SOUTHEAST FLORIDA CORAL REEF INITIATIVE

MARITIME INDUSTRY AND COASTAL CONSTRUCTION IMPACTS WORKSHOP

DANIA BEACH, FLORIDA
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A study to identify and evaluate existing and emerging innovative technologies in coastal construction practices and procedures that minimize or eliminate impacts to coral reefs, hard/live bottoms, and associated coral reef resources in southeast Florida.

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1. INTRODUCTION

1.1 Background

The State of Florida contains a substantial portion of the United States' coral reef ecosystems within its borders and is committed to the preservation and protection of the biodiversity, health, heritage, and social and economic value of coral reef ecosystems and the marine environment. In 2003, with guidance from the United States Coral Reef Task Force (USCRTF), the Florida Department of Environmental Protection (FDEP) and the Florida Fish and Wildlife Conservation Commission coordinated the formation of a team consisting of interagency marine resource professionals, scientists, non-governmental organizations, and other interested stakeholders. The team was tasked with developing a Local Action Strategy (LAS) targeting coral reefs in southeast Florida, from Miami-Dade County, through Broward and Palm Beach, to Martin County. The LAS, now known as the Southeast Florida Coral Reef Initiative (SEFCRI), was completed in 2004. This region was chosen because its reefs are close to a highly developed and densely populated coastal region, and are, therefore, at greater risk of anthropogenic impacts. Prior to development of the SEFCRI, there was no coordinated public education or management plan proposed for reefs located north of the Florida Keys. The SEFCRI Team is divided into four sub-teams, each focusing on one of four recognized threats to local reefs: 1) A lack of public awareness and appreciation; 2) Impacts associated with fishing, diving, and other uses; 3) Land-based sources of pollution; and 4) Maritime industry and coastal construction impacts (MICCI). This document includes the results of the study and workshop proceedings of a MICCI LAS project to identify and evaluate existing and emerging innovative technologies in coastal construction practices and procedures that minimize or eliminate impacts to coral reefs, hard/live bottoms, and associated coral reef resources in southeast Florida.

The general health and conditions of the nearshore coastal habitats in southeast Florida have been, and continue to be, affected by multiple anthropogenic and natural stressors. Coral cover on many Caribbean reefs has declined up to 80 percent over the past three decades (Garner et al. 2003). Southeast Florida reefs, which are a part of the greater Caribbean reef system, are being monitored by the Florida Fish and Wildlife Conservation Commission (FWC) Florida Fish and Wildlife Research Institute (FWRI), and the Nova Southeastern University (NSU) National Coral Reef Institute (NCRI) for diseases, bleaching, and other adverse effects associated with human activities in the coastal regions of the state. Yet, the majority of reef areas in this geographic region is not part of an active long-term monitoring effort and are not protected under a comprehensive management plan. Activities affecting coral reefs and associated reef resources include coastal development, increased nutrient and sediment loads from stormwater runoff and wastewater treatment plant outfalls, and physical destruction from vessel groundings, dredge and fill activities, placement of municipal and utility infrastructure, and increased turbidity and sedimentation from dredging projects. Corals and coral reef resources have been damaged from these activities in many areas. Because corals are very slow growing, this loss represents a serious and significant threat to local coral ecosystems.

1.2 Purpose

The MICCI Team developed the LAS to address threats to coral reefs and coral reef resources that are associated with coastal construction activities and projects in southeast Florida. Large coastal infrastructure projects such as natural gas pipeline and fiber optic cable installation can degrade reef habitats through direct physical damage and related indirect effects. Projects such as commercial and residential shoreline development waterward of the Coastal Construction Control Line and natural dune system, improved and manmade inlets, and the installation and operation of outfalls for public utilities can further damage coral habitat through secondary effects, such as increasing turbidity and sedimentation. Decades of dredging to build and maintain inlets, ports, harbors, and canals have disrupted the natural littoral flow of sediments and, as a result, shoreline erosion down-drift of the inlets is more pronounced. Local municipalities and the U.S. Army Corps of Engineers (USACE) have undertaken beach nourishment and re-nourishment projects, in which sand is dredged from offshore locations, inlet sand traps, or inlet shoals and transported to eroded beaches and nearshore waters to restore the shoreline. Increased turbidity resulting from dredging and beach renourishment can damage coral habitat. Sediments can smother corals and reduce water clarity, which deprives corals' zooxanthellae of the light they require for photosynthesis. Dredging of sediments and substrate for the construction and maintenance of marine navigational channels, ports, and recreational boating facilities may directly affect coral habitats by contributing additional turbidity and sedimentation to the coral reef system.

The cumulative impacts from these activities impair the resiliency of coastal reef habitats by making them more susceptible to anthropogenic and natural perturbations. To address these threats and minimize or eliminate impacts to coastal habitats and coral reef systems, the MICCI Team identified and developed a priority project in the LAS (number 3 of 30 projects that have been proposed) to conduct an investigation and evaluation of existing and emerging innovative technologies for coastal construction activities in southeast Florida. As population densities in southeast Florida continue to increase, it is logical to assume that coastal construction activities will also proportionally rise. Florida's shortage of available land for new housing construction and the increasing demand of permanent and seasonal residents to live and work on, or in proximity to, the water places continued stress on coral ecosystems from coastal construction activities.

This study to evaluate existing and emerging innovative technologies for coastal construction is an effort to find alternative and improved ways of working in and around coral reef and hard-bottom communities with fewer environmental impacts to reef resources. The MICCI Project 3 Team proposed a 2-day workshop to provide environmental managers, regulators, stakeholders, and the coastal engineering and coastal construction-related industries the opportunity to review, discuss, and recommend advances and modifications of existing or emerging technologies that could minimize or reduce the environmental concerns associated with these activities. This document presents the results of the study and the proceedings, including recommendations from the workshop, in an effort to obtain additional insights from stakeholders involved in coastal construction.

1.3 Workshop Agenda, Topics and Participants

The 2-day workshop included representatives and experts from the coastal construction industry, coastal engineers, regulatory agencies, environmental agencies, non-governmental and not-for-profit organizations, and academic institutions. The workshop was widely advertised to bring together people from diverse backgrounds and differing points of view. The workshop agenda is provided in Appendix 1, copies of the PowerPoint presentations by the invited speakers are included in Appendix 2, and the registered participants are listed in Appendix 3.

The MICCI Project 3 Team identified five key topics to be addressed at the workshop and incorporated into the workshop proceedings:

1. Identification of activities or actions that have the potential for minimal/maximal effectiveness toward the protection of coral reefs, hard/live bottoms, and associated coral reef resources;
2. Identification of innovative technologies that minimize or eliminate impacts to reef communities;
3. Identification and recommendations for cost incorporation of advanced and/or emerging technologies into regional beach nourishment, erosion control, inlet management, and infrastructure placement programs;

4. Identification and recommendation of study designs to monitor projects and mitigation associated with coastal construction; and
5. Recommendation of permit conditions that could advance the use of emerging technologies for coastal and marine construction activities while maintaining protection of coral reefs, hard/live bottoms, and associated coral reef resources.

The speakers and their respective topics were as follows:

Day 1

- Ms. Chantal Collier (FDEP, Coral Reef Program Manager)—Opening Remarks and Greetings
- Ms. Sharon Niemczyk (Tetra Tech EC, Inc.)—Workshop Facilitation
- Mr. Billy Causey (Florida Keys National Marine Sanctuary)—Importance of Florida's Coral Reefs: Their Importance and the Threats to Them
- Mr. Paden Woodruff (FDEP, Bureau of Beaches and Coastal Systems)—Innovative Erosion Control Technology in Florida
- Mr. Steve Higgins (Broward County, Environmental Protection Department)—Sand Bypassing at Stabilized Inlets: Sustaining Restored Beaches in Broward County
- Mr. Phil Bates (United States Army Corp of Engineers (USACE)—Silent Inspector Monitoring of Dredging Equipment
- Dr. Pete Peterson (University of North Carolina at Chapel Hill, Institute of Marine Sciences)—Assessing the Environmental Impacts of Beach Renourishment: Universal Lessons About the Need for Rigorous Design and Effective Process to Assess Projects of All Kinds
- Dr. Don McNiell on behalf of Dr. Hal Wanless (University of Miami)—Geological Importance of Sand Compatibility for Sustaining Beaches: Economically Wasteful and Environmentally Damaging Beach Renourishment

Day 2

- Ms. Georgia Vince (FDEP, Southeast Florida District, Environmental Resources Program)—Means of Avoidance and Minimization of Coral Reef Impacts During Offshore Coastal Construction Projects
- Mr. Bill Hanson (Great Lakes Dredge and Dock Company, LLC)—Different Types of Dredge Equipment and Uses in Florida
- Dr. Kerry Black (ASR Limited, New Zealand)—Multi-Purpose Ocean Reefs: Understand, Innovate, and Sustain
- Dr. Bill Dally (Surfbreak Engineering Sciences, Inc.)—Reef Mitigation Gardens

1.4 Process

Following the speakers' presentations on the first day, participants selected one of five sessions covering the five topics of concern. Each session was assigned questions for discussion addressing the key topics identified by the MICCI Project 3 Team (listed in Section 1.3). Each session discussed the issues, identified top priority items and critical components (e.g., issues, technologies, and practices), and made recommendations for coastal construction activities, infrastructure installation, beach nourishment, dredging, and groundings. Each session included representatives from local, state, and federal agencies; academia; coastal construction and related industries; and non-profit organizations. A facilitator led each session and was assisted by a volunteer from that session who recorded the discussion and responses. A participant from each session was also tasked with reporting the findings at the end of the day.

This format was repeated on the second day (Day 2) after additional presentations, and participants were asked to report to the same session as on the day before (new participants could select a session for the day based on their interests). Information from the presentations was used during the sessions to identify activities and innovative technologies that might produce the most significant impact, or provide the maximum amount of protection to coral reefs and associated coral reef resources. Each session was also asked to identify study designs to monitor projects associated with coastal construction activities, infrastructure installation, beach nourishment, dredging, and groundings to determine the efficacy of implementing particular technologies to protect southeast Florida coral reef resources. At the end of Day 2, the group representatives gave a short presentation summarizing their discussions, presented prioritized issues and consensus items, and made recommendations to all workshop participants.

1.5 Session Topics

Session 1 addressed questions pertaining to coastal construction, including physical activities and secondary responses known to affect coral reef systems. Session 2 focused on the review of advanced technologies and/or methodologies that minimize or eliminate coral reef resource impacts, including shoreline and beach erosion controls. Session 3 focused on coastal construction technologies proposed to improve and mitigate impacts from shoreline/beach nourishment and armoring projects. This session was divided into Session 3A and Session 3B to accommodate the large number of participants interested in this topic; however, the results of the two sessions have been combined in this document. Session 4 focused on mitigation, monitoring, and permitting issues.

2. SESSION RESULTS AND CONCLUSIONS

This section presents each session's objective, the questions the participants discussed, and the highlights from each session. The highlights are derived directly from the notes recorded on the flip charts and PowerPoint presentations given by a representative of each session at the end of the workshop. However, definitions and explanations of practices have been expanded beyond the notes from each session. A consensus report has been included at the end of each session to summarize the findings of each session. The consensus report is based on the priority items presented by each session's representative at the end of Day 2. Not all sessions conducted a PowerPoint presentation, nor prepared or presented a copy of a complete presentation of their respective findings; therefore, these presentations are not included in these proceedings.

Each workshop session represents one of the five working groups. As noted earlier, the results from Sessions 3A and 3B have been combined in this document. Each session had an objective, which was the focus for that group. The questions and answers associated with the session follow the objective. The order of the session's responses may have been altered from the session's original notes to accommodate flow and consistency, and ensure that the answers provided corresponded with the appropriate question.

2.1 Session 1

Objective: Identify existing practices that are known to affect coral reef systems (coral reefs, hard and/or live bottoms, and associated coral reef resources).

- Physical activities (i.e., dredging, blasting, beach nourishment, and other coastal construction activities)
- Process-based activities and secondary responses (i.e., turbidity, shoreline erosion)
- Regional beach erosion control programs and infrastructure placement for purpose, method, and effectiveness
- Lessons learned from past beach nourishment and renourishment projects in South Florida

Question 1: What coastal construction practices have caused adverse effects on coral reefs or hard/live bottoms? Name the specific construction practice, identify the impacts caused by the construction practice, and list the effects of those impacts on coral reefs or hard/live bottoms.

Session 1 participants discussed seven coastal activities that have caused adverse effects on coral reefs and hard/live bottoms. These practices include blasting, dredging, beach nourishment, docks and piers, jetty installation, offshore commercial vessel anchorages, and coastal development in general. For accuracy and clarification of the outcome of this question some adjustments were made to the information discussed by the Session 1 participants. Four adjustments were made regarding the identified coastal construction practices. First, blasting and dredging were identified as the same construction practice, although they are different construction practices that can be used to achieve similar or completely different goals. Therefore, blasting and dredging were separated into two different construction practices. Second, jetties are a shoreline stabilization method, so this construction practice was expanded to examine shoreline stabilization methods in general. Third, the problems and impacts associated with the United States Coast Guard (USCG)-designated commercial ship mooring areas outside of Port Everglades were discussed; however, although the participants' concerns with ship groundings, anchor and anchor chain drags, navigation, and vessel positioning within the anchorages were legitimate, this topic was excluded from the response because it is not a construction practice. The fourth construction practice discussed was laying cables and pipelines directly on the seafloor, which warrants discussion and was added to the discussion below.

A. Blasting

Description: Blasting is a construction technique in which explosives are used to fragment hard consolidated materials, such as consolidated bedrock, prior to dredging or bridge piling installation.

Potential Reef and Hard/Live Bottom Impacts and Effects: Blasting activities can result in a direct loss of habitat in reefs and hard/live bottoms when the framework is fractured or buried from displaced material. Sedimentation and turbidity from the activity could smother sessile organisms (hard corals, soft corals, seagrass, and sponges) and substantially reduce light penetration to the light-dependent corals and seagrass. Corals, live bottom organisms, and seagrasses exposed to blasting may exhibit overall reductions in spatial extent and health. Corals may exhibit stress responses and become more susceptible to disease, and the cellular structure of seagrass may also be disrupted from blasting activities (US Army Corps of Engineers, 1997).

Other Potential Impacts: Changes in pressure associated with shock waves have damaged the gas-containing organs of fish and marine mammals. It has been documented that acoustic shock waves have led to some marine mammal strandings, and injury and/or death of sea turtles and marine mammals within the vicinity of blasting activities (US Army Corps of Engineers, 1997).

B. Dredging

Description: Dredging is the removal or displacement of material. There are four basic types of dredge techniques typically used in South Florida: hopper dredges, hydraulic cutterhead dredges, hydraulic suction dredges, and bucket/clamshell dredges. Hopper dredges are self-contained and self-maneuverable dredging vessels with a drag arm moved along the bottom to excavate the material, sediment containment areas (hoppers), and dredge pumps. Hydraulic cutterhead dredges are used to dredge through dense consolidated material. The barge is equipped with a cutterhead mounted on one end and spuds on the other end. The terminus of the cutterhead is equipped with dredge teeth and it moves from side to side along the bottom while the barge rotates on the spuds. Hydraulic suction dredges are barges equipped with hydraulic suction devices used to dredge unconsolidated sediments. Bucket/clamshell dredges can be used in both soft and solid substrates and consist of a bucket apparatus attached to a crane that is mounted on a barge. The bucket is lowered into the water and the bucket removes the material.

Potential Reef and Hard/Live Bottom Impacts and Effects: Impacts from dredging, regardless of the method used, include direct loss of habitat, sedimentation, and turbidity that can smother sessile organisms (hard corals, soft corals, and sponges), and substantially reduce light-penetration to light dependent corals and seagrass, which leads to bleaching and die-offs. This may also result in an overall reduction of spatial distribution and health of seagrasses and/or corals.

Other Potential Impacts: Dredging activities can affect sea turtles and marine mammals. For example, if a dredge arm on the hopper barge is not kept in constant contact with the bottom during dredging activities, sea turtles could be sucked into the apparatus. Also, sea turtles and marine mammals could be crushed between vessels and/or injured from direct contact with dredge machinery.

C. Beach Nourishment

Description: Beach nourishment is a practice used to restore eroded beaches. It involves transporting suitable sand from offshore borrow pits or upland quarries to the eroded beach.

Beach nourishment activities involve multiple components such as dredging sand from borrow pits, placement of pipelines on the seafloor to pump sand up onto the beach, and actually placing the sand on the beach. Shoreline stabilization components (see Question 2 discussion below) can be incorporated with beach nourishment to reduce the rate of future erosion.

Potential Coral Reef and Hard/Live Bottom Impacts and Effects: Direct impacts from these activities include burial of habitat from sand or infrastructure, smothering of sessile organisms from sedimentation, substantial light reduction to light-dependent corals and seagrass from turbidity, and removal or crushing of organisms as a result of the sand itself being dredged, and/or from the pipeline laying on the sea floor. An additional impact or adverse effect that may be caused as a result of beach nourishment is incorrect modeling of the equilibrium toe of fill (ETOF) of the beach profile and new sand being moved or washed away from the nourished beach. These two previously mentioned impacts may result in a larger impact area than originally anticipated. Long-term effects may include a decrease in the spatial distribution and health of the habitat, a reduction in coral recruitment, and perpetual turbidity and sedimentation problems.

Other Potential Impacts: An additional impact that may occur from beach nourishment projects is sand incompatibility. Many times the donor sand site is not evaluated adequately enough and the sand grain size is not properly matched to the existing sand grain size already on the beaches. Improper matching of the sand grain size causes the new beach to become unstable and increased and rapid erosion occurs. Large scarps are created along the beach from large portions of the beach being swept away within one storm event or high wave event. Therefore, a lot of time and money to construct the beach is lost because of no sustainability, and renourishment is then needed at a more frequent interval than what was predicted.

D. Docks and Piers

Description: Docks and piers provide permanent and/or temporary mooring locations for vessels. This category includes single-family home docks and large vessel berthing. Piles driven into the substrate support the framework and the decking. They can be fixed above the water or can be floating and are typically made of concrete or treated wood.

Potential Coral Reef and Hard/Live Bottom Impacts and Effects: Impacts from construction include turbidity and sedimentation from pile installation, anchor and anchor cable drags scraping the bottom, and vessel groundings that remove portions of the habitat. Structures may shade certain habitats that require light for survival if the docks do not allow for light penetration. Additional impacts or adverse effects may be from copper/chromium/arsenic (CCA)-treated wood pilings that are not wrapped with a protective coating and may leach contaminants (copper, chromium, and arsenic) into the water; and, improper discharges of contaminants associated with vessels and docking facilities (i.e., cleaning agents, fuel, oil, grease, and sewage) may occur. These impacts and adverse effects can lead to an increase in coral energy expenditure from attempts to remove sediment particles, reduced light levels from shading and turbidity which decrease light necessary for healthy seagrasses and corals, and increased stress from introduced contaminants. Habitat mortality may increase and organisms may be physically damaged or removed. The overall health and spatial distribution of the habitats may decline.

E. Shoreline Stabilization

Description: Shoreline stabilization structures are used to control the movement of sand and/or upland soil. There are four conventional categories of shoreline stabilization structures: (1) groins—shoreline perpendicular or parallel structures (y-shaped or t-shaped and/or at an angle to the shoreline) constructed to capture sand; (2) jetties—shoreline perpendicular structures constructed at navigational inlets to prevent shoaling; (3) breakwaters and sills—shoreline parallel offshore structures constructed to dissipate wave energy that results in an accumulation of sand landward of the structure; and, (4) seawalls, bulkheads and revetments—shoreline parallel vertical structures constructed at or above the water line to prevent soil/sand movement from upland property.

Potential Coral Reef and Hard/Live Bottom Impacts and Effects: Direct impacts during shoreline stabilization construction activities include burial of habitat from sand or infrastructure, smothering sessile organisms from sedimentation, reduction of light penetration to light-dependent corals and seagrass from turbidity, and removing natural shoreline protection mechanisms (mangroves and beach dunes). Factors such as increased wave energy and changes in longshore drift from the shoreline structures could result in further loss of habitat and reduction in spatial extent and health of seagrasses and/or corals.

F. General Coastal Development

Description: High demands for beachfront developments (resorts, hotels, restaurants, condominiums, single-family homes, etc.) have led to overdeveloped coastlines throughout most of Southeast Florida. This is the ultimate cause of impacts to reefs and hard/live bottoms from coastal construction practices. Without this demand, coastal construction and associated impacts would not occur. Historically, dune vegetation that naturally retained sand have been removed and replaced with permanent man-made structures (bulkheads, buildings, roads, etc.); sewage ocean outfalls have been installed to dispose of human waste; previously dark beaches have been illuminated with artificial lights; and stormwater runoff from roadways discharge directly onto the beach and into the ocean.

Potential Coral Reef and Hard/Live Bottom Impacts and Effects: Some impacts associated with general coastal development have been discussed above in the shoreline stabilization structures and beach nourishment descriptions. Nutrification (excess nutrients) from ocean outfall discharges contribute to algal and bacteria blooms that smother hard and soft corals. Runoff from coastal developments (oils and grease from roadways and parking lots, herbicides and pesticides from landscaping, stormwater discharges) further degrade water quality with the addition of contaminants and turbidity. All of these factors could result in adverse effects on coral reefs and hard/live bottoms such as decreased recruitment, health, and distribution, and increased coral mortality and disease in corals, live/hard bottoms, and seagrass communities.

Other Potential Impacts: Shoreline lighting and beach structures interfere with sea turtle nesting and hatchling orientation.

G. Direct Cable or Pipeline Laying

Description: This construction method is commonly used to place fiber-optic cables or pipes on the seafloor. The cable is fed from a lay vessel and allowed to drop to the seafloor. The cable or pipeline can be secured to the seafloor or covered with boulders or concrete mats to prevent movement and for protection of the cable or pipe.

Potential Coral Reef and Hard/Live Bottom Impacts and Effects: If the vessel position and the tension on the line is not continually monitored and maintained during installation, the cable or pipe could be dragged along the sea floor leaving reefs and live/hard bottoms denuded. The weight of the infrastructure crushes corals and other reef and hard/live bottom organisms in its path. Once installed, if the cable or pipe is not secured sufficiently, the underlying area may be continually scraped by swaying of the cable or pipe due to heavy currents.

Table 2-1 provides an overview of the stressors and impacts associated with the above described coastal construction activities. From the results below it appears that all of the mentioned coastal construction activities are equally damaging and are associated with significant impacts to coral reefs and hard/live bottoms.

Table 2-1. Summary of Stressors Associated with Construction Activities and the Impacts of the Stressors on Coral Reefs, Hard/Live Bottom Habitats (e.g., seagrasses, worm reef, and live rock)

	Associated Construction Practice						
Impact or Effect	**Blasting**	**Dredging**	**Beach Nourishment**	**Dock/Pier Installation**	**Shoreline Stabilization**	**Coastal Construction**	**Cable and Pipe Direct Laying**
Removal of habitat	X	X	X	X	X	X	X
Burial of habitat	X	X	X		X		X
Turbidity	X	X	X	X	X		
Sedimentation	X	X	X	X	X	X	
Shading/reduction of natural light	X	X	X	X			
Storm and waste water discharges						X	
Discharge of contaminants				X		X	
Vessel groundings, anchor drags, and propeller wash	X	X	X	X	X		X
Cable drag		X	X	X	X	X	X

Question 2: What dredging practices have been known to cause the most impacts within the Florida region and why?

Workshop participants identified blasting, filling, continuous dredging (>24 hours), appropriate equipment selection, open trenching, dredge scheduling, and borrow area location as the dredging practices that they believed caused the most impacts within the Florida region. Most of these dredging practices were commonly used when channels and inlets were initially created and subsequently deepened or widened. Technological advancements and more strict regulations prevent some of these dredging practices from occurring today and/or provide minimized impacts (see Session 1, Question 4), yet some still occur. For example, many dredging operations work continuously (24 hours/day) until the job is completed to reduce project costs. In addition, blasting may be necessary depending on the geologic conditions within the dredge area in a port or channel deepening and/or widening project.

The most common concerns associated with blasting, filling, open trenching, and borrow area location include habitat destruction, turbidity, sedimentation, and burial of living marine resources. Coral stress levels and health are concerns associated with continuous dredging operations. Increased respiration and mucus production has been observed in corals from exposure to turbidity and sedimentation at moderate levels for extended periods (Telesnicki and Goldberg 1995). Corals exposed to long durations of sedimentation, such as those adjacent to continuous dredging activities, are constantly expending energy to remove sediments and have difficulty recovering, therefore, making them more susceptible to disease and mortality. Also, concerns were raised with the proximity of sand borrow sites dredged for beach nourishment projects to reefs and hard-bottom communities. If inadequate buffer zones are not provided, resource impacts may occur such as turbidity, sedimentation, and direct contact to the bottom with dredging and vessel equipment.

There are some impacts to consider that are specific to the dredge equipment and disposal methods. Dredges that are not self-propulsive (hydraulic and bucket dredges) require additional equipment and vessels (tugboats, spuds, etc.) for locomotion and stabilization. This increases the potential for tow cable, anchor, and anchor chain drags, and resources may be further affected by spud installation and removal. Using cutterhead dredges instead of suction dredges in soft sediments may increase turbidity and sedimentation. Disposing of material in offshore dump sites adds the potential for inadvertent releases of the dredged material and increased turbidity. Also, non-buoyant cables can scrape the bottom leaving habitats denuded. This was a cause of the major impact at the Hillsboro Inlet Dredging Project in Hillsboro Beach, Florida. Floating (polypropylene) or buoyed cables should be used to prevent cable drags.

Question 3: **What practices associated with beach erosion control programs adversely affect coral reefs or hard/live bottoms?**

Workshop participants identified shoreline stabilization structures and beach nourishment events as practices associated with beach erosion control programs that adversely affect coral reefs and hard/live bottoms.

A. Shoreline Stabilization Structures: Groins, seawalls, bulkheads, breakwaters, and jetties are components of beach erosion control programs to reduce the rate of erosion and/or control the movement of sand. Item E of Session 1, Question 1, above discusses shoreline stabilization structures and associated impacts in detail. These structures interrupt the longshore movement of sand and may cause unintentional and undesirable changes in currents and sand movement that lead to increased erosion problems, smothering and covering of habitats, and changes in habitat types and use.

In an effort to improve beach erosion control programs and prevent negative consequences with conventional shoreline stabilization methods, designs that mimic natural shoreline protection features are being incorporated. For example, in Maryland, Louisiana, and Virginia, dredge spoils and geotextile tubes have been used to create and restore coastal wetlands that provide coastal protection. In Miami Beach, as part of the USACE's National Shoreline Erosion Control Development and Demonstration Program, breakwaters were designed to mimic nearshore reefs and were made of articulated concrete mats and reef ball™ structures. These structures were installed at erosion hotspots and their effectiveness is being studied.

B. Beach Nourishment Events: Beach nourishment is included in beach erosion control programs to replenish sand supplies from eroded beaches. Item C of Session 1, Question 1, above discusses beach nourishment and associated impacts in detail. Impacts may include crushing of corals and coral reef resources from contact with pipelines, burial of corals and reef resources by deposition of sand and increased turbidity, and disruption of natural wave and current patterns at borrow sites that may lead to sand deposition or accretion on resources. To reduce the frequency of nourishment events, many erosion control programs now incorporate innovative shoreline protection measures (dune restoration, artificial reef-like breakwaters, etc.) and sand bypassing to minimize the need for beach nourishment events. Also, recent beach nourishment activities have included environmental education and coral sensitivity training requirements for construction personnel, increased buffer zones between borrow sites and resources, and coral stress studies to minimize and better understand impacts.

Question 4: Have any practices associated with dredging, beach nourishment, or other coastal construction activities protected nearshore coral reefs or hard/live bottoms? If so, describe the advantages of the construction practice, as well as associated challenges.

The workshop participants identified 11 practices or actions associated with dredging, beach nourishment, or other coastal construction activities that have protected nearshore coral reefs and hard/live bottoms. A description of each practice, and the advantages and challenges of each are discussed below. Although permitting is not a coastal construction practice, it was discussed by the participants in this session as a means of regulatory protection associated with coral reefs and hard/live bottoms.

A. Horizontal Directional Drilling (HDD)

Description: HDD is a trenchless construction technique that allows cables and pipelines to be installed underground resulting in no, or minimal, surface disturbance. HDD involves three main stages of construction: 1) drilling of a pilot hole; 2) enlarging the pilot hole to the appropriate diameter, which is done in stages through a process known as "back reaming"; and 3) installing the pipe. HDD can be utilized on various substrates from hard rock to sand and silt formation. Bentonite clay under high pressure is used to lubricate the drill head during drilling.

Advantages: This construction technique avoids and minimizes direct impacts to reef resources by directing efforts underground instead of on or through the resource. Entry and/or exit holes can be sited away from coral reefs, hard-bottom organisms, seagrasses, or other marine resources to further avoid turbidity, sedimentation, and mechanical impacts to these resources.

Challenges: When using bentonite clay at high pressures there is the potential for "frac-outs," inadvertent releases of bentonite to the seafloor. The bentonite is thick and denser than water and will ooze out on the ocean floor. Resources within the frac-out area will be smothered. Also, releases of bentonite at the drill head punch-out and at the entrance pits must be closely managed and monitored, and, if possible, avoided. The high operating costs of this construction technique or the distance limitation may deter its use. Some of the longest successful HDD installations have only been about 7,000 linear feet and, in some instances, longer drills may be needed to clear the resources off shore of Southeast Florida.

B. Tunneling

Description: Tunneling is also a trenchless construction technique that allows cables and pipelines to be installed underground resulting in no, or minimal, surface disturbance. It is typically used on projects that require a large diameter tunnel. It involves four main stages of construction: 1) excavating a vertical entrance shaft; 2) beginning tunneling at the bottom of the shaft using a tunnel boring machine (TBM); 3) installing the carrier pipe that connects the portions of pipe inside the tunnel to those outside of the tunnel; and, 4) installing the main pipe in the tunnel. The teeth (the TBM cutting apparatuses) and faces (front of the machines to which the teeth are attached, and where pressures are maintained and drill spoils enter) of TBMs can be modified to be used in any geologic conditions.

Advantages: This construction technique avoids and minimizes direct impacts to reef resources by directing efforts underground of the resource instead of on or through the resource. Exit pits can be sited away from coral reefs, hard-bottom organisms, seagrasses, or other marine resources to further avoid turbidity, sedimentation, and mechanical impacts to these resources. To further minimize the extent of impacts associated with exit holes, TBM can be left underground, buried, and not recovered.

Challenges: Potential problems with this construction method are subsidence, when the seafloor above the TBM or tunnel collapses, and upheaval, when the seafloor above the TBM or tunnel is thrust upwards. To prevent and/or minimize the likelihood of these occurring, and ensure an adequate overburden above the tunnel, the TBM should be maintained and tunnels lined with concrete, preferably steel reinforced. The high operating costs of this construction technique and the availability of a large open area for staging may deter its use.

C. Stormwater/Sewer Controls

Description: Increasing the level of sewage treatment and upgrading wastewater treatment plants, capping air conditioner drain pipes, upgrading roadways to capture and treat runoff, and improving outfalls to prevent beach erosion are ways to minimize impacts from upland discharges.

Advantages: These improvements would result in fewer discharge locations, less erosion at beach discharge points, and reduced release of contaminants. Improved water quality would encourage the healthy functioning and growth of seagrasses and coral systems.

Challenges: Large-scale retrofitting of existing systems may be costly and in highly developed areas land necessary to increase treatment may not be available. Discharges from new developments are subject to current stormwater rules and regulations; however, discharges from older developments are grandfathered in and are authorized to continue to operate as they have been.

D. Sand Bypassing Plants

Description: The conventional means for handling sand accretions at inlets is to periodically dredge large volumes of sand and then place it in bulk on the beach on the downdrift side of the inlet. Sand bypassing plants use hydraulic or mechanical means to move the sand across the inlet in smaller quantities over longer periods of time from an accreting area updrift to the eroded downdrift area. The material is placed on the beach immediately downdrift from the obstruction. This mechanical means serves to replace the natural littoral movement of sand. The beach that receives the sand then serves as a feeder beach and delivers sand to downdrift beaches (NOAA-Coastal Services Center 2006).

Advantages: Sand bypassing plants move smaller volumes of sand on a regular basis and do not allow sand to over-accumulate. The rate of sand bypassed can be equal to that of the net longshore drift. Turbidity and sedimentation is minimal.

Challenges: Local residents could resist sand bypassing plants because of aesthetics, obstructions of views, and changes in the donor beach (i.e., width). Depending on site-specific conditions, continuous operation and regular maintenance may be required.

E. Global Positioning System (GPS) and Dynamically Positioned Vessels (DPVs)

Description: DPVs use GPS coupled with thrusters located at different points around the vessels to continuously update and maintain position. This capability, known as "station keeping," ensures the proper location of the vessels without the need for anchors or spuds.

Advantages: Impacts to corals, hard bottoms, seagrasses, and other marine organisms from anchoring and/or dropping of spuds on the bottom are avoided.

Challenges: If used in shallow waters, thrusters must be oriented horizontally to avoid high velocity discharge water from scouring the bottom. The high operating costs of using this vessel and limited availability may deter its use.

F. Elevated and/or Grated Docks/Piers

Description: Elevating docks and piers above the water surface and using grated decking with adequate open spaces increases the light penetration to the underlying resources. To allow adequate light penetration, regulatory agencies typically require docks to be elevated 5 feet or more above mean high water and a minimum 1-inch x 1-inch slot dimension for grated decking.

Advantages: Seagrass and corals under and around the structures can function properly and receive some necessary light penetration for growth. The structure does not affect the overall health and distribution of the habitat.

Challenges: Generally, grated decking is not as visually appealing as conventional decking and ingress and egress to vessels at low tide can be challenging when a dock is fixed. Also, incorporating these designs into docks and piers increases the cost of construction.

G. Dock Construction Guidelines (Excluding Fishing Piers)

Description: The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Habitat Conservation Division and the USACE-developed Dock and Pier Guidelines for Florida (NOAA-NMFS 2006) help to reduce the individual and cumulative effects of docks and structures in seagrasses, marshes, and mangroves and to provide regulatory guidance. These guidelines provide specific design criteria for structures over/through these specific habitat types.

Advantages: This regulation guides developers and contractors on how to design projects that result in minimization or avoidance of impacts to submerged resources.

Challenges: Despite the guidelines, increasing land values and decreasing availability of waterfront property is an issue for developers in Southeast Florida. New coastal and waterfront developments propose the maximum number of slips and largest docks possible within site boundaries. Also, marine contractor and developer awareness of the guidelines is minimal.

H. Environmental Training Programs

Description: Many times contractors and subcontractor personnel are not aware of submerged resources within a project area. Requiring that all project personnel are trained on environmental issues associated with the project they will be working on can be a valuable tool to educate construction crews.

Advantages: All project personnel are aware of nearby resources, protected species in the project vicinity, potential impacts to resources, impact avoidance mechanisms, and protocol when impacts occur, etc. Awareness of the resources may minimize the risk of unintended impacts and, in turn, the liabilities and costs associated with unintended impacts would decrease.

Challenges: Ensuring that all personnel undergo the required training and that the information is provided in a clear and consistent manner.

I. Environmental Permits

Description: As the regulatory process has evolved, the rules and regulations to protect resources have generally increased and improved. Specific permit conditions are used to dictate special project restrictions or requirements necessary to ensure that, as permitted, the project is compliant with rules and regulations. Permits for large coastal projects usually include specific condition sections that address construction methodologies, water quality, turbidity, sedimentation, resource monitoring, marine mammal and sea turtle protection measures, reporting and training requirements, and mitigation.

Advantages: Permits provide a detailed description of the authorized activity and a map of do's and don'ts (conditions) for each project.

Challenges: Typically, environmental regulatory agencies are understaffed. Reviewing applications, project-specific conditions, and preparing permits for complex marine projects can be challenging and time-consuming. Furthermore, ensuring compliance and enforcement is difficult with limited resources.

J. Long-Term Monitoring

Description: Long-term monitoring of resources before, during and following construction events provides a baseline for an understanding of the short and long-term effects from the construction activity. Also, it allows for baseline/before-after control impact (BACI) (Peterson Presentation, Appendix 2) monitoring.

Advantages: It provides a means to compare and identify trends and/or changes throughout the project and identification of impacts that may not be apparent until after the completion of the project. It identifies the long-term impacts of an activity. Resource managers and regulators can use the information to identify thresholds and increased resource protection measures.

Challenges: Long-term monitoring can be costly. Adequate monitoring of corals could require a 10 to 20 or even 50-year monitoring period. Companies do not want to be responsible for monitoring over extended periods of time.

K. Dune Plantings

Description: Dune plantings involve the planting of native dune vegetation on the landward side of beaches to restore or create coastal dunes.

Advantages: Dune plantings provide additional natural shoreline stabilization that does not result in the disadvantages associated with armoring or beach nourishment. This can be done pre-emptively and/or in conjunction with restoration efforts along an eroded shoreline.

Challenges: Some challenges with the dune plantings include scheduling plantings to avoid hurricane season and allowing sufficient time for establishment before the next hurricane season, establishing a dune planting area of sufficient size to be effective and retain sand, and keeping beachgoers out of the planting areas.

Session 1 Consensus Report

The group was asked to identify the top priorities that address the session's objective. The top four coastal construction practices that were identified as negatively affecting coral reefs and coral reef ecosystems (not listed in ranked order) are:

1. Dredging and blasting;
2. Shoreline development (including, but not limited to houses, condominiums, office buildings, restaurants, infrastructure, docks and piers);
3. Beach nourishment; and
4. Placement of pipelines and cables.

Participants identified the five most important impacts resulting from coastal construction practices (not in ranked order) as:

1. Water quality changes;

2. Physical damage;
3. Sedimentation/direct fill or burial;
4. Turbidity; and
5. Nearshore habitat loss.

2.2 Session 2

Objective: Review recent applications of advanced technologies and/or methodologies associated with coastal and marine construction activities that minimize or eliminate resource impacts.

- Shoreline stabilization (hardened structures that armor the shoreline landward of the structure to prevent erosion)
- Erosion controls
- Beach renourishment
- Infrastructure placement

Question 1: What technological advances have been used or implemented to minimize or eliminate impacts to coral reefs and hard/live bottoms? Name the technology, describe the technology, the application for which it is used, identify the stressor or impact that it will minimize, and list the advantages and disadvantages of using the technology.

Note: Shoreline armoring used to stabilize shorelines was discussed in this session as a response to this question; however, it was excluded from the analysis below because it is not considered a technological advancement.

A. Coral Stress Index Protocol

Description: The Coral Stress Index is based on laboratory-observed coral stress responses and used as a baseline to compare the level of stress on coral reefs caused by sedimentation and turbidity during borrow site dredging. The technique was first developed in the laboratory at Nova Southeastern University, The National Coral Reef Institute. Testing involved using a series of experiments where sediment was layered onto collected reef corals and monitored for coral stress indicators such as swelling, bleaching, mucous production, and eventually death. The Coral Stress Index was developed from the experimental results.

Application: The Coral Stress Index protocol was developed prior to and for the 2006 Broward County Beach Nourishment Project to determine a pre-set coral stress level, that when reached during dredging activities could be used as a trigger to cease dredging and allow corals time to recover from stress. During the project, divers applied and calibrated this index to corals at over 34 fixed monitoring sites where dredging activities might influence coral reefs throughout the project area. If the index rises above a certain pre-established stress threshold, environmental regulatory permit conditions require county officials to cease dredging in the area until the coral stress levels fall below the threshold. The stress index is valuable to marine managers in coral reef areas as a means to protect and conserve precious coral reef resources.

Impact/Stressor to Corals Minimized/Eliminated: Implementing the protocol allows recovery of corals from turbidity and sedimentation impacts associated with dredging prior to serious injury or mortality occurring.

Advantages: The research will result in a better understanding of the corals' response to turbidity and sedimentation and identifies important coral stress thresholds for determining when dredging activities should cease. Regulators can use this information to write specific permit conditions based on actual data and, if it leads to repetitive shutdowns of dredge operations, it will encourage industry personnel to develop more effective construction methodologies that will minimize the impact.

Disadvantages: The method is applicable to a limited number of species and data collection and analysis is very costly. To date, it has only been developed and used for one renourishment event in Broward County. Additional field and laboratory verification and calibration is necessary.

B. Tunnel Boring Machine

Description: Tunneling is a trenchless construction technique that allows cables and pipelines to be installed underground resulting in no or minimal surface disturbance. It is typically used on projects that require a large diameter tunnel. It involves four main stages of construction: 1) excavating a vertical entrance shaft; 2) beginning tunneling at the bottom of the shaft using a TBM; 3) installing the carrier pipe that connects the portions of pipe inside the tunnel to those outside the tunnel; and, 4) installing the main pipe in the tunnel. The teeth (the TBM cutting apparatuses) and faces (front of the machines to which the teeth are attached, and where pressures are maintained and drill spoils enter) of TBMs can be modified to be used in any geologic conditions.

Application: Tunnel boring can be used as an alternative to direct lay and trenching construction methods. Some projects proposing tunneling in southeast Florida include:

- AES Ocean Express, LLC (AES) and Tractebel Calypso Pipeline, LLC (Calypso) have proposed to transport natural gas from the Bahamas to southeast Florida. Each project is proposing to use TBMs to construct a concrete-lined tunnel (10 to 14 feet in diameter) underneath the reef systems off of Broward County, Florida, for a natural gas pipeline. Niether of these projects have been constructed yet.
- The Port of Miami is proposing a tunnel under a portion of Biscayne Bay to provide direct access from the seaport to I-395 and I-95 to facilitate vehicular access to and from the port. This project has not been constructed yet. (www.portofmiamitunnel.com)

Impact/Stressor to Corals Minimized/Eliminated: Impacts caused from trenching and HDD construction practices are eliminated.

Advantages: This construction technique avoids and minimizes direct impacts to reef resources by directing efforts underground of the resource instead of on or through the resource. Exit pits can be sited away from coral reefs, hard-bottom organisms, seagrasses, or other marine resources to further avoid turbidity, sedimentation, and mechanical impacts to these resources. To further minimize the extent of impacts associated with exit holes, TBMs can be left underground and not recovered.

Disadvantages: Subsidence, when the seafloor above the TBM or tunnel collapses, and upheaval, when the seafloor above the TBM or tunnel is thrust upwards, is a potential problem with this construction method. To prevent and/or minimize the likelihood of these occurring, and ensure an adequate overburden above the tunnel, the TBM should be maintained and tunnels can be lined with concrete, preferably steel reinforced. The high operating costs of this construction technique may deter its use.

C. Biorock Reef

Description: Biorock was discussed in this session as a technological means of increasing the rate of coral growth by the use of electrical charges. Biorock reef is an electrically conductive frame, usually made from readily available construction grade rebar or wire mesh, which is welded together, submerged and anchored to the sea bottom. A low voltage direct current is then applied. Power sources can include chargers, windmills, solar panels, or tidal current generators. This initiates an electrolytic reaction causing mineral crystals naturally found in seawater, mainly calcium carbonate and magnesium hydroxide, to grow on the structure. Coral fragments are wedged into crevices and holes within the structure or attached using plastic cable ties or steel binding wire. Within days to weeks, the mineral accretion grows around the attached coral fragments. Corals on the biorock reef grow at an accelerated rate, which is relative to the electrical current supplied (Global Coral Reef Alliance 2006).

Application: It is used in coral reef restoration in difficult and challenging conditions. It has been installed in the Maldives in the South Pacific to restore a damaged reef.

Impact/Stressor to Corals Minimized/Eliminated: Injured corals can be salvaged and attached to biorock to promote recovery and growth.

Advantages: It provides structure and expedites coral growth and colonization rates making it ideal for restoration, creation, and/or mitigation purposes.

Disadvantages: There are no apparent disadvantages known.

D. Seadozer Technology

Description: This is a hydrodynamic dredging system that relocates sea bottom material through the use of highly directional water jet technology, rather than with suction. It uses no pumps, cutters, pipes, transport barges, anchors, or chains. It can be used in very shallow water where other dredges cannot operate and does not require support vessels.

Application: It can be used along coastlines to move sand from shoals and sandbars onto beaches. This technology has been used during the Malaysian beach nourishment project and in a Myrtle Beach, South Carolina construction project.

Impact/Stressor to Corals Minimized/Eliminated: Because this technology does not require support vessels, the use of offshore borrow sites, and minimizes the need for large-scale beach nourishment events, impacts with traditional beach nourishment activities are avoided (see Item C of Session 1, Question 1, for details on impacts from beach nourishment events). Sedimentation and anchoring impacts on nearby coral reefs are reduced and/or avoided.

Advantages: Seadozer technology generates less turbidity than dredging and filling from beach nourishment/renourishment, incorporates only sands already existing in the nearshore system, and it minimizes the need for large-scale beach nourishment events. Other bonuses are that the vessel requires only two operators, is very mobile, eliminates the need for sand disposal, and has minimal environmental effects.

Disadvantages: This is a relatively new technology with no known disadvantages.

Question 2: Discuss the following technologies or methodologies that have been implemented during projects conducted within the Florida region. Identify where in Florida these technologies have been used. State their advantages and disadvantages.

Note: The USCG Hawkeye GPS used by the USCG to track a vessel's real-time location was discussed in response to this question, but excluded from the analysis below because it has not been used in coastal construction projects and is not available for public use. However, an explanation of the system is provided, as well as advantages and disadvantages if the system was available to the public.

Hawkeye/Global Positioning System

Description: Track location of vessel movement at anchoring locations.

Applications: USCG Research and Development Center (RDC) created the Hawkeye system to increase maritime domain awareness (MDA) for the USCG command centers. In Port Everglades, Florida, the system consists of infrared cameras; long range optical cameras, RADAR, Geographic Information System (GIS)/Automatic Information System (AIS) display, blue force tracking, and a Web portal for sharing information with port partners. Despite the systems non-public use, in May 2006 a member of the USCG spotted a grounded vessel (*M/V Spar Orion*) outside of Port Everglades and reported the event to State of Florida resource management officials (United States Coast Guard 2006).

Advantages: Increased maritime domain awareness for USCG command centers with real-time data (i.e., cameras, sensors and GIS/AIS) can track the path of a grounded vessel before grounding and subsequent re-floating of vessels.

Disadvantages: Hawkeye data is not in an access system that can be captured and is not available to the public at this time.

A. Acoustic Doppler Current Profilers (ADCPs)

Description: Scientists use this instrument to measure how fast water is moving across an entire water column. An ADCP anchored to the seafloor measures current speed, not just at one point on the bottom, but also at equal intervals all the way up to the surface; therefore, providing a representative characterization of all currents in the water column. It measures small-scale currents the absolute speed of the water, as well as how fast one water mass is moving in relation to another, and can measure a water column up to 1,000 meters long.

Applications: An ADCP is used to determine current direction and collect real-time data to predict turbidity plume and fluorometry die movement during dredge and HDD operations and has been used in multiple dredging projects including the following:

1. Miami Ocean Dredged Material Disposal Site (ODMDS)—The primary management objectives are protection of the marine environment, beneficial use of dredged material whenever practical, and documentation of disposal activities at the ODMDS (U.S. Environmental Protection Agency (EPA) 2006).
2. Turbidity baseline study in Biscayne Bay—"Development of Guidelines for Dredged Material Disposal Based on Abiotic Determinants of Coral Reef Community Structure." Three factors were determined to be important aspects of coral and coral community effects of exposure to suspended sediments: 1) intensity, 2) duration, and 3) frequency of the ADCP used to collect current and acoustic backscatter data (McArthur et al. 2002).
3. AES and Calypso pipeline projects—ADCP is intended for use in the proposed Southeast Florida liquefied natural gas pipeline project.
4. Key West Harbor Project—ADCP was used to determine direction and collect real-time data of the sediment plume during dredge operations in Key West.
5. Sediment Transport on Columbia River—ADCP systems were deployed near the mouth of the Columbia River from August 18 through October 21, 1997 by researchers from the USACE Waterways Experiment Station and Oregon State University. The experiment was designed to measure movement of dredged material disposed off the mouth of the Columbia River. The data gathered are to be used for improvement of numerical model predictions of sediment transport.

6. Discharge Measurements in Everglades—ADCP units are being used to continuously measure discharge in three low-velocity tidal tributaries along the southwestern boundary of Everglades National Park, Florida. The tributaries meander through red mangrove forests and swamps, and discharge freshwater into the Gulf of Mexico. The tributaries also experience variable backwater conditions and flow reversals twice per day. The results of this application show that using the ADCP as a velocity-indexing instrument can help provide accurate and reliable discharge data in rivers and streams that historically have been too difficult to measure because of low-velocity tidal conditions, flow reversals, bi-directional flow, or backwater conditions.

Advantages: The ADCP eliminates the need for long strings of current meters; it can be used in deep water columns, and it improves the accuracy of turbidity fluorometry monitoring.

Disadvantages: High frequency "pings" yield more precise data, but low frequency "pings" travel farther in the water so a compromise must be made between the distance that the profiler can measure and the precision of the measurements. ADCPs set to "ping" rapidly also run out of batteries fast. If the water is very clear, the "pings" may not hit enough particles to produce reliable data. Bubbles in turbulent water or schools of swimming marine life can cause the instrument to miscalculate the current. Careful maintenance of transducers must be made to prevent growth of barnacles and algae.

B. Fluorometry

Description: For marine purposes, fluorometry is the use and detection of dyes to assess water quality, mitigate habitat stress, and monitor coral health.

Applications: During marine construction projects, fluorometry is used during HDD activities to help detect if a frac-out occurred and the location of the frac-out (see Session 1, Item A, Question 4). A fluorescent dye is added to the drilling fluid. In the event of a frac-out at the seafloor, the die disperses into the water column. A vessel towing a fluorometer (dye detector mechanism) is used to narrow the frac-out search area.

Advantages: This method improves the accuracy of frac-out detection and location with continual real-time monitoring. Material Safety Data Sheets (MSDS) for wavelength dispersal (dyes and bentonite) are available. The MSDS is a detailed information bulletin prepared by the manufacturer or importer of a chemical that describes the physical and chemical properties, physical and health hazards, routes of exposure, precautions for safe handling and use, emergency and first-aid procedures, and control measures**.**

Disadvantages: This type of fluorometry requires remote sensing and spectrometry (wavelength dispersive spectrometer) specialists and equipment, which can be very expensive to staff and operate.

C. Pipe Collars for Beach Nourishment

Description: Pipelines are used in beach nourishment projects to transport sand. A pipe collar is a large ring-like structure that is used to elevate pipelines off the seafloor so that the pipe will not be laying on corals or live/hard-bottom habitat. Tires have been used as pipe collars during past beach nourishment projects.

Applications: Pipe collars have been used in the Midtown, Phipps, and Broward County beach nourishment projects.

Advantages: Pipe collars may prevent the pipe from crushing and scraping coral reef resources by elevating it off the sea floor. The only impact is from the footprint of the collar.

Disadvantages: The material used to make the collars may not be appropriate (tires may deflate and/or collapse and rigid Styrofoam may not be durable enough). Pipeline stability is unknown during storms and anchoring may be needed to prevent movement over hard-bottom habitat and reefs; therefore, a storm contingency plan must be established when using pipe collars. Pipeline corridor inspections should be performed regularly to ensure that the collars are functioning properly.

D. Revised Turbidity Standards for Marine Organisms

Description: Currently, according to the state water quality standards the threshold for turbidity is 29 nephelometric turbidity units (NTUs) above background, which is not based on the effects of turbidity on marine resources. This threshold should be revised to reflect the stress responses of marine resources to turbidity and incorporate both a concentration and temporal component.

Applications: For the AES and Calypso pipeline projects, the Key West Harbor Dredging project, and the Broward County Beach Nourishment Project, the permit conditions included special turbidity standards and monitoring requirements for activities adjacent to coral reefs. If a turbidity monitoring event revealed turbidity above 15 NTUs but below 29 NTUs, turbidity monitoring frequency was increased. If turbidity continued to exceed 15 NTUs above background for four consecutive tests, operations were shut down until levels dropped below 15 NTUs.

Advantages: This tiered turbidity standard provides more protection for marine resources from the effects of turbidity than current regulations allow.

Disadvantages: More research on the effects of turbidity on coral reefs is needed to establish a threshold effect at protecting marine resources. For this method to apply to all projects, a change in state statutes and rules would be required.

E. Horizontal Directional Drilling

Description: HDD is a trenchless construction technique that allows cables and pipelines to be installed underground resulting in no, or minimal, surface disturbance. See item A to Question 4, Session 1, for details, advantages, and disadvantages associated with this technology.

Applications: American Telephone and Telegraph, Inc. (AT&T) & Tycom Fiber Optic Cables (FOC), multiple other FOC projects, and infrastructure (sewage, water, electric) line construction and maintenance.

Advantages: This construction technique avoids and minimizes direct impacts to reef resources by directing efforts underground instead of on or through the resource, which could prevent unanticipated impacts to surrounding coral resources. HDD is becoming one of the preferred practices for installing pipelines, cables, water and sewer lines, horizontal environmental and potable wells, and other infrastructural elements because positioning is extremely accurate, the timeframes for obtaining environmental permits have been streamlined and reduced, and the equipment uses minimal construction space. The major advantage is the speed and reliability of the installation combined with the aforementioned minimal environmental impact.

Disadvantages: See Session 1, Question 4, Item A.

F. Use of Pre-determined Reef Gaps for Linear Project Installation

Description: Reef trends along Florida's east coast have been examined to determine the locations of naturally existing gaps in the reefs.

Applications: Gaps may be used when routing linear projects such as pipelines or fiber optic cables. The Florida Administrative Code (18-21) states that "while locating in these areas is not required for approval, special consideration areas are designated for telecommunication lines and associated conduits located within the reef-gaps generally described as follows, based on World Geodetic System 84." Actual reef gaps are listed and described in Section 2.3, Session 3, Question 1, Item G).

Advantages: Reef gaps allow for use of a naturally occuring breaks in the reef rather than blasting a channel through the reef.

Disadvantages: Impacts to nearby hard-bottom or reef communities may still occur from turbidity, sedimentation, and gaps that are not very wide or close to reef communities where some impacts are unavoidable.

G. Floating Lines/Cables

Description: Cables are used to tow barges and other non-propulsive vessels to and from construction projects and for other towing operations. A cable made of polypropylene or other buoyant material is preferred to a steel cable that can sink to the sea floor and scrape the bottom removing and/or injuring marine organisms (sponges and hard and soft corals).

Applications: It is now common practice for floating lines/cables to be incorporated as a specific condition in regulatory permits, including the AES and Calypso pipeline projects.

Advantages: Floating lines and cables prevent the line and cable from dragging across corals, reef habitat, and hard bottom that leaves habitats denuded.

Disadvantages: No apparent disadvantages.

H. Use of Cutter Head Dredge

Description: The cutter head is a mechanical tool on the end of the intake pipe of the dredge. It has rotating blades or teeth to break up or loosen the bottom material so that it can be sucked through the dredge. Dredged material is sucked through one end, which is the intake pipe, and then pushed out the discharge pipeline directly into the disposal site.

Applications: This dredge method was used in the Miami Harbor Dredging Project to remove large rocks and the Hillsboro Inlet widening and deepening project to dredge through consolidated material.

Advantages: Oversize material is prevented from entering the pipeline of a suction dredge by a grid placed across the draghead cutterhead. The cutterhead is capable of excavating rock without the need for blasting, and it can pump directly and continuously to disposal sites.

Disadvantages: The cutterhead dredge has limited capability in rough open water and is sensitive to strong currents. Debris and sediment can reduce efficiency of operations.

I. Laser Airborne Depth Sounder (LADS)

Description: LADS is a high-resolution bathymetric topographic survey tool that applies a scientific method to mapping efforts using existing technologies (i.e., USCG). LADS has applicability in clear coastal waters down to -70-meter depth. This new sounding technique features rapid acquisition of large high-quality data sets via variable swath widths that are independent of water depth. Image enhancement of the LADS digital data facilitates recognition of numerous seafloor features and bathymetric patterns.

Application: This advanced airborne laser bathymetric system has been deployed along the Southeast Florida (Palm Beach, Broward, Miami-Dade counties) coast to provide a contiguous data set for 160 kilometers (km) of coast from onshore to 6 km offshore.

Advantages: The advantage of the LADS technology is the collection of depth information for a small pixel size (2- to 4-meter grid). This information is then presented at a map scale that produces the impression of continuous bottom. The digital bathymetric maps that can be produced look like shaded topographic maps that assume an artificial light source that helps make bathymetric patterns and forms more recognizable. LADS assists resource managers in identifying the locations of resources to improve avoidance, quantification of impacts, and resource management. When combined with other data (e.g., geophysical and geotechnical information), this type of analysis can be a powerful tool for interpreting large-scale coastal behavior and showing the distribution of resources on the inner continental shelf.

Disadvantages: This technology requires clear water to accurately map the bottom. Data completeness and accuracy/validation is an issue. It has been apparent that some ground-truthing is necessary after the sea floor has been mapped to obtain the most accurate account of the mapped resources or bathymetric patterns. Data are only available for Miami-Dade, Broward, and Palm Beach Counties, not for Martin County.

J. Vessel Tracking Systems

Description: There has been a steady growth in the development of satellite-based vessel tracking systems and electronics aids for piloting, especially on inland waterways. GPS is a key element in many of the on-water activities that have been undertaken. GPS devices allow detailed tracking of vessels on inland and coastal waterways.

Application: The USCG has spearheaded an interagency effort to enhance awareness of activities that occur within the maritime domain. Maritime domain awareness has been defined as the effective knowledge of all activities associated with the global maritime environment that could affect the security, safety, economy, or environment of the United States. The Maritime Transportation Security Act of 2002 and the Coast Guard and Maritime Transportation Act of 2004 require the USCG to develop vessel tracking systems to enhance vessel identification and tracking capabilities in coastal waters and on the high seas. The Subcommittee plans to oversee the development and expansion of these systems, as well as other measures to improve overall maritime domain awareness.

Advantages: Allows real-time telemetry and line of sight with coastal construction operations.

Disadvantages: The global aspects of the technology do not ensure conformity among emerging systems.

K. USACE Silent Inspector (SI)

Description: SI is an automated dredge monitoring system for impartial automated dredge monitoring (Bates Presentation, Appendix 2). SI monitors dredging parameters (i.e., location, depth, amount and type of material dredged, and location of discharge) in real time, 24 hours a day. Information is recorded on an on-board computer during operations and downloaded to a Website for access.

Application: SI is required on all USACE Operations and Maintenance dredge projects, new construction dredging, and shoreline protection USACE-permitted projects. It has been used in the Key West Dredging Project, Dade County Shore Protection Project, and the Jacksonville Harbor Deepening Project.

Advantages: SI provides automated quality assurance monitoring and monitors dredge position and characteristics. It provides a consistent and reliable source of data to determine compliance with permits. The USACE developed the SI as a low cost, repeatable, impartial system for automated dredge monitoring. Some other advantages are:

- Monitors and documents where and when dredging operations take place;
- Provides coverage of operations 24 hours a day, 7 days a week;
- Reduces paperwork and contractor reporting duties;
- Creates detailed production reports;
- Allows for fast responses to public or environmental concerns;
- Allows for flexible scheduling of human inspectors;
- Improves government estimates and planning;
- Improves project management;
- Standardizes data collection and reporting; and
- Creates a standard base for dispute resolution and avoidance.

Disadvantages: SI has limited access to selected USACE staff. The dredge specific system and all shipboard sensors are the property of the contractor, who is required to purchase and maintain them.

L. Pulse Amplitude Modulation (PAM) Fluorometry

Description: PAM fluorometry consists of a light pulse that shines on the surface of coral polyps or sea grass blades and measures fluorescence of chlorophyll as an estimate of photosynthesis.

Application: PAM fluorometry (fluorescence analysis) is conducted during operations to measure photosynthesis in coral habitat. Fluorometry is used throughout the Florida Keys, in Broward County, and by the USACE. An application example follows:

> During the summer of 1997, seawater temperatures in the Florida Keys remained above normal for several weeks. A research team from the University of Georgia sampled colonies of the dominant Caribbean reef-building coral species, *Montastrea faveolata* and *Montastrea franksi*, over a depth gradient from 1 to 17 meters. They discovered that there was severe damage to the photosystem II in the symbiotic algae. They also surprisingly discovered that a major protein of PSII called D1 had been damaged, impairing the ability of the algae to carry out photosynthesis.

Advantages: PAM can determine if photosynthesis is not occurring during operations (e.g., due to turbidity or sedimentation), which can lead to coral stress. Detectability to parts per billion or even parts per trillion is common. This extraordinary sensitivity allows the reliable detection of fluorescent materials using small sample sizes. Also, field studies can be performed in open waters without sample treatment. Fluorometers are highly specific and less susceptible to interferences because fewer materials absorb and also emit light (fluoresce). Fluorometry has a wide concentration range and can be used over three to six decades of concentration without sample dilution or modification of the sample cell. Fluorometry is a relatively simple yet specific analytical technique that provides expedited analysis. Fluorometer reagent and instrumentation costs are low when compared to many other analytical techniques. Small laboratory filter fluorometers can now be purchased for less than $3,000.

Disadvantages: Interpretation requires data-intensive analysis and a test is expensive ($50,000). Two polyps on the same coral head can give very different results; therefore, the need to conduct polyp-by-polyp monitoring may be necessary. It is basically still considered a research tool and not a practical technology to apply to coastal construction projects.

Question 3: What technologies have been proposed to improve and mitigate impacts from shoreline/beach stabilization, beach nourishment activities, and the unpredicted equilibrium toe of fill that beach nourishment projects are associated with?

A. Sand Bypassing and Bypassing Plants

Description: Sand bypassing is the practice of transporting accumulated sand from the upcoast side of a sediment barrier, such as a jetty, to the eroded side. The process attempts to restore the natural downdrift flow of sand. These plants are designed to mitigate beach erosion caused when dredged navigation channels disrupt nearshore sand movements. Bypass plants, or sand transfer plants, are fixed dredges placed on one side of navigational inlets. As sand moves along the shoreline, it is collected by the plant and transferred across harbor structures to the downdrift beaches. Sand bypass plants use one of two methods: intercept—device or a series of devices that continuously or episodically move material as it arrives; and storage—which consists of a deposition area that is constructed to capture arriving sand and is periodically excavated. The sand is then piped or transported to beaches (Higgins Presentation, Appendix 2).

Impact Mitigated: Utilizes sand that is already in the system.

B. Sand Backpassing

Description: As with bypassing, sand backpassing is the mechanical transport of sand from an accreted stable beach to an eroded beach, but instead the sand is moved from a down current beach to an up current beach against the natural littoral movement of sand, hence the term "backpassing." This method often is utilized in locations where the sand from an eroding beach moves alongshore and is deposited in a more sheltered area. Backpassing essentially "recycles" the sand back to the eroding beach. If the sand volumes are moderate and the haul distances are short, the practice can provide a cost-effective means for beach maintenance. Similar to sand bypassing, the process must be conducted on a regular basis. This technology does not attempt to restore the natural longshore movement of sand.

Impact Mitigated: Sand backpassing utilizes sand that is already in the system without the need for offshore borrow pit excavation. Wave impacts can be custom tailored (for back passing) so that material is not being lost.

C. Glass Beaches

Description: Using recycled glass as a supplement to sand for beach renourishment is attractive because of its potential to eliminate the need for offshore borrow sites. Grain size and color can be customized. Some disadvantages to this technology include the expense and availability of glass sources, and the fact that it has not been fully tested for compatibility with temperature, gas exchange, durability, etc.

Impact Mitigated: It may negate the need to dredge material from offshore sites or seek alternative sand sources from other locations (i.e., Bahamas) to renourish a degraded beach.

D. Hybrid Solutions—Multi-Purpose Reefs/Submerged Breakwaters

Description: Multi-purpose reefs can function as dissipaters, which act to reduce wave energy at the shoreline by breaking waves offshore, resulting in an accumulation of sand landward of the reef. They may also act as rotators as they re-align wave crests and/or spread wave energy to reduce wave-driven currents. These reefs provide substrate suitable for coral colonization and allow existing reefs to increase in marine biomass and species diversity over natural sand seabed. Many communities are beginning to promote multi-purpose reefs for diving, fishing, surfing, and beach activities (Dr. Kerry Black Presentation, Appendix 2, www.asrltd.co.nz). The development of multi-purpose reefs has become increasingly feasible, and is now proceeding due to the relatively new developments in surfing reef design, coastal process, and better assessments through state-of-the-art numerical modeling and biological enhancement research. There are many devices that have been or are currently being used to protect the coast. These include seawalls, groins and artificial headlands, detached breakwaters and submerged reefs, beach nourishment and dune rehabilitation, as well as training walls to stabilize river entrances. Many of these measures deal just with the effect, not the cause of the erosion problem. Multi-purpose reefs are a useful alternative to shoreline stabilization and beach nourishment by providing a long-term reduction in net sediment losses and thereby a more sustainable solution. A common application of the technology is installation adjacent to a headland or artificial structure or along a beach requiring hard engineering or re-nourishment for its protection.

Impact Mitigated: These structures reduce wave-driven longshore currents and may provide a substrate for coral growth. Their design can vary widely from case to case in response to local area needs.

E. Alternative Mitigation Options

Description: Using innovative alternatives to conventional mitigation for coastal construction projects is a growing trend. They can be used to better understand and negate the effects of long-term impacts to complex reef resources. Alternatives to conventional reef mitigation practices (placement of boulders and/or reef-like structures on the seafloor) include such diverse techniques as water quality studies; investigating and implementing ways to prevent future events/impacts (i.e., racon beacons, alternative anchorages); removal of a continuous impact (i.e., tires on reefs); creating nursery grounds for corals (i.e., using artificial reefs); financial funding opportunities for new or continuing research; and constructing, monitoring, and maintenance of reef mitigation gardens (Dally Presentation, Appendix 2).

The relationship between water quality and seagrass community health is direct and well documented. With seagrass impacts, regulatory agencies look favorably upon water quality improvements (i.e., stormwater retrofits) as components of seagrass mitigation plans because the success of seagrass transplantation is minimal and, with the *Halophila* species, long-term survival and establishment of transplanted specimens has not been demonstrated.

Impact Mitigated: Improved conditions for coral resource productivity and recruitment.

Question 4: Have the proposed technologies mentioned above been tested on a small-scale or in special projects? What successes were achieved?

A. Sand Bypassing and Bypassing Plants: Sand bypassing occurs successfully at many inlets in Southeast Florida. For example, Boynton Inlet in Palm Beach County uses a sand bypassing plant. At Hillsboro Inlet, a small suction dredge and a sand pipe is periodically used to pump sand from accretion areas in the inlet to the downdrift beach. At Port Everglades Inlet, a bypassing system is in development.

B. Glass Beaches: In an effort to combat beach erosion and find a more cost-effective outlet for glass collected from recycling programs, Broward County is conducting a pilot study using glass on a beach. Using recycled glass mixed with sand in beach renourishment and erosion control projects can help address both the challenges of beach erosion and glass recycling. The project is a cooperative venture between Broward County, the Broward County Resource Recovery Board and its Technical Advisory Committee, the City of Hollywood, and the FDEP.

The test plot is located on Hollywood Beach at Pierce Street and the Broadwalk in southern Broward County. It contains mixtures of natural beach sand and finely crushed glass and will be in place through the end of April 2007. The test plot is a 10-foot by 40-foot fenced area, and the glass/sand material is 3 feet deep. It contains 16 sections with the following sand to glass ratios:

- Four sections containing 100 percent beach sand,
- Four sections containing a mixture of 75 percent sand and 25 percent recycled glass,
- Four sections containing a mixture of 50 percent sand and 50 percent recycled glass, and
- Four sections containing a mixture of 25 percent sand and 75 percent recycled glass.

Data will be collected on how the exposed glass/sand mixture reacts to the elements and functions for compatibility with temperature, gas exchange, durability, etc. of native sand.

C. Hybrid Solutions—Submerged Breakwaters

The shoreline in the vicinity of 32nd Street, Miami Beach has been established as an erosional hot spot. A coastal processes analysis performed by Coastal Systems International determined that the highly localized levels of erosion were due to the presence of a shoreline protrusion at the hot spot. Numerical modeling of the 32nd Street area confirmed that prevailing wave conditions could generate a strong gradient in wave energy capable of causing localized erosion.

Erosional hot spots are areas within a littoral cell that experience higher than average levels of erosion. Therefore, the erosional activity at hot spots can govern the frequency of beach renourishments for a stretch of shoreline. The mechanisms for the localized levels of higher erosional activity, while not fully defined, are speculated to include irregularities in the shoreline, offshore bathymetry, coastal development, etc. The study of the causes of hot spots can provide design criteria to increase the performance of beach renourishment projects. The results of the evaluation of this hot spot may provide construction cost savings over the life of a project by reducing the need for costly large renourishment events.

This study recommended the use of three artificial headlands to gradually transition the shoreline and to dissipate much of the localized wave energy. Three sections of reef balls, used as artificial headlands, have been placed in parallel rows to reduce wave energy and slow beach erosion.

D. Alternative Mitigation Options

City of West Palm Beach Waterfront Project: An example of regulatory agencies authorizing water quality improvements as mitigation for seagrass impacts includes the seagrass mitigation associated with the City of West Palm Beach Waterfront project. This project involved installing six pollution control devices and an exfiltration trench in stormwater drains leading to Lake Worth Lagoon. The project was successful and eliminated the uncertainties associated with seagrass transplantation.

Calypso Pipeline Geotechnical Investigations: Mitigation for impacts associated with the Calypso pipeline geotechnical investigations included an alternatives analysis to the existing commercial offshore anchorage practices near Port Everglades Inlet. The current anchorage situation involves two designated anchorage areas in proximity to shallow reef resources. Over the past 10 years, there have been numerous groundings, as well as anchor, and anchor-chain-drag incidents that have significantly damaged surrounding reefs. Calypso was tasked with evaluating current anchorage practices and suggesting alternatives to the current practices (more oversight and management, installing commercial buoy mooring fields, etc.) to minimize these impact events.

The project brought a great deal of attention to the anchorage issue and provided invaluable information on anchorage usage, commercial shipping needs, and mooring buoy options. During the study, the USCG began preparing a notice of proposed rulemaking to change the current anchorage practices, which would result in fewer groundings.

Session 2 Consensus Report

The session group identified the following existing technological advances/methods as the top four that offer alternatives for minimizing or eliminating resource impacts during coastal construction activities.

The top four are:

1. Tunneling/HDD/corridors,
2. Integrating habitat characterization with management strategies,
3. Hybrid solutions-multiple technologies within one project, and
4. Turbidity monitoring technologies.

The session group recommended five non-conventional mitigation options and identified them as:

1. Water quality improvements by retrofitting stormwater and discharge structures;
2. Removal or modification of existing structures or uses that cause direct impacts to the reef ecosystem, such as removal of the artificial tire reef in Broward County;
3. Beacons for ships, and removal or modification of anchorages to prevent groundings and anchor damages;
4. Establishment of coral nurseries for laboratory-raised or "rescued corals; and
5. Implementation of all practicable means of avoidance prior to using only minimization.

The positive effects of non-conventional mitigation include long-term and cumulative benefits to the entire reef ecosystem. Difficulties faced with non-conventional mitigation include quantifying the amount of mitigation that is necessary to compensate for the impacts; a lack of agency coordination (federal, state, and local); and regulatory limitations (i.e., laws, regulations, and policy) regarding the types of mitigation that will be acceptable.

2.3 Session 3

Objective: Review emerging technologies for shoreline stabilization, erosion/beach stabilization, and beach renourishment.

- Coastal engineering solutions
- Dredging and industry solutions
- Identify opportunities for incorporation/implementation of advanced/innovative technologies in coastal and marine construction activities and infrastructure placement programs
- Recommend criteria and components for appropriate/acceptable "pilot" renourishment projects designed to minimize impacts to coral reef resources (i.e., corals, hard/live bottom, reef resources)

Question 1: What technologies are emerging to stabilize shorelines and beaches, reduce erosion, or renourish beaches? Name the technology and state which problem it addresses.

A. Pressure Equalizing Modules

Description: Pressure Equalizing Modules (PEM) were invented in Denmark less than 20 years ago as a means to reduce beach erosion and to allow sand to accumulate in areas vulnerable to erosion. The system works by equilibrating groundwater pressure below the beach during a falling tide so that the friction between sand grains increases, causing them to remain on the beach instead of washing back into the sea. Over time, beaches with a PEM system installed may demonstrate a dramatic reduction in erosion or may in fact grow in total width and depth of sand.

The equipment required to create a PEM system consists mainly of a series of drain tubes, several meters long by 6.5 centimeters in diameter, installed vertically throughout the beach zone but completely below the sand. The drain tubes connect the various layers of ground water under the beach, allowing water in the different layers to migrate vertically into the sediment layer that allows the most efficient drainage. Installation is performed using light equipment and no source of power or electricity is required to activate or maintain the system. The system is driven by the ambient pressure differential in the various groundwater layers. Up to 100 drain tubes may be installed per mile of affected beach. After installation, the system is not visible to beach visitors.

Potential: This system may drastically reduce erosion along beaches that historically lose material to longshore currents. It may also provide a net gain in beach sand, potentially building a wider and deeper beach. Beach renourishment efforts may be reduced or even eliminated in some cases, although traditional renourishment can be used in conjunction with this technology to quickly restore a severely eroded beach. This system can be installed quickly using light equipment and with a minimum of disturbance. Once installed, the entire system is invisible to visitors. Additionally, the PEM system requires little maintenance due to the simple design and passive energy balance. According to some literature, strong surf associated with storm events may reinforce the sand accretion potential of this system.

Limitations: This system is described by EcoShore International (the patent holder) as "especially effective at high energy coasts with lots of waves." It can be inferred that this system may not be effective along shorelines with lower energy. Additionally, it is not yet clear how this system may affect intertidal zone infauna due to possible rapid draining of the beach sand during falling tides. Another concern is the potential effect the system may have on sea turtle ecology. The drain tubes could affect nesting activity if gravid females encounter them while excavating their nests. Also, it is unclear whether the system may reduce the moisture content of beach sands where sea turtles have nested and possibly affect the hatch rate of egg clutches or alter the ability of hatchlings to emerge from the nests.

Cost: Should the target site pass an initial evaluation, EcoShore will install a pilot PEM network and monitor the project site for a variety of conditions for 12 months at a cost of $200,000. Should the client be satisfied with the results, they are extended the option to lease the system from EcoShore at a rate of $200,000 for the first mile and $100,000 for each additional mile. Terms of the lease include vendor-supplied maintenance of the system, monitoring, and an annual report. The vendor will include storm repair or replacement for an additional cost. The system is removed by the vendor free of charge should the system be no longer desired for any reason.

Project Results:

- **Denmark**—Several multi-year trials have been completed that appear to confirm the ability of PEMs to protect shorelines against erosion and accrete new sand. Tests with PEMs along shorelines fitted with groins and breakwaters, as well as along natural shorelines, all seemed to build a wider beach within a year. Monitoring the same shorelines after PEM removal indicated a return to pre-test conditions marked by beach erosion.
- **Sweden**—A PEM network installed along a beach where annual renourishment was necessary demonstrated visible gains in the width of the beach and depth of sand after 2 months.
- **Malaysia**—PEMs were installed to drain and stabilize a beach in peninsular Malaysia. Sand was then added to this severely eroded beach, followed by another set of PEMs. Losses of sand have been less than 1 percent per year for the past several years.
- **Africa**—PEMs were installed in an area known for rapid erosion along a high energy beach in west Africa. After 1 year, sand accretion rates reached 17.7 cubic meters per meter of shoreline.

B. Multi-purpose Reefs

Description: Multi-purpose reefs are a form of submerged breakwater placed up to several hundred meters from the beach and are designed to provide various benefits including defense from erosion and recreational opportunities (Dr. Kerry Black, Presentation, Appendix 2). The reef is created by pumping hundreds of tons of sand into geotextile bags that are custom shaped to give the reef a profile that refracts wave energy, reduces shoreline erosion, and can allow the formation of an accreted "salient," or a protrusion of the beach behind the reef. The concept is modeled on the dynamic that occurs naturally between an offshore obstruction and the shoreline immediately behind it, which often has a wider beach than the area on either side of it. Multi-purpose reefs can simply dissipate wave energy before they reach the shoreline or also rotate the incoming waves so they strike the shore at a more desirable angle, depending on the orientation of the reef. This can help to reduce erosion caused by ambient longshore currents.

The multi-purpose reef can be a stand-alone feature or part of a network of units placed along a shoreline that is vulnerable to erosion. The size and configuration of the multi-purpose reef is determined by using a variety of computer models that simulate wave dynamics, circulation patterns, and sediment transport along the target shoreline. Bathymetric, meteorologic, and other physical data are collected at the project site to help determine the dimensions of the artificial reef and its precise location.

Once in place, the multi-purpose reef may provide a variety of recreational benefits including surfing, snorkeling/diving, or fishing. Because the geotextile material that forms the reef surface is designed to promote marine growth, it may attract a variety of marine life that would, in turn, attract divers and fishermen.

Structurally, the multi-purpose reef appears to be stable and resistant to shifting position in severe storms, despite the shallow depths where they have been deployed. Previous trials have indicated that a slight settling (<0.3 meter) of the reef may occur within the first year after deployment. Previous studies have been cited that claim multi-purpose reefs bring 20 to 70 times their full construction cost back to the community through visitor spending.

Potential: A number of case studies have documented varying degrees of reduced erosion and sand accretion along beaches protected by multi-purpose reefs on several continents. The ability of this system to deflect and/or refract wave energy seems to depend largely on accurate data inputs. A comprehensive analysis of ambient conditions at the proposed location should help ensure that the reef or a network of reefs provides the maximum benefit, possibly reducing or eliminating the need for beach nourishment. Few, if any other, technologies have demonstrated the ability to significantly rotate incoming waves and alter the angle at which they strike the beach. In locations where longshore current is at least partially responsible for beach erosion, this technology may help attenuate erosion by interrupting the longshore current enough to slow down the loss of sand.

Other benefits include an increase in recreational activity associated with this artificial reef. The proximity to the beach would make a multi-purpose reef accessible to surfers, snorkelers, and fishermen. Public utilization of a new resource may create economic benefits for the local economy.

Limitations: It is possible that ambient coastal conditions at any prospective location where beach erosion is taking place may not be well-suited for employing this technology. A search of the current literature did not identify specific conditions that might render this approach ineffective; however, the available data from actual trials are not robust enough to assume that this technique works everywhere. A series of well-monitored pilot tests of multi-purpose reefs may help determine larger-scale applicability.

Because of the wide variety of materials available in the geotextile marketplace, accurate estimates of long-term durability are difficult to make. Both woven and non-woven materials made from a variety of synthetic materials at various thicknesses have been specified for multi-purpose reef projects worldwide, but little information is available regarding the longevity of these reef systems. However, maintenance costs seem to be very low and there are no known instances of major structural failure for this technology.

Cost: A unitized cost estimate could not be estimated for multi-purpose reefs due to the high degree of variability in previous trials. Because of variations in project design (size, depth, expanse), construction materials (geo fabric, fill material) and location, project costs vary substantially. However, in a proposal for a multi-purpose reef at St. Francis Bay, South Africa, ASR Ltd. estimated the price of one reef unit in 2006 at the equivalent of $760,000 in U.S. dollars. Filling the reef unit was not included in this price and would vary depending on the source of fill material.

Project Results:

- **Gold Coast, Australia**—A single multi-purpose reef unit was placed to protect a nourished beach and provide surfing opportunities. The longevity of the nourishment effort has met or exceeded expectations and measurable economic benefits resulted from an increase of beach visitors.
- **St. Francis Bay, South Africa**—Decades of residential development along the beach affected the adjacent dune zone and helped to caused rapid erosion. A feasibility study produced by ASR Ltd. to place a multi-purpose reef offshore for beach enhancement and recreational opportunity was deemed likely to achieve its objectives by a qualified independent reviewer.

C. Alternative and Upland Sand Sources

Description: Locating acceptable sources and quantities of sand to renourish eroded beaches along Florida's coasts has become increasingly difficult in recent years. Beach quality sand may be scarce or exhausted in the offshore waters of some counties or abundant in waters off other parts of the state. Upland sources may be equally hard to locate; some regions may be rich in quartz sand while others have only calcium-based sediments. Marine and upland sands may also contain particles that render both unsuitable for use on beaches, such as fine-grained, irregular, or foreign material that becomes suspended and/or is quickly transported from the project site. Fine and soluble materials mixed with the sand can smother nearshore communities by sedimentation and by causing apoxic conditions. It is of critical importance that alternative sand sources conform to minimum standards of size, quality, and composition so that renourishment efforts provide maximum value for taxpayer dollars.

Traditional offshore sand sources have different qualities than beach sand. They may be carbonate instead of quartz, making them less dense and more easily suspended and transported via shoreline currents. Collecting marine sands for renourishment projects may be difficult in some areas due to sensitive benthic communities close to the borrow sites. Some Florida counties are increasingly looking across county lines for acceptable sources of beach sand to reduce impacts to nearshore coral and other hard-bottom reefs. But with increased distance from the project site comes higher costs. However, distant sources of high quality sand may prove economical to retrieve if using it reduces the frequency of renourishing. Oolitic (carbonate) sands retrieved from the Bahamas may prove to be as economical in southeast Florida as retrieving marine sands from several counties away; the distances may be similar and the oolitic sands are more uniform in size and composition.

Potential: Locating and using alternative sand sources to renourish beaches along the Florida coast provides clear and profound economic benefits for coastal communities. Locating sources of sand that do not require laying pipelines across reef systems reduces potential impacts that might otherwise harm the reef and reduce revenues to local reef-dependent industries, such as diving and fishing.

Upland sand sources usually eliminate the need for laying costly and potentially damaging pipelines that would transport the sand slurry in marine dredging applications, because pipelines between offshore dredge sites and the beach nourishment project can damage reefs that lie along the pipeline path. Moreover, if the source is carefully selected, the material can be very clean, of proper composition and uniform in size. Sands with these qualities provide value to renourishment projects because they stay in place longer than lesser quality sands and do not foul nearshore reefs with pollutants. Some good deposits of sand may be found inland along Florida's ancient shorelines, created when sea levels were higher than present day.

Limitations: Alternative sand sources are generally more expensive than using traditional sources because they must be transported to the project site from greater distances and this can be cost prohibitive. Inferior sources of sand for beach renourishment may affect reef and nearshore ecology if there are constituents in the fill material that may become suspended (fines) or dissolved in nearshore waters. Pollutants in suspension can persist for long periods and deprive nearshore reefs of light and oxygen. Additionally, ambient currents at the project site or storms can deposit fill material directly on nearshore reefs, effectively smothering them. Testing protocols need to be inclusive enough to screen any harmful substances and thoroughly analyze local current patterns, but rigorous testing adds expense to renourishing efforts.

Upland sources can have many of the same disadvantages of alternative marine deposits such as cost, and possibly lesser quality material. Pipelines are not commonly an option for transporting sands, and overland transport adds considerable expense to renourishment. Upland sources may also contain undesirable fines and organics that may foul nearshore reefs. Comprehensive quality screening should be practiced to ensure value and protect nearshore ecology.

Cost: Because of the extreme variability in collection locations, costs for these techniques cannot be estimated.

Project Trials: Alternative and upland sand sources have been used regularly with varying degrees of success along Florida's coastline. Efforts have ranged from highly successful to very problematic. Cases include stable, long-lasting renourishment projects with little to no changes in water quality, as well as some projects that experienced significant erosional losses even as the new fill material was placed. Moderate to serious nearshore reef and water quality impacts have been associated with renourishment projects that quickly erode.

D. Recycled Glass

Description: Recycled glass can be ground to various grain sizes and distributed on beaches to combat erosion and help reduce the need to dredge around sensitive reefs. While this technique is still in the early experimental stages, there may be considerable potential for augmenting natural sand in beach renourishment projects. Because of its greater mass to surface area ratio, custom ground glass may be more resistant to transport than sand typically collected from offshore borrow areas. Sands from offshore deposits often contain a high percentage of calcareous (usually skeletal) material that is lighter and more irregular in shape. Also, because glass is an inert substance, it should not affect water quality.

Potential: Recycled glass sand is inert and not likely to cause adverse impacts to water quality or beach flora/fauna, although some testing should be performed to verify this. Also, there is a distinct advantage over dredging that the glass can be custom ground to a grain size that will resist erosion. Deposits of natural sand often contain a large percentage of material that will quickly erode because grain size and shape are not compatible with high energy zones like beaches.

Another advantage of this technique is a reduction in dredging. Dredging reductions also decrease the use of pipelines and their potential reef impacts. Once an appropriate mix of glass and sand is determined, the recycled glass would likely be delivered via land.

Limitations: At this time, it is not known whether recycled glass supplies could meet the possible demand for glass sand should this technique prove economically and practically viable. Demand in the marketplace for recycled glass is strong and may keep costs high and supplies limited. However, there is generally a surplus of green recycled glass in the marketplace because demand for green glass is lowest. Also, the possible effects of adding glass to beaches on flora and fauna is unknown and should be studied for possible impacts.

Cost: Because glass must be collected through recycling channels, ground to specific grain size, and transported overland to renourishment sites, this technique is expensive.

Project Trials: Broward County, Florida is currently conducting a pilot study to investigate how various glass/sand mixtures react to the elements, such as moisture and temperature. The test plot is located on a county beach with 16 sections in an area 10 feet by 40 feet. Four sections contain 100 percent beach sand; four sections contain a mixture of 75 percent sand and 25 percent recycled glass; four sections contain a mixture of 50 percent sand and 50 percent recycled glass; and four sections contain a mixture of 25 percent sand and 75 percent recycled glass. Results of the trial will be summarized in April 2007. Additional studies should investigate how various glass/sand mixtures affect the ecology of beach flora and fauna.

E. Biorock

Description: Biorock is a patented process whereby an accelerated accretion of calcium carbonate (aragonite) on a metallic framework occurs in the presence of a low voltage, direct electrical current. The framework is colonized over time by corals, which have been shown in some experiments to grow more quickly on this artificial substrate. Eventually, the internal framework may become less important for providing stability for the new "reef." This technology has also been shown to provide effective substrate for transplanted corals, either permanently or for rehabilitating damaged natural reefs.

Power sources for providing the required electrical current can be delivered in a variety of ways. Solar, wind, and tidal or current energy can be harvested using now common generating equipment. The Biorock structural framework is usually constructed of readily available reinforcing steel bar stock (rebar).

Research in the Indian Ocean has reportedly demonstrated that corals growing on Biorock modules were significantly more resistant to mortality caused by elevated water temperatures than corals growing on natural reefs. It is not known if the Biorock substrate may endow corals with resistance to other stressors.

To date, this technology has been used predominantly for coral research and reef restoration purposes. Commercial applications have been less numerous and the potential for shoreline protection seems largely theoretical at this time.

Potential: Biorock has demonstrated some success at providing a substrate for coral and other reef-dwelling sessile organisms, even providing accelerated growth rates in some cases. Natural reefs that have been damaged by accidental groundings, storms, or other physical disruption may benefit from Biorock patches that may re-build the reef at an accelerated rate when compared to natural processes. Biorock may also provide a means for temporarily supporting corals that will be transplanted to reef restoration sites.

Limitations: To date, Biorock has been a small-scale method for promoting marine growth on artificial surfaces and may not provide robust shoreline protection, particularly in the short term. The longer term prospects for shoreline protection may be better as limestone and biomass increase on the artificial framework, eventually making the module a permanent, more stable fixture. However, severe coastal storms may be a serious problem for this technology if the Biorock modules cannot be securely anchored to the ocean floor, and Biorock modules dislodged during a storm may damage any natural reefs in the immediate area. While there seems to be promising data collected from several tropical regions, there is a paucity of data for this technology here in the subtropical western Atlantic Ocean. Biomass colonization and limestone accretion rates in tropical areas may differ significantly from expected rates in coastal Florida waters.

Cost: Because there is no true standard size or objective yet for Biorock applications, no cost information was available.

Project Trials:

- **Maldives, Indian Ocean**—One of the earliest test modules, this project has been monitored since 1997. No shoreline stabilization component of the project was intended; however, limestone accretion and coral growth rates for this project have been promising.
- **Bali, Indonesia**—This project is a network of 22 individual Biorock modules occupying an area over 220 meters long. Accelerated limestone accretion and coral growth rates were recorded as in other Biorock projects, as well as high species diversity. It is too early to

determine the potential ability of this project to protect the nearby shoreline. In fact, it does not appear that shoreline protection was intended as a project objective.

F. Horizontal Directional Drilling and Tunneling

Description: Horizontal directional drilling and tunneling are methods for boring horizontally through various geologic strata. These methods of construction are not new or innovative to the general construction industry; however, they are innovative to coastal construction practices for protecting coral reefs and live/hard bottoms. These methods create a passage with a circular cross section of varying diameters and can be used in both terrestrial and marine settings. While these techniques perform a similar function, horizontal directional drilling is more cost effective for smaller borings; tunneling has a much larger maximum bore size.

In both techniques, the excavated tunnels are generally lined with pipe or a reinforcing material to provide stability and a clean passage to meet the requirements of the application. Tunnels are most commonly excavated using a TBM sized for that particular application. This technique can be an alternative to drilling and blasting where localized disruption of soils or rock is not possible. Boring tunnels using this technique also reduces the cost of lining the tunnel because the TBM produces smooth walls. These techniques are relatively new but have allowed excavations in strata that previously did not withstand drilling or tunneling operations.

There have been several proposals to use these techniques for excavating below offshore reefs and other marine strata to allow utility crossings or vehicle access and prevent impacts to the resources above.

Potential: Utility or communications reef crossings can damage coral and other hard-bottom communities when avoidance is not practical. However, horizontal directional drilling and tunneling may allow pipelines to avoid affecting offshore reefs by excavating a tunnel safely below the reef. Because these techniques do not employ drilling and blasting, impacts to benthic flora and fauna may be significantly reduced.

Limitations: Directional drilling and tunneling are expensive and should be even more so for projects located off the coast in relatively deep water. These are new technologies and do not yet have an extensive track record for avoidance and minimization of impacts to marine resources. Turbidity at "punch out" points on the sea floor and releases of drilling mud and sand can be harmful to nearby flora and fauna. Spoil containment may also provide challenges during construction.

Cost: Proposed cost per mile of pipeline created by tunnel boring ranged from $1.39 million per mile to $2.44 million per mile for the High Rock LNG and Calypso LNG projects, respectively (Intelligence Press Inc.). Cost estimates for directional drilling could not be obtained but would vary according to diameter and geology. Costs for directional drilling increase with the diameter of the excavation.

Project Results: HDD was used to avoid and minimize impacts to coral reefs in the AT&T and Tycom FOC projects, numerous other FOC projects, and infrastructure (sewage, water, electric) line construction and maintenance.

AES and Calypso have proposed to transport natural gas from the Bahamas to Southeast Florida. Each project is proposing to use TBMs to construct a concrete-lined tunnel (10 to 14 feet in diameter) underneath the reef systems off of Broward County for a natural gas pipeline. Neither of these projects has been constructed yet.

The Port of Miami is proposing a tunnel under a portion of Biscayne Bay to provide direct access from the seaport to I-395 and I-95 to facilitate vehicular access to and from the port. This project has not been constructed yet (www.portofmiamitunnel.com).

G. Reef Corridors and Gaps

Description: Florida's Atlantic offshore reef network consists of several exposed rock formations that extend along the coast generally parallel with the shoreline. These reefs lie in various depths and contain a large variety of marine life ranging from tropical to subtropical to temperate ecotones. The exposed geology of the reef systems allowed colonization by marine plants and invertebrates that grew over millennia to form the reef systems that currently exist. The exposed strata of rock that form the reef substrate do not have a uniform elevation, leaving a number of sandy gaps or corridors through the reef where relatively little biodiversity exists. These gaps and corridors can provide convenient reef crossing and bypass points for pipelines, underwater cables, and other linear structures that may otherwise negatively affect the reefs.

Potential: Locating linear utility crossings to take advantage of reef gaps may be the best method for reducing impacts to offshore reefs. In many cases, the pipeline or cable would not have to be directionally drilled, bored, or even buried but could rest directly on the ocean bottom. This method of avoidance and minimization would have the additional benefit of saving considerable costs and potentially streamlining the permitting process.

Limitations: Reef gaps in successive reef networks do not often line up with one another in a manner that promotes commercial exploitation. For projects that must traverse all of the coastal reefs, finding successive reef breaks within a reasonable distance from one another could prove difficult. For example, if three reefs must be traversed for a given project, and following a path to utilize the closest reef gaps doubles or triples the distance required to otherwise clear the reefs, the additional material and labor costs may prohibit using this technique. Some existing reef gaps do not line up on land with a suitable route to bring the pipeline or FOC onshore and traverse to an existing transfer station or substation. Onshore connection is not always feasible.

Cost: The costs associated with reef corridors can be calculated by adding the additional materials and installation costs of utilizing available reef gaps and comparing that to the cost of a more direct route through the reef(s) coupled with directional drilling, tunnel boring, trenching, or other methods of avoidance and minimization.

Project Results: Details and locations of the existing reef gaps that have been identified and ground-truthed off Southeast Florida thus far are listed as follows:

- **Lake Worth Gap** (northern Palm Beach County), beginning at the easternmost end at N. Lat. 26 37.659/W. Long. 80 01.341(south side) to N. Lat. 26 38.481/W. Long. 80 01.258 (north side), in a 1,672-yard-wide gap.
- **South Lake Worth Inlet Gap** (central Palm Beach County), beginning at the easternmost end at N. Lat. 26 32.492/W. Long. 80 01.610 (south side) to N. Lat. 26 32.444/W. Long. 80 01.626 (north side), in a 100-yard-wide gap.
- **Delray Gap** (southern Palm Beach County), beginning at the easternmost end at N. Lat. 26 27.393/W. Long. 80 02.765 (south side) to N. Lat. 26 27.641/W. Long. 80 02.726 (north side), in a 508-yard-wide gap.
- **Sea Turtle Gap** (southern Palm Beach County), beginning at the easternmost end at N. Lat. 26 22.672/W. Long. 80 03.224 (south side) to N. Lat. 26 22.748/W. Long. 80 03.224 (north side), in a 154-yard-wide gap.

- **South Broward Gap** (southern Broward County), beginning at the easternmost end at N. Lat. 25 58.438/W. Long. 80 05.278 (south side) and N. Lat. 25 58.821/W. Long. 80 05.271 (north side) and extending westerly on its southerly limits through the following points: N. Lat. 25 58.977/W. Long. 80 05.733, N. Lat. 25 59.132/W. Long. 80 05.997, and ending at N. Lat. 25 59.138/W. Long. 80 06.366, and westerly on its northerly limits through the following points: N. Lat. 25 59.039/W. Long. 80 05.725, N. Lat. 25 59.205/W. Long. 80 06.060, and ending at N. Lat. 25 59.192/W. Long. 80 06.371.

H. Stormwater Retrofits

Description: Stormwater discharge points in coastal areas can accelerate beach erosion if not properly managed. Historically, stormwater discharges were designed to quickly drain excess rainwater that accumulated on roadways and other areas where flooding would present problems. Throughout Florida, summer rainfall can produce large volumes of stormwater in a short period of time, creating a variety of problems where it is diverted. Efforts are increasing to improve the quality of stormwater that is directed into various water bodies, including the ocean, but relatively little attention has been given to erosion caused by stormwater unless the impacts were profound.

Potential: Measures that are employed to help reduce the loss of sand along the coast may translate directly into dollars saved by reducing the frequency of beach renourishing or other management activities that help to minimize erosion. Permeable surfaces along urban beaches would allow stormwater to percolate into the ground, helping to reduce stormwater volumes. Also, stormwater discharge retrofits that disperse flow over a broader area would reduce the velocity of flow and its ability to carry sand and sediments.

Limitations: Stormwater-induced erosion is a modest contributor to total sand losses along beaches, so the cost of stormwater retrofits that address this issue should be carefully considered for return on investment. However, because water quality improvement is almost always an objective of stormwater retrofit projects, an evaluation of total project value should consider this benefit also.

Cost: A review of cost data for the numerous stormwater retrofit projects should provide accurate estimates for similar projects to control beach erosion.

Project Results: Not applicable.

I. Sand Bypass/Backpass

Decription: Sand bypass/backpass is the redistribution of sand within the littoral system along beaches. Sand bypassing is the hydraulic or mechanical movement of sand from an area of accretion to an area of erosion, usually across a barrier to natural sand transport such as jetty structures. Bypassing commonly takes place by two main methods. First, pumping equipment and piping can be constructed that transfers sand from the updrift side of the littoral barrier, and deposits it as a slurry of sand and water on the downdrift side. Depending on the rate of accretion on the updrift side, this equipment may run continuously or only when needed.

A second method involves excavating sand from the updrift side and using dredges or heavy machinery to place it on the downdrift side via land or water-based transport. This process is sometimes referred to as backpassing. Both of these methods can be used to keep navigational channels and other harbor areas free from excess sedimentation in an effort to reduce maintenance dredging requirements.

Potential: Bypassing and backpassing have been used for decades along Florida's beaches and it helps to provide consistent public access to beaches for recreation. They also allow for safe maritime navigation to and from ports that are essential to economic development. Beachfront development is also dependent on bypassing to stabilize the shoreline and help to replenish sand lost to storms. Sea turtles and other marine wildlife benefit from these projects because renourishing eroded beaches replaces high quality beach sand and improves habitat for sea turtle nesting and shore bird foraging.

Limitations: Access to depositional areas and eroded areas may not be adequate to allow heavy machinery/equipment, public access may be sacrificed, infrastructure for delivering sand to eroded beaches may not be adequate, and this method can be costly, particularly where longshore currents are strong.

Cost: Sand bypassing costs estimated for several different alternatives at Port Everglades in Broward County range from around $10 to $16 per cubic yard, excluding the cost of construction. According to a California Beach Restoration Study drafted in 2002, backpassing costs typically run $1.50 per cubic yard.

Related Projects:

- **Miami, Florida**—Miami Beach 32nd Street Hot Spot project was constructed in the spring of 2002, using backpassing and groin construction.
- **Peninsula Beach**, within the City of Long Beach, California—This project commenced in 2002 and is a feasibility study to maintain Peninsula Beach by backpassing.

J. Concrete Mat/Reef Ball

Decription: Reef ball modules have been used extensively for creating artificial reef habitat and to a lesser extent to help attenuate wave energy to prevent beach and shoreline erosion. These precast concrete modules are hollow with many holes and passageways to encourage marine growth and provide habitat for other marine life. They are engineered to provide over 100 years of service and can be moved around if necessary after they are placed on the seafloor. They are usually intended to eventually become overgrown by corals and other invertebrates, thereby forming a permanent reef structure.

Articulating concrete block mats (ABMs) are a means of armoring substrates to protect them from various erosional forces. The mats are constructed by linking individual blocks together using steel cables and the mats can be custom sized for the project site.

Combining these two structures to create a submerged breakwater is being tested by the USACE and Dade County, Florida at Miami's 63rd Street Beach. The reef ball modules will be attached to the ABM to prevent lateral movement and structural integrity. Once the 63rd Street Beach is nourished with upland sands, the reef ball/ABM breakwater will be monitored for its ability to prevent erosion.

Potential: The reef ball/ABM system may prove to be an effective means of erosion control for beaches because both technologies have been proven to do so individually. Reef balls have been known to settle into fine sands over time, lowering the vertical profile, which would reduce efficacy as a breakwater. ABMs alone do not have the vertical profile required to attenuate wave energy, but these two forms together may effectively hinder erosion dynamics at a variety of beach locations. Additionally, this system incorporates a habitat enhancement component to shoreline protection that many other breakwater structures cannot provide.

Limitations: Although reef balls have been known to withstand hurricanes and other violent storms without being displaced, it is not certain that they could do so in every case. However, extensive analysis performed for the 63rd Street Beach predicts that the reef ball/ABM unit will not move. Previous applications have proven that reef balls can become partially buried in fine sediments under certain conditions; however, the ABM substrate should prevent this. This approach to shoreline protection is not inexpensive, costing roughly what both systems would cost for a proposed project.

Cost: An accurate cost estimate is difficult due to the highly variable sizes in which reef ball modules are available and the specific needs of shoreline protection projects. However, cost estimates of the Miami Beach project published in 2002 list reef ball unit cost at $300 and installation at $1,000 per unit. Concrete ABMs are fairly standard and costs can be estimated without difficulty.

Project Results: There are no other projects known that combine these two methods for shoreline protection; however, both systems have individually had success at reducing shoreline erosion and/or accreting sand along beaches. Results of the 63rd Street Beach demonstration project in Miami should provide some indication of this system's potential value when they become available.

NOTE: The following items were discussed by workshop participants in this session and were recommended as emerging technologies to stabilize shorelines, reduce erosion, or renourish beaches. After more detailed research on the following items, it was determined that they are existing methods for shoreline stabilization, erosion reduction, and renourishing beaches, which have been frequently used in the past. They were researched and it was found that no innovative technological advances have been made to the method, or the method failed when it was applied to in situ conditions. In addition, some of the items listed below are not technologies, but are recommendations for innovative ways to avoid or minimize impacts to coral reefs and live/hard bottoms.

A. Breakwater Structures

Description: Breakwaters have been used by man for centuries to help attenuate wave energy in a variety of coastal areas. Some newer designs and materials are providing additional options for shoreline protection, and the size, shape, and configuration of modern breakwaters is virtually infinite. While they all may effectively alter wave energy under ideal circumstances, ambient conditions at any project site will usually require a specific application of methods and equipment to maximize efficacy. Regardless of the breakwater type being considered, a thorough analysis of local conditions will help to prescribe the best approach.

Many of the latest breakwater designs are constructed using concrete to provide an inert yet durable material to deflect wave energy. However, more attention to shape is being incorporated into the latest designs in an effort to tailor breakwater projects to meet specific needs. Breakwaters may be submerged, semi-submerged, or floating, but they all are intended to attenuate wave energy and protect the shoreline or appurtenant structures.

Potential: Breakwaters are proven to diminish the effects of wave energy on the adjacent shoreline. They have become relatively cost effective through the use of inexpensive materials and do not generally require prohibitive maintenance effort. Breakwaters can be custom designed to offer protection along shorelines with varying depth and energy profile and are available in sizes and shapes (usually proprietary) that may offer advantages based on ambient conditions.

Limitations: While breakwaters can be effective at protecting shorelines from erosion, improper installation can create problems as undesirable as those it was intended to mitigate. A thorough understanding of littoral zone wave and current dynamics is needed to design an effective breakwater system for any location. Moreover, even effective breakwater networks can exacerbate erosion along adjacent shorelines if not protected.

Cost: Costs for breakwaters are not usually prohibitive, but are highly variable depending on the specific breakwater profile selected, as well as the expanse, depth, and other individual factors of a particular project.

Project Results:

- **Palm Beach, Florida**—A network of 330 Prefabricated Erosion Prevention (PEP) reef modules were installed off Palm Beach in 1992 to 1993. The breakwater was located between the beach and a natural reef and was intended to reduce wave heights and collect sand on the shoreward side. Results indicated that sand did not accumulate inside the breakwater and the modules were removed 2 years later.
- **Vero Beach, Florida**—A 3,000-foot PEP reef was installed off Vero Beach in 1996 to reduce wave height and stabilize the shoreline. Results indicated the reef was not effective at meeting its objectives.

B. Groin Fields

Description: A groin field is intended to interrupt a longshore current that transports sand within the littoral zone of a beach, causing deposition of sand along the upcurrent side of the groins. Eventually, if the spaces between the groins fill in with sand, a stable stretch of beach may result even after the longshore transport rate is restored.

Groins have historically been constructed of steel, concrete, or wood, but newer designs take advantage of durable synthetic materials that allow for more flexible applications. Many groins may be straight and perpendicular to the shoreline, but zig-zag, angled, and t- or y-shaped groins are becoming more common as site-specific littoral zone conditions are better understood. Groin fields built using fabric-covered sand tubes have been employed recently and may prove to be effective for some areas.

Potential: Groin fields can quickly reduce or prevent erosion along beaches with a longshore current by capturing sand that would normally pass through the littoral zone. In areas where erosion is severe, groin fields may be an effective option to prevent further loss of property and/or public access.

Limitations: While groinfields may create a net gain of sand within the field, adjacent shorelines may be adversely affected by accelerated erosion. Because they are generally placed perpendicular to longshore currents, groins inherently alter conditions on their downdrift side and are notorious for encouraging erosion downcurrent of the groin field.

Project Results: Not enough innovative design information exists.

- **Stump Pass, Charlotte County, Florida**—A geotube groin field was installed to prevent sedimentation of the nearby channel and stabilize a 1,000-foot section of beach. Early results indicated that erosion has slowed in the section of beach between the three groins. Monitoring will continue into 2008 (Beach Restoration, Inc., Lebanon, Tennessee).

C. Beach Vegetation/Dune Stability

Description: Vegetated dunes and beaches offer a measure of protection from erosional forces along beaches and shorelines by helping to hold sand and sediments in place. Many beaches have lost much of their native vegetation to development and subsequent erosion in recent decades has only helped to reinforce erosional patterns along the Florida coast.

In contrast to some armoring and other mechanical efforts to thwart erosion, adding beach and dune vegetation helps to accrete sands along the beach and does not negatively affect adjacent stretches of beach that are not protected. Stabilizing the beach and dunes with appropriate vegetation can help to ensure a reliable source of sand exists to replenish the forebeach through natural dynamics. Sand dunes have been proven to be an important repository for sand that naturally moves back and forth between the forebeach and dunes as environmental conditions change.

Potential: Because vegetating the beach offers resistance to the erosional forces of wind and water, the subsequent retention of sand on the beach can reduce the frequency of renourishment. In many cases, stabilizing the beach by planting native vegetation helps to interrupt the cycle of constantly losing sand. Coastal ecology may also be improved by providing more habitat for coastal wildlife.

Limitations: Violent storms and hurricanes can overtop dunes and vegetation, whereas a hardened shoreline can better protect property. Beach/dune vegetation does not generally restore a beach that has been severely eroded. Stabilizing the beach through planting is more of a protective measure than a restorative one.

Cost: Planting efforts are generally much less expensive than mechanical shoreline protection measures, but are more passive and not usually able to provide immediate benefits, such as creating a wider beach that attracts visitors. Maximum value for this technique may be to plant a renourished beach after some form of protection has been installed. The stabilized beach and dune zones will help to retain sand and reduce the need to renourish.

Project Results: None.

D. Dredge Time Reduction

Description: Workshop participants discussed the recommendation for dredge time reduction meaning the reduction of dredging on different schedules other than 24/7 operations. This is not a technology that can be described as innovative, but simply a recommendation as a means of avoidance and minimization.

Potential: Potential benefits of reducing the dredge time to other schedules besides 24/7 operations could provide daily or weekly timeframes for allowing corals to expend sand particles and to recover from turbidity and sedimentation impacts.

Limitations: Using dredge time reductions can cause the cost of a project to increase significantly and would cause large construction to be working over the reef system for longer periods of time, thereby increasing the potential for impacts.

Cost: Costs would be estimated using the total cost for specific dredge equipment and then increased based upon the amount of time the project would be extended due to dredge time reduction. Some beach nourishment activities can range from $10 per cubic meter (International Coastal Symposium 2000) of sand to $1.6 million per mile (Martin County, Florida, Hutchinson Island Shore Protection Project FY04). The costs for incorporating dredge time reductions would need to consider the time that vessels would not be in use while dredging activities are not occurring.

Project Results: None.

E. Coastal Construction Control Line Revision

Description: The Coastal Construction Control Line (CCCL) defines the zone along the coastline subject to flooding, erosion, and other impacts during a 100-year storm. Properties located seaward of the CCCL are subject to state-enforced elevation, and wind load and construction requirements, which are more stringent than standard building codes and federal flood codes. With few exceptions, construction projects seaward of the CCCL must obtain a state permit.

Revising the location of the CCCL or firmer restrictions on proposed development projects seaward of the CCCL may help in the future to stabilize shorelines and reduce beach erosion and the need for renourishment. However, further restrictions could cause unintended consequences.

Potential: Maintaining more natural shorelines can help reduce beach erosion by not interfering with natural beach and littoral zone dynamics. Reduced erosion may translate directly into cost savings from a reduction in beach nourishment budgets.

Limitations: Development currently within the CCCL would most likely be exempt from further restrictions or not affected by moving the control line, which would have little or no impact on beach conditions. Also, additional restrictions on property seaward of the CCCL could result in a reduction in value and reduced property tax revenue for that county. Other problems resulting from real estate devaluation may also occur.

Cost: Potential cost savings may be realized if revisions to the CCCL prevent future beach erosion and the need to nourish those beaches. However, a potential loss in county property tax revenues may result if revising the CCCL reduces property values on the seaward side.

Related Projects: Not applicable.

F. Dune Management

Description: Managing natural and improved sand dunes along beaches can have a significant impact on the condition of the beaches they help to protect. Dunes are an important repository for sand, and by appropriately managing the vegetation and maintenance of the dunes, beaches are generally wider and more resistant to erosion.

Maintaining appropriate vegetation on the dunes will help protect the sand supply for a beach and allow natural wind and tidal processes to replenish sand when necessary on the forebeach. Should plantings become necessary, they should be undertaken at the appropriate season to reduce the chance of mortality. Periodic mechanical maintenance may be necessary in the dunes to prevent loss of sand landward. Equipment selected for mechanical maintenance should not be damaging to dune vegetation.

Potential: Managing dunes to promote vegetation and sand accumulation can help beaches resist erosion. Plant roots trap sediments and make them available for redistribution throughout the beach. Likewise, prominent dunes help to block the transport of sand inland, keeping sand on the beach. Proper dune management may reduce the need for beach renourishment.

Limitations: Strong erosional events created by storms can exceed a dune system's ability to protect a beach. Even successful dune management has a limited ability to replenish sand lost to erosion. This technique may be best employed in combination with others such as PEMs, multi-purpose reefs, and/or beach plantings, among others.

Cost: Dune management is chiefly a form of preventive maintenance and very little information is available regarding the costs involved. This strategy may involve planting dune vegetation for which cost information is readily available. Costs for other forms of maintenance can be estimated by calculating local operating costs for various types of light and heavy equipment that are used for sand recovery projects.

Project Results: Dune management is generally a maintenance activity and no case studies were found to summarize the results of similar projects.

Question 2: What opportunities are available to incorporate or implement these emerging technologies to solve coastal and marine construction challenges? Identify sites or problems to be addressed.

The following series of lists provide items that were discussed by Session 3 participants identifying where these technologies may be addressed or implemented. The problems that could be addressed or identified with the named opportunities are discussed under each individual technology or method of recommendation above in Section 2.3, Session 3, Question 1.

Regulatory and Permitting

Regulatory agencies should consider:

- Shoreline protection as acceptable mitigation;
- Improved technologies for deep water borrow sites (sand removal);
- Project design/modeling to include dunes;
- Implementation of dune management and sand bypassing, including using more compatible sand first with nourishment as an option;
- Creation of habitat that is effective and new with efficient technology driven by cost and availability;
- Consideration of stormwater retrofits/outfalls as alternative mitigation for beach nourishment impacts and outfall impacts;
- A better understanding of dredge equipment and borrow area design criteria for borrow area identification; and
- Utilization of the best available science and technology to better understand physical and biological processes to help supplement natural processes.

Regional Shoreline Management Practices

Recommended opportunities available for incorporating the above described (Session 3, Question 1) technologies and methods for shoreline management are:

- Greater implementation of sand bypassing;
- Use/modification of jetties for sand bypassing to minimize accretion on one side of an inlet;
- Port Everglades as a potential location for alternative technologies (e.g., anchorage modification, sand bypassing, tunneling) and installation of a sand transfer plant;
- Lobby agencies to use alternative technologies and support pilot projects;
- Project design/modeling to include dunes;
- Wave alignment changes by careful choice of offshore submerged reef alignment and design (deal with the cause [i.e., the waves] not the effect);

- Implementation of dune management and sand bypassing, including using more compatible sand sources;
- Usage of wave gauges to measure nearshore waves for improved modeling;
- More frequent LIDAR surveys (3-meter resolution); and
- The use of T-Head (attached headlands) groins to get wave rotation/circulation to minimize erosional impacts; however, these structures have been found to affect turtle hatchlings.

Policy Changes (Federal, State, and Local)

- Approach the National Dredging Committee for partnering efforts; and
- Convince lobby agencies to use alternative technologies and support pilot projects.

Contractor Practices

- Approach the National Dredging Committee for partnering efforts;
- Pursue partnerships with dredging contractors and regulators prior to permit issuance. Consult with Dredging Contractors of America (DCA), Western Dredging Association (WEDA), or consulting members of the dredge industry prior to work to determine better dredging practices (most site appropriate) suitable for specific locations; and
- Include dunes in project design/modeling.

Science

- Testing for compaction-improved measurement device;
- More frequent beach sampling to better understand natural recovery processes; and
- Utilization of best available science and technology to better understand physical and biological processes, and to help supplement natural processes.

Public Education and Outreach

- Address increased public sensitivity to coastal construction issues.

Question 3: What factors might get in the way of implementing such technologies (e.g., cost, expertise, human resources)?

Cost and Funding

General costs have been discussed above for some of the named technologies or methods described in Section 2.3, Session 3, Question 1. The following items have been listed as general factors that may prohibit or hinder the necessary implementation of the technologies.

- Partnerships between the regulatory agencies, resource managers, the scientific community, and members of the public;
- Lack of technical and scientific expertise at local government and other levels of government;
- Reluctance to experiment on new technologies that may not perform well (budget issues) particularly if the stated goal of the project would not be achieved by the new technology, which may face a second construction effort that would double the cost;
- Competing interest/user groups/stakeholders;

- Limited financial resources;
- Cost and cost sharing;
- Availability of resources for monitoring (money and people);
- Translation of scientific information to non-scientific audiences;
- Lag in scientific information being available for use and actually being applied;
- Lack of public education and awareness of environmental values and impacts;
- Lack of independent peer review of studies;
- Public opinion and local concern from various stakeholders; and
- Lack of access to reports/knowledge of what has already been tried.

Time

- Lag in scientific information being available for use and actually being applied; and
- Timing of funding, permitting, and monitoring.

Policy Issues

- Bureaucratic issues/setbacks, such as lack of government coordination at all levels on engineering and biological impacts;
- Lack of regional standardization in data collection;
- Endangered species issues;
- Better understanding of requirements to permit a pilot program, such as federal experimental project program and state experimental project program; and
- More mechanisms (available programs) to promote pilot projects.

Lack of Participation

- Lack of cooperation by all parties (agency, private industry, public sector, and academia);
- Involvement and input of the scientific community;
- Translation of scientific information to non-scientific audiences;
- Private property rights/tax payer equity; and
- Level of potential conflict of interest.

Question 4: **Which components of these technologies could be used to minimize impacts to coral reef resources?**

Responses to Question 4 are identified in Table 2-2.

Table 2-2. Components of Technologies to Minimize Impacts to Coral Resources

	Components					
Technologies	**Expedited Permitting for Pilot Projects**	**Balance of Permit Design and Productivity**	**Increase in Scientific Data**	**Increase in Natural Shoreline Protection**	**Decrease in Turbidity and Sedimentation**	**Minimization of Direct Impacts**
Pressure equalizing modules	X		X			
Multi-purpose reefs	X	X	X		X	X
Sand recycling back-passing	X	X			X	X
Alternative sand sources	X		X			
Recycled glass beaches			X		X	X
Concrete mat plus reef ball combination	X	X	X		X	X
Upland sand sources					X	X
Accelerated “growing” of reefs to protect shoreline (Biorock)	X	X	X	X	X	X
Modified construction (terraced beach)	X	X	X		X	X
Vegetation for beach/ dune stability	X	X	X	X	X	X
HDD/tunneling under resources		X	X			X
Dredging time reduction		X			X	X
Defined pipeline corridors		X				X
Review Coastal Construction Line locations	X	X	X	X	X	
Dune management	X	X	X	X	X	X
Breakwater structures	X	X	X	X	X	
Groin fields		X				
Sand bypassing/back-passing	X	X		X	X	X
Dredging and fill		X				
Retrofit drainage structures		X		X	X	X
Use of compatible sand				X	X	X

Question 5: What criteria must be established during the planning phase that will minimize impacts during construction?

Responses to Question 5 are listed below.

- Use peer-reviewed project, monitoring design, and performance criteria;
- Apply realistic performance indicators for projects;
- Incorporate and emphasize detailed modeling of effects on shoreline, etc.;
- Apply improved/independent modeling;
- Produce comprehensive monitoring plan and appropriate monitoring design;
- Examine secondary and cumulative impacts, including social and environmental;
- Examine project need/economics of project: cost/benefit analysis;
- Analyze thresholds for halting/modifying projects (e.g., coral stress index);
- Ensure appropriate regional sand bypassing efforts;
- Create best management practices (BMPs) for marine/coastal construction;
- Ensure sediment compatibility (grain size);
- Apply sequencing: avoid, minimize, mitigate;
- Study alternatives;
- Include stakeholders in project development; and
- Consider impacts or benefits of project to all user groups.

Question 6: What kind of oversight/enforcement would be needed to verify that the established criteria were being met? What are reasonable solutions to oversight/enforcement?

Many items that were discussed as oversight/enforcement methods that would be needed for these technologies to be implemented successfully were listed above to also answer Question 5. These methods are not listed again to minimize redundancy. Items that were not redundant recommendations are listed below.

- Use SI technology where available (currently only on hopper dredges);
- Implement independent oversight of quality assurance/quality control (QA/QC) and independent modeling;
- Perform analysis, before, during, and post-construction;
- Avoid using third-party inspectors to enforce BMP criteria (Typically, this cannot be done under contract requirements; the contractor can only report to the contracting officer. If the third party is paid by the contractor or government pays for the work, the third party would not be considered non-biased);
- Conduct compulsory stakeholder consultations every 3 months (NGOs, citizen activists, etc.);
- Open access to all reporting and data (electronic); and
- Conduct more effective regulatory enforcement.

Question 7: Discuss regional bypass strategies in Florida.

In response to Question 7, Table 2-3 identifies the existing inlets along the Florida coast and lists which inlets currently have bypassing abilities and the associated jurisdiction.

Table 2-3. Florida Inlets and Bypassing Status

Inlet	Jurisdiction	Bypassing (occurring or not operating)
St. Mary's	Federal	Yes – $500,000/2 years
Nassau Sound	Federal	Yes – back passing
Ft. George (St. John's)	Federal	Inlets are natural – not bypassed
St. Augustine (Mayport)	Federal	Use ebb-shoal
Matanzas	Federal	Yes – every 3 years
Ponce	Federal	No
Cape Canaveral	Federal	Yes
Sebastian	Tax District	Yes
Ft. Pierce	Federal	No
St. Lucie	Federal	Yes
Jupiter	Tax District	Yes
Lake Worth (2 inlets)	Federal	Yes
Boynton	County	Yes
Boca	City	Yes
Hillsboro	Tax District	Yes
Port Everglades	Federal	No
Haulover	Federal	Yes

Note: According to the USACE there is not a hard plant, but sand has been moved from the Port Everglades channel and placed on Broward County beaches in November 2005 by dredge. USACE has an Environmental Assessment for placement of sand from the Navigation Channel onto John U. Lloyd State Park until 2015. Reference: http://planning.saj.usace.army.mil/envdocs_A-D/Broward/PortEvergladesOperations/EAOMPPortEvergladesFinalEA_2005.pdf

Session 3 Consensus Report

The group participants were asked to list the top five actions and technologies that could reduce impacts to Southeast Florida's coral reef resources during projects such as shoreline stabilization, beach nourishment, or other coastal construction activities. The following were identified:

1. Involvement of the dredging industry early in the permitting process, particularly in the formulation of permit conditions and recommended BMPs. Involve DCA and WEDA for representative review/coordination with partners before permits are issued;
2. Use of multi-purpose reefs to stabilize shoreline and reduce the need for frequent nourishment events;
3. Implementation of regional sand bypassing/back-passing efforts;
4. Use of alternative sand sources such as upland/deep water/beneficial use/manufactured sand; and
5. Operational/technology improvements such as minimization of dredging time.

The following are strategies identified by workshop participants as important steps in maximizing the potential of existing sand bypass plants:

1. Authorize USACE to bypass for shore protection (exists in some cases, but funding is needed);
2. Update State Strategic Beach Management Plan and implement the plan;
3. Consider all bypassing options (technology); and
4. Explore non-traditional partnerships for funding.

The five most important technologies for shoreline stabilization that were identified by this group as being potentially the most beneficial to nearshore coral and hard-bottom habitats were:

1. BMPs to be investigated/implemented where possible;
2. Regional Sand Bypassing Strategic Initiative;
3. Multi-purpose reefs;
4. Modified and improved beach vegetation/dunes (where appropriate); and
5. Highest possible sand quality for improved sand compatibility.

2.4 Session 4

Objective: For the purpose of protecting coral reefs, hard/live bottoms, and associated reef resources, review permit conditions and study designs and criteria for mitigation in innovative or advanced coastal construction activities.

- Discuss and propose reasonable or 'standard' permit condition modifications that could advance utilization of emerging technologies for coastal and marine construction activities
- Review criteria for mitigation associated with coastal construction activities, infrastructure installation, beach nourishment, dredging, and groundings
- Identify and recommend study designs to monitor projects and mitigation associated with innovative/advanced coastal activities

Question 1: What modifications to permit conditions, if any, are necessary to advance the use of emerging technologies that would protect reefs during coastal and marine construction?

Special Conditions for Permits

In most coastal construction projects, the environmental agencies may need to address a significant number of environmental concerns that may be associated with a single project. Concerns such as direct impacts from construction vessels, drilling muds, pipelines, and cables; and secondary impacts such as water quality, including turbidity and sedimentation, must be addressed prior to permit issuance and captured, in writing, as permit special or specific conditions. In regulatory permitting, it is not the project descriptions or the general conditions sections of a permit that offer the most coral reef protection. The project descriptions only give a general description of the coastal project components and the general conditions are typically "canned" language that apply to all regulated projects across the board. It is the "special conditions" placed in a permit that allows the regulator to apply specific environmental protective measures that may be unique to a project.

The following section contains examples of specific conditions that may offer a higher level of protection to coral reef and hard-bottom communities. Most of these examples have been used in offshore coastal construction permits in Florida; however, the conditions can be changed or "modified" to meet the specifics of most coastal projects both inshore (i.e., bays, inlets, estuaries, intracoastal waterways) and offshore (in the oceans). Finally, some of the conditions incorporate the use of the emerging technologies identified in the workshop sessions and the text that includes the specific technology will appear as **bolded**. Using similar formatting, new conditions could be developed that incorporate the use of many of the technologies and practices identified in earlier sessions.

Many thanks goes out to the original authors of the following specific conditions and for sharing their knowledge and lessons learned in permitting coastal projects and for consenting to place their conditions in this document.

A. All Coastal Construction Work

General Conditions

Below is an inventory of specific conditions collected from local regulatory agencies and the workshop participants. They can be used for most coastal projects that occur in the vicinity of seagrasses, coral reefs, or live/hard-bottom communities. They are intended to be used as guidelines to minimize the potential for adverse environmental impacts during coastal construction projects. They can be used as stand-alone conditions or they can be used in conjunction with each other to create a series of protection protocols for a whole construction activity.

Prevention Conditions

- Prior to permit issuance, the permittee shall provide (*insert regulatory agency*) financial assurance in the form of a pre-approved financial instrument for inadvertent or non-permitted environmental damage in the amount of (*insert written number*) million dollars (*insert written numerical amount*). These monies will be used to compensate the agency for the costs of reasonable measures taken to prevent or limit environmental damage; for clean-up and restoration of the environment to its previous state; and to cover costs where responsibility for the damage cannot be determined, or where those liable are insolvent.
- Prior to permit issuance, the permittee at a minimum, shall develop, have approved by the agencies, and implement plans that address the following coastal construction issues:
    - Spill Prevention, Control, and Countermeasures;
    - Marine Biological (Manatee, Cetacean, and Sea Turtle) Monitoring;
    - Marine Turbidity, Sedimentation, and Reef Monitoring;
    - Mitigation and Restoration Plan;
    - Vessel Maneuvering and Anchoring Guidelines;
    - Storm Handling Plan;
    - Emergency Scenario and Response;
    - Coral Relocations; and
    - Environmental Training.
- The permittee shall provide, at its own expense, a consulting firm to act as an independent compliance and enforcement officer for the (*insert regulatory agency*). This third party environmental inspector shall be charged with the responsibility to monitor and assess compliance with (*insert regulatory agency*) requirements and conditions and with reporting responsibility directly to the (*insert regulatory agency*) for the construction activities within State Waters. A draft Request for Proposal shall be submitted to the (*insert regulatory agency*) for its review, comments, additions and approval prior to being sent out to prospective companies, and no less than 120 days prior to commencement of permitted activities. The permittee and the (*insert regulatory agency*) will prepare of list of suitable companies. The (*insert regulatory agency*) and the permittee will review the final list and determine appropriate companies to which the

RFP will be sent. If the permittee and the (*insert regulatory agency*) cannot agree upon the third party consulting firm, then final approval falls to the (*insert regulatory agency*). The chosen firm shall be under contract to the permittee 45 days prior to commencement of construction activities, and shall take part in the pre-construction conferences.

- The permittee shall develop training modules for all workers relating to coral resource sensitivity; nature, configuration, and mapping of coral communities; value; and resource protection measures. The permittee shall submit the training modules to the (*insert agency name*), within 30 days prior to the pre-construction meeting.
- The permittee shall conduct a pre-construction meeting a minimum of 30 days prior to commencement of construction. The permittee shall provide a minimum of a 30-day advance written notification of the pre-construction meeting to the (*insert agency name*) and other federal agency staff so that the agencies can participate.
- The permittee shall conduct pre-, during, and post-construction meetings with agencies and the permittee's staff to discuss lessons learned and to train/educate contractors and associated personnel on environmental resources.

Construction Conditions

- The permittee shall conduct inspections of all work space areas such as vessel transit areas, anchoring areas, work space/corridor areas within 48 hours of work commencement and 48 hours after completion of each phase of the construction. The areas are to be completely investigated, surveyed, and evaluated post-construction (using similar methodologies for the pre-construction surveys) to determine if any additional resource impacts may have occurred. All non-permitted impacts to benthic resources *(name them here)* shall be mitigated for at *(insert number)* times the agreed upon mitigation amount for permitted impacts. All stony corals, soft corals, and sponge colonies visibly damaged or destroyed by the construction activities shall be immediately repaired, counted, identified to the species level, photo- and/or video-documented and non-destructively tagged for future monitoring. This report, along with a revised mitigation proposal shall be submitted to the (*insert regulatory agency*) for review and approval within 60 days of completion of the post-construction surveys.
- All construction barges and vessels shall be designed for zero discharge of contaminants. The platform decks shall be sealed and shall be watertight so that any rainwater potentially contaminated with oils, grease, or other regulated chemicals is retained on board and other materials shall be stored in an enclosed container on board for disposal onshore in upland sites. Protective measures shall be utilized during all operations and during transfer of spoil materials and chemicals from vessels to ensure that releases to waters of the state do not occur.
- This permit does not authorize mooring of vessels over seagrasses, coral reefs, or live/hard-bottom communities. All vessel equipment and materials (including, but not limited to, cables, pipe string, spuds, articulated mats, anchors, anchor lines, tow lines, piles, etc.) shall not encroach into the **buffer zones** established or the demarcated **exclusion zones**.
- All offshore and nearshore work in and around the reefs shall be scheduled to account for weather/rough sea conditions. Any activities occurring in weather or sea conditions which would prevent the environmental inspectors from adequately and sufficiently monitoring the activities shall cease.

Water Quality Compliance Conditions

- Water Quality Compliance Samples are those taken at the edge of the mixing zone, 150 meters down-current from the potential turbidity source. To ensure that the standards established in this permit for water quality in Class II/III waters are maintained during construction activities, any instantaneous Water Quality Compliance Sample reading greater than 29 NTUs above background shall result in the immediate cessation of turbidity-generating activities, and follow-up monitoring shall continue. Upon turbidity levels returning to below 29 NTUs above background at the edge of the mixing zone, construction activities may recommence, **provided that turbidity in the vicinity of marine resources does not exceed 15 NTUs above background** and turbidity monitoring shall resume at 2-hour intervals.

- Water Quality Standards for Reef Organisms Samples are those taken at the nearest down-current reef edge. To ensure that construction-related turbidity does not result in lethal or sub-lethal stress to corals and other reef organisms, turbidity shall not exceed **15 NTUs** above background for an extended period of time in areas of resources, as described below.

  1. If, at any single Water Quality Standards for Reef Organisms Sample location, a turbidity measurement exceeds 29 NTUs above background, there shall be immediate cessation of turbidity-generating activities. Work shall not recommence until the cause of the turbidity has been identified and corrected, and turbidity levels have returned to below 15 NTUs above background.
  2. If, at any single Water Quality Standards for Reef Organisms Sample location, a turbidity measurement exceeds 15 NTUs above background but is less than 29 NTUs above background (exclusive of events that trigger cessation of activities, pursuant to the criteria in number 1, above), a retest shall be conducted every 15 minutes in accordance with the following criteria:

     a. If turbidity levels trend upward (i.e., there is an increase of more than 2 NTUs from the prior reading, for three consecutive readings), there shall be immediate cessation of turbidity-generating activities upon the third reading. Work shall not recommence until the cause of the turbidity has been identified and corrected, and turbidity levels have returned to less than 15 NTUs above background. Upon recommencement of construction activities, monitoring shall continue with samples collected every 2 hours.

     b. If turbidity levels are not trending upward (i.e., there has not been an increase of more than 2 NTUs from the prior reading, for three consecutive readings), the 15-minute incremental monitoring shall continue through up to four retests, in accordance with the following:

        i. If at or prior to the fourth retest, turbidity levels are less than 15 NTUs above background, work may continue, and monitoring shall continue with samples collected every 2 hours.

        ii. If at the fourth retest, turbidity levels remain greater than 15 NTUs above background, there shall be immediate cessation of turbidity-generating activities. Work shall not recommence until the cause of the turbidity has been identified and corrected, and turbidity levels have returned to less than 15 NTUs above background. Upon recommencement of activities, monitoring shall continue with samples collected every 2 hours.

- Turbidity of each sample will be measured using a nephelometer. Turbidity water samples will be collected at 1 meter below the surface, mid-column, and 1 meter above the bottom using a combination of Van Dorn and Kemmerer sampling bottles lowered on a hydrographic wire. Sample depths (based on measured bottom depth at each sampling location) will be pre-marked on the wire prior to deployment, and sample collection triggered by means of a mechanical "messenger." Further discussion of collection methodology can be found at http://www.gvsu.edu/wri/education/manual/watersampling.htm and shall be performed in accordance with Chapter 62-1 60, Quality Assurance, Florida Administrative Code.

- Daily turbidity measurement logs will be submitted to (*insert agency name*) or representative by e-mail or fax, and summaries of all monitoring data will be submitted to (*insert agency name*) or representative within 1 week of collection and will contain the following information: 1) permit number; 2) dates and times of sampling and analysis; 3) a statement describing the methods used in collection of the samples; 4) a map indicating the sampling locations, current direction, plume configuration, and the location of the dredge and discharge point(s); and 5) a statement by the individual responsible for implementation of the sampling program concerning the authenticity, precision, limits of detection, and accuracy of the data. Monitoring reports will also include the following information for each sample that is taken: a) time of day sample was taken; b) depth of water body; c) depth of sample; d) antecedent weather conditions; e) tidal stage and direction flow; f) wind direction and velocity; g) Differential Global Positioning System (DGPS) position; and h) summary of turbidity exceedances, if any, and response actions implemented (including construction shut-down and recommencement times, etc.).

Sedimentation Monitoring Conditions

- In order to measure sediment accumulation, the permittee shall conduct short-term monitoring using sediment accumulator plates, and long-term monitoring using sediment collector ringstands, located at all (*specify specific number of monitoring stations*) of the Sediment Monitoring Stations (SMSs) and one Control Site.
- Two sediment accumulator plates shall be installed at each SMS. The sediment accumulator plates shall be monitored on a weekly basis for rate of sediment accumulation, pursuant to the following:
    - One plate shall be designated for "weekly sedimentation rate accumulation" (Plate 1), and the other plate shall be designated for "total sedimentation rate accumulation" (Plate 2), allowing for comparative measurements between weekly sediment accumulation and total accumulated sediment. During each weekly monitoring event, the sediment depth shall be measured to the nearest 1.0 millimeter (mm) on each plate. Subsequent to taking the measurements, the sediment shall be removed from Plate 1, while the sedimentation shall remain in place on Plate 2 throughout the monitoring period. Sediment depth shall be recorded as an average of 5 measurements at 5 predetermined locations on each plate. **In the event that two of the weekly plates at any individual SMS have an average measure of 1.5 mm depth of sediment per day or greater, the permittee shall conduct the following:**
        1. Cease construction activities causing sedimentation in the immediate area;
        2. Notify the regulatory agency staff of the threshold exceedance within 24 hours of discovery; and
        3. Do not resume construction activities until the cause of the sedimentation is identified and corrected, and the sediment accumulation rate returns to below 1.5 mm/day.
    - Sediment collector ringstands shall be installed at each SMS and the Control Site. The permittee shall conduct baseline monitoring of the SMS, at 60 days prior and at 30 days prior to commencement construction activities, and shall conduct post-construction monitoring of each ringstand, at 30 days post and 60 days post construction. During project construction, the sediment collector ringstands shall be sampled and analyzed for

physical properties to determine average sedimentation rate in milligram/cubic centimeter/day, every 30 days.

- Sedimentation Regular Reporting: Weekly reports shall be submitted to (*insert regulatory agency*) or representative no more than 4 business days following completion of the sampling event. The reports shall include the date, time, locations sampled, and depths of sediment accumulated on the weekly sediment accumulator plate and on the total sediment accumulator plate.

Coral Stress Monitoring Conditions

- In order to monitor corals for project-induced stress, the permittee shall conduct qualitative biological assessment of the four designated representative coral species: hard coral species *Montastraea cavernosa* and *Solenastrea bournoni*, and soft coral species *Erythropodium caribaeorum* and *Briareum asbestinum*. The assessments shall be conducted at all (*specify number of monitoring sites*) of the **Coral Stress Monitoring** Stations (CSMS) and one Control Site. The (*insert regulatory agency*) shall be contacted as soon as possible, but no more than 2 hours after the exceedance of the coral stress threshold is observed.
- **Coral Stress Monitoring** shall be conducted in strict accordance with a Marine Turbidity, Sedimentation and Reef Monitoring Plan, which shall include qualitative biological assessment of the representative coral species, once every week for 6 weeks before commencement of activities, once every week during construction, and once every week for 6 weeks after completion of construction. All sites shall be revisited, photographed, and the representative coral species shall be examined for stress caused by sediment accumulation 6 weeks after construction. Coral Stress Reporting: Weekly summaries of coral stressed monitoring results shall be submitted to the regulatory agency staff. Formal reports shall be submitted to the (*insert regulatory agency*) every 2 months, that include photos, sampling results, and stress indicator determinations. Reporting shall continue until weekly sampling is concluded 6 weeks following completion of the nearshore construction.
- In the event that a **coral stress threshold** is exceeded, the activity causing the turbidity and/or sedimentation shall cease until corrective actions have been implemented to reduce coral stress and the permittee shall contact the (*insert regulatory agency*) as soon as possible, but no more than 2 hours after detecting the coral stress threshold exceedance.

Navigation Vessel Tracking Equipment Conditions

- All project vessels, except monitoring and survey vessels, shall be equipped with **DGPS** and mapping systems that allow vessel operators to track their position relative to the demarcated vessel transit areas, mapped reef edges, and other environmentally sensitive features. All GPS data collected shall observe the following requirements:

1. The accuracy goal of the GPS data collection shall be less than 1 meter.
2. The GPS receiver used shall have a minimum of eight channels.
3. All equipment shall have a **signal-to-noise ratio filter, a Position Dilution of Precision (PDOP) filter, an elevation mask filter**, and shall be able to average the required minimum number of positions to create a point feature.
4. The <u>minimum</u> GPS settings for collection of point features are:
   - PDOP < 6
   - Signal to Noise Ratio > 6
   - Elevation Mask > 15°

  - Positions (Epochs) ≥ 30
  - Logging intervals 1-3 seconds

- The permittee shall use an **electronic positioning system** to navigate during all aspects of the construction project. For this section of the permit, the electronic positioning system is defined as a differential global positioning system or a microwave line of sight system. Use of LORAN-C alone is not an acceptable electronic positioning system for this construction project. If the electronic positioning system fails or navigation problems are detected, all operations shall cease until the failure or navigation problems are corrected.
- The permittee agrees to implement **GPS tracking/mapping technology and an automated placement verification system** on all proposed construction vessels at the discretion of the permitting agency. This technology is to be used for tracking of construction vessel routes while traveling in and out of the project area. The vessel positioning technology shall track the vessel transit paths at a minimum of 1-minute intervals and shall ensure that the contractor does not deviate outside of the approved vessel transit corridors.

B. Beach Nourishment Projects

Below is a list of monitoring technologies, BMPs, and specific conditions relating to beach nourishment activities. Each project has unique challenges depending on size and the proximity to natural benthic resources.

General Conditions

- The permittee shall prevent scouring and/or dredging of benthic resources, corals, and other hard-bottom resources, by any construction activities associated with this project.
- The permittee shall implement a strict QA/QC program during all dredging operations, including borrow area dredging, vessel transit, material transfer, and offshore rock/rubble placement activities. Bridge staff shift changes shall occur on the bridge of vessels and shift periods will be designed so that staff exhaustion and complacency during oversight are avoided. The permittee shall ensure that the contractor schedules personnel to receive a minimum of 6 hours of rest in any 24-hour period. Rest periods may be interrupted in case of emergency, drill, or other overriding operational necessity.
- All operations will be conducted in a manner that eliminates the possibility of dragging cable or other equipment along the bottom and damaging aquatic resources.
- Any towed vessels used for construction, such as barges, scows, and the like, will be either lashed directly to the dredge or the tow vessel, with no cable in the water (e.g., by a "bridle" tow or "on the hip" of a tug), or connected to the tow vessel by floating line.
- All cables must be "floating" lines or cables and shall be used in all water depths to avoid impact to submerged resources.
- The permittee shall develop an operational storm contingency plan that describes their response in the event of storms (e.g., hurricanes, high-seas conditions) and operational failures (e.g., breaks in the dredge pipes, movement of sand pump-out facility/dredge pipes). The plan shall include the following:

  1. A description of severe weather hazards that may potentially occur and steps that will be taken to guard against the hazards.
  2. The time frame of implementing the plan (using as a reference the number of hours remaining for the storm to reach the work site if it continues at the predicted speed and

direction), including the estimated time to move the construction vessels and equipment to safe harbor.

This plan shall be submitted to the (*insert agency name*) and approved within 1 week after submittal.

Ocean Dredging Conditions

- The permittee agrees to implement **GPS tracking/mapping technology and an automated placement verification system** on the proposed dredge vessel. This technology is to be used for tracking of the dredge vessel routes while traveling in and out of the project area. The vessel positioning technology shall track the vessel transit paths at a minimum of 1-minute intervals and shall ensure that the contractor does not deviate outside of the approved vessel transit corridors.
- Prior to dredging, the permittee shall provide to the (*insert agency name*) and the dredge contractor, a map identifying approved vessel transit corridors plotted as polygon targets to be used during transit from the borrow areas to the sand pump-out facility locations. A hard copy of the map shall be submitted to the (*insert agency name*) and an electronic map in electronic GPS form shall be submitted to the contractor. The electronic GPS form shall have 1-meter accuracy or less to allow for electronic positioning, and shall be incorporated into the continuous tracking system on the hopper dredge vessel. The permittee shall ensure that the selected vessel transit corridors avoid and minimize transit over hard bottom as much as possible. The permittee shall ensure that adequate vessel operating depths will be achieved, and to ensure no natural resources will be taken.
- The permittee shall require that the vessel corridors are identified in electronic GPS form, and shall be incorporated into the electronic positioning system with **automatic alarms** if the vessel deviates into the (*insert number*)-foot **buffer zone** or other restricted areas.
- The permittee shall demonstrate that the vessel was accurately navigated through the approved vessel transit corridors, by submitting to the (*insert agency name*) the mapped vessel tracks, once a week during construction activities. The permittee shall identify if any vessel transit paths have deviated outside of the approved corridors.
- If vessel transit deviation has occurred, the permittee shall immediately, within a maximum of 24 hours, notify by telephone (*insert agency name*), and all other action agencies. The permittee shall immediately identify the extent of deviation, depth, draft, drag-arm position, and reef character, within a maximum of 24 hours. After consultation with the (*insert agency name*), the permittee shall ground-truth significant vessel deviation paths and document any impacts. The (*insert agency name*) will determine appropriate recovery actions and mitigation efforts, which will include time lag and risk assessments. The (*insert agency name*) will determine final mitigation upon the applicant's submittal of a mitigation plan within 60 days of the impact incidence.
- During dredging activities and in an effort to avoid and minimize impacts to aquatic resources, the permittee will maintain absolute minimum buffer distances of no less than a (*insert number*)-foot **buffer zone** between all inshore or offshore reef communities and the borrow area boundaries.
- The permittee shall ensure that the contractor inspects the hopper dredge daily for any leaks or failures. The permittee will ensure that the contractor uses **signal devices or alarm devices** on all vessels associated with this project to ensure that leaks from the split hull mechanism, or other sediment handling systems, do not occur. The permittee must ensure that the contractor is operating the hopper dredge in a manner such that the split hull mechanism is closed

completely at all times before leaving the borrow sites. There shall be no random deposits of dredge material over natural resources and outside of the authorized areas.

- All operations including the arm of the hopper dredge, etc., shall be conducted in a manner to eliminate the possibility of equipment dragging on the bottom and damaging natural resources. Before the dredge leaves any/all borrow areas to transfer material to the transfer station, or exiting the boundaries of the site to travel, the drag-arms (hopper arm) must be completely raised out of the water at all times during transit. The permittee must provide, within 30 days prior to construction, a plan that will address what methods or precautions will be taken to avoid operational failures. If operational failures of the drag-arm occur, work shall immediately cease until the cause of failure has been corrected.
- The permittee shall ensure that the dredge contractor will prevent unnecessary runoff from the barges and work vessels into the marine environment and that the contractor complies with Florida Department of Environmental Protection water quality requirements. The permittee agrees and understands that additional safeguards may be required and any impacts to resources from dredge disposal management areas will require recovery or mitigation actions.

Sand Pump-out Facility Conditions

- The sand pump-out facility (where the hopper dredge will connect to deposit sand for the beach) shall be installed using diver-assisted placement to prevent impacts from the spuds of the jack-up structure or spud barge. The permittee shall record, via GPS coordinates, all of the locations of the jack-up structure or spud barge, and provide the data to the (*insert agency name*) once the sand pump-out facility is secured.
- At all times during project construction, the sand pump-out facility shall be adequately secured using appropriate measures to ensure that any movement of the sand pump-out facility or the pipeline, by natural conditions, does not scour or destroy submerged aquatic habitat.
- The permittee agrees to use a spud anchoring system to support equipment for the sand pump-out facility. Prior to construction, the permittee shall identify what methods will be used to secure the hopper dredge to the sand pump-out facility for sand unloading.
- The permittee agrees that in the event that the sand pump-out facility is relocated, activities will be carried out so as to avoid impacts to all submerged aquatic habitat. All cables, lines, buoys, etc., shall be adequately secured on the sand pump-out facility to avoid dragging, scouring, or inadvertent impacts to any submerged aquatic habitat.

Pipeline Conditions

- The permittee agrees that they will identify the exact routing of the sand pump-out pipeline below mean high water, and within the natural reef corridors, to minimize the impacts of the pipeline in a manner that causes the least amount of impacts to submerged aquatic habitats.
- The permittee shall use an appropriate type of anchoring methods for the sand pump-out pipe, including methods to avoid impacts to natural resources and/or scouring from the pipe **(e.g., pipe collars).** The entire length of the pipeline shall be visually inspected twice a week, during continued use, in order to check for potential leaks, which may emanate from the pipeline couplings or other failures. All dredge and fill activities will cease at any time that any substantial (violation of state water quality standards) leaks are found. Operations may resume upon appropriate repair of affected couplings or other equipment, or upon completion of resource recovery activities. After pipeline removal, a detailed survey will be conducted in order to document any impacts that may have occurred as a result of the pipeline placement.

Turbidity and Coral Monitoring Conditions

- Prior to construction, laboratory calibration experiments testing sedimentation rates on corals in aquaria shall determine threshold values of **stress indicators,** called index values. The coral stress index values shall be established to represent the health of the coral. A scale of 0 (zero) to 3 (three) shall be used where, 0 represents no observed bleaching, to mucus production, to polyp extension, to a value of 3 representing the maximum observed changes in the coral species. Prior to construction, the permittee shall submit the laboratory-developed index values to the (*insert agency name*) to be used as guidance for assessing coral health after the construction is complete.
- The permittee shall establish nearshore monitoring stations/cross-shore permanent transects, extending *(insert number)*-ft. seaward of the projected equilibrium toe of fill (ETOF), to monitor and identify potential effects from sediment and turbidity movement and **stress indicators** on scleractinian (stony) and soft coral species, and on adjacent, deeper, and stable nearshore hard-bottom communities. The permittee shall conduct surveys of nearshore hard-bottom resources, fish populations and epibenthos monitoring sites, and depth of sediment, immediately prior to construction (this will be compared to baseline data to get information on natural variability), within 90 days of completion of construction, and annually for the first 3 years after construction, and again at the end of the fifth year.
- The permittee shall monitor the offshore hard-bottom habitat, located adjacent to the borrow sites for sedimentation generated by the hopper dredging operations. Amount and duration of sedimentation will be monitored, as well as **stress indicators** of stony corals affected by the dredge operations, at designated monitoring stations located adjacent to each borrow area.
- If *in situ* coral **stress indicators** exceed defined values and show 2 out of 3 observable **stress indicators** and the sediment monitoring sites for any borrow area has accumulated daily average sediment values below 1.5 mm, then histological tissue analysis of affected corals will be conducted.
- The permittee shall collect data from a boat-towed **ADCP** to assist in predicting sedimentation and turbidity plume dispersion.
- The permittee shall implement a compliance construction-monitoring program. Monitoring of turbidity will occur during all dredging operations at the borrow sites. Turbidity samples shall be collected according to sampling protocols at all times during construction. Background turbidity samples shall be collected daily, *(insert number)*-meters up current of construction. Turbidity samples shall be collected 150 meters down current, or at the nearest edge of resource, from the operating dredge, every 4 hours, at mid-depth in the densest part of the turbidity plume. Dredging at the borrow sites will cease if measured turbidity exceeds ***(pick 15 or 29)*** **Nephelometric Turbidity Units** (NTUs) above background. In the event the water quality standards are exceeded, work shall stop immediately until the cause is corrected.

Filling Conditions

- Fill material used for this project shall be limited to suitable, clean fill material, which excludes items such as trash, debris, car bodies, asphalt, construction materials, concrete block with exposed reinforcement bars, and soils contaminated with any toxic substance, in toxic amounts (see Section 307 of the Clean Water Act). The fill material shall be similar (grain size) to that already existing at the beach site in both coloration and **grain size**.

- The permittee agrees to implement **GPS tracking**/mapping technology and an automated placement verification system on the proposed dredge vessel. This technology is to be used for tracking of the dredge vessel routes while traveling in and out of the project area.
- The permittee shall demonstrate accurate fill placement in the approved areas by submitting to the (*insert agency name*), the mapped vessel tracks and material deposit logs, once a week during construction activities. The permittee shall identify if any "short-dumps" and/or missed targets have occurred.
- If any impacts ("short-dumps" and/or missed targets) have occurred, the permittee shall immediately, within a maximum of 24 hours, notify by telephone, the (*insert agency name*), and all other action agencies including FDEP, NOAA, FWS, and EPA. The permittee shall immediately, within a maximum of 24 hours, ground-truth the deviated paths (provided that they are within safe diving limits and weather permitting) and document any impacts. The (*insert agency name*) will determine appropriate recovery actions and mitigation efforts, which will include time lag and risk assessments. The (*insert agency name*) will determine final mitigation upon the applicant's submittal of a mitigation plan within 60 days of the impact incidence.

C. Horizontal Directional Drilling

Below is a list of monitoring technologies, BMPs, and specific conditions relating to cable conduit and pipeline installations. These practices are intended as guidelines to minimize the potential for adverse environmental impacts that may occur during HDD installations. The most common problem that may occur in HDD projects is the inadvertent release of drilling mud to the surface or waterway bottom. Each HDD project has unique challenges depending on length of drill, the size or diameter of the hole drilled, and the methods and the proximity to natural benthic resources.

General Conditions

- A minimum of 90 days prior to commencement of onshore HDD activities, the permittee shall submit a Detailed HDD a Boring Plan. Upon completion of the applicant's permitted geotechnical investigations, a hydraulic fracturing analysis shall be conducted by the permittee's geotechnical contractor using site-specific data, and utilizing appropriate United States HDD industry analysis similar to the analysis recommended in the scientific paper titled, Rational Method for Evaluating the Risk of Hydraulic Fracturing in Soils During Horizontal Directional Drilling (HDD) (Stauber et al. 2003). The analysis shall include calculations of the maximum allowable borehole pressure curve for each of the HDD bore profiles. Recommendations by the geotechnical contractor for minimizing risk of frac-outs shall be developed based on these assessments. Results of the fracturing analysis shall be used in the development of an HDD Plan to ensure that the bore paths identified are the least likely to contribute to a frac-out, and shall also include recommendations by the contractor for minimizing the risk of frac-out. All geotechnical information, including data, results, conclusions and recommendations, shall be submitted to the (*insert agency name*) with the Onshore HDD Boring Plan. The submittals shall include a statement signed by the permittee's engineering consultant, attesting that the contractor's plan(s) incorporated all necessary recommendations and criteria.

Visual Monitoring Conditions

- The quick detection and rapid clean-up of drilling mud (bentonite) releases to the seafloor and surface waters is paramount in the protection of seagrass, hard bottom, and coral reef biological communities. The permittee shall develop HDD monitoring protocols for their project and those protocols must be approved by (*insert agency name*) staff.

- The permittee shall strictly follow the HDD Monitoring Protocols and the specific conditions of this permit. Any deviations from the monitoring protocol or the specific conditions will require (*insert agency name*) approval in the form of a permit modification prior to construction.
- The volume of bentonite in the upland mud pit and drill string will be monitored at all times during the directional drilling operations. Should a drop in volume of bentonite occur or the drilling mud fail to return to the HDD entry pit, monitoring will continue.
- While drilling activities are underway, the permittee shall conduct twice-daily diver surveys of the HDD path and adjacent sea bottom to inspect for evidence of frac-outs (i.e., release of drilling fluid to the seafloor). Qualified divers will perform visual surveys along transects spaced *(insert number)*-ft apart within a *(insert number)* -foot wide corridor centered on the proposed HDD paths. These surveys will be performed twice during daylight hours and the divers will be on call to conduct additional surveys as needed.
- Results of the corridor assessments shall be reported in weekly HDD monitoring reports submitted to the (*insert agency name*) representative.
- During the twice daily survey dives, the divers shall assess the reef in, and around, the project area for potential impacts to the reef structure and reef organisms from project-induced vibration associated with the HDD operations. Results of these assessments shall be included in the weekly HDD monitoring reports submitted to the (*insert agency name*).
- Within (*insert number*) hours of the HDD punch out, the permittee shall perform a visual inspection of the (*insert name of waterbody*) floor above the subaqueous portions of the HDD corridor to inspect for bentonite releases or frac-outs.

Fluorometry Monitoring Conditions

- To ensure early detection of bentonite releases during HDD operations, including the backreaming of the pilot hole, a **fluorescent dye** analysis activity (using Rhodamine WT Red 388 dye) shall be in continuous operation for the duration of the project. If at any time, existing supplies of fluorescent dye become exhausted, all drilling shall cease until such time that additional supplies of fluorescent dye are obtained. If multiple dye batches are to be used, then instrument calibration shall conform to the particular batch in use.

  a. <u>Dye/Bentonite Mix</u>: When determining the appropriate dye concentration of the bentonite-dye mixture in the reserve pit, the following shall be documented for reporting and the results adhered to:

     - How the appropriate dye concentration will be determined when being mixed with the bentonite;
     - How the need for adding additional dye to the reserve pit during the drilling operation will be determined (e.g., bentonite volume loss);
     - How the amount of dye to be added to the reserve pit will be determined; and
     - How often dye will be added to the reserve bit during the drilling operation.

  b. <u>Calibration</u>: When determining the appropriate methods for instrument calibration, the following detailed description and results of analytical instrument calibration standards shall be adhered to and documented for reporting:

     - The composition of the manufactured dye-standard (volumes and/or masses used);
     - The composition of the subsequent dye-standards (volumes and/or masses used);

- Dilutent used for standards;
- Glassware quality used for standards;
- Submittal of calibration curves;
- The frequency of instrument calibration; and
- The location, duration, and under what environmental conditions (storage apparatus, temperature, etc.) the dye standards are to be retained.

- All HDD in situ field monitoring methods shall be conducted in strict accordance with the following:

a. Continuous dye analyses shall be performed using a continuous-flow filter fluorometer, fiber optic **fluorometer,** flow-through scanning spectrofluorophotomer, Rhodamine WT Sensor, or similar type instrument capable of detecting dye limits less than or equal to 50 nanogram/liter (ng/L) or less.

b. Any modifications to the analytical instrument not designated in the manufacturer's operating or maintenance manual shall be thoroughly documented by the permittee.

c. The analytical instrument shall be connected directly with a computerized hydrography system (CHS) for data logging and charting consisting of a DGPS capable of producing latitude and longitude position to a maximum available accuracy of +/- 0.001 minutes (about 2 meters), computer, electronic nautical charts, and serial multiplexer.

d. If at any time a properly functioning analytical instrument (fluorometer) is not available during the drilling operation (e.g., instrument malfunction), all drilling shall cease until such time that adequate repairs to said instrument have been made or a replacement instrument obtained.

<u>Continuous Sampling Methods</u>

- **Continuous-flow fluorometry** shall be by a towed intake array.
- The complete towed intake array design shall be thoroughly described and documented.
- The number of passes the towed intake array shall make over the expected area of possible releases shall be documented.
- The expected depths relative to ocean bottom that the towed intake array traverses shall be documented. The flow rate and lift capability of the towed intake array pumps shall be sufficient to maintain adequate proper flow through the analytical instrument. This information shall be documented.

Should in-water conditions (e.g., nearshore surf) limit the use of **continuous-flow fluorometry**, then alternative instruments and methods shall be used in accordance with the following:

<u>Discrete Sampling Methods</u>

- Documentation shall include, but not be limited to, the conditions that required the need to conduct the discrete sampling; the method of sample collection; the number of discrete samples collected and the collection locations; the size and type of sample collection containers; and the method of sample storage (e.g., within a cooler on ice).
- The length of time for sample storage, prior to analysis, shall be minimized to the extent possible, and documented.

- No sample preservation is authorized.
- Instrumentation shall be the technical equivalent of that used for the continuous-flow **fluorometry** (i.e., capable of detecting dye limits less than or equal to 50 ng/L, and the instrument brand and model shall be documented).
- Any modifications to the analytical instrument not designated in the manufacturer's brochure shall be thoroughly documented by the permittee.

Side-Scan Sonar Monitoring Conditions

- Prior to the commencement of any HDD activities, the permittee shall utilize a high-resolution, dual-channel side-scan system operating at a frequency of approximately 500 kHz to monitor for evidence of a frac-out. The instrument shall be used to develop a mosaic of the 600-foot-wide corridor along the HDD route, which shall be used as a reference baseline depiction of the seafloor. The **side-scan sonar** will be towed along the corridor to provide overlapping, high-resolution coverage of the corridor. Deposition of bentonite drilling fluid onto the sea floor should create a surface discontinuity (reflectional characteristic), which will likely be different from the surrounding sea floor conditions. Differing reflectional characteristics will be sensed and recorded by the side-scan sonar equipment, producing a unique "fingerprint" of the sea floor conditions. A release can be detected and monitored by comparing initial baseline imagery to subsequent monitoring imagery. The contractor performing the side-scan sonar monitoring shall keep daily logs of survey activity, including details on any detected drilling mud releases. The daily logs and reports shall be compiled for weekly submittals.

ADCP Imaging Monitoring Conditions

- The permittee shall collect data from a boat-towed **ADCP** to assist in detecting frac-outs, and predict sedimentation and turbidity plume dispersion.

Drilling Activity Conditions

- The use of any additives to the drilling lubricant, bentonite, with the exception of Rhodamine WT Red 388 dye, drilling paper, nut plug, cedar fiber, and cotton seed hulls is prohibited.
- Frac-outs, or bentonite releases typically occur in the early and last portions of a directional drill. In order to minimize the possibility of a bentonite release, the site project manager shall use seawater, in place of bentonite, as a drilling lubricant during the first and last 50 feet of the directional bore.
- All HDD activities shall only take place during daylight hours. The permittee shall deploy scuba divers into the water during the drill operations to conduct bottom surveys of the (*insert name of waterbody*) floor for any evidence of bentonite release, and for a quick response should a release, or frac-out, occur.

Clean-up and Reporting Requirements Conditions

- If a frac-out occurs within proximity to benthic resources [on or within (*insert number*) 50 feet of seagrass, coral reef, hard-bottom habitat], cleanup activities will commence immediately. Divers will record any evidence of frac-outs or other bottom disturbance resulting from drilling activities. Because of safety constraints on divers, Remotely Operated Vehicle surveys shall be performed in areas deeper than safe diving limits.
- Should the release of drilling materials occur on top of seagrasses, coral reef, or hard-bottom communities, a cleanup vessel will be dispatched to the frac-out site immediately to gently

vacuum pump the material from the bottom into filter bags for disposal and without damaging the biological resources.

- Should the release of drilling materials occur on top of seagrasses, coral reef, or hard-bottom communities, the permittee will notify the (*insert agency name*) Compliance/Enforcement Section at (*insert agency contact phone number*) immediately when the violation is first detected. No work in or over water shall be continued until approval has been given by (*insert agency name*) staff.
- In the event of detection of a frac-out (i.e., inadvertent loss of returns) during onshore construction along wetland areas or surface water bodies, forward advance of the drill head shall not recommence until the frac-out has been contained, clean-up has been initiated, and the (*insert agency name*) has been notified of the incident and supplied with the following information: 1) an explanation as to the cause, 2) the measures taken to correct the problem, and 3) assurances that drilling can continue without further incident. If necessary to prevent further releases of drilling fluids, the Environmental Inspector shall require that drilling operations be reduced or suspended so that the extent of the release can be assessed and corrective actions, if any are required, can be implemented. Furthermore, a preliminary report shall be submitted to the (*insert agency name*) representative by e-mail or fax within 7 days of any drilling fluid release to surface waters containing the date, time and duration of the release, weather conditions (wind, seas, and currents) from the time of release, coordinates of the release, photographs and observations from the divers' initial inspection, estimated volume and aerial coverage of release, details of the clean-up effort, and photographs from post-clean-up. According to the amount of biological injury, and should there be a release of drilling fluid that cannot be cleaned up, a mitigation plan sufficient to offset the resource injury involved will be included in this report. A finalized report of findings will be submitted within 30 days of any drilling fluid release.
- In the event of a frac-out, a preliminary report will be submitted to the (*insert agency name*) representative by e-mail or fax within 7 days of any drilling fluid release to the seafloor containing the date, time, and duration of the release, weather conditions (wind, seas, and currents) from the time of release, coordinates of the release, photographs and observations from the divers' initial inspection, estimated volume and aerial coverage of released material, details of the clean-up effort, and photographs from post-clean-up. A report will also be made of any biological impact. According to the amount of biological injury, and should there be a release of drilling fluid that cannot be cleaned up, a mitigation plan sufficient to offset the resource injury involved will be included in this report. A finalized report of findings will be submitted within 30 days of any drilling fluid release.
- Within 90 days of a successful installation, the permittee shall submit to the (*insert agency name*) a summary of the installation, problems encountered, and a comparison of the actual impacts to coral reef and hard-bottom habitat versus those estimated permitted impacts included in the impact tables and mitigation plan.
- Within 30 days of the HDD punch out and subsequent corridor inspection, the permittee shall submit a written summary to the (*insert agency name*) Compliance/Enforcement Section, (*insert agency address and contact name*). The permittee shall include the following information:

  a. A timeline of the individual installations;

  b. Any complications encountered during the installations;

  c. Results of corridor dive inspections;

  d. Details of any bentonite clean-up operations;

e. Discussion of possible causes of bentonite discharges (frac-outs); and

f. Location of bentonite discharge, amount of material discharged, amount of material recovered, and the area that was affected by the drilling discharge and details of any biological impacts.

D. Offshore Tunneling Projects

The installation of pipelines and cable conduits have traditionally been installed offshore by horizontal directional drilling. Water-to-water horizontal directional drilling has proven to be difficult in areas of deeper water depths, fast ocean currents, and high wave energy. Another way to traverse a reef system without direct impacts to the benthic resources would be to tunnel under the reef system. Tunneling has provided a way to avoid placing large, heavy objects directly onto the reef; however, there may be other impacts caused by the associated construction vessels and equipment. Below is a general group of conditions that could be applied to tunnel projects located in areas of sensitive resources.

- A minimum of 90 days prior to commencement of permitted nearshore tunneling activities, the permittee shall submit a geotechnical design report and **Tunnel Boring Plan** based on the geotechnical findings which includes, but is not limited to, soil identification, initial stress conditions, mechanical characteristics, hydraulic characteristics, presence/absence of voids, and the presence of geological discontinuities. The submittal shall include a statement signed by the permittee's engineering consultant, attesting that the contractor's plan(s) incorporated all necessary recommendations and criteria. All geotechnical information, including data, results, conclusions, and recommendations, shall be submitted to (*insert agency name*) with the Tunnel Boring Plan. The submittals shall include a statement signed by the permittee's engineering consultant, attesting that the contractor's plan(s) incorporated all necessary recommendations and criteria.
- GPS data from each vessel, except survey and monitoring vessels, as part of the **Vessel Monitoring System**, shall be automatically recorded and reviewed daily by the environmental inspectors, and the (*insert agency name*) shall be notified within 4 hours upon finding evidence of a vessel outside of the authorized areas.
- No drilling fluids or soil conditioners shall be used unless the permittee has first provided MSDS and bioassay toxicity test results to the (*insert agency name*) demonstrating that such fluids and conditioners are not toxic to indigenous aquatic organisms.
- The permittee agrees to conduct pre-construction and post-construction monitoring during tunnel construction beneath the reefs and during the microtunneling operations. This monitoring will consist of twice daily 500 kHz **side-scan sonar** surveys of the tunnel center line and 15-meter offsets. The swath will cover a minimum of 30 meters (15 meters to each side of the tow fish) with a resolution of 0.75 centimeter. These records will be compared to the pre-construction **side-scan sonar** survey data to demonstrate that no unanticipated impacts have occurred as a result of the tunnel and microtunnel construction. The survey data will be maintained at the project field office. Daily e-mail reports of any anomalous results, if any, will be provided to the (*insert agency name*) and all other appropriate regulatory agencies. A summary the daily side-scan sonar logs during tunneling and microtunneling operations shall be submitted to the (*insert agency name*) on a weekly basis. The survey data and a report summary shall be submitted to the (*insert agency name*) after micro-tunnel construction is completed.

Turbidity Monitoring and Reporting Conditions

- Turbidity will be monitored every 2 hours, or as TSS **ADCP** readings indicate increasing turbidity, to assure that levels do not exceed the compliance standards established in this permit. If the levels exceed the compliance standards, the permittee shall notify (*insert agency name*) no more than 2 hours after the exceedance was discovered.

Procedures to be taken in preparation for and during each turbidity monitoring event are as follows:

a. Determine the prevailing current and turbidity plume orientation and relative density using boat-mounted ADCP; Calibration of the ADCP measurement will be performed to account for site-specific conditions. Measurements of depth, temperature, and salinity will be performed and included in the calibration process to correct for the varying acoustic absorption properties of water. Other factors as needed for the particular system used to obtain optimal ADCP performance will also be measured and applied.

b. In order to give guidance on the turbidity represented by varying levels of ADCP response, water samples will be collected during the ADCP calibration process. The samples will be collected from areas where various levels of response are obtained. The samples will be analyzed for turbidity (NTU) and a table indicating ADCP response vs. NTU will be developed and submitted with weekly monitoring reports. Similarly, during the project monitoring, a table showing ADCP response vs. NTU will be maintained and submitted weekly with the turbidity reports. The table will be used during project operations to help indicate the level of turbidity that is being encountered. In the routine monitoring program, samples will be taken at times when the ADCP signal indicates an above standard level of turbidity, if such a signal occurs. If no such signal occurs, then the samples will still be taken at some point during each monitoring period.

- Turbidity sampling sites will be located down-current of the construction activities. Sampling at each location shall be done in triplicate in the densest portion of any detectable plume to minimize sampling error and each replicate sample location identified by **ADCP.**
- Within 60 days after completion of the tunnel installation, the **ADCP**-recorded sedimentation field and turbidity plumes shall be mapped, and a map that includes an overlay of the original results of the sediment transport modeling results and the ADCP mapped plumes (if any) shall be provided. If the instrumentation and associated mapping yield additional areas of impact, the resources within those areas should be examined for signs of impact as prescribed in the reef monitoring plan. If any impacts to resources are observed, they should be tagged, photo-documented with the geographic location recorded, and included in the monitoring protocol.

E. Cable Laying Projects

During the past 30 years, there have been many fiber optic and other telecommunication cables installed on the ocean floor. The most common impacts to coral reef and hard-bottom communities caused by these projects have been cable sweep. In some projects, cables were laid taut across or on top of reef and hard bottoms causing shading, abrasions, or complete removal of corals and sponges. Below is a list of conditions that include monitoring techniques and BMPs collected from local regulatory agencies and the SEFCRI workshop participants. These practices are intended as guidelines to minimize the potential for adverse environmental impacts during cable installations in the seafloor. Each project has unique challenges depending on cable size, the number of the cables, and the proximity to natural benthic resources.

- In order to avoid impacts to coral reef and hard-bottom resources, the applicant shall lay the cable within the agreed-upon gap in the third reef system and will horizontal directional drill beneath the first and second reef systems.
- Prior to the arrival of a cable laying vessel, a clear route into and out of the reef gaps will be marked by the use of a buoy system. The buoys will be installed by divers and will not be

attached to the ocean floor in areas of benthic resources such as seagrass beds, hard-bottom communities, or coral reefs.

- To the extent practicable and considering weather, safety, and navigational control, the speed of the cable-laying vessel shall not exceed 2 knots speed over ground (SOG).
- The permittee shall ensure that vessels associated with the cable project are not anchored on hard bottom and that divers will visually inspect the bottom before anchoring.
- Prior to dropping the cable onto the ocean floor, the cable will be attached to floating buoys and placed into a safe position before dropping the cables onto the ocean floor.
- The permittee shall have divers in place for a post-lay to ensure the cable is moved to free pinned corals and severed or dislocated corals are tagged for repair or relocation.
- All severed and/or dislodged hard corals must be repaired and re-attached as close to the injury site as possible. This area must be far enough away from the cable so that the newly repaired corals will not be affected by cable strumming in significant storm events.
- Over time, there may be natural recruitment of benthic organisms onto the cables. In the event a cable needs to be repaired, the cable owner/operator will contact the regulatory agencies immediately and will be required to obtain a permit modification.

F. Coral Transplantation Projects

Many times impacts to benthic resources cannot be fully avoided. One way, though not preferable, to minimize the environmental impacts of a coastal project may be to transplant as many coral reef organisms out of harm's way prior to commencement of construction activities. The following conditions can be used as guidance for those projects that may affect coral reef and hard-bottom resources.

- In an effort to minimize the impact to coral reef and hard-bottom habitats, the permittee shall create and implement a Coral Transplantation Work Plan.
- The permittee will implement the transplanting of approximately *(insert number)* scleractinian corals from the area proposed to be affected by the *(insert activity*) and will transplant them to a designated mitigation reef area. Within 60 days after transplantation is complete, the permittee will assess the total number of corals transplanted. If transplantation achieves less than 80 percent survivorship, the permittee and the (*insert agency name*) will re-assess the mitigation accordingly, if needed.
- The permittee shall implement a QA/QC plan to ensure that coral transplantation efforts are successful. The permittee shall ensure that all participants conducting project activities are held to the standards and methods set forth in the Coral Transplantation Work Plan.
- At a minimum, the relocated corals shall maintain an 80 percent survival rate after 6 months from the initial relocation date. Thereafter, the relocated corals shall maintain that 80 percent survival throughout the life of the monitoring program. Should the (*insert agency name*) determine that the relocated corals are not achieving the survival criteria, additional mitigation may be required, as deemed appropriate, by the (*insert agency name*) through a permit modification. The permittee agrees to prepare a report that clearly describes in detail possible reasons for not reaching an 80 percent survival rate. The permittee agrees to monitor the mitigation reef and corals at 6 months from the initiation of coral transplantation, 1 year, 2 years, 5 years, and 7 years post-transplantation. The permittee agrees to submit a mitigation reef monitoring report within 90 days after each monitoring event to document the status of the

relocated corals. The permittee will not be held to any failures caused by natural events that may hinder coral transplantation success rates.

- The permittee or his contractor shall notify *(insert contact names)* of permitted/approved scientific experts or aquaculture organizations for the rescue, removal, and collection (not for commercial sale) of all corals that are not proposed to be transplanted and any benthic organisms projected to be affected by the project designs. These resources will be used to further scientific research on resource management or to support future reef restoration projects in South Florida. E-mail notification of the list of members must include a minimum of 45-days advance notice (prior to construction start date) for planning and logistics purposes (including permitting). The permittee shall allow a 30-day collection window to commence and complete additional collections. The permittee agrees to provide electronic maps that will ensure and assist that these scientific experts are collecting within the project design.

Question 2: **What rule changes might be required to ensure that coral reefs, hard/live bottoms and associated coral reef resources are protected during these activities?**

Changing regulatory rules can be a difficult and long process. There are many steps and many parties involved when the decision is made to change existing rules. This paragraph describes the process that governs any changes. The federal **Administrative Procedure Act (APA)** of 1946 governs the way in which administrative agencies of the United States federal government may propose and establish regulations. The basic purposes of the APA are: (1) to require agencies to keep the public informed of their organization, procedures, and rules; (2) to provide for public participation in the rulemaking process; (3) to establish uniform standards for the conduct of formal rulemaking and adjudication; (4) to define the scope of judicial review.

A majority of workshop participants agreed that there are a number of federal and state regulatory rules already existing that address coral reef protection; however, many feel there is a significant lack of sufficient enforcement of those regulations for those who violate them. When asked about making changes to the existing rules and regulations, the workshop groups offered many suggestions that are listed below.

Suggested Rule Changes for Environmental Protection

- The agencies should define what is "reasonable assurance" or what are reasonable assurances an applicant might demonstrate to the agencies that an environmental resource will not be directly impacted or affected;
- There should be an establishment of marine protected areas that are identified in local, state, and federal rules;
- The agencies should be provided with the ability (rule-based) to reject insufficient application requests at the regulatory level;
- Environmental impact statements (EIS) and environmental assessments (EA) need to include a more comprehensive cumulative impact analysis and the National Environmental Policy Act (NEPA) regulations must reflect this change;
- Agencies should establish standards for environmental conditions, monitoring standards, and protocols that are necessary for coral recruitment and health;
- The agencies should impose more stringent regulations relating to grain size requirements for beach nourishment/renourishment projects;

- There should be a more stringent criteria for evaluating borrow areas;
- The agencies should fully evaluate the lessons learned from completed projects and should use that information to develop written BMP documents;
- The agencies should adopt rule revisions that would allow the establishment of formal *and* non-traditional partnerships between agencies for implementation of resource protection strategies; and
- There should be a system developed to gather all baseline and monitoring data into one centralized database in order to develop a long-term data set for monitoring and use by agency and non-agency personnel. This would prevent continued duplication of efforts and encourage contractors to modify their projects to have less impacts based on previously collected project data.

Changes Specifically Relating to Water Quality

- Water quality rules and protection criteria should be more stringent and afford specific protections;
- Water quality rules should be changed to lower turbidity allowance and to incorporate specific turbidity monitoring protocols; and
- Agencies should require that applicants obtain National Pollutant Discharge Elimination System (NPDES) permits for beach nourishment projects.

Changes for Local Regulatory Agencies

- The counties should develop county level discharge prohibitions; and
- It would be beneficial for Broward County to re-instate their old ordinance to ensure compliance with rules regarding discharges and drainages that are diverted over the beach.

Mitigation and Monitoring Requirement Changes

- The agencies should approve out-of-kind mitigation to allow for water quality improvement projects;
- All mitigation projects should require that the mitigation replaces lost ecological functions;
- Agencies should be provided with the ability to regulate or require research as part of a permit or as mitigation. They should require the use of centralized monitoring/research database, if one is implemented, and require literature reviews;
- Mitigation should be required for impacts caused by chronic turbidity, and should allow for a requirement of research regarding impacts associated with chronic turbidity (data are needed to improve construction practice and regulatory criteria);
- Permits should require long-term monitoring of cumulative impacts associated with sand placement (e.g., beach nourishment/renourishment), and that the monitoring complies with statistical "rules" or principles;
- Regulatory agencies need to confirm that the actual mitigation performed satisfied their requirements through functional assessments;
- Agencies should establish consistent/standard success criteria for mitigation, though it may be very difficult to incorporate into rule; and
- The agencies should re-evaluate the Unified Mitigation Assessment Method (UMAM), Chapter 62-345, for appropriateness as applied to nearshore habitats and submerged aquatic vegetation.

Question 3: What mitigation criteria should be established for coral reefs affected by coastal construction, infrastructure installation, beach renourishment, dredging or groundings? Identify the activity, its impact on reef resources, and how the mitigation criteria will protect the reef.

Activities such as coastal construction, infrastructure installation, beach renourishment, dredging, and vessel groundings have been discussed in previous sessions of the workshop. Impacts of those activities were identified in Session 1 and Session 2, as well as throughout various portions of the workshop proceedings. Workshop participants also discussed mitigation alternative options in Section 2.2, Session 2, Question 3, Item E above.

The following is a detailed discussion of suggested mitigative measures/mitigation criteria that are recommended as a means to avoid or minimize impacts and mitigation criteria that should be established to protect coral reefs during the above-mentioned coastal construction activities.

Mitigation Criteria for All Coastal Construction Activities

Certain mitigative measures for coastal construction projects can be established during the regulatory permitting process of an activity. Items such as additional project oversight by a local sponsor (i.e., non-associated contractor or agency personnel) could be established to provide impartial monitoring of construction activities. This measure would provide non-biased monitoring of the project, would add possible additional compliance, and help agencies enforce permit conditions where an agency may be short-staffed in this department. Participants recommended that permittees should be required to submit more detailed resource information, data assessments, and mapping prior to project approvals to more accurately identify sensitive marine resources within a project area. It was also recommended that sensitive areas, coral reefs, and live/hard-bottom habitats be physically marked with barriers (i.e., buoys) that shall remain in place for the duration of project construction. These barriers would aid in delineating the reef edge and sensitive areas to avoid so that contractors will be informed of these areas at all times during constructing, thus facilitating avoidance. Participants recommended that a general database be created to store and compile all resource data available. This database would be considered as a one-stop library location for regulatory/resource managers to utilize during project evaluation and to verify contractor assessments. Items such as resource maps, photos, survey data, project locations, monitoring reports, etc. could be compiled throughout each county and could aid in reducing duplicated efforts and costly surveys. This database is highly recommended because it could be used as a tool to monitor cumulative impacts and secondary impacts from one project proposing to impact an already mitigated area.

Mitigation Criteria—Out-of-Kind

Recommendations are being made for regulatory agencies to consider the use of out-of-kind mitigation. There are several types that are being recommended. The primary recommendation of out-of-kind mitigation options is stormwater retrofits, which would offset water quality impacts, would eliminate increased nutrification and algal blooms, and would provide better overall water quality for coral reef systems. A second method of out-of-kind mitigation that is highly recommended is in the form of funding through multiple scenarios. It is recommended that regulatory agencies consider authorizing permittees to contribute funds towards coral nursery efforts and restoration projects within the county of the proposed construction activity; contribute to an ecosystem approach for habitat enhancement, restoration, or creation; and provide funds towards research projects or academia that may have some type of association to impacts of a permitted activity.

Mitigation Criteria for Dredge Industry Projects

Recommendations are being made as a mitigative measure, prior to permit issuance, for the regulatory agency staff and the dredging industry to build partnerships during the review and permitting of beach nourishment projects. These partnerships would help the regulatory agency staff to better understand dredge equipment and the limitations of the different types of equipment. In addition, these partnerships would help the dredge industry to better understand the importance and location of sensitive marine resources within a project area.

Question 4: Can monitoring programs track the success, or identify failures, of new technologies in relation to protection of reef resources?

YES – If some of the following recommendations occur:

Science/Statistics

- Ensure scientifically and statistically sound studies are conducted that include minimum sample size, and pre- and post-impact controls; and
- Ensure the monitoring program has replication, and a spatial/temporal study component, and is hypothesis driven, time sensitive, and have a sound design such as before/after control impact (BACI).

Regulatory

- Regulatory agencies should require more stringent monitoring programs;
- Monitoring plans should be peer-reviewed before monitoring begins;
- Data collection standards should be established for acceptability that must be met (e.g., precision, accuracy, completeness); and
- Data validation should occur during the project by regulators and a peer review team.

Monitoring

- Conduct pre- and post-construction controlled investigations (BACI, Peterson Presentation, Appendix 2);
- Conduct independent peer reviews (cost may be a factor);
- Set acceptable data collection standards and have data publicly available for independent analysis review;
- Establish contingency plans for acceptability; and
- Establish an independent scientific advisory panel for complex projects so that regulatory agencies can use this oversight committee for guidance. This may be difficult in cases where only the contracting officer has the legal authority to direct the contractor.

Examples of Successes as a Result of Monitoring

- Submerged aquatic vegetation—Monitoring is being conducted by various universities (e.g., Florida International University) and other groups throughout Florida, including areas such as Keys National Marine Sanctuary, Tampa Bay, and Biscayne Bay to establish successes and failures of seagrass transplantation.

- Monitoring of impact-salvaged corals that are collected from an impact site and taken to a coral nursery. Once the corals have been monitored and recovered to certain standards they are returned to the ocean/reef and additionally monitored to show preliminary success. This is occurring through the Coral Nursery Project (CNP) being conducted through a partnership between the National Coral Reef Institute (NCRI), local county government (Broward County Environmental Protection Department), and a volunteer dive group (Ocean Watch Foundation).

Question 5: Which factors must be considered in the design of a monitoring program for a particular site?

The workshop participants made the following recommendations as factors to consider for designing monitoring programs.

Project Type

- Identify project type (e.g., in-kind/out-of-kind, research, restoration, enhancement, creation);
- Consider available research/literature for similar projects, as well as lessons learned;
- Consider industry needs for data/information—long-term data on cumulative ecosystem impacts from beach nourishment/effects of chronic turbidity, effective alternatives to dredging (sand bypass), submerged aquatic vegetation incident light monitoring, etc.; and
- Identify monitoring techniques and appropriate methodology based on habitat types (e.g., transects, quadrates).

Resources

- Identify dominant resources at the project site (submerged aquatic vegetation, fish, coral, etc.); and
- Collect resource-specific data. For example, monitoring of coral and submerged aquatic vegetation should include an examination of turbidity, sedimentation, water temperature, and adjacent live-bottom condition, etc.

Monitoring Criteria

- Determine the threshold for acceptable levels of impact;
- Identify the tolerance for error in predicted impacts;
- Establish duration and frequency of sampling;
- Require photo/video documentation of baseline conditions and subsequent monitoring events; and
- Monitor winds, waves, and currents during beach nourishment projects.

Project Management

- Identify who is accountable for data collection and analysis; and
- Establish time frames and reporting requirements.

Question 6: Which monitoring methods or techniques provide data to answer the question of what reef impacts are occurring before impacts are visible?

Responses to Question 6 are listed below.

- Evaluation of impacts associated with previous beach nourishment projects in Florida (i.e., cumulative impacts) to design monitoring plans for future projects;
- Biomarkers and histopathology of corals (e.g., SEFCRI Land Based Sources of Pollution (LBSP) project in Broward County);
- Epidemiology to identify coral stressors;
- Measurement of turbidity and sedimentation; and
- Collecting and analyzing coral tissue samples.

Question 7: What should be done with the data that is collected and who (regulated community or regulator agencies) is responsible for reporting problems to the parties involved in the project?

Responses to Question 7 are provided below.

Data Management

It was mentioned above in Question 3 of this session that an electronic library database should be created to compile monitoring reports, resource data, maps, etc. to be used as a one-stop database to manage, review, and compare information. Both analysis and practical application of the information in this database can be used to generate "Lessons Learned." The database would create a long-term record of lessons learned (living document) for the continuity of institutional knowledge. This method was used with a post-project team during the Key West Harbor Dredge Project. Regular communication between all groups is essential to achieve the best end result of a project.

Data Reporting

Data should be delivered to agencies, or other involved parties, by contractors or their representative, agency staff, third party environmental inspectors, local interested parties, and members of the public in a manner based on the resource risk and the activity. High risk activities require immediate data transmission via FTP, e-mail, fax, phone, etc., and low risk activities may allow for transmission via periodic (daily, weekly, or monthly) reports, through input into a central database.

Session 4 Consensus Report

The participants in this session were asked to identify the top issues discussed for protecting nearshore coral reef resources during coastal construction activities through changes in permitting, rules, monitoring programs, and data collection efforts. Multiple examples of specific permit conditions have been provided under Question 1 of this session. These specific conditions can be tailored to many different types of coastal construction practices that have been identified in this document. Additional important issues identified were:

1. Monitoring plans need to incorporate hypothesis-driven monitoring that is time sensitive, adaptive, and has proven statistical and experimental design.

2. Construction vessels should be equipped with real-time vessel positioning equipment to monitor vessel location and proximity to resources; in addition, operations alarm systems shall be implemented on the vessels.
3. Rule changes are necessary for more stringent protection of coral live/hard-bottom resources, but it is a difficult and long process.
4. Pre-, during, and post-construction meetings should be required to discuss lessons learned and to train/educate contractors and associated personnel on environmental resources within a project area.
5. Lessons learned from coastal construction projects must be transformed into written BMPs and posted in a central location (e.g., MICCI Team Project 11, if implemented) for all to access.
6. Coral-stress monitoring with established thresholds and shutdown provisions should be required to adequately protect resources before physical and macro-level manifestations of impacts occur. Thresholds and shutdown provisions should be based on histopathological and biochemical studies of field-sampled corals or other (surrogate) organisms.

3. WORKSHOP RECOMMENDATIONS

This section presents the consensus recommendations developed during the workshop. Drafts of this document were submitted to the MICCI Project 3 Team, the speakers, the participants, and the public for review and comment. Their suggested revisions have been incorporated to improve the clarity and consistency of this report; however, the consensus recommendations from the workshop have not been altered.

Participants reached consensus on many of the issues associated with coastal construction activities as each group identified similar concerns and ways to reduce damage to coral reef resources. Participants agreed that current practices can result in adverse water quality changes and physical damage to stationary benthic organisms such as corals, gorgonians, and seagrasses; increased release of suspended sediments can fill or bury reef topography and contribute to turbidity; and direct or indirect nearshore habitat loss can occur from the dunes to the subtidal shelf waters. The practices that were of most concern were: 1) dredging and blasting used in construction of harbors, canals, and beaches; 2) development along shorelines, including roads and high-rise buildings, with inadequate consideration of stormwater and air conditioning discharges and shading effects; 3) the ongoing beach nourishment and renourishment requirements for Southeast Florida; and 4) placement of pipes and cables directly on and through reef resources.

Participants suggested that avoiding construction along Southeast Florida shorelines should be considered a feasible alternative whenever possible. However, when construction practices are required that may alter the shoreline and could potentially affect the integrity of nearshore benthic communities, workshop participants made the following recommendations. These are not presented in any particular order. To the extent possible, most or all of these recommendations should be considered and implemented, as appropriate, to achieve maximum benefit to Southeast Florida reefs and other coastal habitats.

3.1 Dredging and Blasting

Workshop participants suggested that the use of ADCP/acoustic backscatter and fluorometry to monitor for increased levels of turbidity or sedimentation during a project would help to identify potentially harmful conditions before a problem developed. They agreed that minimization of dredging time and implementation of other technological advances would be beneficial. The specific technological advances identified included modifications to allow pumping up slurry density or pushing sand, changes in borrow area design to improve dredge efficiency, the recycling of "skim" water, designated pipeline corridors in reef gaps, and refined work areas. Working group members suggested that applying hybrid solutions, or multiple advanced technologies, in a single project would help maximize project performance and resource protection.

3.2 Water Quality

Participants discussed a number of water quality improvements that would effectively protect coral reefs, hard/live bottoms, and associated coral reef resources. Among them, they suggested that the retrofitting of stormwater and discharge structures along developed shorelines, and the implementation of advanced water treatment practices, would be helpful. In addition, participants agreed that developing alternatives to wastewater ocean outfalls and deep well injection would serve to improve water quality. Finally, group members reached consensus that the establishment of individual county master plans for water treatment, which address cumulative impacts and provide resolutions for impacts resulting from sewer, septic, deep well injection, stormwater, landfills, and oceans outfalls, would be greatly beneficial. It was also noted that Miami-Dade County is currently in the process of developing this type of master plan.

3.3 Beach Nourishment and Renourishment

The activities of beach nourishment and renourishment were discussed in an effort to identify ways to reduce the impacts of these activities on coral reef systems. Workshop participants reached consensus that practices which would reduce the need for these activities should be implemented. Submerged structures such as wave breaks and multi-purpose reefs to stabilize shorelines were identified as two ways of pre-emptively addressing the issue. In cases where beach nourishment or renourishment is needed, they suggested that the use of adequate and compatible sand is critical. This includes sand of appropriate grain size, color, and quality. The workshop participants also stated that the use of sand bypassing and/or backpassing technology would be helpful, as well as identifying alternative sand sources and implementing more stringent criteria for evaluating borrow areas. Finally, they recommended that improvements in the enforcement of state regulations on discharge prohibitions across the beach is necessary and that county level prohibitions should be developed.

3.4 Resource Management and Permitting

Workshop participants identified resource management issues that must be addressed to reduce or eliminate the impacts to coral reef systems resulting from coastal construction activities. They agreed that the integration of habitat characterization with management strategies would be beneficial. Additionally, the groups suggested the establishment of coral nurseries for laboratory-raised or "rescued" corals.

As part of the resource management discussion, the workshop participants discussed actions that regulators could take in an effort to ensure protection of coral reefs and associated resources. Among the recommendations made, participants suggested that the USGS Hawkeye/LVTS/GPS and the USACE Silent Inspector provide regulators with tools to protect and manage the resources; however, they reiterated that the data must be made easily accessible to them. They also identified LADS/LIDAR technology as a useful tool in identifying the location of resources, making management decisions, and quantifying resource impacts.

Permitting was specifically pinpointed during working group sessions as one area that could be improved to better protect coral resources and reduce the number of impact incidents through better construction practices. Participants identified certain requirements that should be included as specific permit conditions that would involve construction industry personnel, contractors, and regulators early in the permitting process and throughout the project. They suggested that regulators should require more statistically rigorous pre-, during, and post-nourishment monitoring and reporting. Group participants also recommended that it would be beneficial to have pre-project monitoring data reviewed by dredging contractors and/or their industry representatives (DCA/WEDA) to determine the most appropriate methods and equipment to be used for each project. Workshop participants suggested that regulators should require pre-, during, and post-construction meetings, as well, to educate contractors on environmental resources, discuss lessons learned throughout the project, and to ensure regular communication between all parties involved. In addition, they reached consensus that regulators should require that EISs and EAs include a more comprehensive cumulative impact analysis.

In addition to general regulatory practices that were identified, workgroup participants listed particular requirements that should be included as specific permitting conditions for coastal construction activities. They suggested that implementation of specific BMPs for the type of operations proposed should be required. Real-time monitoring and operations alarm systems were recommended in an effort to help avoid reef damage. Participants suggested that the complex needs of specific species must be addressed in permitting conditions in order to prevent habitat loss. As such, they agreed that time frames for dredging should be established in the permit conditions that would take into consideration the spawning and nesting cycles of turtles, fish, and birds, and/or would not contribute to cumulative impacts resulting from seasonal events (i.e., temperature changes or storm events). Workgroups recommended the implementation of statewide or, if more appropriate, site-specific turbidity, sedimentation, and other thresholds to protect coral reef or hard-bottom resources (based on experimental research on health and recruitment). Additionally, they reached consensus that permit conditions should require regular maintenance of dredging sites and equipment, real-time tracking at frequent intervals of all vessels operating within the project area, and the use of floating lines and/or cables.

3.5 Monitoring and Mitigation

Monitoring activities were discussed by workshop participants to identify ways in which to improve current monitoring efforts and develop more beneficial monitoring of coral reef resources. They concurred that ecological functions of potentially impacted resources must be assessed through research that is hypothesis-driven, time sensitive (e.g., real time), and has good statistical and experimental design, such as BACI. They agreed that the monitoring program and design should be peer-reviewed before monitoring begins and that data collection standards for acceptability must be met (e.g., precision, accuracy, completeness). Participants also suggested that the data collected should be validated during the project by regulators and a peer review team and that it could be used to develop sensitive organism sublethal stress thresholds and parameter levels, above which the construction activity would be shut down in an effort to reduce impacts.

In order to adequately address impacts resulting from coastal construction practices, workshop participants stated that mitigation must be appropriate to compensate for resource impacts. They agreed that mitigation projects should be based on review of past data collection, should incorporate adaptive management strategies, and include measurements of multiple parameters to address spatial, temporal, water quality, and organismal changes. Participants suggested that mitigation should include a plan to submit data, based on risk associated with the activity, to appropriate archives, such as to the overseeing regulatory agency, or the proposed electronic compendium of coastal construction data (MICCI Team Project 11) for long-term use. One form of coral reef mitigation that was identified is the removal or modification of existing structures or uses that cause direct impacts to the reef ecosystem, such as tire removal in Broward County.

3.6 Vessel Groundings and Other Direct Vessel-Related Impacts

Vessel groundings and other direct impacts to coral resources were addressed by the workshop participants. They identified ways to reduce these types of impacts in South Florida. Among the suggestions was the removal or modification of existing large ship anchorages to prevent or minimize the likelihood of vessel groundings and anchor damage. Participants suggested that the establishment of perimeter buoys or beacons to indicate large vessel anchorage areas would be a useful modification to existing mooring areas. Additionally, they reached consensus that required training for all vessel operators would help reduce the number of incidents that cause damage to reef resources, including seagrass communities, sea turtles, and manatees.

3.7 Placement of Pipelines or Cables

Placement of pipelines and cables along Florida's southeast coast has raised concerns over the direct and secondary impacts to coral reefs and associated resources, such as seagrass communities. Workshop participants discussed ways to avoid impacts to those resources by implementing various technologies, including tunneling or the use of HDD under resources. They also reached consensus that LADS/LIDAR technology provides useful information that can be used to locate resources. With that information, existing corridors can be identified, and avoidance and/or minimization are more likely.

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5. GLOSSARY OF TERMS

Advanced water treatment (AWT)—the level of water treatment that requires an 85-percent reduction in pollutant concentration, also known as tertiary treatment.

Armor structures—shore erosion control practices using hardened structures that armor and stabilize the shoreline landward of the structure from further erosion or plantings or organic materials to restore, protect, or enhance the natural shoreline environment.

Backpassing—involves the mechanical transport of sand material from a wide stable beach to an upcoast sediment-starved beach; essentially "recycles" the sand back to the eroding beach.

Bentonite—clay formed from volcanic ash, which can absorb large amounts of water and expands to many times its normal volume. Used to retain the sides of excavations in wet, unstable soil.

Berm—a terrace formed by wave action along the backshore of a beach. The area of shore lying between the average high-tide mark and the vegetation, and affected by waves only during severe storms.

Bypassing—hydraulic or mechanical movement of sand from the accreting updrift side to the eroding downdrift side of an inlet or harbor entrance.

Conventional mitigation—constructing artificial reefs with limerock and/or reef balls, seagrass transplantation, and the filling of dredge holes to grade.

Downdrift—in the direction of net longshore sediment transport.

Draghead cutterhead—a type of equipment used to dredge geological material (e.g., rock, sand).

Earth Pressure Balance Machine (EPBM)—can be used deep below the water table. This pressurizes the cutter head with air or another fluid in order to balance the water pressure.

Equilibrium toe of fill—an equilibrium profile is the response of a beach to long-term or extreme wave conditions governed primarily by sediment size characteristics. The equilibrium toe is the outermost point of this equilibrium profile.

Filling of dredge holes to grade—inserting material into a previously dredged area to raise the level of the bottom to be the same as the surrounding area.

Florida Water Quality Standards (WQS)—Chapter 62-302 (and 62-302.530), Florida Administrative Code. The federal Clean Water Act provides the statutory basis for state water quality standards, as published in 40 CFR 131. The WQS includes components for water body classifications, criteria, an anti-degradation policy, and special protection of certain waters (Outstanding Florida Waters).

Frac outs—releases of drilling lubricants from drilling or dredging machinery.

Global positioning system (GPS)—a worldwide satellite navigational system formed by 24 satellites orbiting the earth and their corresponding receivers on the earth. The GPS satellites continuously transmit digital radio signals that contain data on the satellites' location and the exact time to the earth-bound receivers. GPS can calculate the longitude and latitude of the receiver, as well as altitude, depending on the number of receivers utilized.

Horizontal directional drilling (HDD)—a trenchless construction technique, which uses guided drilling for creating an arc profile.

LADS (Laser Airborne Depth Sounder)—rapid acquisition of large high-quality data sets via variable swath widths that are independent of water depth; facilitates recognition of numerous seafloor features and bathymetric patterns; applicable in clear coastal waters down to -70-meter depth.

LIDAR (Light Detection and Ranging)—uses light waves emitted by a laser to gather data and determine the distance from the laser to a given object; can provide such information as sea-surface roughness, wind velocity, or vegetation density.

Material Safety Data Sheets (MSDS)—is a detailed information bulletin prepared by the manufacturer or importer of a chemical that describes the physical and chemical properties, physical and health hazards, routes of exposure, precautions for safe handling and use, emergency and first-aid procedures, and control measures.

Nourishment activities—processes in which sand or sediments lost by longshore drifts or erosion are replaced on a certain area of a beach.

NTU—stands for Nephelometric Turbidity Unit which is the unit used to measure turbidity in water.

Out-of-kind mitigation—compensatory mitigation in which the adverse impacts to one habitat type are mitigated through the creation, restoration, or enhancement of another habitat type.

Pulse amplitude modulation (PAM)—a form of signal modulation where the message information is encoded in the amplitude of a series of signal pulses. This may be conducted during dredging operations to test whether or not the symbiotic algae associated with corals are photosynthesizing. If photosynthesis is not occurring, it may be due to smothering of the corals resulting from operations.

Reef mitigation gardens—areas where natural rock is covered by a thin veneer of sand. Hydraulic dredging is conducted using a gentle suction-head and then either a low-sill wall is constructed or a sacrificial buffer around the garden is dredged.

Shear resistance—approximated by grain size, grain density, and angle of repose.

Shear stress—the stress resulting from the application of forces parallel to each other, but in opposite directions, resulting in a failure in which the material rips or tears as a result of the applied shear stress.

Shoreline/beach stabilization—structures or activities intended to prevent erosion along a shoreline or beach (e.g., seawalls, riprap, revetments, groins, native plantings).

Silent Inspector (SI)—an automated dredge monitoring system for impartial automated dredge monitoring.

Spectrometry (WDS)—the procedure of observing and measuring the wavelengths of light or other electromagnetic emissions.

Spud—an anchorage during dredging or drilling provided by a steel post underneath a dredger that can be lowered until it is secured in the seabed or riverbed.

State of Florida NTU standard—less than or equal to 29 NTUs above natural background conditions (Chapter 62-302.530, Florida Administrative Code).

Subsidence—lowering or sinking of land caused by compaction, wind and water erosion, oxidation of peat soils, and other causes; settling; a gradual sinking to a lower level.

Tunnel boring machine (TBM)—used to excavate tunnels with a circular cross section through a variety of geological strata. It can be used to bore through hard rock or sand and almost anything in between; tunnel boring machines are used as an alternative to drilling and blasting.

Turbidity—the amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter; thus, making the water cloudy or even opaque in extreme cases.

Updrift—the direction to which the predominant longshore movement of beach material approaches.

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