan.

March 25, 2011 – Town staff provided an FY 2012 Proposed Coastal Management Program Budget and FY 2012 – FY 2021 10-Year Forecast to the SPB for their review and consideration at the April 4, 2011, SPB meeting. This staff document, reviewed by three (3) of the Town's coastal engineering consultants, labeled as Plan B, outlined a cost conscious long term approach to addressing storm protection in the Town. Plan B identified a 10-year plan (FY 2012 – FY 2021) which included a total cost of $58.8 million. For comparison purposes, Town staff also identified the total cost of an updated Plan A ("Required", "Recommended", and "Under SPB Consideration") between FY 2012 – FY 2021. The cost of Plan A would exceed $140 million over a 10-year period.

April 4, 2011 – Town staff presented the Plan B document and explained that this plan achieves the objective of maintaining the same rate of spending that the Town had historically been investing in beaches, but achieves more storm protection. The SPB heard a presentation from Erickson Consulting Engineers, Inc. (ECE), a consultant hired by the Save Our Shore (SOS) and Neighborhood Association of Palm Beach (NAPB) organizations. ECE requested 60-90 days to review the Town staff recommendation. The Town Council members present were in agreement to allow 60-90 days for ECE to

review the SPB's recommended plan.

April 28, 2011 – The SPB Continued discussion of the FY 2012 coastal budget. No representatives of SOS, NAPB, or ECE spoke at this meeting. Plan B, including FY 2012 – FY 2021 was approved by the SPB. This recommendation was advanced to Town Council, who approved the FY 2012 proposed coastal budget and delayed action on the 10-year plan pending ECE's review.

October 25, 2011 – ECE provided a 32-page document entitled "An Independent Review of the Town of Palm Beach Coastal Management Plan" to Town staff for distribution to the SPB members.

October 27, 2011 – At a SPB meeting, ECE presented their findings from their October 25, 2011, peer review of the Town's Coastal Management Plan.

November 30, 2011 – Town staff provided a 29-page response to ECE report.

December 6, 2011 – At a SPB meeting, Town staff presented its response regarding the ECE peer review. Town staff reminded the SPB that the board's recommendations on Plan B have been held in abeyance for Town Council consideration until completion of the review of the report from ECE. Ms. Erickson requested a month to review the staff response to her report and give an additional report in January 2012.

December 13, 2011 – The SPB provided an annual report to the Town Council. Town Council directed SPB to consider any revisions suggested by ECE and submit their final recommendations to Council, preferably in time for the March 2012 Town Council meeting.

January 26, 2012 – ECE presented additional commentary to the SPB. After listening to Karyn Erickson and extensive public comment, SPB identified areas of agreement and asked staff to prepare a proposed FY 2013 coastal budget and 10-year forecast and to provide a presentation to the SPB at the February 2012 meeting.

February 23, 2012 – SPB approved the FY 2013 coastal budget and FY 2013 – FY 2012 10-year forecast, as prepared by Town staff, with certain unresolved matters to be addressed in the coming months. These unresolved matters are identified on the attached spreadsheet with asterisks.

In its current form, the SPB's recommended plan would require funding of roughly $7 million per year. Since the unresolved matters mentioned above may add tens of millions of dollars to the program, it is recommended that Town Council delay formal action on the plan until additional information is available. While the SPB continues its further consideration, Town Council may choose to concurrently have a peer review performed by Woods Hole Group (WHG). WHG reviewed the 1998 Comprehensive Coastal Management Plan and offered valuable input, most notably in its advocacy of the "Adaptive Management" approach to coastal protection.

CURRENT RECOMMENDED SPB PLAN, NOTABLE PROJECTS

Please refer to the attached spreadsheet for the SPB recommended FY 2013 – FY 2022 Coastal Management Program budget in its entirety. The following are significant projects in the program:

- The existing North Ocean Boulevard seawall, east of the Palm Beach Country Club, is scheduled for replacement in FY 2014. The estimate of $4 million is based on the seawall length of approximately 1,600 linear feet and the anticipated $2,500 cost per linear foot. This is a bondable project.

- Mid-Town Beach Nourishment Project (w/ structures) – Includes a partial renourishment in November 2014 (FY 2015) and full renourishment in November 2017 (FY 2018). The partial renourishment would utilize upland sand with an expected volume of approximately 75,000 cubic yards. The addition of 1 or 2 groins at the south end of the municipal beach, consistent with the *Coastal Structures Plan, March 2011*, by Coastal Technology Corporation, is being considered for construction concurrently with the partial renourishment. The structures would be bondable. Permit required tasks, such as tilling, escarpment removal, sea turtle nesting monitoring, environmental monitoring, and physical monitoring are all included within the current recommended SPB plan.

- Phipps Ocean Park/Reach 7 Beach Nourishment Project (w/ structures) – Includes two (2) full nourishments in November 2013 (FY 2014) and November 2021 (FY 2022). The footprint of beach nourishment is expected to be extended south to include the Reach 8 properties north of the Lake Worth Pier. Conceptual design concluded that the construction of two groins within Phipps Ocean Park would help stabilize the shoreline in this "hot spot" location. In conjunction with the ECE review, the SPB has expanded the scope (more structures covering more area from Phipps Park to Sloan's Curve) of planning for the structural element of this project. Please see below for additional discussion of this unresolved matter.

- Repetitive Dune Restoration in Reach 8 (south of the Lake Worth Pier) – Includes three (3) repetitive dry beach sand placement projects in Novembers 2013, 2016 and 2019 (FY 2014, 2017, and 2020, respectively). The 2013 project would be constructed concurrently with the Reach 7 beach nourishment, as was performed in 2006, and likely utilize 25,000 to 33,000 cubic yards of offshore sand. The successive projects in 2016 and 2019 would utilize upland sand.

ITEMS UNDER FURTHER SPB CONSIDERATION (ASTERISKED ITEMS)

The items listed below are the program elements still under consideration by the SPB. Related line item numbers include 4, 13, 14, 21, 44, 47, 48, and 55. The potential costs of these elements are not included at this time in the overall program budget.

- Lake Worth Inlet Maintenance Activities – This includes the Sand Transfer Plant Phase II Construction and the Incremental Cost for Dry Beach Placement (associated with

USACE dredging). These items are expected to be significantly influenced by the pending litigation between the Town and the United States of America. These activities have costs which exceed $10 million over the FY 2013 – FY 2022 planning period. The Federal Government is expected to pay a significant portion of these costs.

- Groin Rehabilitation (Reaches 2-6) – The SPB has requested that a consultant peer review the *Coastal Structures Plan, March 2011*, by Coastal Technology Corporation, and re-evaluate the rehabilitation priorities as prescribed in the report. If the board decides to add this capital improvement project back into the plan, the costs during the FY 2013 – FY 2022 period are expected to be approximately $5 million. A proposal will be provided to the SPB at the March 2012 meeting and potentially advanced to Town Council for consideration at the April 2012 meeting.

- Reach 7 Structures Extending North to Sloan's Curve – The SPB has requested that Advanced Design (results expected at the March 2012 SPB meeting) be performed for several structural alternatives associated with the next Reach 7 beach nourishment. One of the alternatives to be considered is the placement of structures north of Phipps Ocean Park and into the Sloan's Curve area. The permitability and cost of this alternative will be presented to the SPB in March 2012. If the Town decides to advance this alternative for permitting, the cost of this item (currently $14.5 million of which approximately $5.5 million would be bondable) will increase to approximately $23 million (of which approximately $11 million would be bondable).

- Reach 8 Experimental Project – A concept of this project was first introduced at the February 23, 2012, SPB meeting at the request of SOS and ECE. The project includes the placement of approximately 200,000 cubic yards of Aragonite (Bahamian sand). This experimental project is roughly the same size as the beach nourishment project (South End Palm Beach Restoration) currently in State and Federal permitting. The costs associated with this project are largely unknown. Absent of mitigation, construction costs based on the computed unit price of Bahamian sand ($45/CY) would be $9 million.

If all of the above items are added into the current SPB recommended plan, the total cost for the FY 2013- FY 2022 10-year plan would increase from approximately $67 million to nearly $100 million.

PEER REVIEW

Town Council has previously expressed interest in obtaining additional peer review of the Coastal Management Program. Woods Hole Group (WHG) was selected as a qualified coastal consultant on the Town's roster to perform peer reviews. WHG is internationally respected, performed the peer review of the Town's Comprehensive Coastal Management Plan Update of 1998, and has successfully provided similar services to many other coastal communities.

If requested, staff can solicit a proposal from WHG and return to Town Council on April 10, 2012, for contract approval. WHG would review all the information which has been passed through the SPB (by Town staff, Town consultants, and outside consultants over the past several years) and provide objective advice regarding a reasonable program to provide adequate storm protection to the Town. WHG's report would be prepared during the SPB's summer hiatus and

be reviewed by the SPB and Town Council early next season.

If Town Council chooses to move forward with a peer review of the proposed program, we anticipate the following schedule:

- March 22, 2012 – Following a presentation by Coastal Technology Corporation, SPB affirms or modifies their recommendation to Town Council regarding Phipps Ocean Park/Reach 7 Beach Nourishment (with structures).

- April 2012 – Pending approval by Town Council, WHG begins peer review process.

- Summer 2012 – WHG peer review completed and distributed to the Town Council and SPB.

- October-December 2012 – SPB reviews 10-year plan based on input from WHG. Finance and Tax Committee reviews the SPB's recommended plan. Town Council considers the SPB's recommended plan and the Finance and Taxation Committee recommendation(s) regarding funding.

FUNDING/FISCAL IMPACT

Attached is a spreadsheet that includes the proposed FY 2013 Coastal Management Program Budget, as prepared by Town staff and recommended by the SPB, and the 10-year forecast for the period between FY 2013 and FY 2022. The average annual cost is higher than the FY 2012 10-year Coastal Management Plan because the lower cost of FY 2012 (no construction projects) is being replaced by an anticipated higher cost of FY 2022 (Phipps Ocean Park/Reach 7 renourishment). Other small adjustments have been made, as needed, to reflect changed circumstances and/or decisions made by the SPB and/or the Town Council during the past year.

Attachment

cc: Shore Protection Board
Jane Struder, Finance Director

Palm Beach Shore Protection Board Recommended
FY 2013 Proposed Coastal Management Program Budget
INCLUDING 10-YEAR (FY 2013 - FY 2022) FORECAST

Red = Permit Required Purple = Influenced by Pending Town/USACE Relations

309 ACCOUNT ITEMS [CAPITAL]

Item #	Project	Unencumbered †, as of 2/17/2012 (Previous SPB Recommended Budgets FY09, FY 10, FY 11, and FY 12)	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
	TOWNWIDE											
1	Offshore Sand Search	146,000										
2	Groin Assessment	0		60,000					60,000			
3	Groin Analysis	6,000										
4*	*Groin Rehabilitation (Reaches 2-6)*	200,000										
5	General Coastal (Engineering/Legal/Lobbying)	50,000	50,000	55,000	60,000	65,000	70,000	75,000	80,000	85,000	90,000	95,000
10	SPB Operating Funds	0										
	LAKE WORTH INLET MAINTENANCE IMPLEMENTATION PLAN											
12	Sand Transfer Plant Phase II Permitting	187,000										
16	Tri-Party Dredging Permitting	15,000										
17	Lawsuit Technical Assistance	50,000										
18	Maint. Dredge Sand Permitting, Placement Extension	200,000	100,000									
20	Expanded Settling Basin Study	200,000										
	REACH ONE											
23a	Sea Turtle Monitoring/Beach Tilling/Escarpment Removal	40,000	33,000	33,000	33,000	33,000	42,000	42,000	42,000	42,000	42,000	53,000
23b	Beach Tilling	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
23c	Escarpment Removal	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
	REACH TWO											
27	*North Ocean Boulevard Seawall*	250,000		*4,000,000*								
	REACH THREE/FOUR (MID-TOWN)											
29	Beach Nourishment Permitting	250,000	100,000									
30	Beach Nourishment Construction				3,300,000			12,000,000				
	Groins at Gulfstream Rd.	20,000			*1,700,000*							
31	*Beach Nourishment Construction Mitigation*	3,000,000										
32a	Sea Turtle Monitoring	40,000	32,000	32,000	32,000	32,000	41,000	41,000	41,000	41,000	41,000	52,000
32b	Beach Tilling	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
32c	Escarpment Removal	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
33	Biological Monitoring	183,000	105,000	110,000	165,000	121,000	128,000	184,000	141,000	148,000	155,000	162,750
	REACH SEVEN (PHIPPS), NORTH OF THE LAKE WORTH PIER											
43	Beach Renourishment Permitting	238,000										
44*	Beach Renourishment Construction			9,000,000								12,000,000
47*	*Structures Construction*			*3,000,000*								
48*	*Structures Construction Mitigation*			*2,500,000*								
50a	Sea Turtle Monitoring/Beach Tilling/Escarpment Removal	40,000	32,000	32,000	32,000	32,000	41,000	41,000	41,000	41,000	41,000	52,000
50b	Beach Tilling	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
50c	Escarpment Removal	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
51	Biological Monitoring	550,000	105,000	220,000	116,000	121,000	128,000	134,000	141,000	0	0	325,000
	REACH EIGHT, SOUTH OF THE LAKE WORTH PIER											
53	Critical Beach Erosion Designation	10,000										
54	Beach Restoration Permitting											
55*	Beach Restoration Construction											
56	*Beach Restoration Mitigation*				*1,000,000*							
57	Dune Restoration (R-129 to R-134)	208,000		500,000			1,500,000			1,500,000		
58	Structures Study (Env. Impact Statement)											
59	Potential Structures Permitting		200,000									
60	*Structures Construction*											
61	*Structures Mitigation*											
62a	Sea Turtle Monitoring	40,000	32,000	32,000	32,000	32,000	41,000	41,000	41,000	41,000	41,000	52,000
62b	Beach Tilling	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
62c	Escarpment Removal	10,000	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
63	Biological Monitoring			50,000	100,000	50,000	50,000					
64	Reach 8 Project Engineering Report											
		6,003,000										

309 ACCOUNT, "PAY-AS-YOU-GO"			FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
COLUMN SUB-TOTALS:		**Permit Required**	**419,000**	**547,000**	**3,798,000**	**467,000**	**517,000**	**12,587,000**	**551,000**	**411,000**	**440,000**	**824,750**
	Recommended	**Permit Required**	**869,000**	**10,212,000**	**3,958,000**	**582,000**	**2,137,000**	**12,662,000**	**691,000**	**2,010,000**	**530,000**	**12,919,750**

309 ACCOUNT, BONDABLE [ALL APPLICABLE PROJECTS *ITALICIZED* ABOVE]			FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
COLUMN SUB-TOTALS:		**Permit Required**	**0**	**0**	**1,000,000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Recommended	**Permit Required**		**9,500,000**	**2,700,000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
LEVELIZED FOR 30 YEARS:			**813,333**	**813,333**	**813,333**	**813,333**	**813,333**	**813,333**	**813,333**	**813,333**	**813,333**	**813,333**

581 ACCOUNT ITEMS [OPERATING]		FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
65	Annual Sediment Budget	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
66	Physical Monitoring	68,000	72,000	75,000	79,000	83,000	87,000	91,000	96,000	101,000	101,000
67	Sand Transfer Plant Operating	310,000	320,000	330,000	340,000	350,000	360,000	370,000	380,000	390,000	400,000
68	LWI Maintenance Implementation Plan Physical Monitoring	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	26,000	27,300
69	Mid-Town Physical Monitoring	37,000	38,000	40,000	42,000	45,000	47,000	49,000	52,000	54,000	56,700
70	Mid-Town Bch. Project Engineering Report	10,000	11,000	11,000	12,000	12,000	13,000	13,000	14,000	15,000	16,000
71	Phipps Ocean Park Project Physical Monitoring	26,000	28,000	29,000	30,000	32,000	34,000	35,000	37,000	39,000	40,950
72	Phipps Ocean Park Project Engineering Report	10,000	11,000	11,000	12,000	12,000	13,000	13,000			16,000
73	Reach 8 Project Physical Monitoring	26,000	28,000	29,000	30,000	32,000	34,000	35,000	37,000	39,000	40,950
74	Coastal Management Program Operating Expenses	205,000	213,000	220,000	227,000	235,000	244,000	254,000	258,000	262,000	275,100

581 ACCOUNT			FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
COLUMN SUB-TOTALS:		**Permit Required**	101,000	107,000	111,000	117,000	123,000	130,000	134,000	128,000	134,000	156,950
	Recommended	**Permit Required**	720,000	751,000	776,000	805,000	835,000	868,000	897,000	913,000	941,000	990,000

309 AND 581 ACCOUNTS [CAPITAL + OPERATING], BONDABLE PROJECTS LEVELIZED			FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
COASTAL MANAGEMENT PROGRAM GRAND TOTALS		**Permit Required**	**1,333,333**	**1,467,333**	**4,722,333**	**1,397,333**	**1,453,333**	**13,530,333**	**1,498,333**	**1,352,333**	**1,387,333**	**1,795,033**
	Recommended	**Permit Required**	**2,402,333**	**11,776,333**	**5,547,333**	**2,200,333**	**3,785,333**	**14,343,333**	**2,401,333**	**3,736,333**	**2,284,333**	**14,723,083**

Summary of Costs		
	FY 2012 - FY 2021 RAW TOTAL	**$67,266,750**
	BONDABLE TOTAL	**$12,200,000**
	10-YEAR RAW TOTAL MINUS BONDABLE	**$55,066,750**
	BONDABLE PAYBACK ANNUAL COST	**$813,333**
	AVG. ANN. COST (WITHOUT BONDABLE)	**$5,506,675**
	TOTAL AVG. ANNUAL COST (W/ BOND.)	**$6,320,008**

LAKE WORTH INLET ACTIVITIES, Pending Litigation (ADD LANGUAGE FROM SPB MOTION)		FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
13*	*Sand Transfer Plant Phase II Mitigation*	*2,000,000*									
14*	*Sand Transfer Plant Phase II Construction*	*3,850,000*									
21*	Incremental Cost for Dry Beach Placement (1 Event)	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
COLUMN SUB-TOTALS:		**6,350,000**	**500,000**	**500,000**	**500,000**	**500,000**	**500,000**	**500,000**	**500,000**	**500,000**	**500,000**

309 AND 581 ACCOUNTS [CAPITAL + OPERATING], RAW			FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
COASTAL MANAGEMENT PROGRAM GRAND TOTALS		**Permit Required**	520,000	654,000	4,909,000	584,000	640,000	12,717,000	685,000	539,000	574,000	981,700
	Recommended	**Permit Required**	1,589,000	20,463,000	7,434,000	1,387,000	2,972,000	13,530,000	1,588,000	2,923,000	1,471,000	13,909,750

Note: Numerical values in U.S. Dollars

† Unencumbered funds are funds that have been appropriated by Town Council but not yet specifically committed to any particular vendor. They remain part of the Coastal Protection Fund's fund balance.

* These items are continuing to be actively reviewed by the SPB, with assistance from Town staff and consultants, and with input from the public. Scope and cost of these items could change significantly as the SPB completes its review.

APPENDIX C. RESPONSE TO COMMENTS ON DRAFT REPORT

C-1 RESPONSE TO COMMENTS ON DRAFT REPORT

An April 25, 2013 Woods Hole Group letter outlined comments from the Town Council March 14, 2013 public meeting that were to be addressed in the Final Report. Comments from a March 28, 2013 Shore Protection Board meeting were to be addressed as well. Woods Hole Group outlined an approach for addressing the comments that included: 1) support from Town staff; and 2) recognition that some comments could be addressed, but not fully resolved within the scope of the Technical Review (*italicized items* below). For those comments not fully addressed, a follow-up action plan was incorporated into the Recommended Plan submitted to Council in the Final Report. For instance, a full assessment of groin ownership, detailed updated cost estimates, and an assessment of hot-spots will require more detailed follow-up as part of the overall Coastal Structures program. Likewise, the Reach 8 specific plan cannot be recommended at this time, pending further engineering and the EIS process recommended by Woods Hole Group for that Reach.

This Appendix provides an itemized response to comments, including references to specific sections of the Final Report where applicable.

Town Council comments from March 14, 2013 are itemized below with bulleted responses:

1) Prioritize recommendations: There are many #1 priorities identified in the Draft Report. There is a need to rank the recommendations to facilitate decision-making in case all #1 priorities cannot be implemented.
    - The recommendations presented in the Draft Report were consolidated into a subset of prioritized activities summarized on Table ES-1 in the Final Report Executive Summary. A Recommended Plan is provided for Council deliberations.

2) Clarify recommendations in report: Modify the language in the report to emphasize clearly what next immediate steps are recommended.
    - The Recommended Plan includes immediate next steps termed Priority 1 items and Essential Town items that have cost implications. Recommended Management Strategies are included as well for guidance, but do not have cost implications per se. This Recommended Plan is clearly identified on Table ES-1.

3) *Develop a cost estimate: Assign estimated costs to each prioritized recommendation, and propose a corresponding schedule for projects/costs.*
    - The Recommended Plan outlined in Table ES-1 includes a cost estimate, which has highest confidence for FY2014. Estimated costs for subsequent years, particularly beyond FY2016 will require annual refinements pending project performance, storm activity, EIS outcomes, and overall community needs.

4) Validate costs: Offer opinion on cost estimates developed by SPB and Town.
    - A preliminary cost estimate was developed independently by Woods Hole Group, and subsequently compared with Town staff estimates to offer Town Council a

uniform estimated budget for deliberations (Table ES-1 and subsequent coastal program we understand will be submitted to Town Council by Town staff). The FY2014 budget, in particular, is offered with confidence for Town Council approval.

5) *Reach 1: Recommend specifically when (or under what conditions) to fill Reach 1 and when to move sand to other places.*
   - Included with the Recommended Plan for FY2014 is a CCMP update with clear design standards for Reach 1 defining the level of protection required (e.g., beach width, elevation, and advanced nourishment). Should the impounded sand in Reach 1 and northern portion of Reach 2, where inlet sand disposal is permitted, exceed the design standard, then the sand would be recommended for distribution elsewhere. Impounded STP sand, for instance at the northern portion of Reach 1, is recommended for forepassing by truck haul farther south within the approved inlet disposal template (approximately 2,500 ft south from the inlet). Should the approved inlet disposal template be filled, then additional sand dredged from the inlet is recommended for direct pumping to Mid-Town, and/or hopper dredge pumpout to Mid-Town, Phipps, or Reach 8. Adaptive management strategies will be required to make these decisions.

6) *Reaches 2/3 groins: Recommendations for rehabilitating groins are appreciated, but there is a need to know who owns them as a basis for determining responsibility for costs to perform repairs.*
   - Preliminary Town research indicates variable ownership of groins. For instance, the groins included within the Mid-Town project design are deemed the Town's responsibility. Town records (e.g., long scroll map for groin work between 1926 and 1931) suggest other groins may have been constructed by Town forces, but the cost of services were assessed to the private property owner who maintained liability for downdrift influences. Resolving groin ownership is not within the scope of Woods Hole Group's technical review contract; however, next steps are included in the Coastal Structures Program included in the Recommended Program outlined in Table ES-1. More details are provided in Section 3.5 of the Final Report.

7) Dune cores: Need to expand on the explanation for these. Be specific on why/why not useful at Palm Beach, and include in prioritized recommendations if appropriate.
   - Dune cores are not recommended for municipal projects, but may be pursued by private interests. There is an unpredictable required liability associated with maintaining and covering dune cores (Per Chapter 62B-56, Florida Administrative Code), rendering them difficult to incorporate into a municipal program (i.e., uncertain budgetary requirement for public funds). Private owners may wish to pursue them as a supplement to dune restoration activities assuming the owner(s) are willing to assume the financial liability to maintain the dune cores in accordance with State Code. A summary of dune cores with more specifics is provided within Section 3.7 of the Final Report.

8) Rock revetments: Be specific on whether rock revetments are recommended as part of the overall seawall program. There are perceived benefits in terms of adding stability to seawalls and helping to dissipate wave energy and trap sand.
    - Rock revetments will continue to be part of the overall program. The decision to have a concrete seawall, rock revetment, and/or composite structure is site-specific, and should be offered by a design engineer and reviewed by Town staff for consistency with CCMP. Rock revetments are addressed in more detail within Section 3.5 of the Final Report.

9) Sand bar mining: Need to explain whether sand bars, that harbor beach quality sand, should be mined for beach sand nourishment.
    - Nearshore sand bars should not be mined for purposes of beach nourishment as the bars provide natural shore protection, and are within the active profile. Mining sand from this active section of the beach would disrupt the natural movement of sand and negatively influence the overall beach by allowing waves to propagate to the shoreline without being dissipated by a healthy sand bar. Effectively transporting and operating equipment close to shore in shallow water at reasonable cost also is a limiting factor. More details related to sand bars and sand bar mining is provided in Sections ES-2 and 3.4.2 of the Final Report.

10) Palm Beach Country Club seawall: The seawall is overtopped on a regular basis as evident during seasonal storms with visible dead grass. Causes and potential solutions should be identified, along with other similar areas if similar concerns exist.
    - Consultations with Town staff indicated salt spray often blows over the wall, particularly during northeast storms with winds from the east. The dead grass is believed to be mitigated through improved onsite irrigation and maintenance. Although not within the scope of this review, a coastal structures program is recommended to inventory seawalls on the Island, and identify candidate structures for maintenance. One element of the seawall program would be to establish design guidelines (including recommended crest elevation necessary to provide adequate storm protection). Should the observed landward impacts continue, The Palm Beach Country Club seawall is a candidate for review. More details about the Country Club seawall is within Section 3.5 of the Final Report.

11) Reach 8 critically-eroded status: Should this be pursued or not? If so, offer information related to likelihood and requirements for approval.
    - As of April 8, 2013, the entire Town of Palm Beach shoreline, including Reach 8 south of the Lake Worth Pier, is designated by FDEP as critically-eroded.

12) Reach 8 specific plans: Need to offer an estimated cost and timeframe for Reach 8 recommendations in terms of the EIS and related projects.
    - A specific plan is recommended for Reach 8, including proceeding with the EIS, dune maintenance with truck haul sand from the next Mid-Town project in FY2014, and plans to bolster Reach 8 with a feeder beach south of the Pier together with the next full Phipps nourishment in FY2016 (assuming positive outcome from the EIS). Subsequent Reach 8 plans related to expanded beach

nourishment and/or structures are in the out-years of the plan subject to feeder beach project performance, EIS outcomes/flexibility, and the overall adaptive management approach. At the time the Final Report was published, USACE was interviewing consultants to initiate the EIS process, which will include a series of scoping and scheduling meetings. As the EIS process is expected to last multiple years and require a budget approaching $1M, it is premature to speculate on the details of the outcome other than the planning level items in the Recommended Plan. Details and costs related to the Reach 8 plan are provided in the Executive Summary and Section 5.1 of the Final Report.

13) *Hot-spots: There needs to be a greater emphasis on these. Identify and propose a plan for what to do about them.*
    - The Recommended Plan includes a truck haul provision along with each nourishment project, which affords flexibility to maintain hotspots. Future coastal structures also are contemplated, pending performance of beach nourishment projects specifically for areas including Gulfstream Road at Mid-Town, the northern portion of Phipps, and the southern portion of Reach 8. More details related to hotspot management are provided in Section 3.2 of the Final Report.

Several Shore Protection Board comments from the March 28, 2013 meeting were consistent with Council requests. Additional requests are itemized below with bulleted responses:

1) Clarify whether additional sand nourishment is recommended north of Lake Worth Pier.
    - Yes, additional sand nourishment is recommended north of Lake Worth Pier, including an expanded beach nourishment template as part of the refined Phipps Park beach nourishment project design. Specific dimensions and quantities will be provided by the design engineer. This specific item is included in the Recommended Plan outlined in the Executive Summary and Section 5 (including Recommendation Tables) of the Final Report.

2) Be more specific, if possible, on locations and scope for experimental project(s).
    - Demonstration projects are contemplated for Reaches 2, 7, and 8, including specific concepts for each area (e.g., strategically located terminal groins in Phipps, low profile/adjustable groins in Reaches 2, 7, or 8). No specific action is included in the Recommended Plan, though, since such actions are not likely to be permitted in the short-term concurrent with the recommended activities in Reaches 7 and 8. Perhaps the most feasible opportunity for a demonstration project is within Reach 2 where groins already exist that could be rehabilitated in conjunction with sand nourishment from the inlet. Should the combination of groins and modest beach nourishment prove effective at maintaining a beach while limiting potential impacts to nearshore hardbottom in Reach 2, there may be evidence to help advance projects elsewhere. However, the project would not be essential to advance the CCMP objectives, and would require added voluntary expense. Demonstration projects are discussed in Section 5.2 of the Final Report.

3) Offer a specific recommendation for condominiums not on pilings.
    - A specific recommendation would require evaluation of the actual condominium of interest on a site-specific basis. However, the Recommended Coastal Sructures Program would inventory the presence/absence of seawalls and pile-supported foundations (i.e., conforming structures). Candidate solutions for condominiums not on pilings would include seawalls (where permissible), dunes, and beach nourishment.

4) State whether bulkhead improvements should be made on the Lake side.
    - There are certain areas on the Lake side currently subject to flooding that should pursue improvements. FEMA maps reveal areas within flood zones, and the Recommended Coastal Structures Program would identify these specific properties. The Priority 2 Vulnerability Assessment would also identify flooding pathways and candidate areas for future risk. The actual design would be performed on a site-specific basis by a qualified engineer. Sections 3.5 and 3.8 of the Final Report address Lake side bulkhead matters.

5) Be clear on sand source priorities and recommended grain size (e.g., there was a perception that aragonite was recommended above regional sand borrow sites).
    - Securing inlet sand on the Island's beaches is the number one priority, with the understanding that regional sand borrow sites will realistically provide the majority of sand for beach renourishment projects at least for the next 10-year period. A high priority also should be placed on identifying and securing a position for the Town as a recipient for more regional offshore sand sources. Aragonite was determined to be not feasible at this time primarily due to its price and uncertainties related to environmental impacts, durability, and importation. Ortona sand should be considered a viable option, although expensive. Until aragonite is at least proven to perform as well and be available at lower cost than Ortona sand, aragonite is not a viable alternative. Many details about sand sources and priorities are provided in Section 3.4 of the Final Report.

6) Clearly make a recommendation about the pipeline extension.
    - The Town should not pursue the pipeline extension at this time. A financial commitment from USACE to cost-share the project should be secured, though. A detailed rationale for postponing the pipeline extension is provided in Section 5.1 of the Final Report, and is largely based on likely high cost to the Town, and lack of evidence that the extension will benefit the Town's overall coastal system as intended.

7) Provide an example of a 5- or 10- or 50-year storm if possible.
    - Storms are often attached a particular return period like the 100-year storm; however, there is no single storm that represents a specific event. From a coastal engineering perspective, projects are often designed to withstand a particular return period, such as a 5-, 10-, 25-, or sometimes 50-year condition. What's important to understand is that the return period is a purely statistical quantity. A 10-year event, for instance, has a 10% chance of occurring in any given year.

Likewise, a 50-year storm has a 2% chance of occurring any year. There are no stipulations that multiple 50-year storms can't occur in back-to-back or even the same year; it's just statistics and probability. What is relevant to Palm Beach coastal engineering is the specification of project design criteria that are clearly understood, so that when storms occur one can definitively determine whether the project performed as expected and if the design criteria was tested or exceeded. Woods Hole Group item O-1.2, which is included in the Recommended Plan, specified the need for a clear definition of design criteria, including storm surge elevation, storm wave conditions, and storm duration. With these parameters, projects can be designed to withstand specific conditions and performance can be measured when events occur.

- For perspective, FEMA estimates storm surge elevations for Palm Beach corresponding to 10-, 50-, and 100-year return periods are 4.3-4.5, 6.0-6.3, and 6.8-7.0 ft above NGVD29, respectively. Although direct measurements are not available, NWS reported maximum storm surge of between 2 and 4 ft for Hurricanes Frances and Jeanne. Coastal Systems International (CSI) did an extremal analysis for offshore waves at Palm Beach and estimated 25-year waves to be 35.1 ft (significant wave height) at 11.8 seconds (peak period). Corresponding nearshore waves at the mitigation reef sites proposed for Reach 8 were 6.0 to 9.3 ft at 10.3 to 11.1 seconds. Data obtained from offshore NOAA buoys reported maximum waves for Frances (24.6 ft), Wilma (19.7 ft), Andrea (18.3 ft), Fay (16.7 ft) and Sandy (26.5 ft). Regarding storm duration, Hurricane Sandy had sustained large offshore waves over 10 ft lasting 84 hours. By comparison, Wilma had waves over 10 ft for 17.5 hours.

8) Consider whether it would be helpful to rebuild and maintain the sand bars that apparently provide wave protection in the wake of Sandy and other subsequent storms.
    - Yes, sand bars should be maintained through the overall sand nourishment program that supplements the overall sediment supply, and allowing for natural bar/berm profiles to evolve. Sand bars are important to the overall littoral system, and should not be mined as explained in Sections ES-2 and 3.4.2 of the Final Report.

9) Clarify what is meant by possible northern transport of sand from Reach 3 to Reach 2.
    - There is a natural diffusion of beach nourishment sand from Reach 3 north into Reach 2. Although the net direction of transport is from north to south, there also is episodic northerly sand transport when waves break along the coast from a southerly angle.

10) Consider whether stability to beaches added by groins in existing locations is evidence that groins will be effective in Reaches 7 and 8.
    - Although each groin design is site-specific, groin performance in other areas of Palm Beach will provide insight that can be leveraged for a future design for groins in Reaches 7 and/or 8.

11) Reference is made to a "new" cutterhead dredge used for the USACE inlet dredging project. Clarify what is meant here.
    - This was not intended to be a reference to a new dredge or new dredging method; rather, it is simply a newly preferred method by USACE as the least cost alternative for dredging the inlet. The significance to Palm Beach is the ability of the cutterhead hydraulic pipeline dredge to pump the material directly onto the dry beach and surf zone, as opposed to the intermediate water depth disposal often practiced in the past with the hopper dredge.