

BIG BELL ISLAND



ENVIRONMENTAL IMPACT ASSESSMENT

**MARCH 2010
(REVISED FEBRUARY 2011)**



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EXECUTIVE SUMMARY

Project Overview, Location, Nature of the Development

Big Bell Island is located in the Exuma Cays of the central Bahamas. More specifically, the island is found within the Exuma Cays Land and Sea Park, as depicted below.



Figure 0.1 Southern Portion of the Exuma Cays Land and Sea Park

The project described herein consists of a private yacht basin, excavated from a small salt pond and capable of accommodating approximately twenty vessels. The yacht basin will offer fueling, sewage pumpout, electric, and water services. In addition, improvements will be made to the service dock / barge landing area, as well as, a small existing utility and storage area. The channel to the proposed yacht basin will be dredged to maintain the safe depth of -14 feet mean low water (MLW). Additional improvements on the island will include modifications and additions to the existing upland structures and road network.

Environmental Impacts Analyzed

The entirety of the 349 acre island is in private ownership. Within that area, the impacts of the proposed development are limited to less than 5 acres of natural area, which consists primarily of coastal coppice and salt pond habitat. The private yacht basin entrance channel and barge landing / service dock area will entail impacts to approximately 4.8 acres of benthic habitat.

Environmental impacts include changes in land cover and land use as well as losses of flora and fauna through landclearing, dredging of the basin, improvements to the service dock / barge landing, expansion of the utilities and storage area “back of house”, improvements and additions to the existing upland structures and road network, creation of the access channel, and construction of protective jetties. Temporary impacts related to construction work consist of increased noise, people, and sediment transport and possible deposition in terrestrial and marine communities.

Positive aspects of the project include eradication of a large casuarina stand, socio-economic benefits, marine habitat creation (breakwaters), a native plant nursery, and revegetation plans to use native flora in landscaping.

Significant Environmental Impacts Mitigated to Levels Below Significance

Mitigation efforts include, but are not limited to:

- methods to minimize adverse impacts of construction work through turbidity management and sediment control.
- commitment to promote best management practices for the yacht basin and “back of house” area.
- a native plant nursery to revegetate, landscape, and promote native plant use on the island.

Environmental Management Plan

To operate the project in a manner that maintains environmental considerations in the highest regard, an Environmental Management Plan (EMP) will be developed and implemented. This plan will include, but is not limited to:

- detailed construction guidelines including mitigation measures to be followed both during and after construction.
- any monitoring requirements necessary to insure compliance with construction guidelines
- emergency measures.
- post-construction operation details.

Details will be coordinated and finalized with the Ministry of the Environment and the Bahamas National Trust once approvals are in place and the plan is a true reflection of the final project design and the expected as-built conditions.

CHAPTER 1 INTRODUCTION AND OBJECTIVES

1.0 Objective of the Environmental Impact Assessment (EIA)

This Environmental Impact Assessment (EIA) is being provided to assess and quantify impacts to the physical, biological, and socio-economic environment that may result from the planned private yacht basin and service dock / barge landing and other improvements proposed on Big Bell Island. The purpose of an EIA is to accurately and objectively characterize and quantify natural resources present on the site and to reasonably describe expected changes that might result. The EIA provides details on potential negative impacts and positive improvements including removal of non-native exotic plant species and the preservation of protected plant species

Environmental Impact Assessment reports are a prerequisite for development approval and an important natural resource management tool in the Bahamas. In the absence of additional regulatory mechanisms, the EIA is the most important method to achieve development that is sensitive to the unique natural resources of the country while allowing sustainable economic growth. The EIA process, through mapping and habitat survey, can allow better planning and locating of proposed development.

1.1 Scope of the EIA

The scope of the current report is limited to the immediate vicinity of the project area in terms of:

- its physical and biological concerns.
- the socio-economic aspects.
- the Exumas specifically.
- and the country of the Bahamas as a whole.

Effects on migrating fauna have not been considered except where indicated. Impacts are those which can be reasonably inferred given the nature of the development and subject site and are based on experience with similar projects. Long-term monitoring was not part of the data gathering for this report. Most data gathered for this report was obtained for assessment and establishment of baseline conditions. Thus, species may use the site that were not observed during the fieldwork period. Sincere attempts have been made to consider long-term and wider geographical scale in the consideration of impacts.

CHAPTER 2 PROJECT DESCRIPTION AND ALTERNATIVES

2.0 Detailed Description of Proposed Development

The Big Bell Island project is composed of the expansion of an existing utility and storage area, and improvements to an existing service dock / barge landing. A private yacht basin, excavated from the salt pond, will be constructed and offer fueling, sewage pumpout, electric, and water services for up to approximately 20 vessels.



Figure 2.1 Project Areas

Yacht Basin

The private yacht basin will be created for vessels up to 50+ meters in length. Depths in the basin will be cut to approximately -14 feet below Mean Low Water (MLW). The basin will be excavated from the shallow salt pond in the southeast corner of the Island. Excavation will be carried out with backhoes. Beach compatible material will be stored and used for beach replenishment. Non-beach compatible material will be utilized to assist in the construction of the protective jetties; though it is likely that a harder rock, possibly acquired in Freeport, Grand Bahama, will also be used.

Excavation of the yacht basin will be done in the dry to prevent turbidity and tidal fluctuations. Dewatering will be carried out through the utilization of deep well injection, as used successfully at

Albany. Basin docks may be concrete floating or fixed. It is likely that both systems will be utilized. Any wood CCA piling used will be wrapped with polyvinyl chloride (PVC) to prevent leaching of preservatives into tidal waters, while extending the life of the pilings. The basin was designed with an optional flushing culvert to be located west of the entrance channel. Modeling exhibited that the flushing culvert would not be needed due to the adequate flushing of the basin within 24 hours.

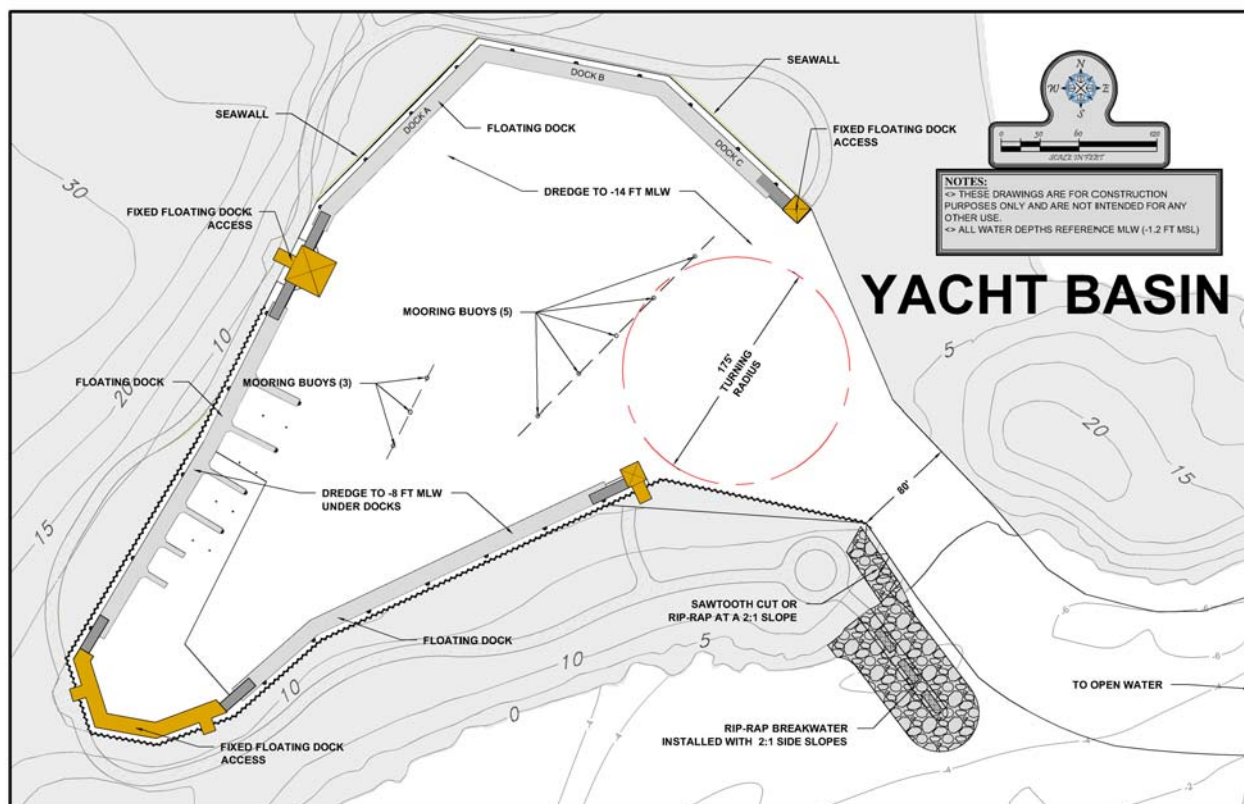


Figure 2.2 Yacht Basin Site Plan (Exhibit 1)

An access channel initiated off of the southeast most point of the island will be dredged to meet -14 feet MLW. The basin entrance will be protected by the installation of a riprap jetty, constructed with the dredged rock from the basin excavation and/or harder rock from Freeport, Grand Bahama. This jetty will help divert water flow, thus reducing the possibility of sand accretion within the proposed channel and thereby reducing future maintenance dredging. Where the jetty ties into the natural wall of the basin, sawtooth rock contours or rip-rap will be used to further dissipate wave energy within the basin entrance. The channel will be cut to a minimum of 80 feet at bottom width. Harder rock will be box cut and where overlaying sand is found, edges will be dug at an approximate 10:1 slope away from the channel.

The jetties on Big Bell Island will feature a centerline-planting shelf. The top of the breakwater will be at +5 feet MSL with a crest width of at least 12 feet, leaving planters approximately 20 feet long, 6 feet wide, and 4 feet deep. The vegetation sources will include the Bell Island Native Plant Nursery, which is described in detail in Section 3.3.1 of Chapter 3. The use of native and island-grown species will reduce aesthetic pollution in the Exumas Park. Salt tolerant plants will be used and drip irrigation will be installed to ensure success.

In an effort to maintain marine safety in the Exumas Park, navigational lights will be placed at the entrance to the yacht and barge landing basins to aid the array of vessels servicing Bell Island. A combination of warning lights at each jetty and buoy placement will also be utilized for safety. A service road will be provided to each jetty for maintenance access. All navigational aids will be maintained in good working order.

Power will be supplied to the yacht basin by upgrading the existing generators located in the island's utility and storage area. Water needs will be supplied by an upgraded version of the existing reverse osmosis (RO) system, also situated within the utility and storage area. Sewage pumpout will be provided to each of the larger vessels that generate black or grey water. A vacuum system will be used to pump the wastewater into a septic tank located in the vicinity of the basin with an associated deep well, as permitted by Water and Sewerage Corporation. Fueling will be supplied via an underground double walled pipe, originating in the utility area adjacent to the barge landing. All details of the fuel storage and transmission line will be reviewed and permitted by The Ministry of Works, Volatile Division. Proper fueling procedures will be posted and followed. This will include identification of emergency shutoff locations and training of all applicable personnel in spill prevention and the proper handling and delivery of fuel to vessels. Personnel will be trained in the use of spill containment booms and clean-up materials, which will be kept on site both at the yacht basin and the barge landing. Vessel repair activities will not take place within the yacht basin.

Service Dock / Barge Landing Improvements

The service dock improvements include the construction of a new marginal dock protected by a breakwater to provide safe mooring. The current configuration of the service dock is not conducive of safe boarding or loading/offloading of materials. The proposed boatlifts will alleviate much of the deterioration of the work fleet; thus, minimizing the need for boat repair while reducing the release of pollutants within the service dock / barge landing area. The reconfigured service dock will be sheltered through the utilization of a natural rock breakwater, extending from the south side of the barge landing, and a small rock outcropping tied into the natural rock shoreline on the north side. The breakwater will feature a centerline planter shelf. The top of the breakwater will be at +6 feet MSL with a crest width of at least 12 feet, leaving planters approximately 20 feet long, 6 feet wide, and 5 feet deep. The vegetation sources will include the Bell Island Native Plant Nursery, which is described in detail in Section 3.3.1 of Chapter 3. Salt tolerant plants will be used and drip irrigation will be installed to ensure success.

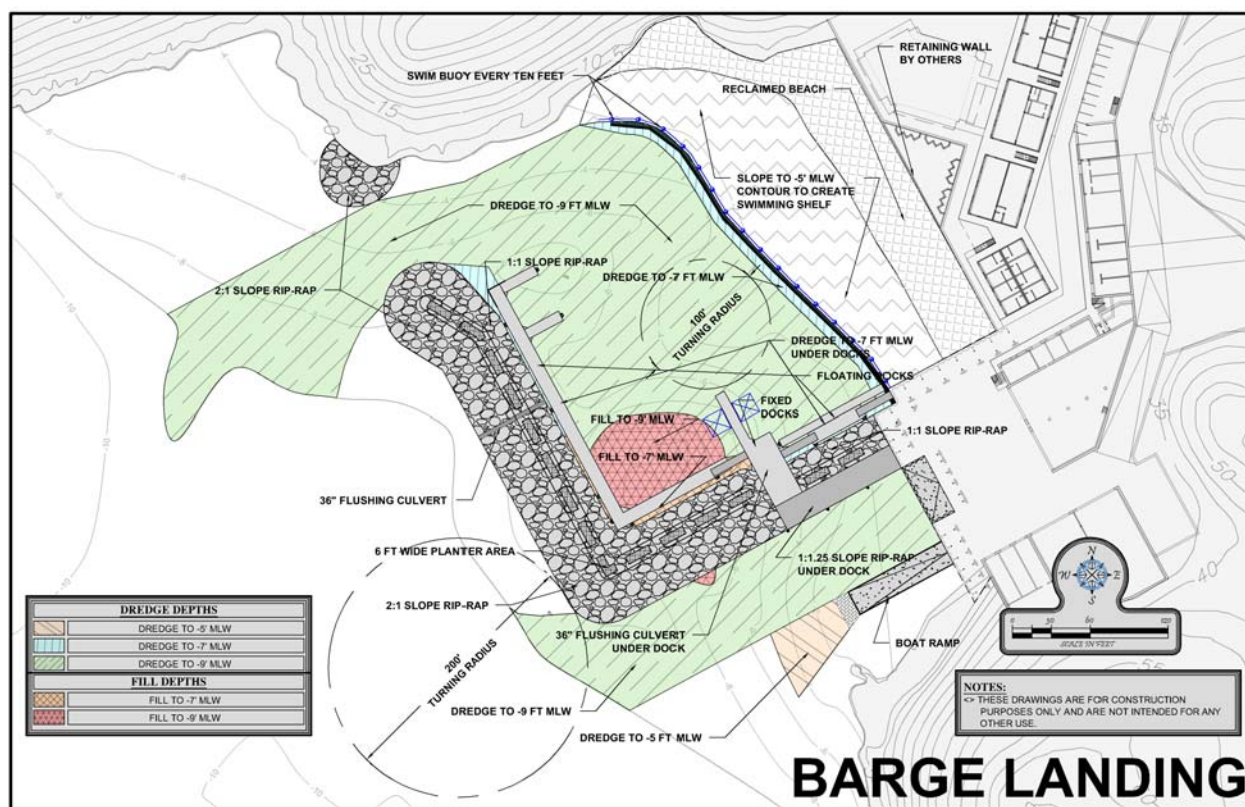


Figure 2.3 Barge Landing Site Plan (Exhibit 2)

The existing barge landing area will be improved by constructing a new concrete landing platform with a 20 foot wide boat ramp situated to the south. The new landing will be cut into the soft rock of the island's rocky shoreline. Existing overwater fuel pumps will be relocated to the protected barge landing area, thus reducing spill potential. In addition to the relocation of the existing pumps, high speed diesel pumps will be incorporated into the fueling system. The majority of the service dock / barge landing area will be dredged to -9 feet MLW, which is 3 feet shallower than the depth originally proposed in the EIA, and some areas, will only be dredged to -7 MLW. These reductions in dredge depth decrease the dredge area by 160,520 sq ft and the volume by 30,377 cu yds. With the submission of the final plan, an additional area of dredging adjacent to the breakwater was eliminated and the area in front of the boat ramp was further reduced to -5 ft MLW. This reduced the dredge volume an additional 830.6 cu yds.

Overall the offshore dredging of the Barge Landing area has been reduced by 31,041.8 cu yds less than what was originally submitted in the March 2010 EIA. This equates to a 72% total Barge Landing dredge volume reduction.

Utility and Storage Area Expansion

The current utility and storage area will be expanded in the same general vicinity and built into the rock face of the adjacent hill. The proposed expansion will increase the "back of the house" capabilities with additional fuel tanks, storage, and power generation equipment.

Road Network and Other Improvements

A proposed limestone road will meander along the south side of the island from the main house to the yacht basin. A policy decision was made to build, modify, and or close roads so as to avoid any gradient above 7% through out the Island's road network. This policy will include efforts to reduce existing or new cut and fill on the Island, reduce scarring, reduce the amount of new landscaping that will be required, as well as, reduce vehicular gas emissions. The exact footprint of the road network will be field-located so that negative impacts to mature and protected species are avoided to the greatest extent possible and areas of interest are highlighted.

A small, but important native plant nursery has been incorporated into the Island's project plan. The proposed native plant nursery is currently planned to be located in the vicinity of the casuarina removal area. The final design of the nursery will be contingent on factors such as landscape management needs, access, elevation, exposure, orientation, aesthetics, and conservation of existing native plant communities.

2.1 Description of Alternatives to the Proposed Development

An initial consideration was proposed to locate the basin directly behind one of the crescent beaches on the islands eastern side. The preliminary layout would have increased upland impacts to the coastal coppice immensely. This would have correlated to greater ramifications to the local wildlife currently utilizing this habitat. In order to gain access to the basin, a channel would have been cut directly thru existing seagrass beds and sand beaches. The combination of these two habitats are pivotal to the life cycle of the protected queen conch (*Strombus gigas*). The photo below, taken at a near by beach, exhibits the species utilization of the sensitive areas. This alternative was rejected on the basis that it would have created unnecessary environmental impacts.

The plan proposed in the original EIA submittal, dated March 2010, consisted of a more intensive dredge footprint and significantly deeper dredge depths. The following is a detailed description of changes made to the originally submitted dredge areas and volumes associated with the Big Bell Island project. A dredge reduction exhibit is also attached to provide further illumination.

Barge Landing Reductions					
Design Phase	Dredge Depths (ft. MLW)	Dredge Area (sq ft)	Difference in Area from March 2010 EIA (sq ft)	Dredge Volume (cu yds)	Difference in Volume from March 2010 EIA (cu yds)
March 2010 EIA	-12 ft	269,341.00	N/A	43,279.00	N/A
Jan 2011 Revised EIA / EMP	-9, -7 & -5 ft	95,045.60	-174,295.40	12,237.20	-31,041.80
Yacht Basin Reductions					
Design Phase	Dredge Depths (ft. MLW)	Dredge Area (sq ft)	Difference in Area from March 2010 EIA (sq ft)	Dredge Volume (cu yds)	Difference in Volume from March 2010 EIA (cu yds)
March 2010 EIA	-14 ft	110,890.00	N/A	31,195.10	N/A
Jan 2011 Revised EIA / EMP	-14& -8 ft	111,956.40	1,066.40	31,128.50	-66.60

Barge Landing Dredging

- The original dredge area and depth were established to provide yacht access into the barge landing fuel area. Big Bell eliminated the need for yacht access into the barge landing for fueling by providing fueling within the yacht basin instead. As a result, the needed dredge depth of the barge landing area was reduced from -12 ft MLW to -9 ft MLW and the dredging proposed at the northwestern tip of the island was eliminated altogether. This change in the project concept greatly reduced the amount of spoil to be exported from Bell Island. To further reduce the needed dredging, the area under the docks and area leading to the boat ramp were also reduced to -7 ft MLW.
 - The plan alterations described above decreased the barge landing dredge volume total by 30,211.20 cu yds.

- With further revisions to the final plan, an additional area of dredging adjacent to the breakwater was eliminated and the area in front of the boat ramp was reduced to -5 ft MLW.
 - These plan alterations reduced the dredge volume by an additional 830.60 cu yds.
- Overall, the offshore dredging of the Barge Landing area has been reduced by 31,041.80 cu yds from what was originally submitted in the March 2010 EIA. This equates to a 72% total reduction in Barge Landing dredge volume.

Total Dredge Reduction					
Design Phase	Area/Volume % Reduction from EIA	Dredge Area (sq ft)	Difference in Area from March 2010 EIA (sq ft)	Dredge Volume (cu yds)	Difference in Volume from March 2010 EIA (cu yds)
March 2010 EIA	N/A	380,231.00	N/A	74,474.10	N/A
Jan 2011 Revised EIA / EMP	46 / 42	207,002.00	-173,229.00	43,365.70	-31,108.40
* Upland excavation was excluded from this comparison					

Offshore Dredging

- Total offshore dredge volume has been reduced by 31,108.4 cu yds from what was originally submitted in the March 2010 version of the EIA. This equates to a 42% total reduction in offshore dredge volume. Additionally, total project offshore dredge area has been reduced by 173,229.00 sq ft from what was originally submitted in the March 2010 version of the EIA, which means a 46% total dredge area reduction.



Figure 2.4 Barge Landing Dredge Reductions (Exhibit 11)

A detailed study was carried out in order to ascertain whether or not there is ecological importance, biological uniqueness, biodiversity and/or productivity within the salt pond located on Big Bell Island. The habitat was investigated to determine if the pond would be a feasible site to create a sheltered basin by dredging and opening the basin to flushing from the sea. It was concluded that this particular pond does not provide a unique habitat. The full report of "Bell Island and two neighboring salt ponds: A study of their characteristics" is included for review as Appendix II.

Hydraulic dredging was considered for this project; however, it was concluded that mechanical dredging would be more easily contained. Hydraulic dredging was determined to be more impactful than mechanical dredging for various reasons described below. It would require more open land than is available in the yacht basin or on the island, requiring removal of a large area of natural vegetation. This land would need to be cleared for the settling ponds since hydraulic dredges pump mostly water which is mixed with sediment that needs time to settle out, thus requiring large settling ponds. Even after settlement, water is returned to the sea often with remaining turbidity. An additional problem is the introduction of salt water in the settling ponds which could affect the sparse groundwater resources.

Mechanical dredging does not require the settling ponds that hydraulic dredging requires and can be done in a much smaller area of upland impact. Turbidity can be controlled with berms and turbidity curtains, in this case possibly more safely than with a hydraulic dredge. Mechanical dredging is less prone to catastrophic failures, such as blown out pipelines, that can have negative consequences with large releases of sediment laden water in one area at one time.

2.2 "No Action" Alternative

A "no action" alternative also has legal and constitutional implications which are beyond the scope of this study and have not been addressed other than to note that Big Bell Island was one of several islands which had already been granted as private property before the creation of the BNT Exuma Cays Land and Sea Park (ECLSP) lease. These private property rights, which would include some reasonable development, and private accessibility are preserved.

CHAPTER 3 AREA AND BOUNDARIES OF THE DEVELOPMENT



Figure 3.1 The Exumas

3.0 Location of Site

Big Bell Island is located in the Exuma Cays of the central Bahamas. The 349 acre island lies on the eastern edge of the Great Bahama Bank, near the southern end of the Exuma Cays Land and Sea Park. Islands to the north and south are O'Brien's Cay and Little Bell Island, respectively. Big Bell Island is fringed by O'Brien's Cut, a deep pass, on the north.

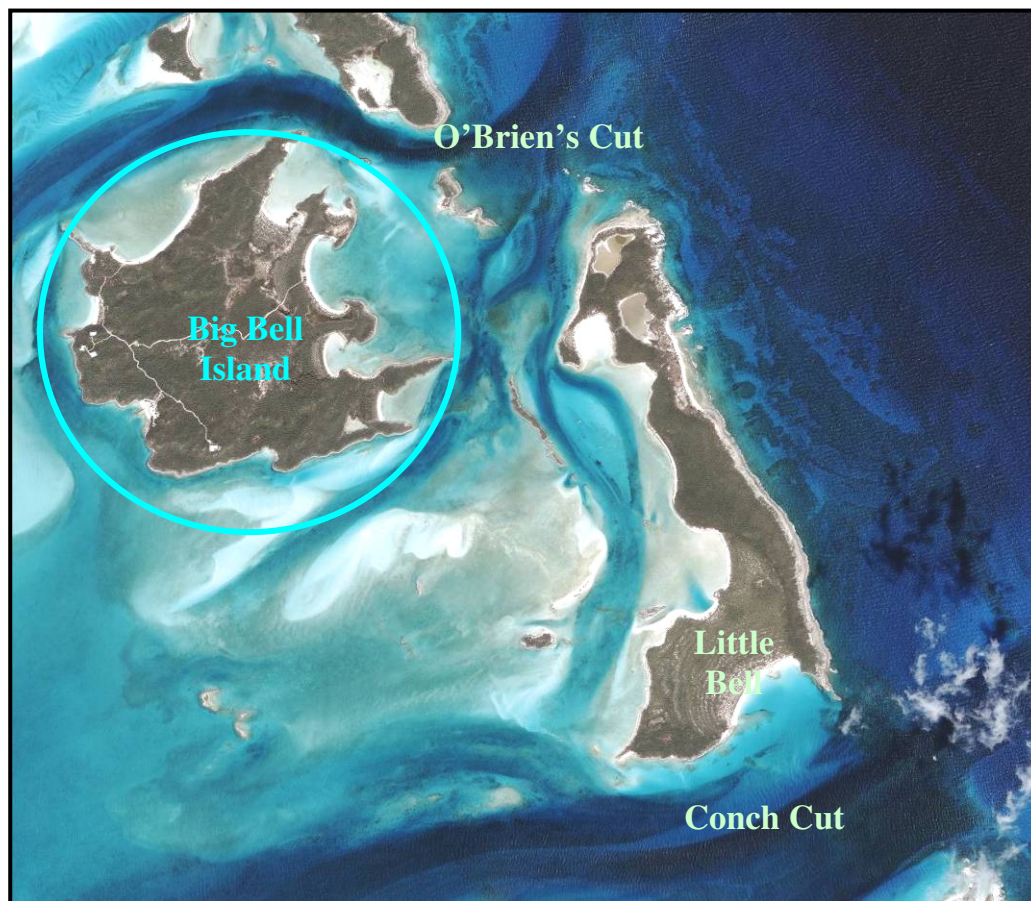


Figure 3.2 Big Bell Island and Surroundings

3.1 Site Boundaries

The boundaries of the site are defined by the limits of the approximately 349 acre island. The project area will include the proposed development of the private yacht basin and channel, improvements to the service dock / barge landing area and channel, and the related utilities and storage area, all of which will entail less than 5 acres of direct impacts to upland or salt pond areas. These areas are depicted in Figures 3.3, 3.4, and 3.5 (identified with white outline). Dredging impacts associated with the barge landing / service dock and the yacht basin access channel will occur within 4.8 acres of sand flat marine habitat. These areas are depicted in Figure 3.6 and discussed in further detail in Chapter 5. The casuarina area, displayed as Figure 3.7, will consist of 2.7 acres of casuarinas to be removed and the land ecologically restored.

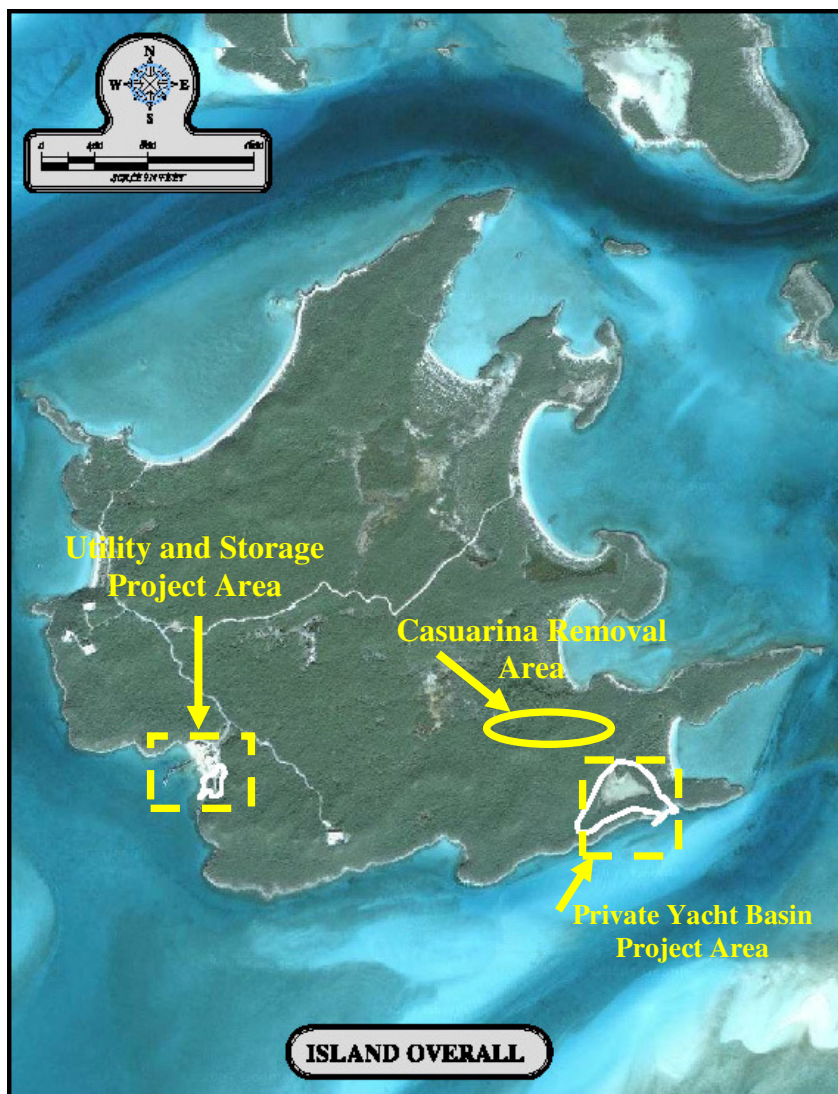


Figure 3.3 Big Bell Island Project Limits

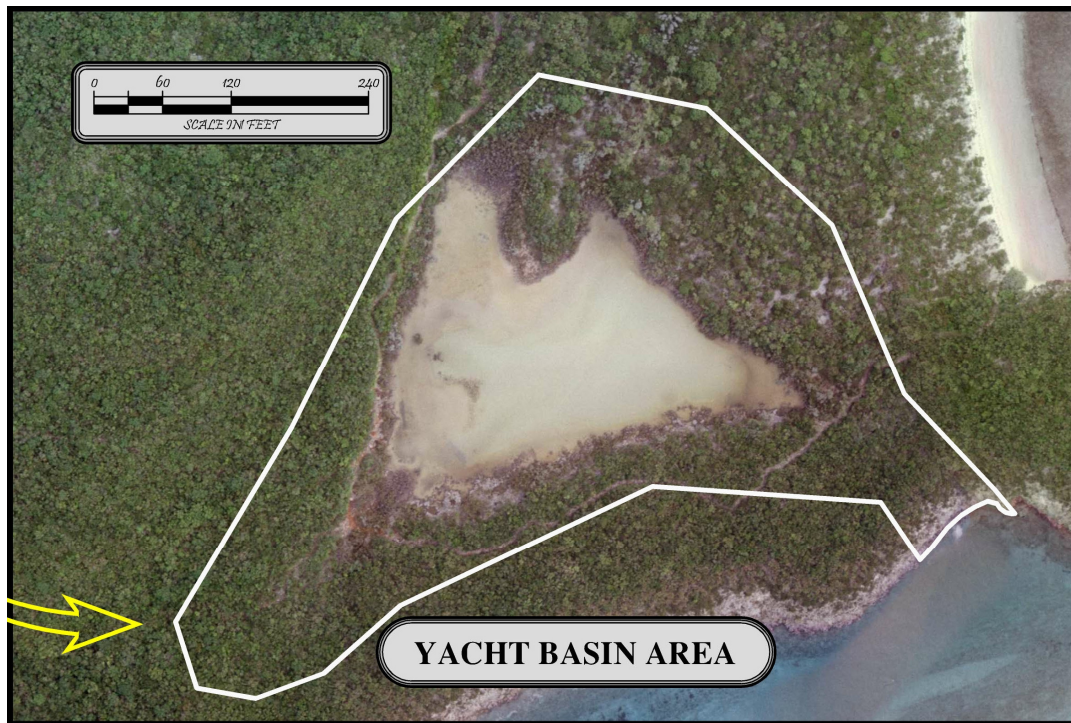
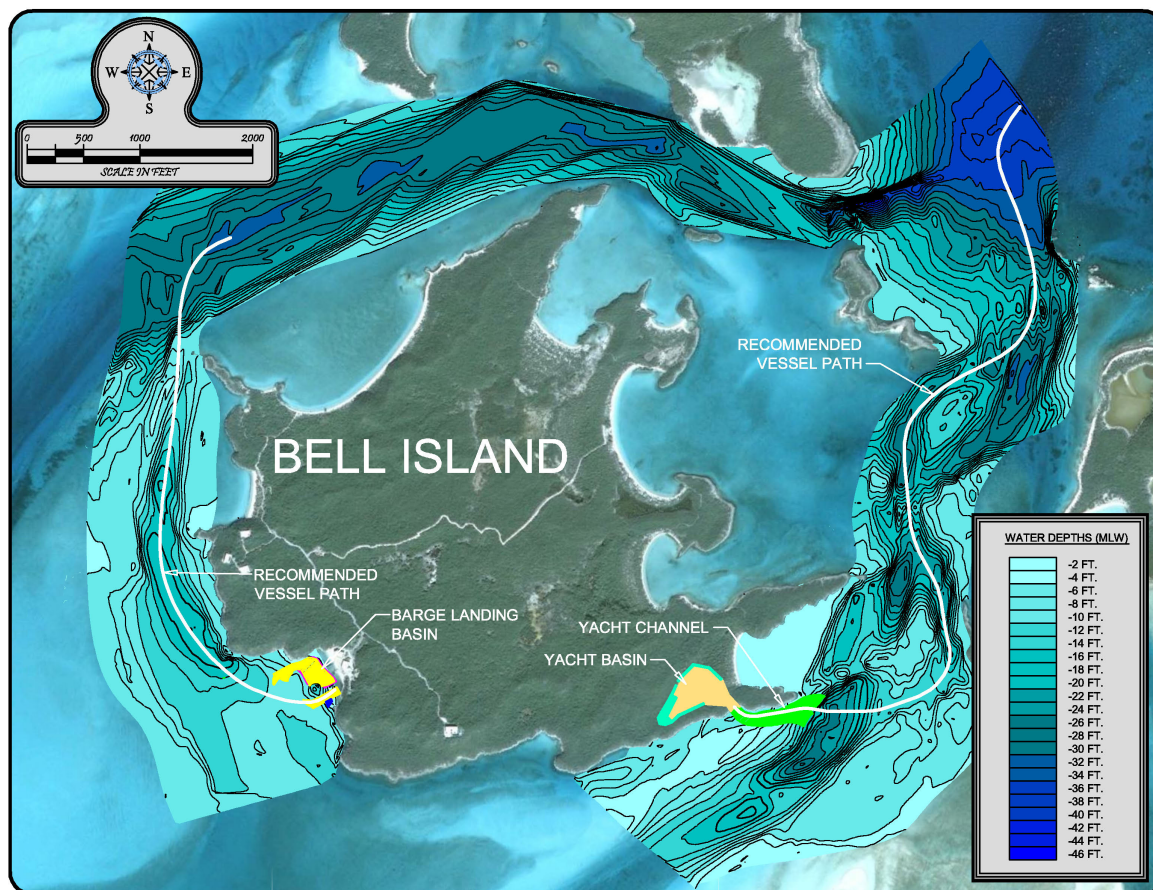








Figure 3.4 Limits of Private Yacht Basin Project Area



Figure 3.5 Limits of Utility and Storage Expansion Area



BARGE LANDING	
	DREDGE TO -5' MLW
	DREDGE TO -7' MLW
	DREDGE TO -9' MLW

YACHT BASIN	
	EXCAVATE TO -8' MLW (BASIN)
	EXCAVATE TO -14' MLW (BASIN)
	DREDGE TO -14' MLW (CHANNEL)

NOTES:

- <> THESE DRAWINGS ARE FOR DISCUSSION PURPOSES ONLY AND ARE NOT INTENDED FOR ANY OTHER USE.
- <> THESE DRAWINGS ARE FOR DESIGN PURPOSES ONLY AND ARE NOT INTENDED FOR CONSTRUCTION
- <> BATHYMETRIC DATA WAS COLLECTED ON AUGUST 28, 2009 BY TURRELL, HALL & ASSOCIATES
- <> ALL DEPTHS ARE IN REFERENCE TO MLW
- <> MLW WAS ESTABLISHED DURING A TWO DAY TIDAL STUDY WHILE DATA WAS COLLECTED
- <> MLW = 1.3 FT. MSL

BARGE LANDING BASIN DREDGE VOLUMES		
AREA DESC	TOTAL AREA (ft ²)	DREDGE VOLUME (yds ³)
-5' MLW	2417.4	192.9
-7' MLW	6450.9	806.2
-9 MLW	86177.3	11238.1
TOTALS	95045.6	12237.2
YACHT BASIN EXCAVATION VOLUMES		
AREA DESC	TOTAL AREA (ft ²)	DREDGE VOLUME (yds ³)
-8' MLW	34689.7	13786.0
-14' MLW	148233.8	91397.5
TOTALS	182923.5	105183.4
YACHT BASIN CHANNEL DREDGE VOLUMES		
AREA DESC	TOTAL AREA (ft ²)	DREDGE VOLUME (yds ³)
-14' MLW	111956.4	31128.2
TOTALS	111956.4	31128.2
AVERAGE CUT DEPTH (ft)		
BARGE LANDING	3.3	
BASIN	15.7	
BASIN CHANNEL	7.4	

Figure 3.6 Dredge Plan
(Exhibit 3)

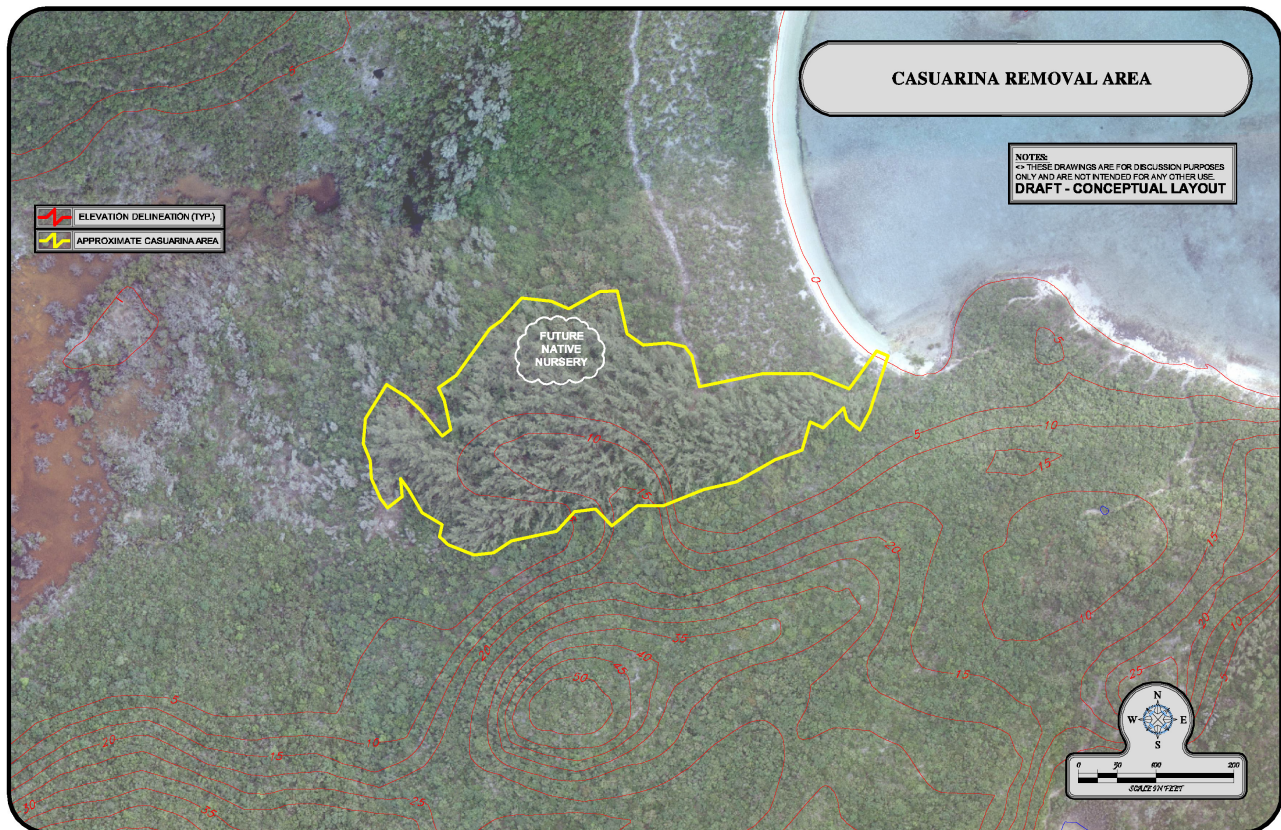


Figure 3.7 Casuarina Removal Area
(Exhibit 4)

3.2 Area of Influence

Environmental impacts of the proposed work are considered to be predominantly local, within the island boundaries, and temporary in nature. In socio-economic terms, the project will likely have a positive influence on the Exumas through the creation of additional jobs and the need for services generated. Additional employees for the Island may come from the Black Point settlement which is located on Great Guana Cay approximately 17 miles to the southeast. It is the largest settlement in the area. See the illustrations of the Exumas, Figure 3.1, and the southern portion of the Exuma Cays Land and Sea Park, Figure 3.8.



Figure 3.8 Southern Portion of the Exuma Cays Land and Sea Park

CHAPTER 4 BASELINE DESCRIPTION OF THE DEVELOPMENT SITE

PHYSICAL ASPECTS

4.0 Climate, Including Major Events

The Bahamian Islands stretch for over 700 miles with a land mass of 2,300 square miles. They cover a marine area of over 5,000 square miles. The islands lie within the tropical and sub-tropical climatic belts. As a consequence, the weather systems are dominated by the influence of the trade winds and the surrounding ocean. Essentially two seasons are experienced. The wet season occurs in the summer and the dry season occurs in the winter. Typical rainfall and temperature data is provided in Table 4-1. Annual rainfall for the Exumas is estimated at 53 inches (BEST, 1995).

The center of the summer trade winds shift to the north so that the Bahamas lie closer to the southern border of the trade wind belt and almost constant, moisture-laden breezes blow from the east or south-east. In winter the trade winds shift southward and the winds are less constant. Weather is then more influenced by fronts advancing from the North American continent, sometimes twice weekly. This brings cooler conditions although temperatures never reach freezing, due to the fact that they are being moderated by the surrounding waters. Cold fronts are typically preceded by winds from the southwest, which clock to the west, then northwest, as the front passes with strong winds of 20-25 knots and cooler air. In general terms, winds are predominantly southeast during the summer and northeast during the winter.

Historical meteorology for the site is based on data collected at the Nassau Airport on New Providence Island. The airport is approximately 65 nautical miles from the property and is generally representative of typical conditions. Table 4-1 presents meteorological statistics for temperature, precipitation, wind, barometric pressure, relative humidity, wind, and sunshine. Information from Nassau was utilized because The Greater Exumas weather records were not readily available.

The monthly mean temperature ranges from 70.7°F to 82.5°F. The mean daily minimums range from 62.1°F to 74.8°F, while the mean daily maximums range from 77.3°F to 89.3°F. The data reflects the temperate climate of the Bahamas with a narrow fluctuation in air temperature.

Table 4-1: Average Climatic Data for The Bahamas (Nassau Airport Meteorological Statistics)

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature Statistics													
Monthly Mean **	°F	70.7	70.9	72.6	74.9	77.8	80.6	82.1	82.5	81.5	79.1	75.2	72.1
Mean Daily Maximum	°F	77.3	77.5	79.7	81.8	84.6	87.3	89.1	89.3	88.4	85.4	81.8	78.7
Mean Daily Minimum	°F	62.1	62.5	63.8	66.2	69.8	73.3	74.7	74.8	74.4	71.9	68.0	63.8
Hourly Means													
07h	°F	65.9	66.2	68.1	71.2	75.9	79.4	80.6	80.2	78.5	75.7	71.4	67.5
13h	°F	75.2	75.4	77.5	79.5	82.1	84.6	86.6	86.7	85.6	83.2	79.8	76.6
Highest Maximum	°F	86.4	88.7	87.8	91.2	92.3	93.2	93.4	95.4	93.2	91.8	90.0	86.7

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lowest Minimum	°F	41.4	45.8	44.6	48.6	55.5	59.0	64.2	64.4	59.5	56.0*	51.0*	41.5
Mean Dew Point	°F	62.6	62.6	63.5	64.9	69.6	73.5	74.6	75.0	74.7	71.8	67.6	64.0

Rainfall Statistics

Rainfall Monthly Total	Inches	1.86	1.59	1.57	2.12	4.58	9.17	6.21	8.5	6.75	6.91	2.23	2.04
Maximum Rainfall/Day	Inches	4.62	3.47	3.48	11.23	3.48	6.55	4.08	6.23	5.31	8.07	2.68	4.64
Number of Days		8	6	6	5	10	15	17	18	17	16	9	8

Other Statistics

Pressure	mmHg	19.6	19.3	20.2	21.1	24.5	28.1	29.3	29.5	29.2	26.4	23.1	20.6
Mean R. H.	%	78	78	76	74	77	79	77	79	81	80	78	78
Mean Wind Speeds	MPH	8.0	8.6	8.9	8.3	7.9	7.2	7.1	6.9	6.2	7.4	8.1	7.8
Sunshine Mean Daily	Hours	7.1	7.6	8.3	9.2	8.7	7.7	8.8	8.6	7.1	7.2	7.4	6.9

*Occurred outside the 30-year means 1961-1990

**Period of record: 1874 to 1987

Highest/lowest temperature on record: 95.4°F High; 41.4°F Low

4.0.1 Precipitation

The data indicates that the highest rainfall occurs during the summer and early fall months. Of the total average rainfall of 53 inches per year, more than two-thirds of it, 38 inches, falls from June through October.

4.0.2 Winds

The mean wind speeds do not appear to vary significantly on a monthly basis. The average monthly wind speeds vary from 6.2 mph in September to 8.9 in March. The highest average winds are experienced during the late fall and winter months (Table 4-1).

4.0.3 Storms

The Exumas in their entirety and Big Bell Island specifically are within the Atlantic Tropical Cyclone basin. This basin includes much of the North Atlantic, Caribbean Sea, and the Gulf of Mexico. On average, six (6) to eight (8) tropical storms form within this basin each year. The 2004/2005 hurricane season produced significantly higher than average activity. The formation of these storms and possible intensification into mature hurricanes takes place over warm tropical and subtropical waters. Eventual dissipation or modification, averaging seven (7) to eight (8) days later, typically occurs over the colder waters of the North Atlantic or when the storms move over land and away from the sustaining marine environment.

Due to the destructive nature of these storms, landfall can result in significant damage to upland development and facilities from storm surge, waves, and wind. A good example of this would be

Hurricane Frances which formed in 2004. Table 4-2 lists the number of tropical storms and hurricanes that passed within 200 miles of the project area over the past 20 seasons including 1987 through 2007 as reported by the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. Data presented by Hurricane City (www.hurricane-city.com) indicates that Greater Exuma Island, on average, is brushed or hit by a hurricane once every 4.15 years, and is directly hit once every 15.2 years. Recent storms of record are Hurricanes Andrew, Floyd, and Frances. The passage of Hurricane Lili in 1996 resulted in 105 mph winds and a storm surge that caused moderate damage on Greater Exuma Island.

Table 4-2: Number of Tropical Storms and Hurricanes Passing within 200 Miles of Eleuthera

Year	Number of Storms
1987	2
1988	1
1989	0
1990	1
1991	2
1992	1
1993	0
1994	1
1995	2
1996	2
1997	0
1998	1
1999	2
2000	0
2001	1
2002	0
2003	0
2004	2
2005	4
2006	2
2007	1

The hurricane season lasts from June 1st to December 1st. The Bahamas are north of the path of most Atlantic hurricanes and east of those of the south Caribbean Sea and Gulf of Mexico. Nevertheless, storm frequency within The Bahamas as a whole is once every ten (10) years on average.

4.1 Topography, Lithography, Pedology, Surface Characteristics, Features of Note

The low-lying islands of the Bahamas sit on limestone caps thousands of feet thick. The islands are separated by deep ocean trenches including the dead-end Tongue of the Ocean between New Providence and Andros Islands. The Northwest Providence Channel, which is 3 miles deep and 150 miles long, is the deepest and third longest marine canyon in the world. It is situated north of New Providence and separates the Little and Grand Bahama Banks¹ (White, 1998). The Exuma Sound, just east of the Exuma chain, extends to the west to Eleuthera and Cat Island.

The islands, including Big Bell Island, were likely formed by the remains of calcarenite dunes during the Pleistocene Age. These windblown deposits of sand became exposed during times of lower sea level and hardened to form the rolling hills that characterize the island's topography. Features of note include a large salt pond in the southeast quadrant of the island and approximately 32 acres of impounded mangrove wetland habitat mostly concentrated on the eastern half of the island. The terrain is entirely composed of limestone rock with sparse soil coverage. Shoreline areas are sand or rock.

Soils on Big Bell Island are predominantly composed of windblown and hydraulically deposited calcareous sand, silt, and clay. These soils range from lagoonal, inter-tidal, supra-tidal, and upland deposits with moderate to low organic content. The upland soil is a thin veneer over the underlying calcareous limestone. The upland soil has undergone only minor soil genesis and should not be considered significant. The humus content of the upland soil is minimal. The shallow soil horizons lack significant trace elements and the basic nutritional compounds including nitrogen, phosphorus, and potassium that would sustain traditional agriculture without considerable anthropogenic assistance.

4.2 Hydrology and Hydrogeology, Water Resources, Surface Waters, Drainage, Flood-prone Areas

In The Bahamas, rainwater sinks rapidly into the porous limestone and sits underneath the surface as a freshwater lens riding above the denser saltwater. No river or freshwater lake features exist on Big Bell Island. Big Bell Island is a small island and natural water reserves are insufficient to supply the resident population. Hence, reverse osmosis or desalination is utilized to supply fresh water. A salt pond was identified on Big Bell Island, but tidal connection maintains the salinity near that of the surrounding waters.



Figure 4.1 Aerial photograph of the Big Bell Island salt pond.

4.3 Air Quality

The remote, undeveloped nature of the Exumas and the subject island specifically provide air quality of unsurpassed standards. Activities currently underway with the potential to degrade air quality are limited to generator and incinerator operation as well as the occasional use of motorized vessels and golf carts. The proposed construction activities have the potential to elevate emissions for the short-term time frame associated with the land clearing and construction activities. The prevalent breezes and ambient air quality are such that the expected short-term elevation of emission levels will be minimal and of no impact to local air quality

4.4 Noise Pollution

Similarly, no activities other than generator and incinerator operation coupled with occasional boat and golf cart use are underway that cause any increase above ambient noise levels. Proposed construction activities and improvements may temporarily elevate noise levels; however, they will not rise to nuisance or dangerous levels.

BIOLOGICAL ASPECTS

4.5 Terrestrial Habitats

Ground truthing, aided by low-level aerial photography, was carried out to prepare maps (provided as Exhibits 4,6,7) that characterize and quantify the different habitat types present within the project and mitigation areas of the Island. Initially, aerial images were used to gain an understanding of habitat delineations. These were confirmed by ground truthing and subsequently delineated within the proposed project boundaries. A species inventory was then made by traversing a series of meandering transects throughout the project areas. The acreages given are approximate and are provided to enable quantification of impacts associated with the proposed private yacht basin development, service dock / barge landing improvements and utilities and storage area expansion. An inventory of predominant plant species noted is provided in Table 4-3.

Proximity to the coast has reduced the development of microclimates and buildup of soil which would have promoted development of broadleaf coppice habitat with hammock type plants on the island.

HABITAT 1: COASTAL COPPICE



Figure 4.2 Typical coastal coppice habitat.

The coastal coppice community is found throughout the majority of the project impact area. This community showed only minor variations in the densities of the species present. A species of bromeliad, swollen wild pine (*Tillandsia utriculata*) and orchid species *Encyclia gracilis* and *Vanilla barbellata* were observed in greater diversities along the western side of the salt pond. There was also an increase in canopy height of the various tree species on the west side.

Hog cabbage palm (*Pseudophoenix sargentii*) and the other three species listed above that are located within the impact area of the private yacht basin are planned to be salvaged to the maximum extent possible, saved and relocated to the native plant nursery and other areas on the island. The palms growing in pure rock substrate will not be moved.

Wild dilly (*Manilkara bahamensis*), ram's horn (*Pithecellobium keyense*) and pigeon plum (*Coccoloba diversifolia*) were the most common canopy and midstory species. Also noted were hog cabbage palm (*Pseudophoenix sargentii*), Joewood (*Jacquinia keyensis*), poison wood (*Metopium toxiferum*), and lignum vitae (*Guaiacum sanctum*). The last of which was found to be common on the northwestern side of the salt pond. The most common groundcover included sandfly bush (*Rhachicallis americana*).

HABITAT 2: BUTTONWOOD FRINGE



Figure 4.3 Buttonwood fringe habitat.

A buttonwood and mangrove fringe was identified bordering the majority of the salt pond. This area was vegetated by green buttonwood (*Conocarpus erectus*), silver buttonwood (*Conocarpus erectus* var. *sericeus*), and white mangrove (*Laguncularia racemosa*). The observed specimens were stunted as mature specimens measured less than 48 inches in height.

HABITAT 3: SALT POND



Figure 4.4 Big Bell salt pond.

The salt pond habitat was devoid of any vegetation with the exception of fuzzy finger algae (*Batophora spp.*). This particular pond has been included in a study specifically focusing on salt ponds of the Exumas. Several parameters were analyzed and sediment samples collected to determine the presence of benthic invertebrates and general physical characteristics of the ponds. The full report of “Bell Island and two neighboring salt ponds: a study of their characteristics” is included for review as Appendix II.

HABITAT 4: ROCKY SHORELINE



Figure 4.5 A typical rocky shoreline habitat.

The rocky shoreline consisted primarily of shrub species the most dominant of which were sandfly bush (*Rachicallis americana*), joewood (*Jacquinia keyensis*), golden beach creeper (*Ernodea littoralis*), ram's horn (*Pithecellobium keyense*), sea purslane (*Sesuvium portulacastrum*), and thatch palm (*Thriniax morrisii*). The rocky shoreline varied from 20 to 30 feet in width.

HABITAT 5: CASUARINA



Figure 4.6 The casuarina stand to the northwest of the proposed basin.

A dense stand of casuarinas (*Casuarina equisetifolia*) just shy of 3 acres in size was identified on the southern boarder of the mangrove mitigation area. Other species noted were ram's horn (*Pithecellobium keyense*) and various species of stoppers (*Eugenia spp.*). The area exhibited common characteristics of a casuarina stand, with approximately four (4) to six (6) inches of pine needle duff and little to no ground cover. Land crab holes were common throughout this habitat.

Table 4-3 Floral Species Inventory

Common Name	Scientific Name
Bahama dildo	<i>Cephalocereus millspaughii</i>
black mangrove	<i>Avicennia germinans</i>
bushy salmea	<i>Salmea petrobioides</i>
(-)casuarina	<i>Casuarina equisetifolia</i>
century plant	<i>Agave sisalana</i>
cinnecord	<i>Acacia choriophylla</i>
crabwood	<i>Ateramnus lucidus</i>
darling plum	<i>Reynosia septentrionalis</i>
common ernodea	<i>Ernodea littoralis</i>
green buttonwood	<i>Conocarpus erectus</i>
gumbo limbo	<i>Bursera simaruba</i>
hog cabbage palm	<i>Pseudophoenix sargentii</i>
box briar	<i>Randia aculeata</i>
cancer tree	<i>Jacaranda coerulea</i>
joe wood	<i>Jacquinia keyensis</i>
lignum vitae	<i>Guaiacum officinale</i>
*orchid	<i>Encyclia gracilis</i>
pigeon plum	<i>Coccoloba diversifolia</i>
poison wood	<i>Metopium toxiferum</i>
ram's horn	<i>Pithecellobium keyense</i>
red mangrove	<i>Rhizophora mangle</i>
royal poinciana	<i>Delonix regia</i>
sandfly bush	<i>Rachicallis americana</i>
(-)schefflera	<i>Schefflera actinophylla</i>
sea purslane	<i>Sesuvium portulacastrum</i>
seven year apple	<i>Casasia clusifolia</i>
silver buttonwood	<i>Concarnus erectus</i> var. <i>sericeus</i>
stoppers	<i>Eugenia</i> spp.
strumpfia	<i>Strumpfia maritima</i>
swollen wild pine	<i>Tillandsia utriculata</i>
thatch palm	<i>Thrinax morrisii</i>
wild cane	<i>Lasiacis divaricata</i>
wild dilly	<i>Manilkara bahamensis</i>
white mangrove	<i>Laguncularia racemosa</i>
worm vine	<i>Vanilla barbellata</i>

* Endemic to The Bahamas
(-) Non Native Species

All species cross referenced using Flora of the Bahamian Archipelago (Correll & Correll, 1982)

4.5.1 Terrestrial Wildlife Observations

A list of fauna noted on site during the survey period is provided below. Several curly tailed lizards (*Leiocephalus* spp.) were noted. Bird life at the time of the survey was sparse. Observed avian species included Antillean nighthawk (*Chordeiles gundlachii*), short-billed dowitcher (*Limnodromus griseus*), black-necked stilts (*Himantopus mexicanus*), and green heron (*Butorides virescens*).



Figure 4.7 The short-billed dowitcher is shown above.

Every effort will be made to preserve and promote wildlife utilization on the property. Methods and activities used to enhance wildlife utilization will include:

- ecological restoration of natural areas currently overgrown with Casuarina.
- wildlife-friendly practices will continue to be utilized by residents and guests.

4.6 Caves and Blue Holes

Small potholes were present throughout the project area of the island. However, no large blue holes or cave features were located.

4.7 Aquatic Habitats, Fresh and Saline Wetlands

Mangrove and salt pond habitats are described in section 4.5. The salt pond located on Big Bell Island was analyzed and incorporated into a salt pond study. The full report "Bell Island and two neighboring salt ponds: a study of their characteristics" is included for review as Appendix II. No freshwater wetlands were noted within the proposed project area. It may be possible that small depressional areas in the interior of the island retain standing water and support a reduced wetland plant assemblage. However, none of these were noted in the project area or are included in this report.

4.8 Marine Habitats

Marine areas surveyed in detail by Turrell, as a part of this EIA, were comprised of two categories. The first included the proposed private yacht basin, service dock / barge landing area and the approaches to both, all areas that will be directly impacted by the planned work. The second comprised of preserve areas and where no direct impacts are anticipated, specifically areas adjacent to impact. Construction activities associated with the proposed yacht basin include an 80 foot wide ingress/egress channel dredged to -14 feet MSL and protected by the installation of a rock jetty. The barge area work entails construction and improvements to the existing service dock / barge landing. The majority of the service dock / barge landing area will be dredged to -9 feet MLW, and some areas only to -7 or -5 MLW. Initial

Preliminary alternative site plans suggested situating the basin so that the access channel would cut through one of the crescent shaped sandy beaches along the eastern side of the island. These seagrass sand flats adjacent to the above mentioned sandy beaches were also surveyed to assess the resources preserved by opting for the current layout. This alternative has been discarded.

The marine habitat survey was conducted by traversing underwater transects approximately 15 feet from the shoreline. The parallel dive transects were oriented to follow the rocky shoreline and approximately 15-20 feet apart. While traversing transects, habitat and species identification were noted and documented through the use of underwater still photography. A description of each habitat along with photos and the species identified follows. An exhibit depicting the location of dive transects in relation to the proposed work and preservation areas is also provided in Figure 4.9.

To assure accuracy of the existing marine resources and impact assessment a third party, Dr. Erich Mueller of eVm Research and Design, was hired to perform an independent analysis of the area. Erich Mueller (Ph.D., 1983, Univ. of Miami) has been studying corals and reefs for over 30 years at numerous locales across the world. As Director of Mote Marine Laboratory's Center for Tropical Research (Florida Keys), Erich's work included the use of coral culture for both research and applications such as reef restoration. In conjunction with the Florida Keys National Marine Sanctuary, he developed training programs for reef damage assessment and restoration. With the Caribbean-wide increases in coral diseases, research efforts began in 1997 to compare disease prevalence throughout

the Florida Keys with sites in the Exumas and Abacos. A pilot study in 1998, led to establishing coral culture and other reef research at the Perry Institute for Marine Science's facility on Lee Stocking Island, Exuma (LSI). Since 2004, Erich has held an appointment there as Senior Research Scientist and expanded work from the LSI area south to Elizabeth Harbour (Great Exuma) and north into the Exuma Cays Land and Sea Park. His most recent work continues coral culture at LSI, developing methods to assess coral stress/resilience, field education programs and public outreach (youth and adults) throughout the Exumas. The findings within Dr. Mueller's report, "Reconnaissance of Proposed Channel and Dockage Sites: Bell Island, Exumas" are consistent with the information provided in this EIA and can be found in its entirety as Appendix III.

Bathymetric data was collected on 150 ft. transect lines for the areas immediately adjacent to the proposed basin and barge landing. Data for the channels around the island that lead to deep water were collected on 300 ft. transect lines. Contours were generated by interpolating the data and standardizing the water depths to mean low water (MLW).

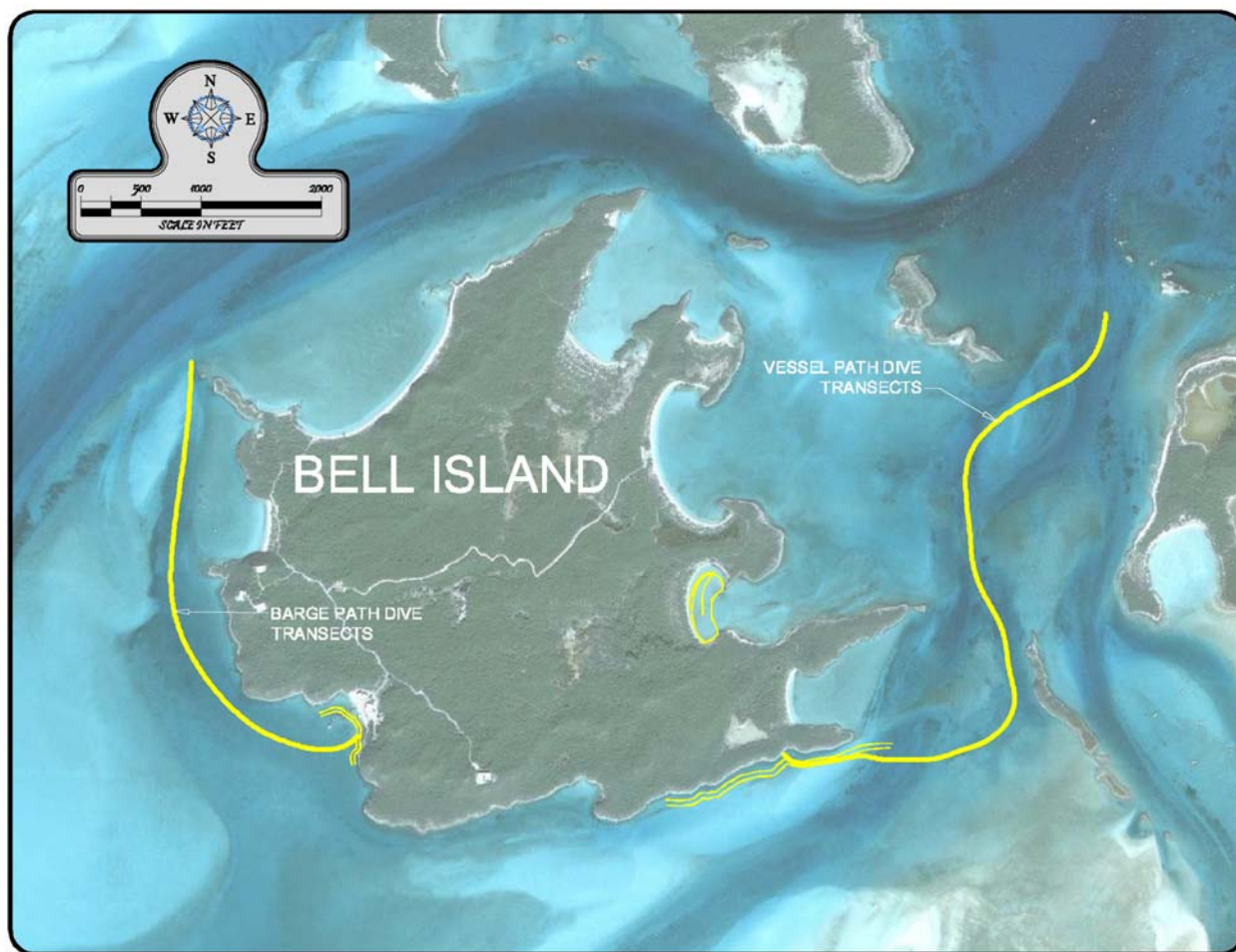


Figure 4.8 Dive Transect Map
(Exhibit 5)

HABITAT 1: ROCKY SUBTIDAL

A rocky bottom area predominated from 5-15 feet seaward of the rocky shoreline, where the water depth was approximately 4-6 feet. This is where the majority of the listed marine species were located. These areas will not be impacted by the planned construction. As recommended in Dr. Mueller's report, Appendix III, the inner limit of the yacht basin entrance channel has been offset from the rocky shore water line 20 feet.



Figure 4.9 A small coral head located outside of the dredge area.



Figure 4.10 Shoreline near the proposed basin entrance.

Left: The underwater photograph of black ball sponge (*Ircinia strobilina*), shaving brush algae (*Penicillus dumetosus*), thin finger coral (*Porites divaricata*), slippery dick wrasse (*Halichoeres bivittatus*), sargassum (*Sargassum spp.*), depressed brain coral (*Diploria labyrinthiformis*), tube sponge (*Pseudoceratina crassa*) and squirrelfish (*Holocentrus adscensionis*).

Right: The underwater photograph depicts typical rocky subtidal habitat.

HABITAT 2: SAND FLATS

Much of the area observed in the vicinity of both of the proposed access channels consisted of sand flats, with light patches of algal turf. The sand flats were found in water depths of six (6) feet and greater. Fuzzy finger algae (*Batophora spp.*) was the predominant species. Dr. Mueller's analysis of this habitat concluded that no significant environmental impacts are anticipated as a result of project work within this habitat.



Figure 4.11 The barge landing entrance channel, depicting fuzzy finger algae (*Batophora spp.*) and a barracuda (*Sphyraena barracuda*).

HABITAT 3: SEAGRASS SAND FLAT

The habitat observed in the vicinity of the proposed seagrass sand flat preservation area consisted of sand flats, with varying seagrass coverage. Seagrasses were found in water depths of three (3) feet and greater. The seagrass habitat consisted almost entirely of turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*). Mature and juvenile queen conch (*Strombus gigas*) were observed in the area of the seagrasses.



Figure 4.12 Typical seagrass habitat exhibiting turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*)

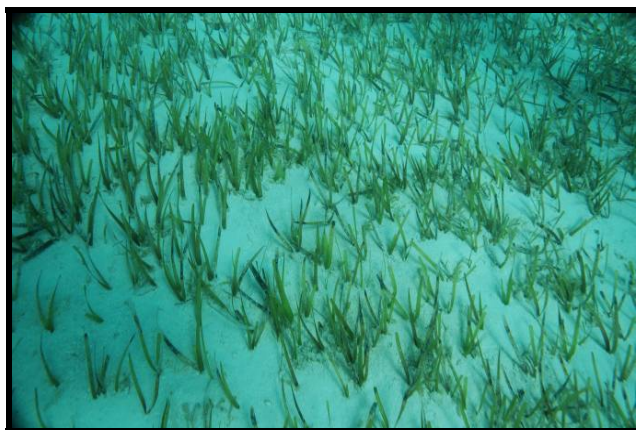


Figure 4.13 A turtle grass bed

4.8.1 Marine Wildlife Observations

Big Bell Island provides some habitat for marine turtles and marine mammals. No evidence of sea turtle nesting was found during the site investigations. The presence of the sandy beach habitat could potentially support sea turtle nesting and has been taken into account by the development plan. The construction of ingress/egress channels through rocky shoreline as opposed to sandy beaches will minimize potential impacts to nesting or hatching turtles. No impacts to any of the sandy beach areas are proposed.

Additional boat traffic created by the private yacht basin could have a minor impact on the marine animals in the form of potential collisions or fouling of the waters, but it is not anticipated due to the minimal increase in boat numbers associated with this project. Boater education and awareness are felt to be the best means of minimizing these potential impacts. Control of stormwater runoff is another means by which potential impacts to local water quality can be avoided. The methodologies to be outlined in the forthcoming EMP will address these issues. However, other than the minimal potential threat of collision, no other direct impacts to any marine mammals or sea turtles are expected.

Table 4-4 Underwater Species List

Grasses	
manatee grass	<i>Syringodium filiforme</i>
turtle grass	<i>Thalassia testudinum</i>
Corals	
common rose coral	<i>Manicina areolata</i>
depressed brain coral	<i>Diploria labyrinthiformis</i>
mustard hill coral	<i>Porites astreoides</i>
shallow-water starlet coral	<i>Siderastrea radians</i>
thin finger coral	<i>Porites divaricata</i>
Algae	
brown algae	<i>Dictyota guineensis</i>
calcareous algae	<i>Avrainvillea fenicalii</i>
fuzzy finger algae	<i>Batophora spp.</i>
green mermaid's wine glass	<i>Acetabularia calyculus</i>
mermaid fan	<i>Udotea spp.</i>
pink calcareous algae	<i>Neogoniolithon strictum</i>
sargassum	<i>Sargassum spp.</i>
shaving brush algae	<i>Penicillus dumetosus</i>
three finger leaf algae	<i>Halimeda incrassata</i>
white scroll algae	<i>Padina jamaicensis</i>

Sponges

black ball sponge	<i>Ircinia felix</i>
branching tube sponge	<i>Pseudoceratina crassa</i>
branching vase sponge	<i>Callyspongia vaginalis</i>
loggerhead sponge	<i>Spheciospongia vesparium</i>
red boring sponge	<i>Cliona deletrix</i>
red finger sponge	<i>Amphimedon compressa</i>
tube sponge	<i>Pseudoceratina crassa</i>
variable sponge	<i>Anthosigmella varians</i>
yellow boring sponge	<i>Siphonodictyon coralliphagum</i>

Gorgonians

common sea fan	<i>Gorgonia ventalina</i>
porous sea rod	<i>Pseudoplexaura spp.</i>

Worms

social feather duster	<i>Bispira brunnea</i>
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Vertebrates and Invertebrates

barracuda	<i>Sphyraena barracuda</i>
beaugregory damselfish (juvenile)	<i>Stegastes leucostictus</i>
blue chromis	<i>Chromis cyanea</i>
blue tang (juvenile)	<i>Acanthurus coeruleus</i>
bluehead wrasse (juvenile)	<i>Thalassoma bifasciatum</i>
curleycue anemone	<i>Bartholomea annulata</i>
French grunt	<i>Haemulon flavolineatum</i>
lionfish	<i>Pterois volitans</i>
Nassau grouper	<i>Epinephelus striatus</i>
queen conch	<i>Strombus gigas</i>
queen triggerfish	<i>Balistes vetula</i>
sea egg (collector urchin)	<i>Tripneustes gratilla</i>
sergeant major	<i>Abudefduf saxatilis</i>
slippery dick wrasse (juvenile)	<i>Halichoeres bivittatus</i>
squirrelfish	<i>Holocentrus adscensionis</i>
tomtate (juvenile grunt)	<i>Haemulon aurolineatum</i>
yellowtail snapper	<i>Ocyurus chrysurus</i>

This list is representative of the species seen during the dive transects.

4.8.2 Marine Habitats Further Described

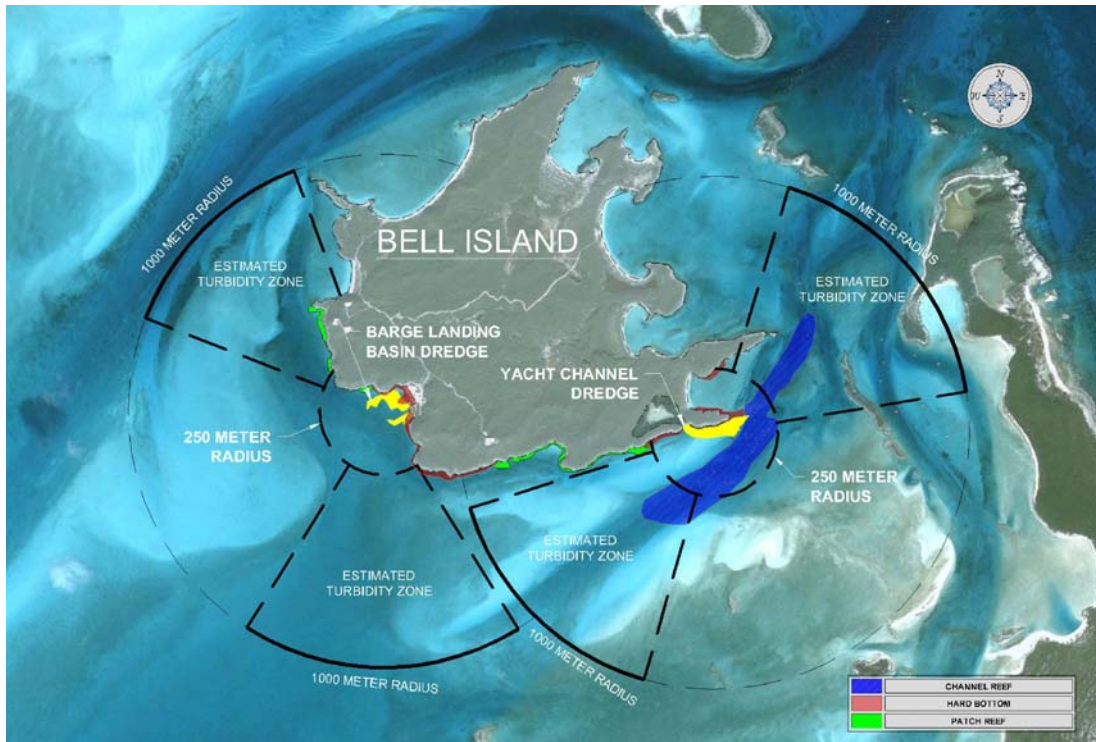
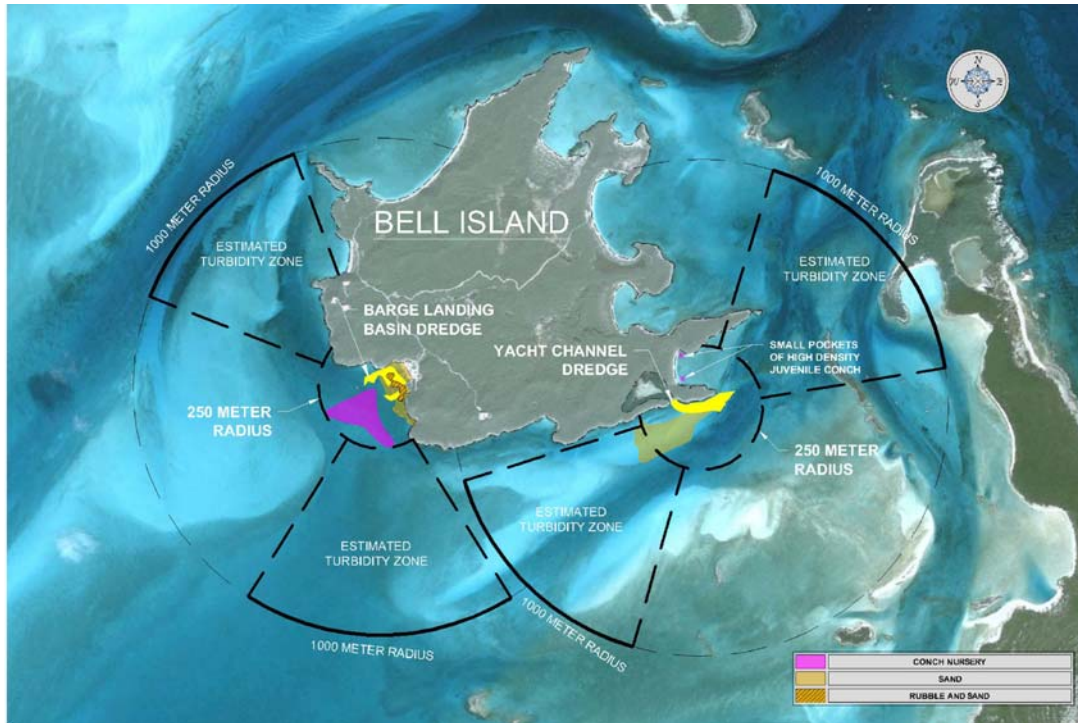
To gain even further understanding of the marine resources potentially impacted by the proposed dredging activities and within the “Estimated Turbidity Zone” Dr. Craig Dahlgren of the Perry Institute conducted an additional marine survey. In his report “Habitat Mapping and Biological Assessment of Marine Resources around Bell Island, Bahamas” marine habitats have been mapped within a 250m radius “Impact Zone” around each proposed dredging site and within an “Estimated Turbidity Zone” which includes areas within 1km of the proposed dredging site that may be impacted by sediment plumes due to transport in tidal currents. Within these areas, objectives were to (1) map habitats and (2) assess biological resources including corals, seagrass, and other benthic organisms, as well as fish and economically and ecologically important invertebrates such as conch, crawfish and the long-spined sea urchin *Diadema antillarum*. A description of the field portion of mapping is presented below.

A baseline habitat survey of the marine construction sites, their immediate surroundings and nearby control areas was conducted prior to any conservation (i.e. movement of corals or micro-patch reefs) or construction activity. Surveys defined habitat types described in earlier reports as well as subtypes, such as nursery areas for conch or other species. Mapping was done using a handheld GPS to allow integration with bathymetry data previously obtained by Turrell and Dr. Mueller. All mapping surveys will be shared with contractor personnel upon their selection. After any conservation activity, the appropriate areas will be updated in all associated documents and exhibits.

Habitat Mapping

Dr. Dahlgren systematically characterized marine habitats within 250 meters of the proposed dredged areas on Big Bell Island. A snorkeler was slowly towed behind a boat and signaled the habitat type, which was recorded approximately every 20 m and marked using a handheld GPS. The diver was towed in a grid pattern that ran transects across the survey area with the distance between transects ranging from approximately 20-50m. Within 30 m of the shoreline, due to safety concerns involving the boat, transects were conducted via snorkeling. Additional data points were collected from spot checks on special features that appeared on an aerial photograph of the area and from biological surveys conducted in seagrass areas. Habitats were classified into 6 main habitat groups and 3 unique habitats that occurred in specific areas. These habitats are listed below and their documented locations are depicted in Figure 4.14. A detailed habitat description can be found in Dr. Dahlgren’s full report provided as Appendix VII.

1. *Sparse – Medium Density Seagrass*
2. *Dense Seagrass*
3. *Hardbottom*
4. *Patch Reef*
5. *Sparse Seagrass and Algae*
6. *Rubble and Sand*
7. *Sand*
8. *Channel Reef*
9. *Seagrass Detritus*



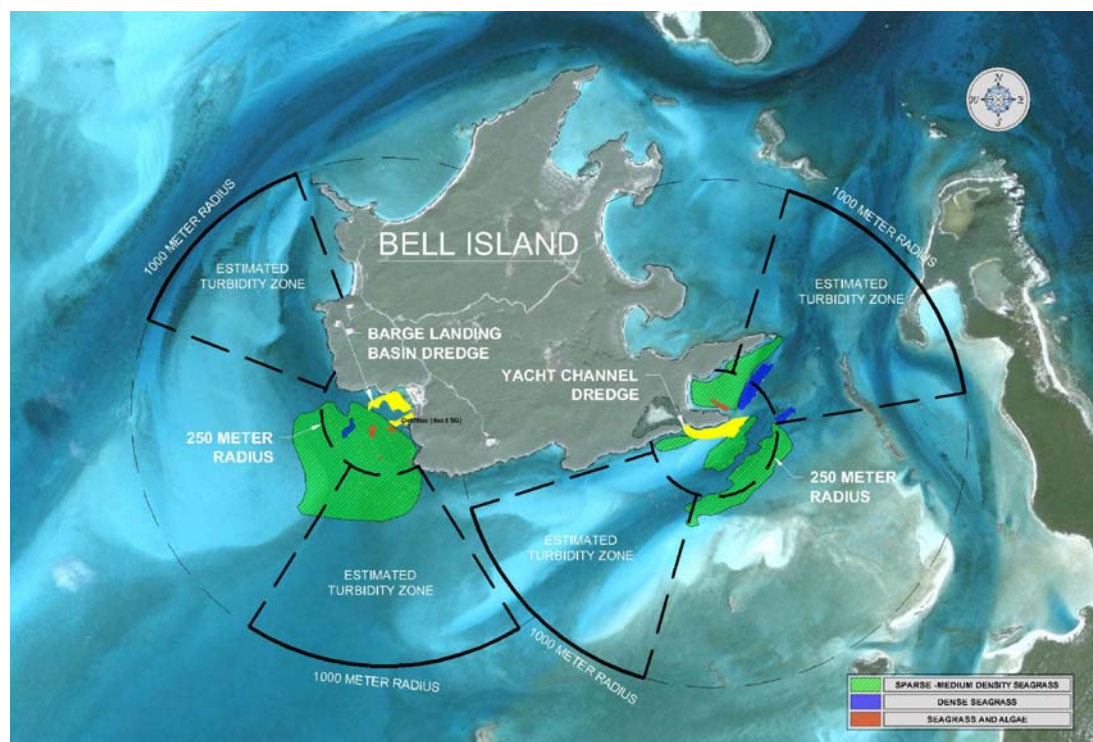


Figure 4.14 Marine Habitat Maps (Exhibit 8)

Biological Surveys

In addition to Habitat Mapping, Dr. Dahlgren's study included biological surveys of fish and benthic communities as well as conch populations within some of the sensitive habitat areas. Understanding what biological resources are present in various habitats that may be affected by the proposed dredging operations will allow for actions to lessen dredging impacts on these resources and monitoring of potential impacts. The quantitative surveys conducted were designed to assess representative areas of some of the more significant habitats that may be affected by dredging – Seagrass, Patch Reefs and Channel Reefs.

Fish and mobile invertebrate communities were assessed using 30m x 2 m belt transects in which all fish and select mobile invertebrates (Queen conch, Caribbean spiny lobster, long-spined sea urchins) were identified, their size estimated and counted. Along the same transect, substrate type and benthic organism cover was assessed at 50 cm intervals (60 points per transect). For analyses, substrates were divided into soft and hard substrates and hard substrate benthic organisms were grouped taxonomically into broad categories – Algae, Hard Coral, Gorgonians (soft corals), Sponges. In seagrass beds, the number of shoots for each species (*Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii*) and blade length for 10 shoots chosen haphazardly was assessed within a 25 cm x 25 cm area at 10 m intervals along each transect (4 surveys per transect). In both reef habitats, the species, number, size and percent living tissue of coral colonies larger than 5 cm was assessed within the same belt transect used for assessing fish. It is important to note that many larger coral colonies were mostly dead and fragmented into small pieces of living tissue. When it was easy to determine whether scattered fragments of live tissue were part of the same colony they were considered as part of that

colony (i.e., their living tissue was expressed as a % of the larger colony). For patch reef habitats, coral colonies were assessed throughout the entire 30 m x 2 m belt transect. High number of corals in the Channel Reef habitat (and difficult survey conditions due to currents) resulted in corals only being surveyed in a 15m x 2 m area.

Relocation of Significant Corals and Assemblages

Based on biological surveys, patch reefs and channel reefs within the 250m radius impact zones and in the Estimated Turbidity zones contain some of the biological resources that are most likely to be impacted by dredging activities. Live corals in reef areas within dredging zones should be relocated, and live corals on reefs that are likely to see high sedimentation from dredging should also be relocated. It is important to note that while relocation of living corals can minimize loss of reef building corals, it is likely that reef structure (i.e., fish habitat) may still be lost since much of the structure within patch reef habitats at present is dead coral heads, which may be difficult to relocate based on their size and the fact that boring organisms may have weakened the reef framework and cause it to fall apart if moved. In these cases options that will minimize dredging impacts (e.g., reducing sediment loads reaching these sites) might be more effective at maintaining the ecosystem than transplanting corals. If reef structure is to be removed from an area, large rubble pieces from the dredging operation may provide similar structure for fish and, if positioned properly and colonized by corals, may supplement transplanting efforts by filling a similar function to patch reefs. For transplanting corals, several suitable areas (e.g., areas with similar environmental conditions to where corals are currently growing in the impact zones) exist around Bell Island but specific sites should be examined in a bit more detail prior to translocation efforts. Patch reefs and Channel reefs in impact areas and Estimated turbidity zones affected by dredging activities should be monitored and changes on these reefs compared to nearby control reefs to assess impacts of dredging activity on biological resources in these areas.

The relocation areas will be monitored annually for two years following construction completion to document relocation success.

Conch Relocation

Conch should be removed from the immediate dredging areas prior to dredging and during dredging operations. There are many suitable relocation sites nearby to dredging areas. The conch nursery near the Barge Landing basin dredging area is one that should be monitored to ensure that the habitat remains suitable for conch and that conch continue to persist in this area.

Water Quality Assessment

Representative stations will be established around Big Bell Island and at several control sites for water quality sampling. It is estimated that 5-10 stations will be needed with locations to be determined through collaborative discussions. Basic parameters (temperature, salinity, turbidity) will be profiled using a Manta 2-35 multiprobe instrument (eureka environmental engineering, Austin, TX). At several selected sites, loggers (Alec Electronics, Kobe, Japan) will be deployed for continuous measurement of temperature, salinity (Compact CT) and depth (MkV/D; tidal cycle). Measurements will be made at 10 minute intervals and averaged to produce hourly values. Both the Manta and Alec instruments will be calibrated immediately before and after deployment using standards and protocols provided by the manufacturers.

Water samples will be examined with a suite of more advanced measurements and used to establish a baseline to compare to possible future testing associated with the operational phase of the project. The sampling is to include dissolved inorganic nutrients (NO_2^- , NO_3^- , NH_4^+ , soluble reactive phosphorous), chlorophyll *a*, and hydrocarbons. DIN and chl *a* measurements will be conducted at Florida International University's Southeast Environmental Research Center (SERC; Miami, FL). The assays employed at SERC are specifically designed to determine the low levels expected in oligotrophic tropical waters. Virtually all of seawater quality monitoring in South Florida is conducted by SERC.

Total Petroleum Hydrocarbon (TPH) assays will be conducted by Southern Analytical Laboratories, Inc. (Oldsmar, FL) using the State of Florida-approved FL-PRO (petroleum-related organics) method. This method provides a "fingerprint" of hydrocarbons 8-40 carbons long that can identify gasoline and diesel-related hydrocarbons.

All synoptic measurements (profiling and water sampling) will be made near the end of one ebb and one flood tidal cycle. All sampling and storage protocols specified by the recipient laboratories will be followed.

4.9 Biodiversity Including Protected Species of Animals, Birds, and Plants

The Bahamas ratified the United Nations Convention on Biological Diversity (CBD) on September 9, 1994. Since becoming a party to the CBD, their participation in enabling activities has allowed the completion of the National Biodiversity Data Management Assessment in 2004. This resulted in the establishment of the National Clearing-House Mechanism (CHM) for biodiversity information and the CHM website (BEST, 2005).

The Bahamas became a party to the Convention on International Trade of Endangered Species (CITES) on June 20, 1979. Since then the government has solidified its commitments to the management of endangered and threatened species through its enactment of appropriate legislation. Trade in such species has been restricted throughout The Bahamas.

Endangered species include the West Indian whistling duck (*Dendrocygna arborea*) and the loggerhead turtle (*Caretta caretta*). Threatened species include the queen conch (*Strombus gigas*) and the Bahama parrot (*Amazona leucocephala bahamensis*). Under The Wild Animals Protection Act of 1968, wild horses on the Island of Abaco are protected. Also recognized are the Bahamian hutia (*Geocapromys ingrahami*) and the rock iguana (*Cyclura spp.*) (BEST, 2005).

Approximately 300 species of birds have been recorded in the Bahamas. Of these, 109 species breed and are permanent residents, while the rest are either vagrants or migrating transients, (White 1998). The national bird is the greater flamingo (*Phoenicopterus ruber*). Three (3) bird species are endemic to the islands: the Bahama woodstar (*Calliphlox evelynae*), Bahama yellowthroat (*Geothlypis rostrata coryi*), and Bahama swallow (*Tachycineta cyaneoviridis*). The islands are a strategic stop-over or wintering ground for species escaping cold North American winters. Most species are West Indian in origin. This fact is related to patterns of glaciation during the last ice age when a shallow channel separated Cuba and The Bahamas. The circumstance created a short migration route for most of the flora and fauna found in the islands today.

The piping plover (*Charadrius melodus*) is a winter migrant. The West Indian whistling duck (*Dendrocygna arborea*) is threatened by hunting and is found on Andros and Hog Cay, off Long Island. The Kirtland's warbler (*Dendroica kirtlandii*) is a species for which the Bahamas are the only known wintering ground. These three (3) species have been recorded in the Bahamas (White 1998) and are considered vulnerable by Birdlife International. Countrywide, species of concern include the white crowned pigeon (*Columba leucocephala*) and the Bahama parrot (*Amazona leucocephala bahamensis*). The Bahama parrot is restricted to southern Abaco and Great Inagua. Hunting controls have successfully stabilized pigeon populations by closing the season at the end of September. Protected fauna include the rare hutia (*Geocapromys ingrahami*), the rock iguana (*Cyclura spp.*), and three (3) species of snakes. Bahama hutia are rodent-like mammals and are the dominant animal species on East Plana Cay. In a move to protect this species, a small Bahama hutia population was transplanted to two locations, Little Wax Cay and Warderick Wells. These three locations now host the only known populations of hutia.,.

The only species of concern observed on Big Bell Island was queen conch (*Strombas gigas*). However, their abundance was noted within the seagrass sand flat preservation area outside of any

impact areas. This same habitat allows Big Bell Island the possibility to support a bonefish (*Albula spp.*) population, though none were noted during the time of the site visit, it is important to note that no critical habitat will be permanently impacted as a result of this project.

The following species of trees are protected throughout the Commonwealth of the Bahamas (BEST, 2005) under the Conservation and Protection of the Physical Landscape of the Bahamas, as specified within the Declaration of Protected Trees Order of 1997 (BEST, 2005).



Of the above pictured species of flora, site observations were limited to lignum vitae (*Guaiacum sanctum*).

4.10 Uses of Biodiversity

While no quantitative data is available, the reefs and deep water just offshore are an important resource in terms of the recreational diving and educational opportunities they provide within the Exumas. No crabbing or hunting is allowed to take place on Big Bell Island because of its inclusion in the area of the Exuma Cay Land and Sea Park.

4.11 National Parks, Protected Areas, and Marine Reserves within the Area of Influence

On July 13, 1959 a special act of parliament directed the Bahamas National Trust to care for historical and natural beauty areas within the Bahamas. The park was designated as a no-take zone in 1986. Park visitors are told to “take nothing but photos and leave nothing but footprint.” The Exuma Cay Land and Sea Park is one of 25 national parks that is managed by the Bahamas National Trust. The park is 22 miles long and eight (8) miles wide. It covers approximately 176 square miles, and is 95 percent sea and only 5 percent land.

SOCIOECONOMIC ASPECTS

4.12 Adjacent Communities

Big Bell Island is privately owned and intermittently inhabited by the owner and personal staff. A census report for the year 2000 gave an approximate population of 3,571 for The Exumas. The nearest resort to the project site is the Sampson Cay Club located on Sampson Cay. It has proved to be a popular destination. The nearest large settlement is located on Great Exuma Island and is called George Town.

4.13 Existing Opportunities for Employment

There are presently few opportunities for employment associated with the Island in its current condition other than maintenance and preparation for any work proposed in this EIA.

4.14 Present Land Use

The island is privately owned and equipped for year round habitation.

4.15 Transportation, Docks, Roads, and Airports

Big Bell Island is accessible only by boat and helicopter. A public 3,000 feet airstrip is located about 10 miles to the south on Staniel Cay. Black Point, the largest population cluster in the area at approximately 300 people, is located about 17 miles south of Big Bell Island. The majority of employees commute from Black Point to Big Bell Island via boat.

CULTURAL ASPECTS

4.16 Historical Overview

“The Bahamas National Trust shall be established for the purpose of promoting the permanent preservation for the benefit and enjoyment of The Bahamas of lands and tenements (including buildings) and submarine areas of beauty or natural or historic interest and as regards lands and submarine areas for the preservation (so far as practicable) of the natural aspect, features, and animal, plant and marine life.”

*Statute Law of The Bahamas
Chapter 355, Section 4
Paragraph 1*

The paragraph above and much of the history was taken from The Cruising Guide to The Exuma Cays Land and Sea Park, 1994 by Stephen Pavlidis with Ray Darville.

The Exuma Cays Land and Sea Park is the first park of its kind in the world. It is also The Bahamas' oldest park. The park is one of 25 National Parks that is managed by the Bahamas National Trust. It is home to the rare stromatolites, hutia (*Geocapromys ingrahami*), rock iguanas (*Cyclura spp.*), and tropic birds. Conch Cut, within the park, has a stand of pillar coral (*Dendrogyra cylindrus*) that is over 4 feet tall and is one of the largest remaining coral remnants in the region.



Figure 4.15 Exuma Cays Land and Sea Park signage.



Figure 4.16 Pirates Lair sign on Warderick Wells Cay.

The Exuma Cays Land and Sea Park was first conceived by a man named Daniel Beard. He suggested setting aside an area to preserve the natural beauty of The Bahamas. In 1955, Colonel Ilia Tolstoy proposed to the government that they allocate an area for a land and sea park. A year later, the Bahamas government designated a stretch of 22 miles from Shroud Cay to Little Bell Island as the Exuma Cays Land and Sea Park. The Crown also gave one year for an organization to step forward, explore, and take responsibility for the upkeep of the park. Carleton Ray, from the New York Aquarium, and Daniel Beard surveyed the recommended area to see how viable the park would be. The Crown gave the men additional time in 1958 to continue their work. The survey led to establishing the Bahamas National Trust, park boundaries, regulations, and the need for a warden. The proposed warden station was to be located on Norman's Cay, but later was placed on Warderick Wells. On July 13, 1959, a special act of parliament called for the Bahamas National Trust to care for the historical and natural beauty of areas within the Bahamas. In 1986, the Exuma Cays Land and Sea Park was designated as a "no-take" zone. Park visitors are told to "take nothing but photos and leave nothing but footprints."



Each area within the Exuma Cays Land and Sea Park has unique characteristics. Little Wax Cay is home to the hutia (*Geocapromys ingrahami*), which is the only terrestrial mammal native to The Bahamas. Hawksbill Cay contains Loyalist settlement ruins from the 1700s. Warderick Wells Cay also contains Loyalist settlement ruins and the Pirate's Lair. Pasture Cay was once a cattle pasture. The Rocky Dundas possess' impressive stalactite and stalagmite formations that are found nowhere else in the world. The conch shells on the opposite side of the island are said to date back to the 1500s.

4.17 Archaeological and Historic Resources

A specific archaeological survey was not carried out. Pedestrian walkovers conducted during the survey periods uncovered no archaeological evidence such as mollusk shells or pottery fragments.

4.18 Paleontological Resources

No fossil resources or signs were located during the survey periods. A specific paleontological survey was not completed.

4.19 Tourist and Recreational Areas

The Exuma chain is a sparsely populated area of the Bahamas with approximately 3,571 permanent residents according to the census taken in the year 2000. Most people reside on Great Exuma Island. There is an increasing number of foreign seasonal visitors, many of whom own second homes. The primary interests in the area are for its marine resources, including sportfishing opportunities, where deep water can be readily accessed, and for the quality of diving.

4.20 Aesthetics and Visual Impacts

The periphery of Big Bell Island is strikingly beautiful with white sand beaches and rocky shorelines plunging directly to the sea. The vegetative communities present on the island will provide guests and visitors the opportunity to appreciate nature in The Bahamas.

4.21 Community Organizations

As Big Bell is a privately owned residential island no "community organizations" exist.

PROVISION OF SERVICES

4.22 Potable Water

The utility and storage area is presently equipped with potable water thru RO equipment and the expansion will increase the demand on the system to the threshold which would require an upgraded unit. Potable water will be supplied to the basin via underground connection piped from the island's improved reverse osmosis system.

4.23 Sewerage and Wastewater

The upland facilities are currently equipped with permitted septic treatment for all sewerage and wastewater. These facilities are planned to be supplemented with deep well injection.

Sewage pumpout will be provided in the yacht basin to each of the larger vessels that generate black or grey water. A vacuum system will be used to pump the wastewater into a septic tank located in the vicinity of the basin with an associated deep well, as permitted by Bahamas Water and Sewage Corp.

4.24 Roads

No vehicular traffic is currently supported on the island. Shell and rock pathways have been created throughout the island and are capable of accommodating golf carts and/or ATVs necessary for daily transportation and the proposed construction activities.

All roads will be approved by the Ministry of Works. There will be limited vehicles which will be required for construction activity. Any roadways created specifically for construction purposes will be regraded and vegetated after construction completion.

LEGAL AND REGULATORY

4.25 Pertinent Laws and Regulations, Including the Antiquities, Monuments, and Museums Act

- The Bahamas Environment, Science and Technology (BEST) Commission
- The National Creeks and Wetlands Restoration Sub-Committee
- Department of Agriculture
- Department of Fisheries
- Ministry of Public Works and Transport
- The Port Authority
- Ministry of Health
- Department of Environmental Health Services
- Ministry of Maritime Affairs
- Water and Sewerage Corporation
- Ministry of Tourism
- District Councils and Town Committees
- Town Planning Committee

Additionally, a series of specialized laws have been passed in The Bahamas which affect activities occurring within the coastal zone.

- *Antiquities, Monuments and Museum Act* (1998)
- *Conservation and Protection of the Physical Landscape of The Bahamas Act* (1997)
- *Local Government Act* (1996)
- *Archipelagic Waters and Maritime Jurisdiction Act* (1993)
- *International Persons Land-Holding Act* (1993)
- *Environmental Health Services Act* (1987)
- *Wild Birds Protection Act* (1987)
- *Plant Protection Act* (1987)
- *Fisheries Resources (Jurisdiction and Conservation) Act* (1977)
- *Water Supply Corporation Act* (1976)
- *Wild Animals (Protection) Act* (1968)
- *Coast Protection Act* (1968)
- *Agriculture and Fisheries Act* (1963)
- *Town Planning Act* (1961)
- *Bahamas National Trust Act* (1959)
- *Immovable Property (Acquisition by Foreign Persons) Act and Quieting of Titles Act* (1959)
- *Water skiing and Motor Boat Control Act*
- *Hotels Act*
- *Port Authorities Act*
- *Marine Mammal Protection Act*

International Agreements

The Bahamas is a party to several international environmental agreements that either affect or may affect the management of the coastal resources of The Bahamas. For example, the *Ramsar Convention on Wetlands* (1971) calls for the conservation and wise use of wetlands to achieve sustainable development. Operational wetlands conservation guidelines, as well as funding opportunities for individual wetlands conservation projects are available through the *Ramsar Convention* to party nations. Currently, The Bahamas has no national law or regulation that specifically addresses wetlands protection. The *Montreal Protocol on Substances that Deplete the Ozone Layer* (1987) addresses ozone depletion, which is an environmental issue with indirect impacts on the coastal zone, because of its interconnection with global warming and sea level rise. The *Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (The Cartagena Convention)* (1986), coordinated by United Nations Environmental Program (UNEP), includes three protocols: the *Oil Spill Protocol*, the *Specially Protected Areas and Wildlife (SPAW) Protocol*, and the *Land Based Sources of Marine Pollution (LBSMP) Protocol* (not yet finalized). The *SPAW Protocol*, which went into effect in June 2000, calls for the protection, management and development of marine and coastal resources individually and jointly among countries. Although The Bahamas is not a party to the Protocol, several other Caribbean countries have entered into these agreements and their actions may have impacts on the coastal zone of The Bahamas.

Additionally, provisions of the World Bank and World Health Organization regarding noise pollution will be met.



4.26 Government Agencies Involved in Permitting and Licensing

Bahamas Investment Authority

The Bahamas Environment, Science & Technology Commission

Department of Environmental Services

Ministry of Works and Utilities

Port Department

Water and Sewerage Corporation

Department of Lands & Surveys

CHAPTER 5 ENVIRONMENTAL IMPACTS

5.0 Methodology for the Impact Assessment

To accurately assess environmental impacts associated with the proposed project, fieldwork was undertaken to map and describe habitats, species, and physical parameters of the impact areas. The upland sites were surveyed on foot with observed species noted and photographed and physical conditions described. Ground-truthing was accompanied by low-level flights and photography to map and depict on-site features.

Marine portions of the project and the surrounding area that would be affected by the private yacht basin channel and barge landing / service dock, construction, armoring, and dredging were snorkeled and habitats characterized, photographed, and described. These same areas were independently assessed by Dr. Erich Mueller of eVm Research and Design. His report, "Reconnaissance of Proposed Channel and Dockage Sites: Bell Island, Exumas" concluded that no significant environmental impact is anticipated in the project area. The full document is provided as Appendix III. To gain even further understanding of the marine resources potentially impacted by the proposed dredging activities and within the "Estimated Turbidity Zone" Dr. Craig Dahlgren of the Perry Institute conducted an additional marine survey. In his report, "Habitat Mapping and Biological Assessment of Marine Resources around Bell Island, Bahamas" marine habitats have been mapped within a 250m radius "Impact Zone" around each proposed dredging site and within an "Estimated Turbidity Zone" which includes areas within 1km of the proposed dredging site that may be impacted by sediment plumes due to transport in tidal currents. The report in its entirety is provided as Appendix VII.

Bathymetric data was also collected on 150 ft. transect lines for the areas immediately adjacent to the proposed basin and barge landing. Data for the channels around the island that lead to deep water were collected on 300 ft. transect lines. Contours were generated by interpolating the data and standardizing the water depths to mean low water (MLW).

Consideration of the possible results of the planned work was made based on knowledge of proposed construction methods and experience with similar projects. The following descriptions address the likely impacts and cover how negative effects will be countered both during and after construction. These are summarized from Chapter 6, Proposed Minimization and Mitigation Measures.

IMPACTS TO THE PHYSICAL ENVIRONMENT

5.1 Erosion, Sedimentation Impacts

Aspects of construction and operation of the proposed project which may result in increased erosion or sediment production include:

1. Clearing of land for the construction of the yacht basin, associated infrastructure, trails, and utility and storage area.

Of all land use changes, construction activities have the greatest potential to produce short-term increases in erosion and sediment production. The primary cause of erosion and sediment production is the removal of stabilizing vegetation. It is exacerbated when natural landform is converted to impermeable surface area that leads to direct rainfall runoff, which takes with it the large quantities of dust and debris. Windborne dust can also be a source of sediment deposition in the vicinity of construction activities.

A sediment control plan will be prepared and disseminated to construction personnel to minimize this potential on-site clearing activity. This plan will outline methods to properly manage sedimentation impacts. It will also provide information regarding the maintenance of sediment control devices such as turbidity curtains, silt fencing, sandbags, mulching, and water spraying.

2. Dredging and maintenance dredging for the yacht basin and access channel as well as the service dock / barge landing and access channel.

Sources for increased mobilization of sedimentary material during construction of the marine portions of this project are: dredging/excavation of the basin access channel, dredging of the service dock / barge landing and access channel, and deposition of dredge generated material in the designated upland receiving area.

To minimize these unavoidable negative impacts, the following factors will be incorporated;

- *Construction schedule that restricts impacts to a short time period* - Best efforts will be made to work with marine contractors to expedite the earth-moving work associated with excavating the basin and completing navigational improvements.
- *Stabilization of unconsolidated shorelines* – Installation of seawalls, riprap, and where necessary, protective filter cloth to reduce the chronic suspension of fine materials from just-cut surfaces.
- *Construction methodology to compliment turbidity management* - The yacht basin will be excavated from the salt pond area prior to tidal connection. Keeping the basin excavation isolated from tidal waters will not only keep turbidity from entering the adjacent water body, but it will also make excavation of the basin easier since tidal currents and rapid changes in water levels will be eliminated. During access channel dredging, for both the private yacht basin and the service dock / barge landing, weighted turbidity curtains will be employed to limit the introduction of suspended sediment. Curtains will be placed across the mouth of the

access channel while excavation is proceeding to connect the basin to the sea. A larger system will be utilized to surround the dredge equipment during access channel dredging. Turbidity monitoring will proceed throughout construction in order to manage curtain locations. Turbidity readings will include a background check upstream of the work and within the densest portion of any notable turbidity plume. Should work indicate an increase in readings over acceptable levels, dredge activities will be halted and curtains will be repositioned to better contain the suspended sediment produced.

- *Containment of upland receiving areas* - A settling basin adjacent to the basin will be constructed to allow turbidity-laden water to filter and drain away, leaving clean sediment to the extent possible.

3. Flushing considerations for the proposed yacht basin.

The flushing potential of any yacht basin is a vital part of its design as it deters stagnant water, which is often associated with poor water quality. The yacht basin at Big Bell Island was designed so the flushing characteristics are beneficial to water quality to the greatest extent possible, as summarized below and provided in detail in "Big Bell Island Flushing Memo", provided as Appendix I.

The proposed basin depth will be approximately -14 feet Mean Low Water (MLW), which will accommodate the draft of the owners and guest vessels. The yacht basin was engineered to allow water to flow in and out smoothly throughout the duration of the typical tidal cycles. It also avoids any "dead" pockets of water, such as angular corners or holes in the bottom of the basin. The basin was designed with curved shorelines to help better circulate water during tidal periods and discourage stagnant water from accumulating in sharp, dead-end corners. Ultimately, the size of the proposed basin is relatively small and the flushing period will be comparatively short. It will not pose a threat to the existing water quality of the area.

Wind-driven currents within the basin are expected to further mix the waters and enhance flushing. The basin is directly exposed to Atlantic Ocean breezes over the low eastern island terrain. Consequently, it is relatively exposed to the prevailing winds in the summer and winter seasons. Therefore, wind-driven mixing will assist with tidal flushing and other factors to maintain water quality.

The basin will be designed with an optional flushing culvert to be located southwest of the entrance channel. The flushing culvert is to be constructed in the future only if water quality within the completed basin does not meet standards.

Other Best Management Practices (BMPs) will be implemented to maintain good water quality. Such BMPs will include:

- wrapping of all copper chromated arsenate (CCA) treated pilings with PVC to prevent leaching of CCA into the water column. The wrapping will also increase the life of the piling.

- prohibiting the discharge of sewage or waste in the basin and providing a sewage pump-out system that will be available to all boats using the basin.
- allowing the installation of boatlifts for smaller vessels, which will reduce or eliminate the contact of lead or copper based paint (vessel hulls) to basin water. Boats that are stored on lifts often forgo painting their hulls, since the lift keeps the vessel dry, free of barnacles, and other bottom encrusting, or staining, organisms. The boatlifts will also allow vessels more protection from storm surges which will, on occasion, affect this area of The Bahamas.

4. Increased long-term boat use.

During regular operation of the project, increased usage of the approaches and area waters have the potential to stir up small amounts of sediment.

Proper navigational markings and the utilization of charts and yacht basin guidelines will limit the potential for accidental groundings.

5. Increased impermeable surface areas.

Limitations on impervious surfaces and protection of undeveloped areas have been recognized as important sediment control methods. By limiting impervious surfaces, precipitation has the opportunity to infiltrate the ground, resulting in less stormwater runoff. This reduces erosion and makes stormwater management easier. Prohibiting or restricting clearing in steep-slope areas can avoid potential sediment problems such as surface erosion and, in some cases, landslides.

As only yacht basin development, service dock / barge landing improvements, and utility and storage area expansion are proposed, a significant increase in impermeable surface area is not expected to adversely impact the island. On-site vegetation is to be retained to the fullest extent practicable.

5.2 Viewscape Impacts

There will be little to no impact to the viewscape of Big Bell Island from the sea and surrounding cays by the proposed activities. The private yacht basin was designed to intentionally provide privacy and be hidden from view to a large extent. By situating the yacht basin where the island's salt pond currently lies, all evidence of proposed basin will be concealed from offshore vantage points, save for the access channel and its protective jetties. Service dock / barge landing improvements and the utilities and storage area expansion will only serve to enhance the appearance of the island's infrastructure currently in use.

5.3 Hydrologic Impacts

No groundwater resources were located on the property that would be affected by the proposed work.

5.4 Air Quality Impacts

Air quality will be affected only marginally when boats, vehicles, and machinery are necessary and cause emissions during the building and operational phases of the project. The lack of existing industrial activity in the vicinity and high standards of air quality via constant ocean breezes which blow across the island minimize the impact of any project-related detrimental effects.

5.5 Noise Impacts

Small increases in ambient noise levels will be attributable to the project both during construction and operation. This will not be at levels which could be considered a nuisance or deterrent to either humans or wildlife in the area.

5.6 Solid, Liquid, and Hazardous Waste Impacts

Solid waste generated during construction and operation will be transported to nearby designated dump sites.

Should a fish cleaning station be included in the yacht basin layout, it will be located close to the basin entrance to minimize waste disposal into the enclosed basin. Other fish-cleaning stations are located throughout the Exumas without detrimental effect. Fish-cleaning at the Big Bell Island facility is anticipated to be infrequent and would consist of fish that were caught outside of the park boundary. Most fish cleaning will take place at the barge landing / service dock.

Recommendations are for on-site mulching of the cleared vegetation material to be used in landscape activities throughout the island.

5.7 Fire and Hurricane Risks

Upon construction of the facilities, safety manuals will be prepared outlining protocol and procedures for emergency situations such as fires and storms. Proper containment of dangerous situations will be available for any hazardous materials and staff will be required to undergo training in emergency procedures and operation of equipment such as fire extinguishers and hurricane securing devices. The plan of action for such events will be described thoroughly in the EMP.

BIOLOGICAL IMPACTS

5.8 Habitat Loss and Degradation Impacts

The impacts of the proposed activities are limited to the loss of less than 5 acres of natural upland areas, primarily coastal coppice and salt pond habitats. The dredge impact areas associated with the service dock / barge landing area and the basin access channel consist of approximately 4.8 acres of shallow sand flats.

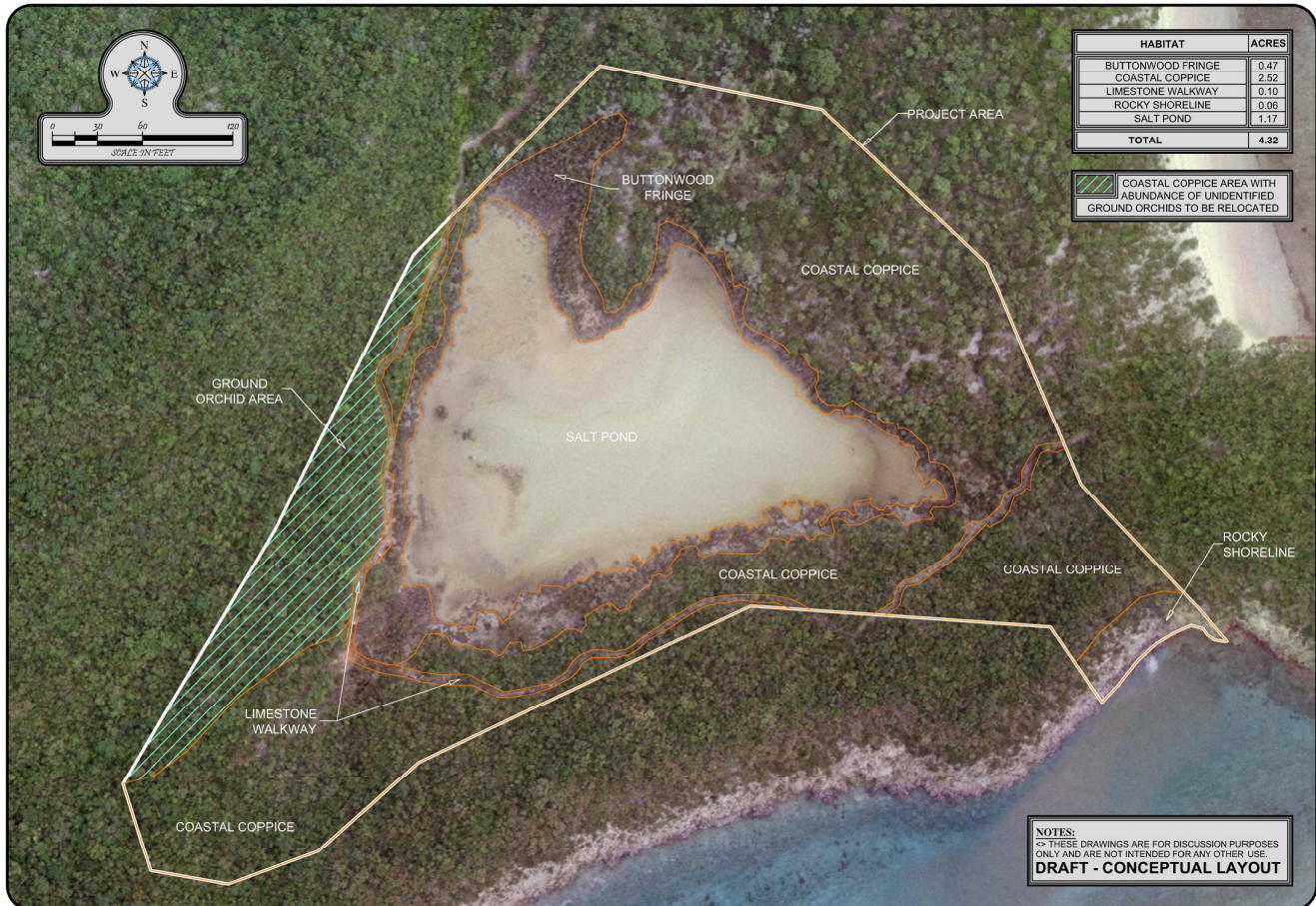
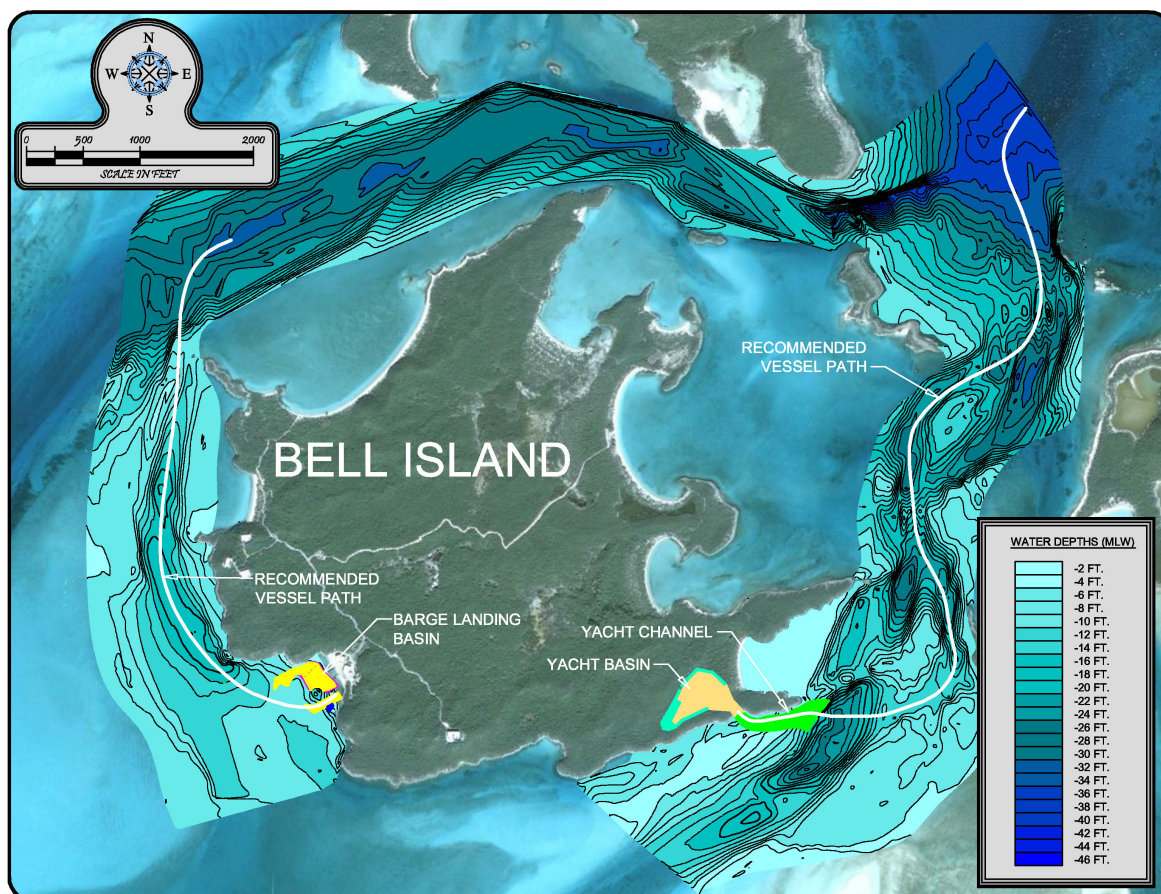








Figure 5.1 Private Yacht Basin Upland Impacts
(Exhibit 6)



Figure 5.2 Utility and Storage Area Upland Impacts
(Exhibit 7)



BARGE LANDING	
	DREDGE TO -5' MLW
	DREDGE TO -7' MLW
	DREDGE TO -9' MLW

YACHT BASIN	
	EXCAVATE TO -8' MLW (BASIN)
	EXCAVATE TO -14' MLW (BASIN)
	DREDGE TO -14' MLW (CHANNEL)

NOTES:

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- <> THESE DRAWINGS ARE FOR DESIGN PURPOSES ONLY AND ARE NOT INTENDED FOR CONSTRUCTION
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- <> MLW WAS ESTABLISHED DURING A TWO DAY TIDAL STUDY WHILE DATA WAS COLLECTED
- <> MLW = 1.3 FT. MSL

BARGE LANDING BASIN DREDGE VOLUMES		
AREA DESC	TOTAL AREA (ft ²)	DREDGE VOLUME (yds ³)
-5' MLW	2417.4	192.9
-7' MLW	6450.9	806.2
-9 MLW	86177.3	11238.1
TOTALS	95045.6	12237.2
YACHT BASIN EXCAVATION VOLUMES		
AREA DESC	TOTAL AREA (ft ²)	DREDGE VOLUME (yds ³)
-8' MLW	34689.7	13786.0
-14' MLW	148233.8	91397.5
TOTALS	182923.5	105183.4
YACHT BASIN CHANNEL DREDGE VOLUMES		
AREA DESC	TOTAL AREA (ft ²)	DREDGE VOLUME (yds ³)
-14' MLW	111956.4	31128.2
TOTALS	111956.4	31128.2
AVERAGE CUT DEPTH (ft)		
BARGE LANDING	3.3	
BASIN	15.7	
BASIN CHANNEL	7.4	

Figure 5.3 Dredge Area Impacts
(Exhibit 3)

5.9 Habitat Fragmentation Impacts

The restricted clearing limits associated with the minor areas of impact and the low-intensity nature of the proposed activities renders this impact minimal.

Yacht basin channel alignment will disrupt only a sand flat fringed by subtidal rocky habitat that is routinely subjected to harsh tidal currents. Service dock / barge landing improvements are planned for the approach currently utilized by the supply barge. Dr. Mueller's report, Appendix III, and Dr. Dahlgren's report, Appendix VII, both provide independent peer-review of these findings.

5.10 Biodiversity Impacts

A detailed botanical survey will be carried out prior to the commencement of clearing in order to mark populations and individuals of any unique or protected plant species. Hog cabbage palm (*Pseudophoenix sargentii*), a species of bromeliad, swollen wild pine (*Tillandsia utriculata*) and orchid species *Encyclia gracilis* and *Vanilla barbellata* were observed within the impact area along the western side of the salt pond. These species are planned to be salvaged to the maximum extent possible, collected and relocated to the native plant nursery and other areas on the island. The palms growing in pure rock substrate will not be moved.

Lignum vitae was noted within the coastal coppice and outside of the impact areas and thus will be avoided. Eradication of invasive plants will add to species complexity on the island. The extent of natural areas remaining on-site, post-development, will allow for continued use by protected fauna not observed at the time of survey.

5.11 Marine Resource Impacts

Based on biological surveys by Dr. Craig Dahlgren, patch reefs and channel reefs within the 250m radius impact zones and in the Estimated Turbidity Zones contain some of the biological resources that are most likely to be impacted by dredging activities. The Patch Reef habitat type includes areas of unconsolidated, often widely scattered living and dead coral heads surrounded by either hard or soft substrates. The key feature that separates this habitat type from hardbottom habitats is the three dimensional structure that living and dead coral colonies provide and the value of this structure for supporting diverse fish and invertebrate communities. Individual coral colonies may range in size from 30 cm to 10m in diameter and may be comprised of 100% living coral to colonies with <10% cover by live coral tissue.

Live corals in reef areas within dredging zones will be relocated. The general location of the coral resources that are planned for relocation can be found at the western origin of the yacht basin channel, as shown in Exhibits 9 and 10. Dr. Dahlgren also recommended that live corals on reefs that will not be directly impacted but may be likely to see high sedimentation from dredging, should also be either relocated or afforded increased protection from dredge impacts. It is important to note that while relocation of living corals can minimize loss of reef building corals, it is likely that reef structure (i.e., fish habitat) may still be lost since much of the structure within patch reef habitats at present is dead coral heads, which may be difficult to relocate based on their size and the fact that boring organisms may have weakened the reef framework and cause it to fall apart if moved. In these cases options that

will minimize dredging impacts may be deemed more effective at maintaining the ecosystem than transplanting corals. These options consist of reducing sediment loads reaching these sites by employing additional turbidity curtains to surround the resources. This procedure will most likely be utilized between the north edge of the yacht basin channel and the rocky shoreline to prevent sedimentation from settling on the resources.

Dr. Dalhgren's report states that there were no major conch habitats observed within the proposed dredge area and thus, making unlikely for a conch nursery to be impacted. As a preventative measure live conch will be removed from within to 100 m beyond the immediate dredge area.

5.12 Impacts on Special Features, Such as Caves and Blue Holes

While no caves or blue holes have been identified on the island, there are several large solution holes noted throughout.

SOCIOECONOMIC IMPACTS

5.13 Land Use Impacts

Chapter 4.5 provides a baseline description of existing land uses. Once completed, the site will consist of a yacht basin, improved service dock / barge landing, an expanded utility and storage area, a native plant nursery, an improved road network, and possible future mangrove restoration. The proposed mitigation associated with the development activities will rid the island of casuarina invasion.

5.14 Impacts on Neighboring Communities

While project owners are non-Bahamian, the use of foreign labor has been and will be minimized. Where skilled Bahamians are available to work, they will be preferentially employed to the extent possible.

5.15 Population Relocation Impacts

There will be no relocation impacts associated with this project.

5.16 Traffic Impacts, Including Marine and Air Impacts

By increasing visitation and use of the site, additional boat traffic may result. These impacts are both directly and indirectly associated with the proposed work. Boat traffic will be as a result of yachts and small dinghies visiting in the basin. Currently, during construction, and less frequently during operations, barges and vessels do and will visit. These would be used for the transportation of fuel, materials, and supplies around the Exumas.

Impacts from these changes include hydrocarbon emissions: dust, fumes, and waterborne oils, and greases. The minute increase in fuel use must also be considered. Fuel is a known contributor to greenhouse warming and creates the potential for spills in off-site locations. Given the small scale of the project and the anticipated utilization of the facility, these are considered as minor changes and are not expected to adversely affect ambient conditions.

Operating a clean facility with modern and well maintained fuel spill containment equipment and regularly tested procedures are important components of the proposal. So are safe disposal of hazardous wastes and a sewage pumpout facility for visiting vessels. Guidelines for safe boating practices will be available for all guests.

Within the property, the primary means of transportation will be gasoline or electric powered golf carts and/or ATVs. Golf carts will reduce fume emissions due to a lesser demand for fuel as well as to contribute to noise reduction.

Note that Blue Flag standards will be sought for the marine and beach facilities.

5.17 Economic Impacts

By providing jobs both during construction and later operation, the project is expected to have a positive impact on the economic base of the region and the country as a whole. A more widespread demand for goods and services can be projected beyond the work directly required by the project.

5.18 Aesthetic and Visual Impacts

Retaining the ambience and natural aesthetic appeal of the island is in the best interest of the project owners. Cleanup of existing nuisance vegetation is regarded as a positive impact. Conservation of natural vegetation around the project, as well as planting of native landscaping species within the nursery and around the island, will minimize the visual impact of the planned structures and help them blend into the background.

CULTURAL IMPACTS

5.19 Losses of Archaeological, Historic, and Paleontological Resources

No cultural resources were located during the site survey. The historically undeveloped nature of the site reduces the potential that any resources of cultural significance are located on Big Bell Island.

5.20 Preservation of Resources

Prior to construction, all contractors and their staff involved in site-clearing will undergo an environmental training session. The project is placing enormous effort towards positioning the proposed private yacht basin and all other development in areas that will precipitate the fewest negative impacts possible.

CHAPTER 6 PROPOSED MINIMIZATION AND MITIGATION MEASURES

Mitigative actions, warranted by significant environmental impacts, are described below, together with aspects of the project plans that serve as those measures.

6.0 Casuarina Removal

Casuarina (*Casuarina equisetifolia*), sometimes referred to as Australian pine, is native to Australia, Southeast Asia and the south Pacific Islands. Casuarina is a non-native nuisance species in The Bahamas. It was originally brought over in the 1800's to south Florida and was planted in the mistaken belief that the trees could prevent erosion and from there quickly spread to The Bahamas around the 1930's. The Florida Exotic Pest Plant Council rates Australian pine as a Category I plant. This category is defined as an "invasive exotic that is altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives."

In spite of its common name, Australian pine is not a true pine but rather a flowering tree. Casuarina has what appear to be long, soft, gray/green needles but these "needles" are actually multi-jointed branchlets. Its shallow roots rarely penetrate deep into the soil. Planted in many areas to prevent erosion, this tree actually increases erosion by eliminating native vegetation with deeper roots. The shallow roots also make these trees prone to wind-throw during storms.

Casuarinas do not rely on living organisms for pollination; it casts its pollen to the wind, known as anemophilous pollination. The tree is very effective at out competing native plants for light and nutrients. When established it alters the temperature, light, and chemistry of soils, which drastically affects the native plants and animals beneath it. Casuarina is thought to possess allelopathic properties. Allelopathy is the ability to exude chemicals that inhibit growth of other species beneath it. Casuarinas are known to decrease soil pH, which has a dramatic effect on the capacity of the soil to retain nutrients.

Big Bell Island possesses a stand of casuarinas to the northwest of the salt pond measuring approximately 2.7 acres in size. That stand of casuarinas is slated to be eradicated in an effort to mitigate for the minor construction activities proposed in this report. The trees will be felled and properly disposed of. The remaining stumps will be treated with an herbicide to prevent resprouting and insuring a halt to seed dispersal.

6.1 Marine Mitigation Commitments

Mitigation for marine construction activities, those which may result in the alteration of benthic habitat and temporary turbidity impacts will be through the use of BMPs previously mentioned, as well as the commitments that follow.

- Commitment to uphold construction guidelines which include turbidity management and monitoring.
- Channel and yacht basin alignment which results in the least possible loss of marine resources and dredging requirements.

- Agree to monitor and document colonization and recolonization of the yacht basin and access channels by marine benthic communities.
- Installation and maintenance of a sewage pumpout operation for the private yacht basin facility.
- Pledge to pursue Blue Flag Certification for the private yacht basin facility.
- Significant live corals in reef areas within dredging zones will be relocated.
- Live corals on reefs that are likely to see high sedimentation from dredging will also be relocated.
- Conch should be removed from the immediate dredging areas prior to dredging and during dredging operations, as further detailed in the EMP



6.2 Long-term Mitigation Commitments

Secondary impacts which result from increased use of terrestrial and marine resources by future visitors to the island and boat basin are an example of impacts which cannot be precisely quantified. Over the long term, there may be additional pressure on natural resources stemming from the greater use of the area. Included in this regard are the minor impacts associated with noise, air quality, water use, and waste generation that additional boats and visitors might generate. Aspects of the project which are considered to be compensatory for these residual impacts include:

- Educational efforts focused on the Exuma Cays Land and Sea Park. Hopefully, gaining an appreciation of the natural resources of The Bahamas may serve to strengthen public opinion about conservation concerns through an attractive and well-run boat basin and ranger's station
- Increased tax revenues for the Bahamian Government which may in the future be directed towards environmental protection efforts.

CHAPTER 7 ENVIRONMENTAL MANAGEMENT PLAN

An effective Environmental Management plan can be prepared quite accurately after preliminary approvals for the project are in place and the site plans have been finalized in conjunction with the Ministry of the Environment and Bahamas National Trust. After the preliminary steps have been completed, the document can then include the following specific guidelines which: outline a monitoring plan to ensure aspects of the project which are relevant to environmental protection; will create a means by which the guidelines will be adhered to; encourage the project to be built as specified. A commitment to the following inclusions is made in this EIA document; a full scope of recommendations for the EMP will be prepared according to Ministry of the Environment and Bahamas National Trust guidelines and submitted for review and approval.

- erosion and sediment control will include construction guidelines: to minimize building generated sediment, for overseeing turbidity management, to assure correct installation, for the maintenance of silt curtains, etc.
- hazardous and solid waste management section will identify locations and criteria for secure hazardous material storage and to outline the disposal techniques for solid and hazardous waste.
- private yacht basin management plan will cover sewage pumpout operation, basin rules, and guidelines for visiting vessels.
- emergency management portion will outline procedures, protocols, and location of relevant equipment in the event of a hurricane, fire, or other natural hazard.
- monitoring plan for turbidity, exotic plant removal, and terrestrial sediment control will be scrutinized during construction.

The draft EMP contains the following integrated parts and intended outcomes:

- the purpose, scope, and content section will summarize the purpose and identify the project components and activities to which the plans will apply.
- the summary of impacts, accidents/malfunctions portion will summarize the predicted ongoing environmental and socio-economic impacts from the proposed activities during the various stages of the project. This section will also describe various accidents including fires, explosions, natural events and/or malfunctions due to acts of sabotage that could possibly occur, as well as the nature and scope of the impacts these occurrences could pose to the environment and the public.
- the summary of environmental regulatory bodies and standards segment will identify the relevant regulatory bodies having jurisdiction relating to environmental protection as applicable to the implementation of each stage of the project. The section will also summarize the proposed environmental standards for each affected resource impacted by activities associated with the development.

- the description of the planned mitigation measures section will describe the planned mitigation measures that could be applied to meet the environmental standards established for the project. Each mitigation measure is briefly described in relation to the impacts associated with the project. Also referenced are those specific mitigation plans that may be applied during project implementation.
- the description of measures for responding to potential accidents part will describe the measures to be undertaken in response to fires, explosions or major spills that could occur as a result of accidents, natural events, acts of sabotage, or malfunctions.
- the description of planned environmental monitoring section will describe any monitoring programs including the relevant protocols that will be used. The monitoring programs will describe: the parameters to be measured, methods to be used, sampling location(s), frequencies, detection limits, and thresholds or benchmarks used to signal the need for corrective actions.
- the description of the responsibilities and accountabilities portion will identify the processes, procedures, and mechanisms for implementation of the mitigation and monitoring plans as well as for responding to emergencies. It will include responsibilities for mitigation, accident response, and monitoring and it will identify the party responsible for insuring any reporting that is to be coordinated with applicable governmental agencies.
- the training segment will describe the type of training, participants, information content, and schedule that will be implemented to ensure that those responsible are knowledgeable about applying mitigation, responding to emergencies, monitoring, and reporting.

CHAPTER 8 CONCLUSIONS

The proposed plan has been designed with the existing habitats and landforms in mind. Sincere attempts have been made to provide the most ecologically intelligent land utilization. It is the opinion of the report authors that environmental impacts associated with the planned work are addressed by proposed avoidance, minimization and mitigation measures. To assure accuracy of the existing marine resources and impact assessment a third party, Dr. Erich Mueller of eVm Research and Design, was hired to perform an independent analysis of the proposed dredge and surrounding areas. Erich Mueller (Ph.D., 1983, Univ. of Miami) has been studying corals and reefs for over 30 years at numerous locales across the world, with much of his experience throughout the Exumas. The findings within Dr. Mueller's report, "Reconnaissance of Proposed Channel and Dockage Sites: Bell Island, Exumas" are consistent with the information provided in this EIA and can be found in its entirety as Appendix III.

To gain even further understanding of the marine resources potentially impacted by the proposed dredging activities and within the "Estimated Turbidity Zone" Dr. Craig Dahlgren of the Perry Institute conducted an additional marine survey. In his report, "Habitat Mapping and Biological Assessment of Marine Resources around Bell Island, Bahamas" marine habitats have been mapped within a 250m radius "Impact Zone" around each proposed dredging site and within an "Estimated Turbidity Zone" which includes areas within 1km of the proposed dredging site that may be impacted by sediment plumes due to transport in tidal currents. The report in its entirety is provided as Appendix VII.

Impacts will include the removal of small amounts of terrestrial and marine habitat which in total would be less than 5 acres of terrestrial habitats and approximately 4.8 acres of sand flat marine habitat which correlate to 43,365.70 cubic yards of dredging. Native vegetation will be preserved and/or transplanted, to the greatest extent possible, around these impact areas to minimize the need for landscaping and irrigation, as well as for the conservation of native habitat for those animals that utilize the area.

A native plant nursery is being designed and constructed on Big Bell Island to preserve and propagate native plant species on the island. The nursery site is located in a previously disturbed area that was dominated by large Casuarina trees. The Casuarina trees are being removed and the nursery is being blended with the existing, retained, native plant communities. Native plant seeds are currently being collected. Rare, endangered and endemic native plant species will be a significant part of the growing program in the BINPN.

The first alternative included cutting into one of Big Bell's beautiful crescent beaches to provide an access channel to a private yacht basin carved into a lush coastal coppice area. This led to research that eventually eliminated the aforementioned possibility by illuminating the fact that the salt pond was devoid of unique habitat and / or wildlife.

Also proposed in the original March 2010 EIA and now an alternative, the plan proposed consisted of a more intensive dredge footprint and significantly deeper dredge depths. Revisions were made to the originally submitted dredge areas and volumes associated with the Big Bell Island project. A dredge reduction exhibit is also attached to provide further illumination.

The original dredge area and depth were established to provide yacht access into the barge landing fuel area. Big Bell eliminated the need for yacht access into the barge landing for fueling by providing fueling within the yacht basin instead. As a result, the needed dredge depth of the barge landing area was reduced from -12 ft MLW to -9 ft MLW and the dredging proposed at the northwestern tip of the island was eliminated altogether. This change in the project concept greatly reduced the amount of spoil to be exported from Bell Island. To further reduce the needed dredging, the area under the docks and area leading to the boat ramp were also reduced to -7 ft MLW. The plan alterations described above decreased the barge landing dredge volume total by 30,211.20 cu yds.

Revisions to the final plan, eliminated an additional area of dredging on the outside of the breakwater was also eliminated and the area in front of the boat ramp was further reduced to -5 ft MLW. These plan alterations reduced the dredge volume by an additional 830.60 cu yds.

Overall, the offshore dredging of the Barge Landing area has been reduced by 31,041.80 cu yds from what was originally submitted in the March 2010 EIA. This equates to a 72% total reduction in Barge Landing dredge volume.

Total offshore dredge volume has been reduced by 31,108.4 cu yds from what was originally submitted in the March 2010 version of the EIA. This equates to a 42% total reduction in offshore dredge volume. Additionally, total project offshore dredge area has been reduced by 173,229.00 sq ft from what was originally submitted in the March 2010 version of the EIA, which means a 46% total dredge area reduction.



Figure 8.1 Barge Landing Dredge Reductions (Exhibit 11)

EXHIBIT 1

PRIVATE YACHT BASIN SITE PLAN

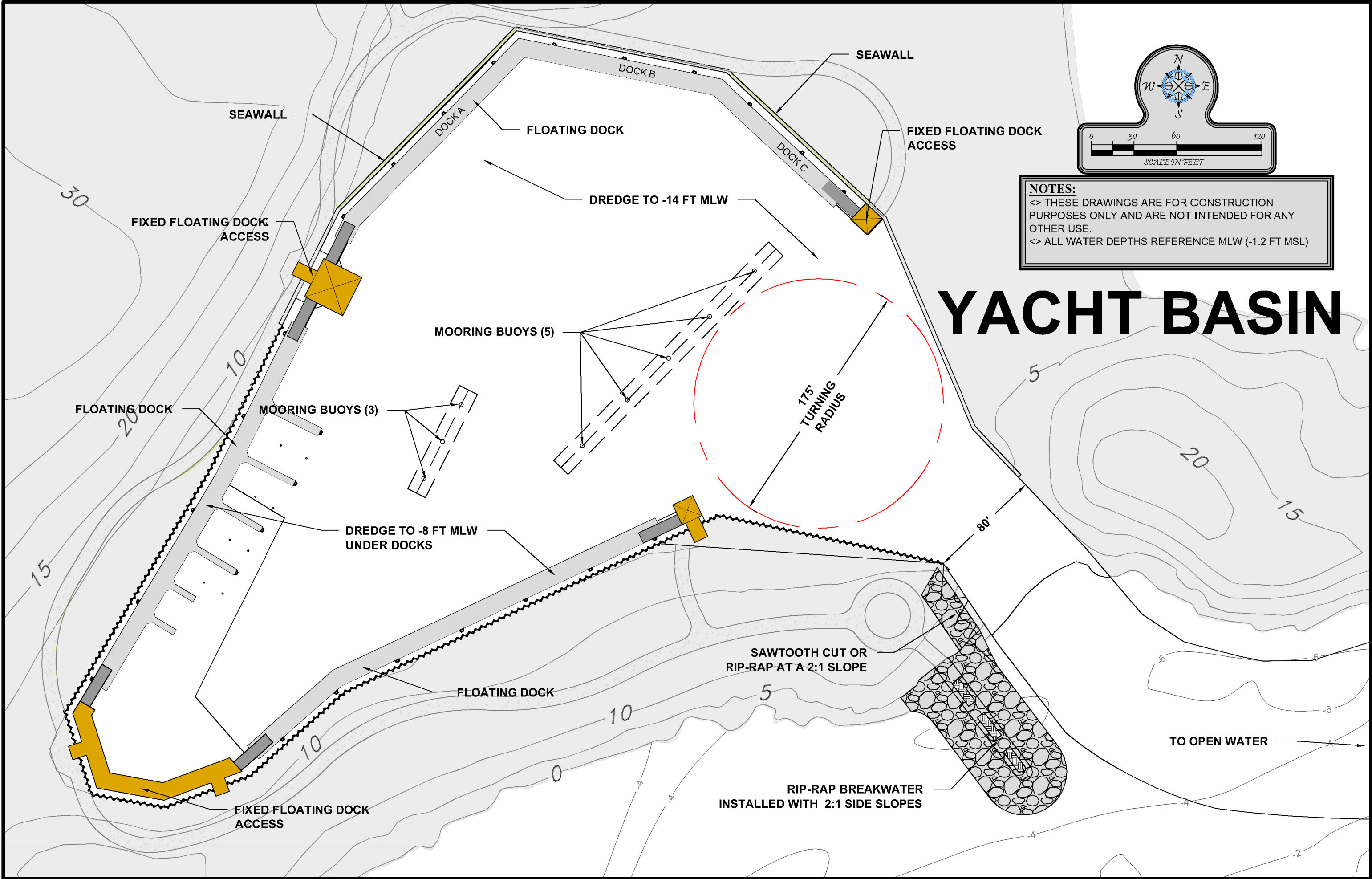
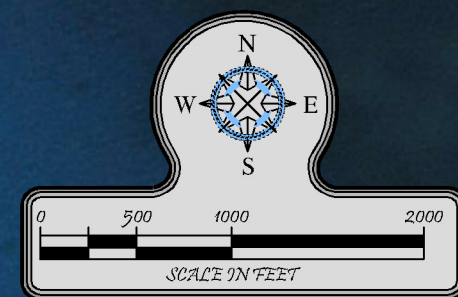
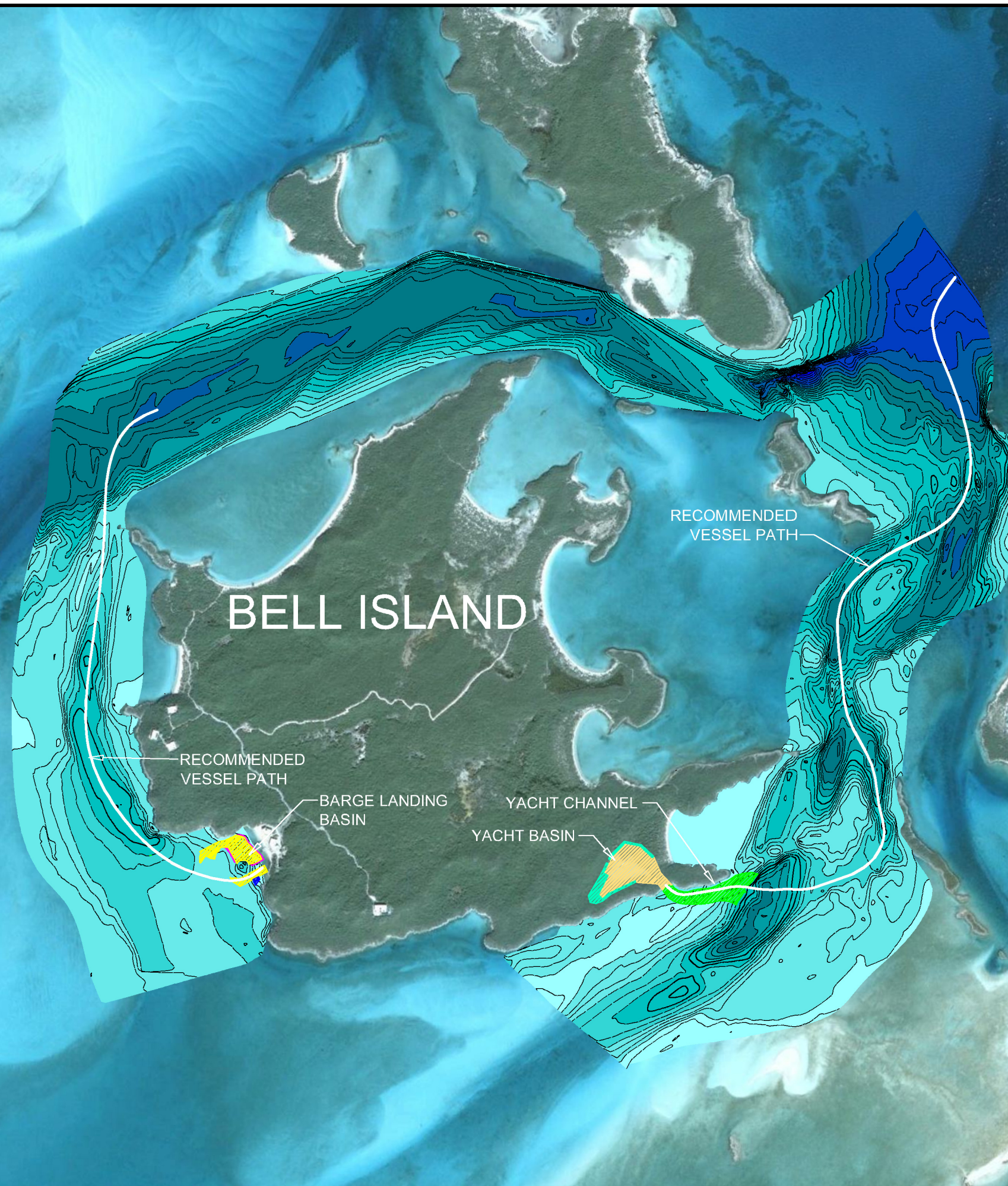





EXHIBIT 2




BARGE LANDING / SERVICE DOCK, UTILITY AND STORAGE EXPANSION SITE PLAN

EXHIBIT 3

DREDGE PLAN



YACHT BASIN	
	EXCAVATE TO -8' MLW (BASIN)
	EXCAVATE TO -14' MLW (BASIN)
	DREDGE TO -14' MLW (CHANNEL)

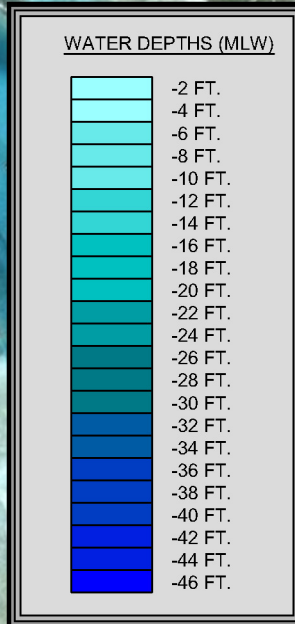
BARGE LANDING	
	DREDGE TO -5' MLW
	DREDGE TO -7' MLW
	DREDGE TO -9' MLW

BARGE LANDING BASIN DREDGE VOLUMES		
AREA DESC	TOTAL AREA (ft^2)	DREDGE VOLUME (yds^3)
-5' MLW	2417.4	192.9
-7' MLW	6450.9	806.2
-9 MLW	86177.3	11238.1
TOTALS	95045.6	12237.2

YACHT BASIN EXCAVATION VOLUMES		
AREA DESC	TOTAL AREA (ft^2)	DREDGE VOLUME (yds^3)
-8' MLW	35591.0	14156.5
-14' MLW	145634.0	89671.2
TOTALS	181225.0	103827.7

YACHT BASIN CHANNEL DREDGE VOLUMES		
AREA DESC	TOTAL AREA (ft^2)	DREDGE VOLUME (yds^3)
-14' MLW	111956.4	31128.2
TOTALS	111956.4	31128.2

AVERAGE CUT DEPTH (ft)	
BARGE LANDING	3.3
BASIN	15.7
BASIN CHANNEL	7.4



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EXHIBIT 4

CASUARINA REMOVAL AREA

CASUARINA REMOVAL AREA

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ONLY AND ARE NOT INTENDED FOR ANY OTHER USE.
DRAFT - CONCEPTUAL LAYOUT

 ELEVATION DELINEATION (TYP.)

 APPROXIMATE CASUARINA AREA

FUTURE
NATIVE
NURSERY

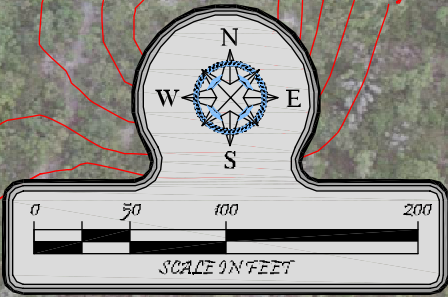
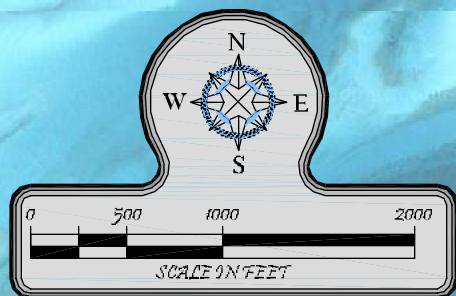


EXHIBIT 5

DIVE TRANSECT MAP



BELL ISLAND

VESSEL PATH DIVE
TRANSECTS

BARGE PATH DIVE
TRANSECTS

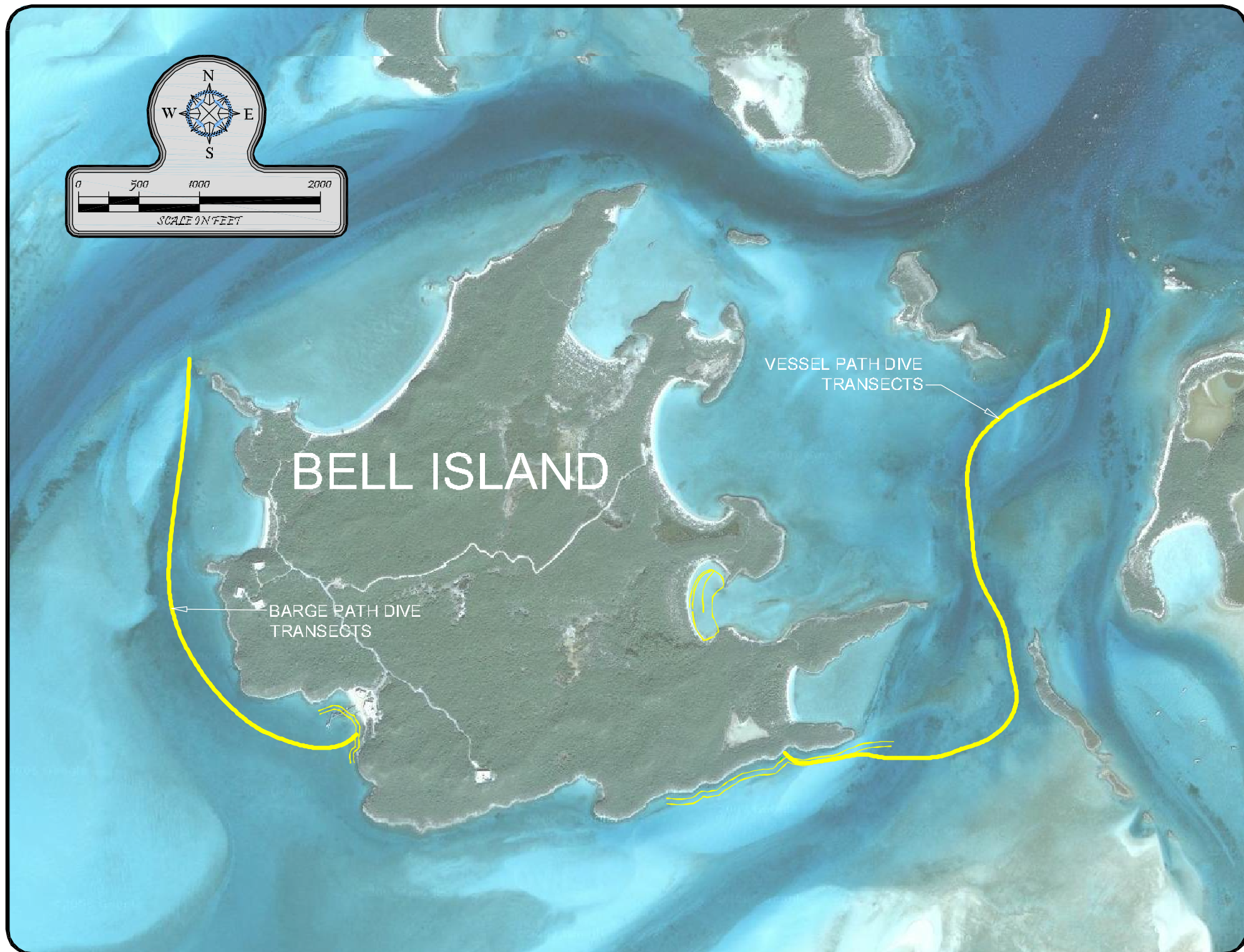
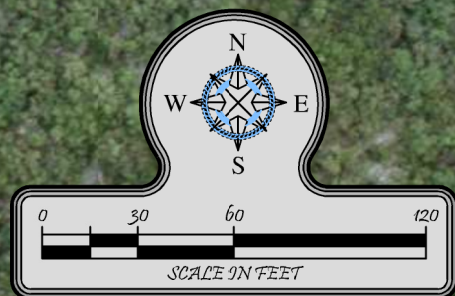



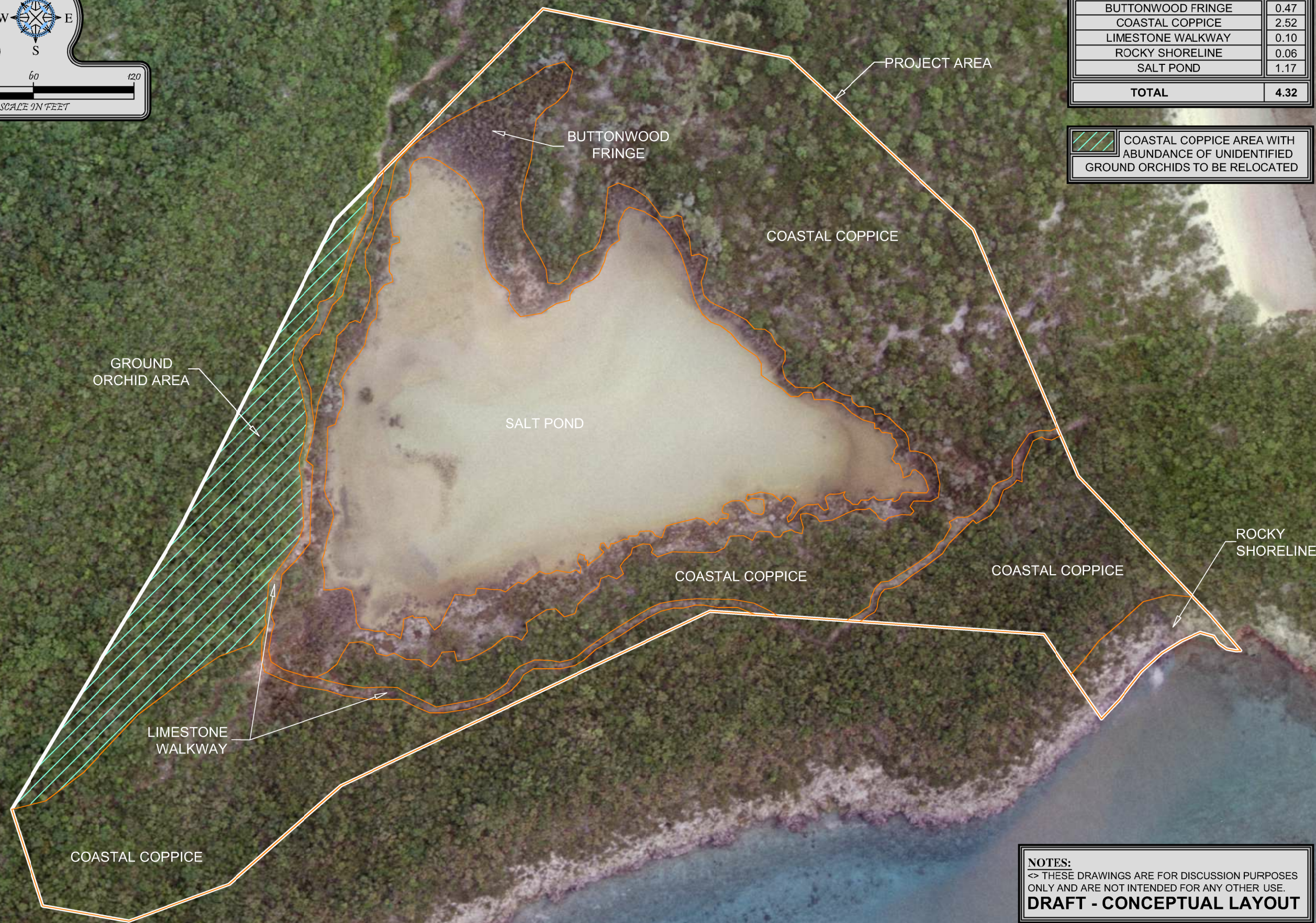
EXHIBIT 6

PRIVATE YACHT BASIN UPLAND IMPACTS



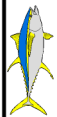
HABITAT	ACRES
BUTTONWOOD FRINGE	0.47
COASTAL COPPICE	2.52
LIMESTONE WALKWAY	0.10
ROCKY SHORELINE	0.06
SALT POND	1.17
TOTAL	4.32

	COASTAL COPPICE AREA WITH ABUNDANCE OF UNIDENTIFIED GROUND ORCHIDS TO BE RELOCATED
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NOTES:
⋈ THESE DRAWINGS ARE FOR DISCUSSION PURPOSES ONLY AND ARE NOT INTENDED FOR ANY OTHER USE.
DRAFT - CONCEPTUAL LAYOUT

BIG BELL ISLAND MARINA - HABITAT

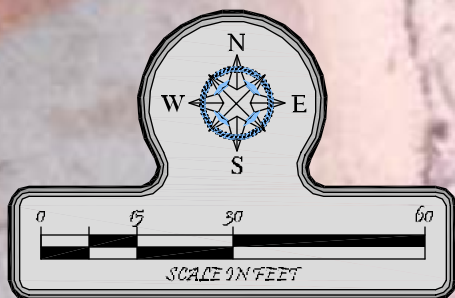

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TAB NAME: MARINA HABITAT	REVISIONS: 00-00-00
FILE NAME: 0929 big bell island drawing (0) EIA Exhibit THA-0929-ELP 6 UPR AND	00-00-00

DRAWN BY: LAB	REVIEWED BY: THT
PROJECT #: 0929	SHEET: 1 OF 1
DATE: 09-15-09	
SCALE: 1"=60'	

EXHIBIT 7

UTILITY AND STORAGE AREA UPLAND IMPACTS



HABITAT	ACRES
COASTAL COPPICE	0.14
ROCKY SHORELINE	0.11
TOTAL	0.25

ROCKY SHORELINE


PROJECT AREA

COASTAL COPPICE

NOTES:
<> THESE DRAWINGS ARE FOR DISCUSSION PURPOSES ONLY AND ARE NOT INTENDED FOR ANY OTHER USE.
DRAFT - CONCEPTUAL LAYOUT

BIG BELL ISLAND

BARGE LANDING HABITAT



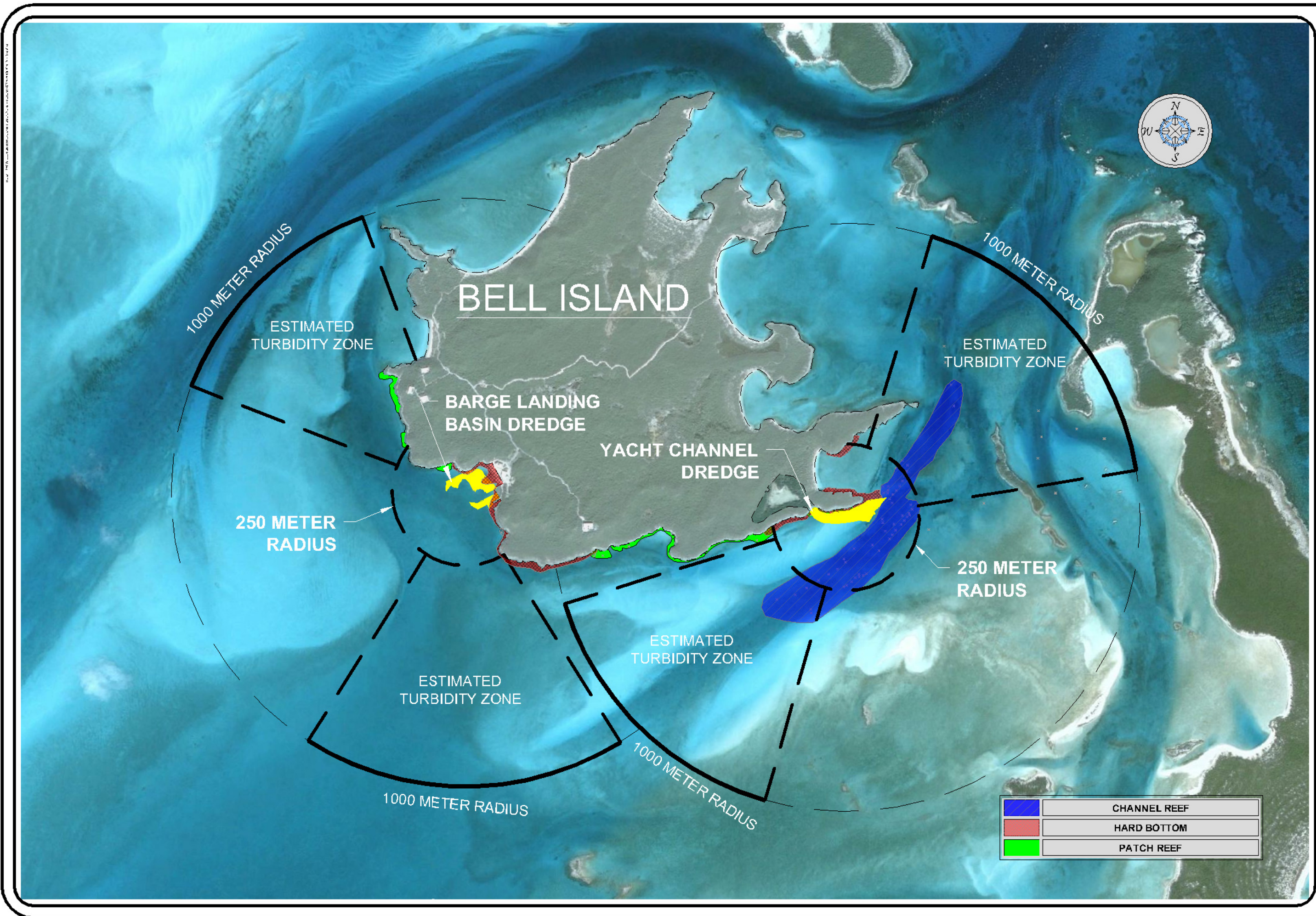
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TAB NAME:	REVISIONS:
BARGE HABITAT	00-00-00
	00-00-00
FILE NAME:	

DRAWN BY:	REVIEWED BY:
LAB	1111
PROJECT #:	SHEET:
0929	1 OF 1
DATE:	
09-15-09	
SCALE:	
1"=30'	

EXHIBIT 8

MARINE HABITAT MAP



BELL ISLAND
MARINE HABITAT-REEF



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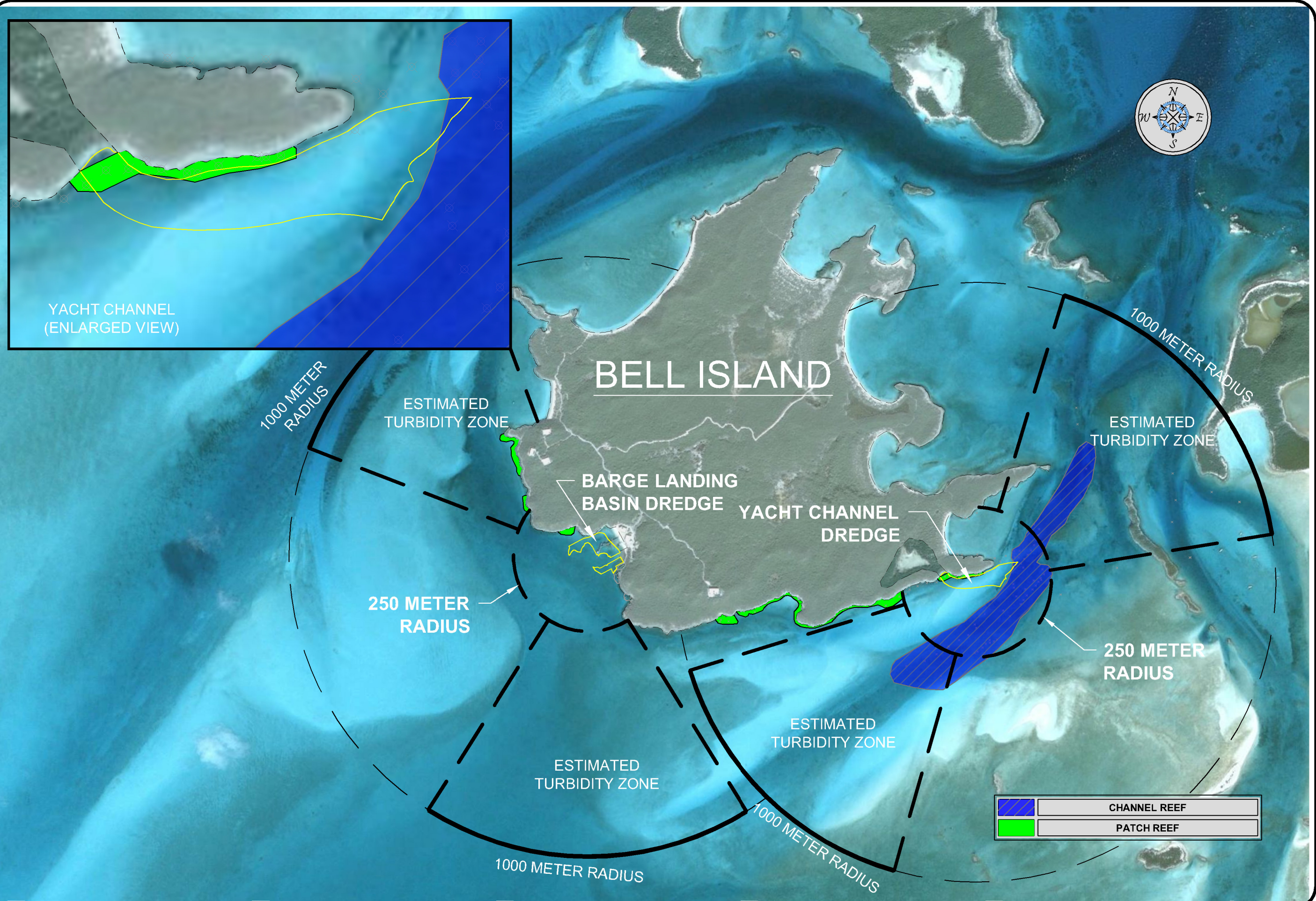
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FRI. EOT	0929	
NOTE	01-27-2011	
SLASH	N/A	
LOCUS	REF	

EXHIBIT 9

MARINE HABITAT - CORAL



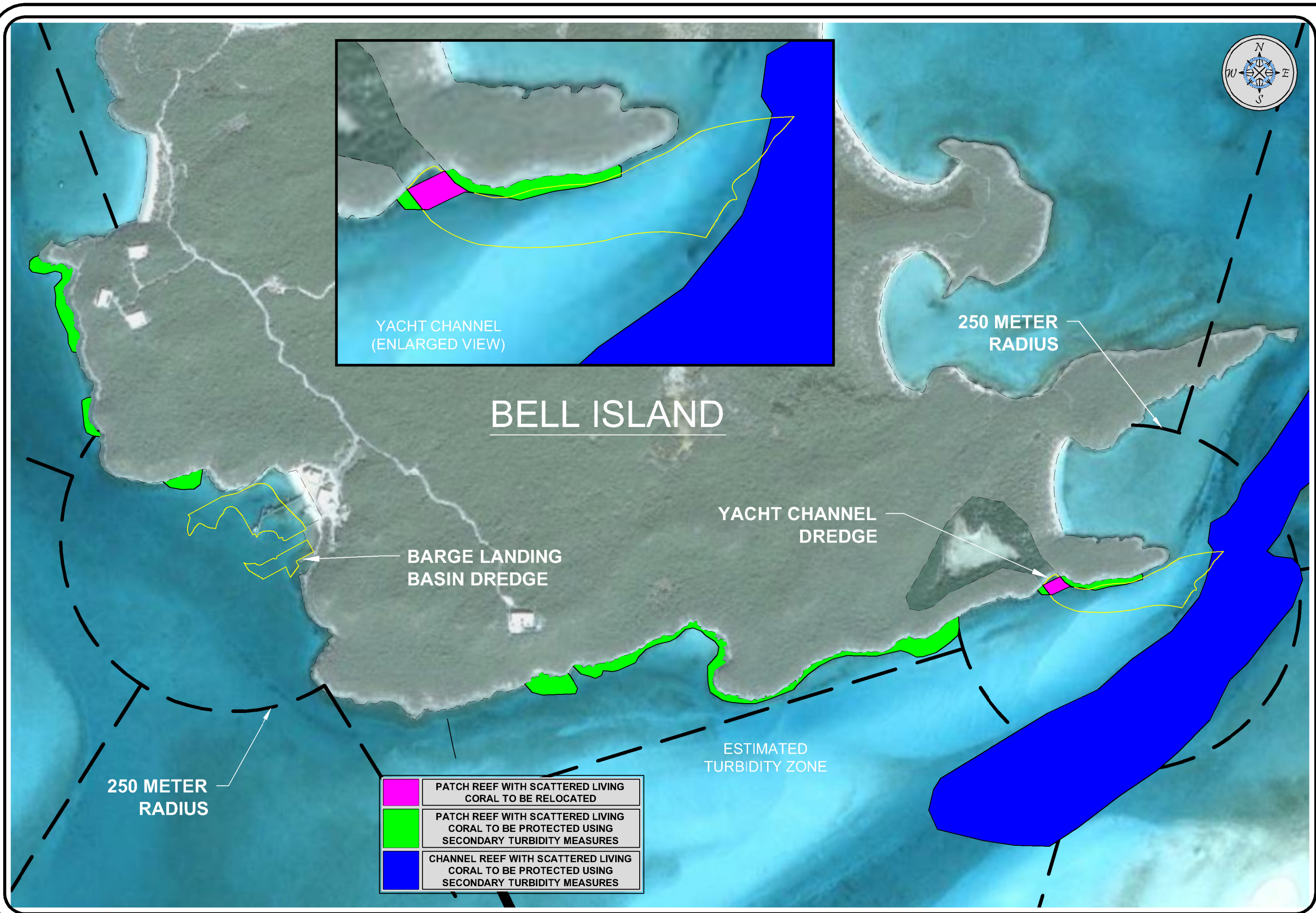
BELL ISLAND
MARINE HABITAT - CORAL

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OWNED BY: BCB	REVIEWED BY: TTTT
PROJECT: 0929	SHEET: 1
DATE: 02-10-2011	
SCALE: N/A	
LAYOUT: CORAL	

EXHIBIT 10

CORAL PROTECTION PLAN



BELL ISLAND

CORAL PROTECTION PLAN



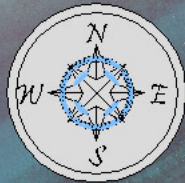
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PROJECT:	0929	SHEET:	1
DATE	02-11-2011		
SCALE:	N/A		
LAYOUT:	CORAL (2)		

EXHIBIT 11

BARGE LANDING DREDGE REDUCTIONS



BARGE LANDING
CHANNEL DREDGE

BELL ISLAND

YACHT CHANNEL
DREDGE

BARGE
LANDING
BASIN
DREDGE

YACHT BASIN
EXCAVATION

BARGE LANDING BASIN
(ENLARGED)



	ELIMINATED DREDGE AREA
	CURRENT DREDGE AREA

EXHIBIT 12

HABITAT ANALYSIS EXHIBITS FOR IMPACT AREAS FOR CRAIG DAHLGREN, PHD

HABITAT ANALYSIS EXHIBITS FOR IMPACT AREAS
FOR
CRAIG DAHLGREN, PhD
FEB. 18, 2011

The information contain in this supplement dated February 18th 2011 draws on information provided in the main body of the Dalhgren report dated January 27, 2011, and provided as Appendix VII. The table and exhibits to follow were prepared to assist in the description of the marine resources observed in the vicinity of the Yacht Basin and Barge Landing dredge areas of the Bell Island project. The exhibits illustrate individual locations of corals and conch habitat with corresponding photographs; while the table further describes the attributes of each of these locations. The table directly relates to the locations identified in the Yacht Basin Dredge Impact exhibit and the Barge Basin Dredge Impact exhibit.

The data presented in the table is an excerpt from the information on the following pages:

- Pages 5-8 discuss the various habitats present. This information can be found on the exhibit through the pictures represented.
- Pages 11-12 discuss the Benthic communities and the percent of coral reef colonies
- Page 4 explains Sea Grass Habitat - Spares to Medium density depicted as BL4a, 4b and 5
- Page 5 discusses Hardbottom Habitat shown as BL6 and YB4
- Page 6 describes Patch Reef Habitat illustrated as BL 2 and YB 2

PHOTO #	MAJOR SPECIES OBSERVED	GPS (UTM-WGS 1984 datum, Zone 18 North, Meter)		% COVER LIVE CORAL	VIABILITY	MEAN SIZE	ACTION TO BE TAKEN
		X	Y				
YB 1	<i>Montastraea annularis</i> , <i>Montastraea faveolata</i> , <i>Porites astreoides</i> , <i>Porites porites</i>	342672.523	2688530.5322	9	87%	13 cm	Relocation (to included prominent corals where the channel is to cut into the basin)
YB 2	<i>Montastraea annularis</i>	342474.4707	2688433.6699	27	80%	42 cm	Preservation
YB 3	<i>Montastraea faveolata</i> , <i>Porites astreoides</i> , <i>Porites porites</i>	342646.3256	2688515.3483	2	92%	13 cm	Relocation
YB 4	<i>Porites astreoides</i> , <i>Montastraea annularis</i> , <i>Porites porites</i> , <i>Siderastrea siderea</i> , <i>Diploria labyrinthiformes</i> .	342708.1514	2688530.0086	2	94%	13 cm	Relocation
BL 1	<i>Montastraea annularis</i> , <i>M. faveolata</i>	341581.1025	2688559.8838	9	83%	26 cm	Relocation
BL 2	<i>Diploria labyrinthiformes</i>	341606.3265	2688459.0207	5	80%	30 cm	Preservation
BL 3	<i>Siderastrea siderea</i>	341570.5925	2688524.6868	5	83%	26 cm	Relocation
BL 6	<i>Manicina areolata</i>	341512.2619	2688663.3736	1	95%	5 cm	Relocation
SEAGRASS HABITATS				% COVER	SHOOT COUNT	BLADE LENGTH	
BL 4a	<i>Thalassia testudinum</i>	341402.9577	2688589.3022	5-10	66/m ²	3-10 cm	Part of Conch Relocation Plan
BL 4b	<i>Thalassia testudinum</i>	341545.3684	2688560.4092	5-10	66/m ²	3-10 cm	Lost
BL 5	<i>Thalassia testudinum</i> , <i>Strombus gigas</i>	341441.3193	2688472.1539	20	72/m ²	5-15	Part of Conch Relocation Plan

CORALS – VIABILITY = Mean % Living Tissue on Individual Colonies
 MEAN SIZE = Mean diameter of Individual Colonies

2

1

1 ALTERNATE VIEW

Montastraea annularis, *Montastraea faveolata*, *Porites astreoides*,
Porites porites

(4)

(3)

2

Montastraea annularis

BELL ISLAND

YACHT BASIN DREDGE IMPACT



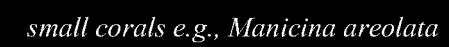
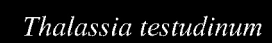
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PROJECT:	0929	REMOVED BY:	TTTT
DATE:	02-17-2011	SHEET:	1
SCALE:	N/A		
LAYOUT:	YACHTBASIN		

BARGE LANDING DREDGE

250 METER RADIUS



BELL ISLAND

BARGE LANDING DREDGE IMPACT



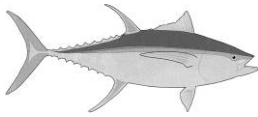
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DATE: 02-17-2011 SCALE: N/A	LAYOUT: BARGELANDING

APPENDIX I

BIG BELL ISLAND FLUSHING MEMO



TURRELL, HALL & ASSOCIATES, INC.

MARINE & ENVIRONMENTAL CONSULTING

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MEMORANDUM

FOR: Bell Island Environmental Impact Assessment

FROM: Joshua W. Maxwell, E.I.T.

DATE: January 26, 2011

RE: Big Bell Island Flushing Analysis

Flushing is an important characteristic within basins, as healthy exchange of water between basins and the open ocean helps to prevent degradation in water quality. Proper flushing discourages stagnant water which is normally associated with poor water quality and nutrient buildups. It also helps to flush out any pollutants that are accidentally released into the immediate area via vessels or upland stormwater systems.

To assess the exchange of water between the proposed basin and the surrounding waters, hydrodynamic modeling was implemented via software through RMA-2 and RMA-4 processing. The equations for the RMA-2 and RMA-4 processing were developed by the US Army Corps of Engineers for calculating the current and contaminant movements within aquatic environments. Millions of equations are solved, while taking into account tides, roughness of the basin material, and how water could flow throughout the basin. The RMA2 function calculates how the tides affect the flow of water within the basin, then shows flow characteristics of the basin at each time step. The RMA4 function calculates how a contaminant reacts when introduced to the tidally influenced basin.

Yacht Basin: This basin was designed to moor multiple mega yachts; however, since this is just a temporary mooring site while the owner and guests are on the island, a fueling facility has not been included within this basin. All Bell Island vessels will be fueled at the service/barge landing area on the western side of the island, therefore aiding the overall cleanliness of the yacht basin.

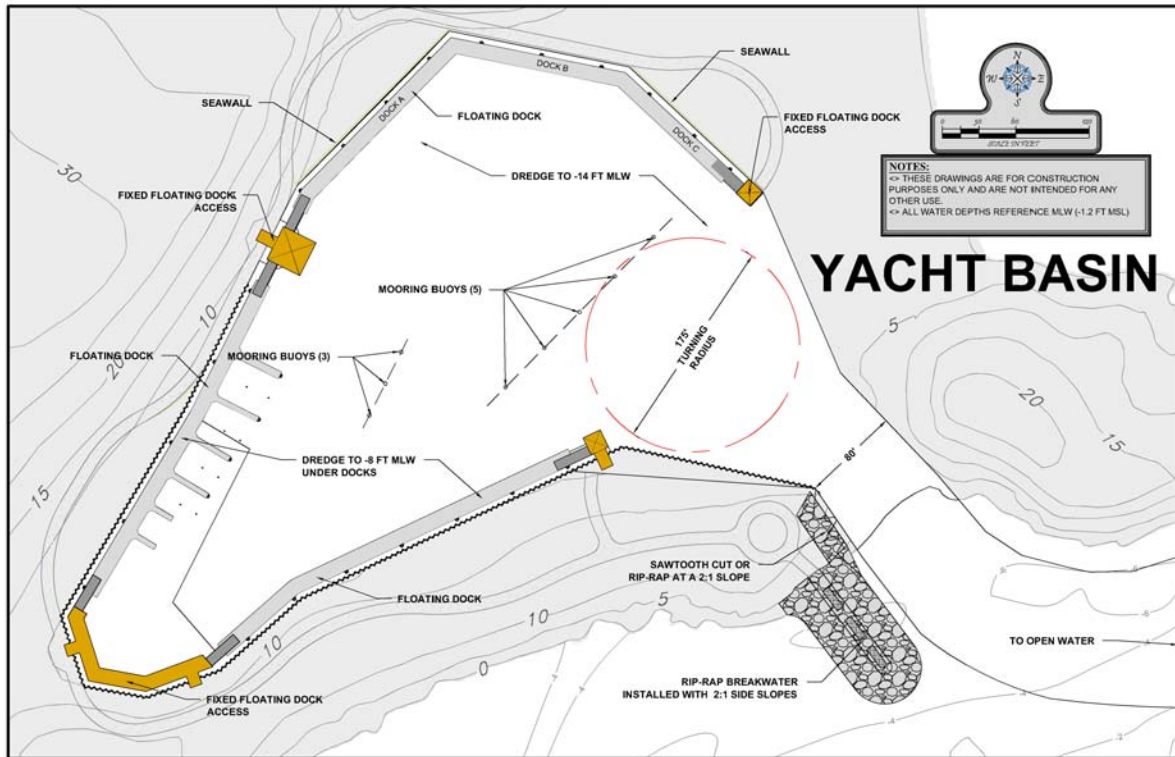


Figure 1: Proposed Bell Island Yacht Basin

A point source pollutant has been chosen for this flushing study, representing a realistic scenario (ie. sewage spill). The contaminant was released into the basin over a period of four (4) hours to simulate the worse case scenario of a holding tank malfunctioning. At hour four (4) the contaminant is no longer added, thus the maximum concentration of one hundred (100) percent. This represents a scenario more extreme than this basin would ever be exposed to due to the highly trained island staff. The contaminant was added at the beginning of the transition from an ebb tide to a flood tide. This provides the worse-case-scenario, trapping the contaminant in the basin for the first six (6) hours. The diffusion of the pollutant was then observed over the next eighteen (18) hours. A proposed flushing culvert was also analyzed to show the improvement of adding one later on, if water quality deems unfit. After twenty-four (24) hours the contaminant percentage had been reduced to eighteen percent (18.0%) without the culvert, and to fourteen percent (14.0%) with the flushing culvert. This proves that the proposed yacht basin, even without the flushing culvert, will adequately flush, preventing the buildup of pollutants or nutrients, and thus creating a healthy marine environment.

Service/Barge Landing: This area was designed to facilitate the permanent mooring of the working vessels of the island, fuel the owner's or guest's vessels, and the loading and unloading of supplies and equipment from supply barges.

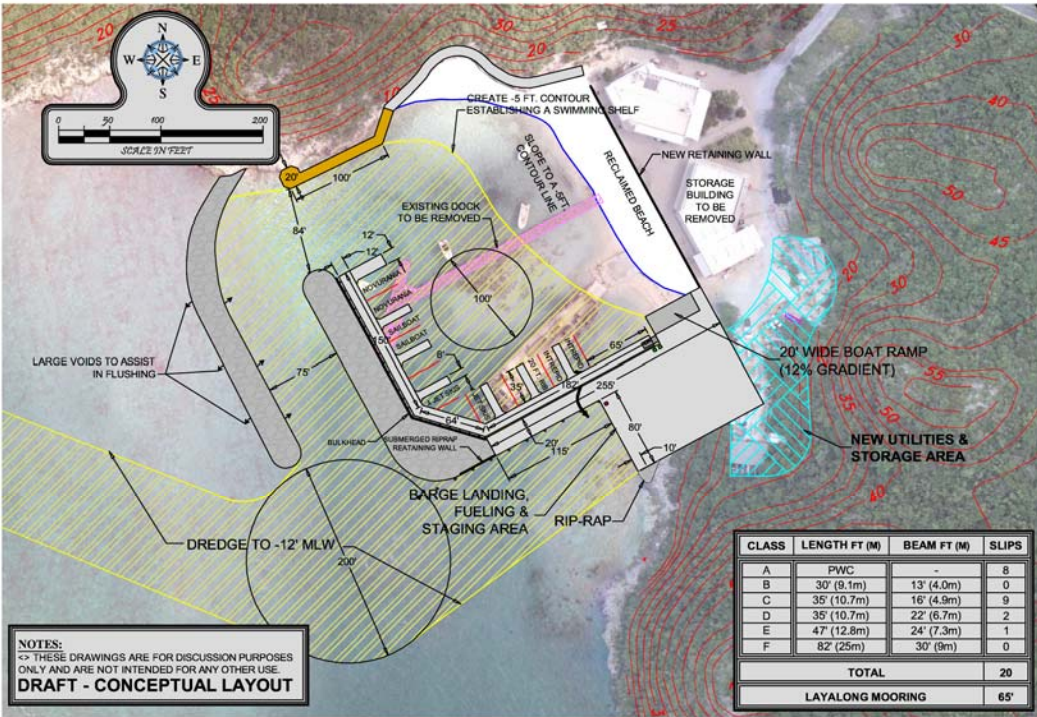


Figure 2: Proposed Bell Island Service/Barge Landing

A point source pollutant has also been chosen for this flushing study representing a realistic scenario (ie. a fuel or sewage spill). The contaminant was released, just like the yacht basin, over a period of four (4) hours to simulate a worse case scenario of a holding or fuel tank malfunctioning. This represents a scenario more extreme than this basin would ever be exposed to due to the highly trained island staff and regularly maintained vessels. After twenty-four (24) hours the contaminant percentage had been reduced to fifteen point nine percent (15.9%) without the culvert, and to ten point six percent (10.6%) with the flushing culvert. This proves that the proposed service/barge landing, even without the flushing culvert, will adequately flush, preventing the buildup of pollutants or nutrients, within the service/barge landing area.

This area has undergone major revisions and an updates since the initial flushing study was performed. An updated layout of the proposed basin can be found in Figure 3. The new barge landing and service basin will facilitate loading and unloading supplies and equipment from supply barges, loading and unloading of guests to the island, and provide safe mooring for the island’s working fleet.

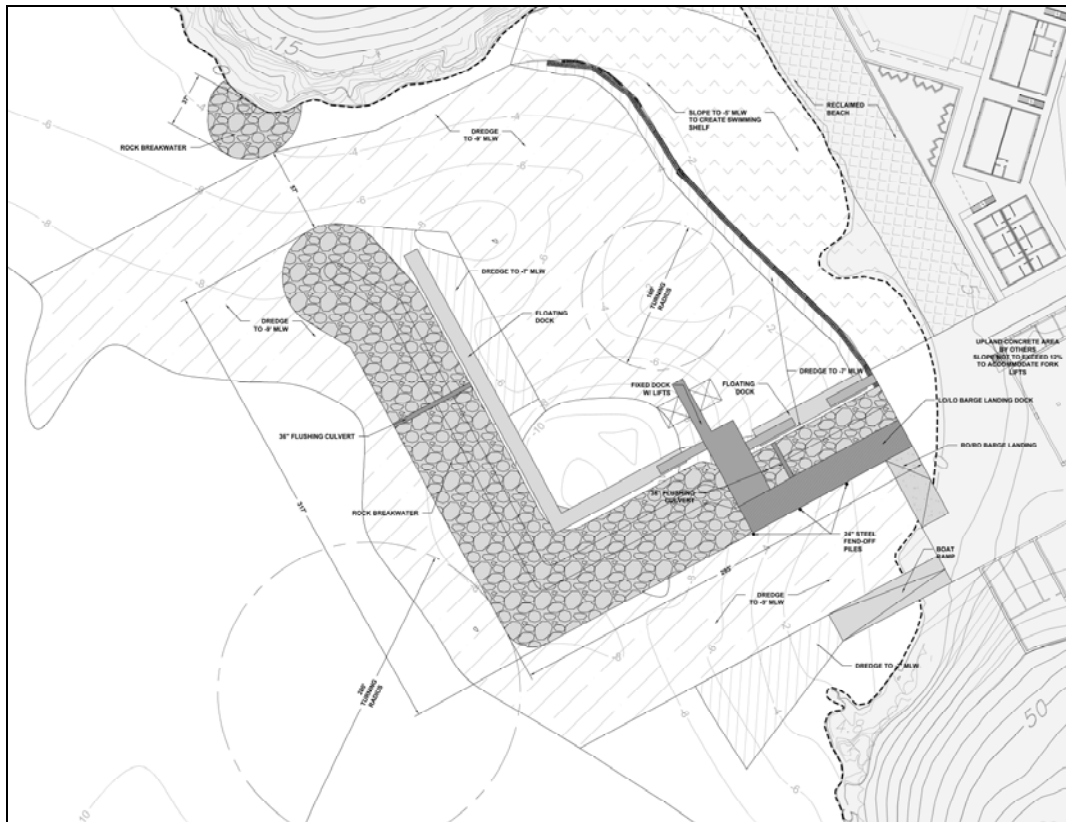


Figure 3: Updated Bell Island Service/Barge Landing

It is expected that the new service basin will flush better than the originally proposed layout. The outside breakwater was reduced allowing water to enter and exit the basin more freely. Two flushing culverts are proposed, one within the western leg of the structure and one underneath the fixed dock. These culverts will aid in increased water circulation preventing stagnant water and the build up of pollutants and nutrients within the basin. These improvements will promote a healthier marine environment than originally proposed.

APPENDIX II

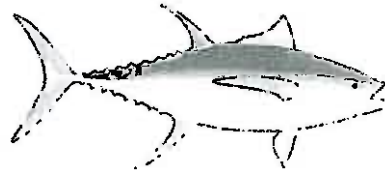
“BELL ISLAND AND TWO NEIGHBORING SALT PONDS: A STUDY OF THEIR CHARACTERISTICS”

**BELL ISLAND AND TWO NEIGHBORING SALT PONDS:
A STUDY OF THEIR CHARACTERISTICS**



Prepared by:

**Turrell, Hall & Associates, Inc.
3584 Exchange Avenue
Naples, Florida 34104
(239) 643-0166**



September 2009

BELL ISLAND AND TWO NEIGHBORING SALT PONDS: A STUDY OF THEIR CHARACTERISTICS
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BELL ISLAND AND TWO NEIGHBORING SALT PONDS: A STUDY OF THEIR CHARACTERISTICS
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BELL ISLAND AND TWO NEIGHBORING SALT PONDS: A STUDY OF THEIR CHARACTERISTICS
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1	Sampling Station Location Maps
2	Estimated Salt Ponds in the Exuma Islands

1.0 INTRODUCTION

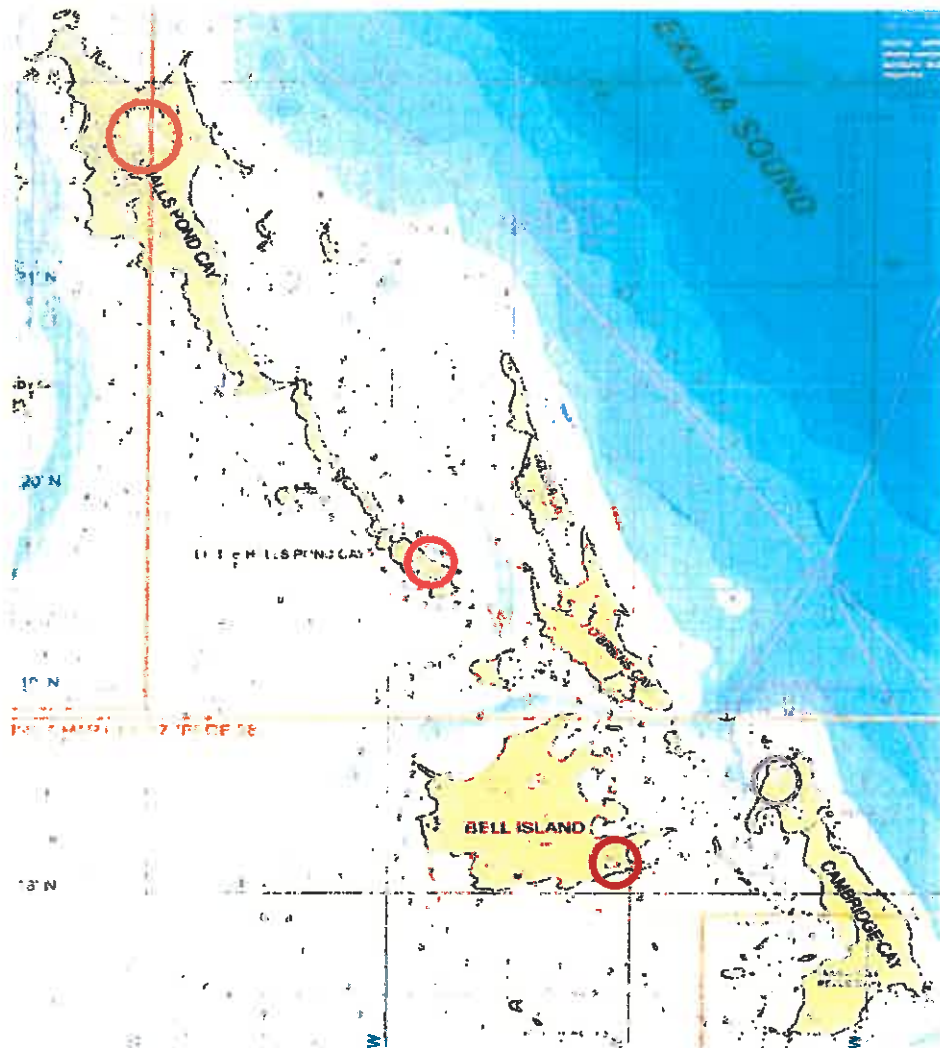


Figure 1: Location map of ponds sampled for this report (2009 in red and 2007 in pink)

A study of salt ponds on three neighboring islands in Exuma, Bahamas was conducted to assist in better understanding of the basic environmental characteristics of these ponds. Salt ponds appear all over the Bahamas, but a particularly large number estimated at 112 are located within the Exuma chain (see Exhibit 2 for pond locations). Due to a lack of remaining undeveloped safe anchorages in the Bahamas and the ever expanding fleet of yachts (and megayachts) wanting to visit, salt ponds are being considered more frequently now for the creation of marina basins. Only a small amount of research has been done on salt or hypersaline Bahamian ponds, so a general understanding of them and how they might differ needs to be examined as the need for new boat basins continues to rise.

This survey included sampling on Bell Island, Little Halls Pond Cay and Big Halls Pond Cay, while a previous sampling in 2007 of Little Bell Island (Cambridge Cay) is also discussed and noted in Exhibit 1. The Islands chosen were within an approximate four mile radius, with three being privately owned and one (Big Halls Pond Cay) being owned by the Bahamian government.

This report will detail basic properties of each pond, along with observed flora, fauna and sediment descriptions to provide a more thorough understanding of environmental concerns associated with these salt ponds.

2.0 LOCATION AND SITE DESCRIPTIONS

Bell Island Pond

Bell Island's pond is located on the southeast side of the island, approximately 190 feet from the southern rocky shoreline and 230 feet from a beach directly east. Rock and vegetation lines the pond's rim. The vegetation fringe primarily consists of scrubby mangroves such as White mangrove (*Laguncularia racemosa*), Buttonwood (*Conocarpus erectus*) and Silver buttonwood (*Conocarpus erectus* var. *sericeus*), with small amounts of Red mangrove (*Rhizophora mangle*) appearing mostly on the west end. Within 15-20 feet of the pond, the same island-wide

composition of coastal coppice begins. Karstic features were found throughout the island and surrounding this pond, which may be providing sea water to the pond in small amounts.

Bell Island's pond is shallow, varying from 2 to 8 inches in depth, with water temperatures found to be between 32 and 36°C, depending on which end of the pond was being sampled. Two species of birds: black-necked stilt (*Himantopus mexicanus*) and dowitcher (*Limnodromus* sp.), were noted foraging in the pond.

Little Halls Pond Cay Pond

Little Halls Pond is located at the south end of Little Halls Pond Cay, with a path extending across a high area near the north end. The pond itself averages between 6 and 10 inches in depth, with scattered rocks protruding from the silty surface. Surrounding vegetation consists of *Conocarpus erectus*, *Conocarpus erectus* var. *sericeus*, *Laguncularia racemosa* and small amounts of *Rhizophora mangle* growing out of a rocky shoreline. No karstic features were observed en route to the pond, but the island was also not explored any further than the path from dock to pond. The pond temperature was found to be approximately 31°C.



Figure 2: Bell Island Pond



Figure 3: Little Halls Pond

Big Halls Pond Cay Pond

Big Halls Pond Cay has a network of roads cut throughout the island by a previous island owner and several ponds on the north end. The largest pond was examined for this study. A rocky shoreline, with mangrove and buttonwood fringe surrounded this pond, in exactly the same manner as the other two ponds examined. Buttonwoods and White mangrove were the predominant species noted.



Figure 4: Big Halls Pond

Pond depth varied from approximately 3 to 12 inches and the surface consisted of a solid, slippery red mat that flexed when walked upon. No silty material was present on the surface of this pond. Unlike the other two ponds, this pond was very hot and salt levels were extremely high. Water temperatures varied from 36 to 37°C. Dead land crabs were scattered around the pond and one brined crab was found floating in the pond (Figure 5). Faunal species noted were: black land crabs (*Gecarcinus ruricola*) and mangrove land crab (*Ucides cordatus*).



Figure 5: Brined Mangrove Land Crab found floating in Big Halls Pond

Little Bell Island (Cambridge Cay)

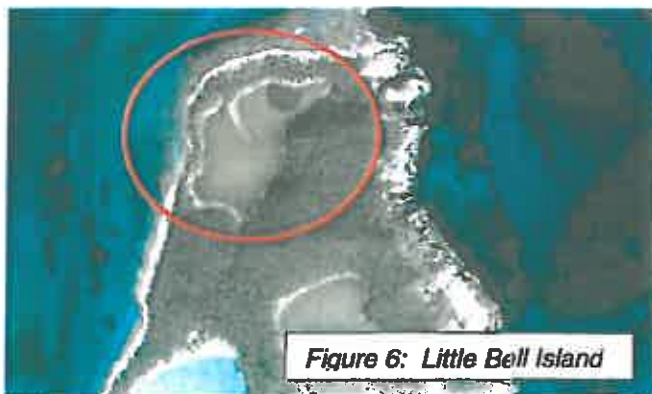


Figure 6: Little Bell Island

In 2007 Biologists sampled the sediment of Little Bell Island's northern-most salt pond. The pond was lined primarily with Silver Buttonwood (*Conocarpus erectus* var. *sericeus*) and pond depth was typically 12 inches, with a depressional area of 4 to 5 feet toward the center. Observed fauna included black-necked stilt (*Himantopus mexicanus*) and American oystercatcher (*Haematopus palliatus*). Brine shrimp were also noted living in the pond.

3.0 SAMPLED PARAMETERS AND BACKGROUND INFORMATION

Dissolved Oxygen

Dissolved oxygen (DO) is a measurement of the oxygen (O_2) amount mixed in a solution. DO was read and will be reported in milligrams per litre (mg/L) for this study. Ideally DO levels should be between 9 and 12 mg/L to sustain a healthy, typical aquatic environment with fish. If DO levels fall below 5.0 mg/L then a system becomes stressed and if they remain below 3 mg/L for more than a few hours, typically large fish die-offs occur (Murphy, 1997).

Oxygen enters the water from the atmosphere and as a by-product of photosynthesis taking place under water. Oxygen is removed from the water by respiration processes and decomposition of organic material. Typically DO levels are directly related to a host of environmental factors, but for our study salinity and temperature appear to be the primary factors from the list which would influence DO. As salinity and temperature increase, it is expected that DO will decrease (Sherwood et al., 1991).

pH

The pH scale (Figure 6) ranks the acidity or alkalinity of a substance from 0 to 6 as acid and 8 to 14 as alkaline. A pH value of 7 is considered neutral and a value of 8 is typical for seawater. Calcium carbonate, which is being constantly precipitated out in the Bahama Banks, can also affect pH by buffering it. The bicarbonate-carbonate ratio provides the main control of pH in sea water (Brown et al., 1989).

In a study of oxygen, hydrogen sulfide and pH within the sediment mats of the hypersaline Solar Lake, Sinai, there was a notable increase in pH as the mats were exposed to sunlight throughout the day (Revsbech et al., 1983). The upper 0.8 mm of mat pH in the Solar Lake sediment study went from just above 8.0 during the transition time between night and sunrise, to 9.6 during the daytime hours and then almost returned to the original levels within 70 min after dark. This significant change was only noted within the first 3 mm of the 5 mm examined. Where light was not reaching the sediment (>3 mm), the pH remained between 7.2 and 7.6.

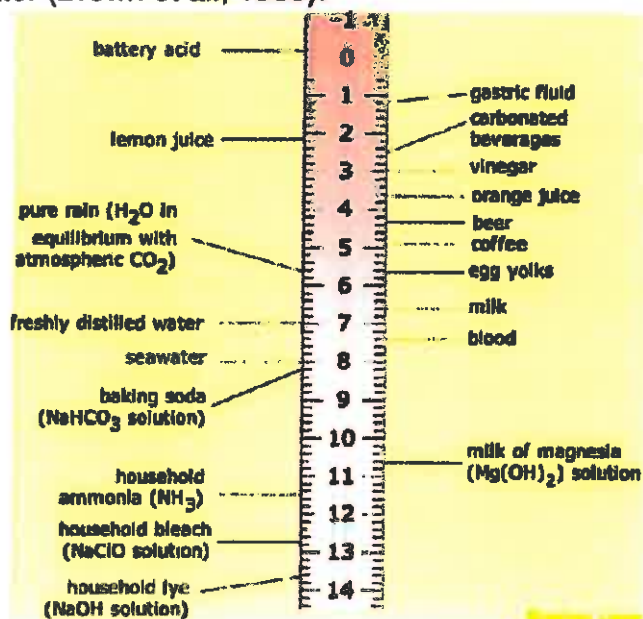


Figure 7: pH Scale

Based on Revsbech's study, it is apparent pH levels in the pond water tested could vary depending on the time of day it was sampled. All testing for the purposes of our study were done between approximately 10:45 a.m. and 3:45 p.m., so the readings should have all been at their highest levels. Sediment pH was not tested during sampling for this study though, only surface water pH.

Salinity

There are typically 11 dissolved ions comprising 99.9% of sea water (Brown et al., 1989). These ions include Chloride, Sulfate, Bicarbonate, Bromide, Borate, Fluoride, Sodium, Magnesium, Calcium, Potassium and Strontium. Ionic proportions remain virtually the same except in shallow, warm waters where chemical and biological precipitation of calcium carbonate occurs regularly (Brown et al., 1989). Salinity is also very dependent on evaporation exceeding precipitation and the mixing of deep and surface waters.

Salinity can be measured by several different methods, but for the purpose of this study parts per thousand (‰) was used to describe salt levels found during sampling. According to the Thalassic Series (Figure 8), brackish waters range in salinity from 0.5 to 29‰, while euhaline seas (open oceans) vary from 30 to 35‰. It has been noted by (Brown et al., 1989) that in shallow warm water shelves, typical salinity readings can be as high as 40‰ and as low as 28‰. There appear to be some scientific variations in the definition of metahaline waters which have been documented to vary from 36 to 40‰ (Brown et al., 1989) and 36 to 50‰ (Jarecki and Walkey, 2006). Hyperhaline (or hypersaline) waters would be considered to have salinities above that of metahaline limits. For the purposes of this study we will consider any salinity reading above 50‰ to be hypersaline, since background seawater readings taken at Bell Island were already at 40‰.

THALASSIC SERIES	
>300	hyperhaline
60 - 80	metahaline
40	mixoeuhaline
30	polyhaline
18	mesohaline
5	oligohaline
0.5	

Figure 8: Thalassic Series Table for salinity measurements in parts per thousand

A study of the depositional history of Salt Pond, San Salvador, Bahamas indicated the salinity varied from 20 to 356 ‰ depending on rainfall and time of year (Shamberger and Foos, 2004). The highest salinities were reported in the month of July due to low water levels and low rainfall. Water levels in Salt Pond have fluctuated as much as 57 cm in recent years.

Temperature

Ambient temperature and daylight play a crucial role in the conditions of salt ponds. Elevated temperatures decrease dissolved oxygen, thereby reducing the species composition which can survive in the pond. As temperature increases, frequently

evaporation is also increasing, thus the salinity increases if the evaporative process exceeds rainfall. This is often the case in the Exumas.

Only extremophiles can survive some of the daytime temperatures of the Bahamian salt ponds in July and August. Most marine species can not survive for any period in nearly 37°C waters at high salinities and with low dissolved oxygen levels, yet some of the ponds studied were near this temperature throughout most of the day.

Flora and Fauna

According to Jarecki and Walkey, (2006) the primary mangrove species found around the edges of salt ponds are *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa* and *Conocarpus erectus*. The ponds sampled for this study did not include *Avicennia germinans* (Black mangrove) and only very little *Rhizophora mangle* (Red mangrove) was noted, however a large percentage of *Conocarpus erectus* var. *sericeus* (Silver buttonwood) were noted. In two of the ponds studied, fuzzy finger algae (*Batophora* spp.) was observed growing on top of pond sediment.

Fauna typically associated with salt ponds are brine shrimp (*Artemia* sp.) and carnivorous insects such as waterboatman (*Trichocorixa* sp.), various mayflies (Tanner et al., 1999) and a few species of shells (Shamberger and Foos, 2004). There have also been some documented bird species known to forage in these hypersaline ponds. In Inagua, Bahamas the Caribbean flamingos have inhabited the salt lagoons left by the Morton Salt company when they were mining salt on-island. Three species of Flamingos (Chilean, James's and Andean) also inhabit the salt lakes of the Andes Mountains in Chile and Bolivia, at over 7,000 feet above sea level (Figures 9 and 10).



Figure 9: Andean Flamingo



Figure 10: Red Brine shrimp eggs

Photos taken by Turrell staff in 2009 at Atacama Salt Lake, Chile (~7,000' above sea level)

In addition to visible fauna, there are microorganisms which are also common to hypersaline environments. Such organisms include the algae *Dunaliella* sp., the red chemotrophic (or sulfur reducing) bacteria *Halobacterium* and *Halococcus*, and the cyanobacteria *Spirulina* (Larsen, 1980). The red bacteria are truly halophilic since they require a very salt saturated solution to thrive. Microorganisms can survive these harsh

environments by either accumulating molar concentrations of potassium chloride (KCl) or sodium chloride (NaCl), like the chemotrophic bacteria, or they exclude salt from the cytoplasm and synthesize organic compatible solutes that don't interfere with enzymatic activity (Oren, 2008). It is believed the red pigment in *Halobacteria* and *Halococcus* help to protect the organisms from the bright sunlight, while absorbing light and increasing water temperature to stimulate their metabolisms (Larsen, 1980). *Dunaliella* (green algae) prefer slightly lower salinities than that of the red bacteria.

These organisms survive in extreme environments, such as Mono Lake in California, where not only is the salt content three times higher than that of sea water, but the pH is roughly the same as Windex (10.0). Extremophiles in Mono Lake have been studied fairly frequently in recent years and form the basis for what much of the scientific community knows about the organisms which can survive in harsh conditions. NASA scientist Richard Hoover was contacted prior to the field survey for advice on sampling and potential findings. Mr. Hoover and Elena Pikuta (also with NASA) have identified and named two previously unknown species of microscopic extremophiles in Mono Lake since 2003: *Tindallia californiensis* and *Spirochaeta american*.

Sediment

Sediment from salt ponds can vary in make-up and coloration. A study done in Salt Pond on San Salvador, Bahamas by Shamberger and Foos (2004), described the sediment layers of the pond from samples taken as: evaporates and silty flocculates, carbonate mud, carbonate sand, laminated cyanobacterial zones, peat and basil sand and silt. They also found *Anomalocardia auberiana* (Pointed Venus) and *Cerithidia costada* (costate horn shell) in the carbonate sand layer.

Typically the green (and sometimes brown) layers consist of primarily cyanobacteria, though brown layers can also be representative of the presence of diatoms in some cases; red or purple layers are either Archea (salt-tolerant *Halobacteria*) or they can be also be partially colored by the presence of brine shrimp (*Artemia*) eggs; and black coloring is typical of an anoxic layer where organic material has been deposited (correspondence with Richard Hoover, 2009) and (Caumette et al., 2006).

Many of the sediment layers described in the San Salvador study also describe what was found in the Exuma ponds surveyed. Two species of shells were also noted, but instead of *Anomalocardia auberiana* being found in the Exuma ponds, marsh clam (*Polymesoda floridana*) was observed.

In salt ponds there is typically a layer of black dissolved organic matter below the cyanobacteria indicating anaerobic activity from sulfate reducing bacteria. Primary producers are concentrated at lower salt levels and as the salinity increases over time, they die off. When they die, they become food for the chemoautotrophs (halobacteria).

4.0 METHODOLOGY

Three ponds were sampled for observable comparisons to illuminate some of the basic characteristic differences of Exuma salt ponds. The ponds chosen were on Bell Island, Little Halls Pond Cay and Big Halls Pond Cay. Previous work has also been done on Little Bell Island (across from Bell Island) and those results will be mentioned in Chapter 5.0, but not included in the methodology followed for this study.

Sampling materials included: aials, permanent markers and pens, clear plastic sediment sampler tubes with caps, white laminated paper with a ruler drawn to photograph sediment samples, black laminated paper to photograph sediment samples, a digital camera, a hand held GPS, a DO meter, pH test strips, a refractometer, distilled water, a test tube, ethanol, Rose Bengal stain, a knife and spoon for stain and samples, a 1 mm sieve and a 500 μ m sieve, and labeled sample collection jars.

Protocol for sampling was as follows:

1. Mark sample location on aerial (sample jar number) and with GPS
2. Test pH and record
3. Test salinity with refractometer and record
 - 3 a. Dilute to 50% with equal parts distilled H₂O if needed, then 75% if still needed for a reading
4. Test dissolved oxygen in mg/L and record
5. Take sediment sample (approx 4 to 6 inches deep)
 - 5 a. Cap top at desired depth,
 - 5 b. Dig out the bottom and cap
6. Lay sediment tube on laminated ruler paper and photograph
7. Lay sediment tube on black laminated paper and photograph
8. Note any features (colors, texture, materials, etc.) in sediment
9. Sieve material (larger sieve on top)
10. Record features of larger sieve (snails, shells, etc.) by approximate number and photograph
11. Move material from smaller sieve into sample jar
12. Place small amount of stain into jar
13. Fill the jar with ethanol

Sampling included dissolved oxygen (DO), pH, salinity, temperature, time, tides, photos, sediment analysis, sediment preservation for microscope evaluation, and noted flora and fauna in and around the ponds.

Dissolved oxygen was measured in milligrams per litre (mg/L) by a hand held ExStik II DO meter. Temperature was also recorded on the same DO meter in degrees Celsius ($^{\circ}$ C) and later translated into degrees Fahrenheit ($^{\circ}$ F). The DO meter was turned on and calibrated at each sampling location prior to submerging the membrane. After

several minutes of the membrane being submerged a reading would stabilize for recording.

Salinity was measured with a VEE GEE Refractometer, which has a range from 0 to 100 parts per thousand. A water sample was placed on the glass and the lid was closed to be read. The glass was cleaned between readings and rinsed with distilled water. Salinity was measured in parts per thousand (‰) and will be reported as such. If the salt content was over 100 ‰, then the sampled water was diluted by 50%, then by 75% if needed to obtain a reading. Dilution of the pond water was only a factor on Big Halls Pond Cay and reportedly was also a factor on Little Bell Island.

The pH of pond water at each sampling location was analyzed by using pHydration Brilliant 0.0-6.0 and 6.5-13.0 testing strips. A 0-6.0 strip was dipped into the water at each location and compared to the color chart provided for a pH reading and if it read 6.0, then the 6.5-13.0 strip was tested. Scientific data from the test strip manufacturer regarding temperature compensation factors being included in the test strip results has not been received at this time, so the results will be reported both with a temperature correction value ($\pm X$) and without.

Sediment was sampled by inserting a 2 inch x 12 inch clear plastic tube into the sediment until the top of the tube reached the bottom surface or the tube could not be pushed deeper. A cap was then placed over the top of the tube and the bottom of the tube was hand-dug out and capped to reduce sediment loss. The capped, sediment filled tubes were then photographed on both white and black paper to bring out various colors and striations, then layers were described and measured.

A 1 millimetre (mm) and a 500 micrometre (μm) sieve were stacked (largest on top) in shallow water while the sediment was moved from the tube into the top (1 mm) sieve. A thin layer of water remained on top of the sediment while it was sifted until only larger fragments and shells were left in the top sieve. Types of shells and approximate numbers were recorded and photographs were taken of the sieve. Then the lower sieve (500 μm) material was removed and placed into a sample jar, filling it approximately half way to the top. Rose Bengal stain was placed in the sample jar and the remainder of the jar space was filled with ethanol for preservation.

Upon returning to the office, the preserved sediments were examined under a 10x W.F. microscope to identify the smaller macroinvertebrates.

5.0 RESULTS

Table 1: Sampling Results

Samples	DO	pH (Temp Correction)	Salinity	Temp	~Time	~Tide
Bell Island						
4A	6.2 mg/L	7 (+0.21)	40 ‰	32°C/ 89.6 F	1:20 PM	INCOMING
4B	5.6 mg/L	7 (+0.24)	43 ‰	33.4°C/ 92.1 F	1:50 PM	INCOMING
4C	4.45 mg/L	7.5 (+0.33)	45 ‰	36.1°C/ 96.9 F	2:20 PM	INCOMING
Point of Water Entry	1.05 mg/L	Not taken	40 ‰	34.3°C / 93.7°F	2:55 PM	INCOMING
Little Halls Pond						
2A	3.42 mg/L	7 (+0.18)	63 ‰	~31°C/ 88°F	10:00 AM	LOW
2B	3.11 mg/L	7 (+0.18)	64 ‰	~31°C/ 88°F	10:30 AM	LOW
2C	3.4 mg/L	7.5 (+0.18)	66 ‰	~31°C/ 88°F	11:00 AM	LOW
Big Halls Pond						
3A	1.11 mg/L	7.5 (+0.36)	300 ‰	37°C/ 98.6°F	11:50 AM	INCOMING
3B	1.14 mg/L	7.5 (+0.33)	280 ‰	36.7°C/ 98.1°F	12:20 PM	INCOMING
3C	1.06 mg/L	7.5 (+0.33)	300 ‰	36.6°C/ 98.6°F	12:50 PM	INCOMING
BACKGROUND TAKEN AT BEACH DIRECTLY EAST OF POND						
	2.65 mg/L	Not taken	40 ‰	31.6°C / 88.9°F	3:15 PM	NEAR SLACK
Little Bells Cay (Sampled 2007)						
	Not taken	Not taken	160 ‰	Not taken	Not taken	Not taken

Background salinity was taken in one of the Bell Island bays to compare with the various salt pond salinity readings. Background was found to be 40‰, which would make the Exuma waters in August metahaline (36-50‰) in salt content instead of the expected euhaline measurements (30-35‰) typical salt water seas.

Bell Island

If background salinity of the Exuma waters is 40‰, then Bell Island's salt pond would also be considered metahaline in the Thallasic Series according to Jarecki and Walkey (2006) and not hypersaline. Samples A, B and C had salinity readings of 40, 43 and 45‰, respectively. It was also noted there were small areas along the southern shoreline where water with a salinity of 40‰ was being introduced into the pond from under limestone karstic features. In addition to salinity being near that of surrounding open waters, there were also patches of fuzzy finger algae (*Batophora* sp.) noted in the pond (Figure 11).



Figure 11: Fuzzy finger algae in pond

The more extreme readings for temperature, pH and salinity were noted in a very shallow area of the pond near the southwestern corner at Station 4C (Exhibit 1). Sampling occurred from approximately 1:20 p.m. until 2:55 p.m.

Pond depth varied from 2 to 8 inches; dissolved oxygen varied from 4.5 to 6.2 mg/L, decreasing with increasing temperature; and pH remained relatively constant except in sample 4C, which increased by 0.5. Species noted foraging in the pond were black-necked stilt (*Himantopus mexicanus*) and dowitcher (*Limnodromus sp.*) as seen to the right (Figure 12).



Figure 12: Dowitcher foraging in pond

Sediment descriptions are found below.

Sample 4A

- 6 cm silty material with live worms (unknown species)
- 12 cm sandy material with salt and pepper coloring interspersed with reddish granules
- gleyed mud at bottom of tube

Figure 13: Sediment sample 4A



Organisms identified under microscope from 500 μ m sieve: live worms (unknown species), shell fragments, juvenile costate horn snails (*Polymesoda floridana*), and marsh clams (*Anomalocardia auberiana*)

Organisms identified from 1 mm sieve: 1 live marsh clam, approximately 75 half marsh clam shells, hundreds of costate horn shells, and 1 specimen of fuzzy finger algae (*Batophora sp.*).

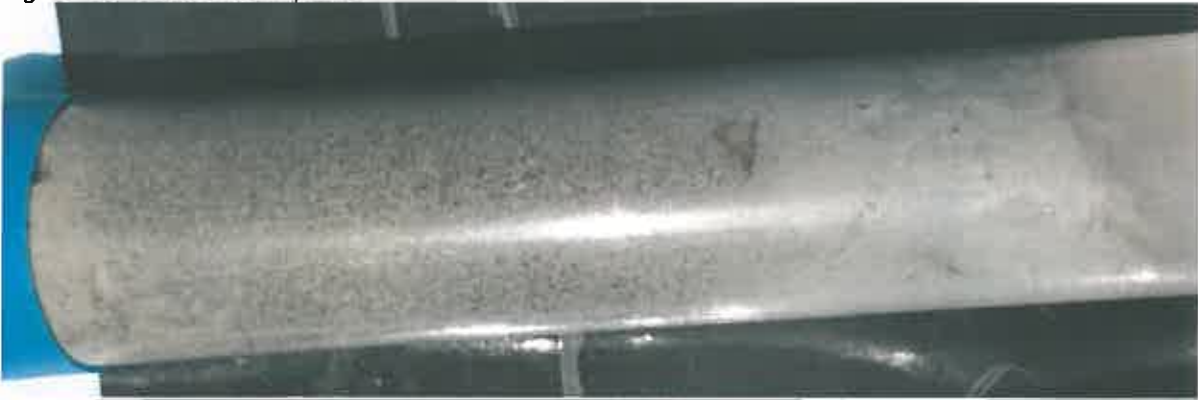


Figure 14: Sample 4A 1 mm sieve

Sample 4B

- 6 cm silty material with live worms (unknown species)
- 10 cm sandy material with salt and pepper coloring interspersed with reddish granules
- gleyed mud at bottom of tube

Figure 15: Sediment sample 4B



Organisms identified under microscope from 500 μ m sieve: high number juvenile marsh clams (*Polymesoda floridana*), juvenile costate horn shells (*Anomalocardia auberiana*) and shell fragments.

Organisms identified from 1 mm sieve: 2 live marsh clam, approximately 50 half marsh clam shells, and hundreds of costate horn shells.



Figure 16: Sample 4B 1mm sieve

Sample 4C

- 0.5 cm red/orange algae with green/yellow just below
- 0.5 cm black/gray
- 8 cm brown, with salt and pepper sandy zone full of shells
- gleyed mud, with oxidized orange streaks

Figure 17: Sediment Sample 4C



Organisms identified under microscope from 500 μ m sieve: marsh clams (*Polymesoda floridana*), costate horn shells (*Anomalocardia auberiana*), and shell fragments.

Organisms identified from 1 mm sieve: 0 live marsh clams, approximately 50 half marsh clam shells, hundreds of costate horn shells, and green algae.



Figure 18: Sample 4C 1mm sieve

Big Halls Pond Cay

Big Halls Pond would be classified as extremely hypersaline and moderately alkaline. In order to obtain salinity readings with the refractometer, the pond water had to be diluted by 75% to get a reading of 75 parts per thousand, which correlates to a salinity of 300‰ (or 7.5 times that of surrounding seas).

No birds were noted foraging in this pond, but there were two types of land crabs found dead in fair abundance: black land crab (*Gecarcinus ruricola*) and mangrove land crab (*Ucides cordatus*).

Figure 19: Red mat surface of pond

Unlike the other two ponds, Big Halls pond was covered in a spongy red algal mat, that was firm enough to stand on in most places, but flexed when walked upon (Figure 19). The entire mat surface was covered in tiny brine nodules that were firm and slippery to the touch. The mat was approximately 2 inches in thickness, with a red layer on the surface, followed by a green layer, a gray-black layer and finally a brown-green layer as seen in Figure 20.

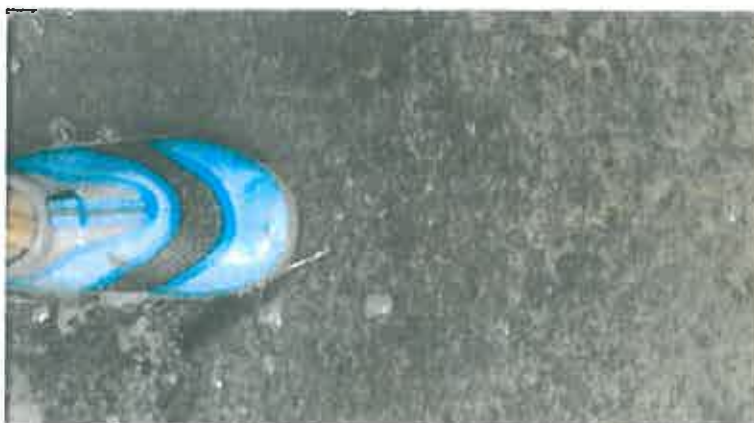


Figure 20: Profile of the sediment mat at Big Halls Pond



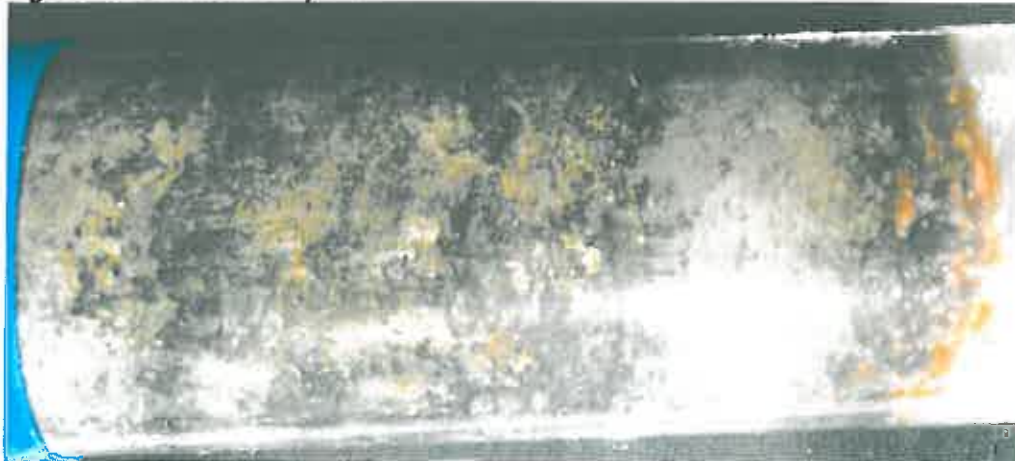
Temperatures in the pond were extremely uncomfortable and varied between 36.6 and 37°C. As would be expected with high temperatures, the dissolved oxygen was extremely low (1.06 to 1.14 mg/L) and well below what most marine species can tolerate for any length of time. If correction factors are needed for the recorded pH readings, then the pond would have a pH in excess of 7.8, making it slightly alkaline.

Sampling at Big Halls Pond was done in the middle of the day between approximately 11:50 a.m. and 12:50 p.m. Sediment descriptions are found below.

Sample 3A

- 1.5 cm orange/burgundy algae-like, with some dark patches
- 2 cm gleyed, silty mud
- remaining sediment was very striated with brown, tan, and black coloring

Figure 21: Sediment sample 3A

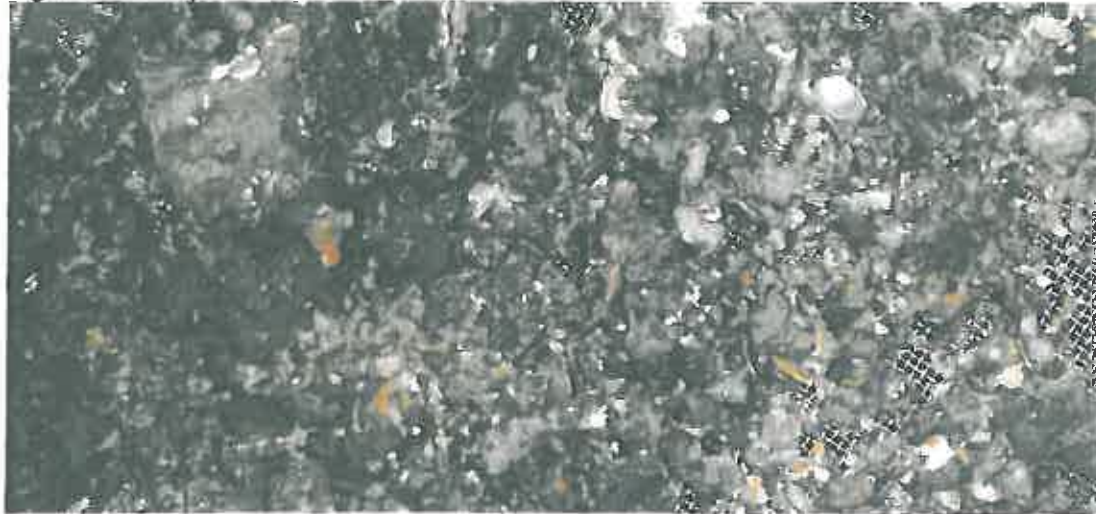


Organisms identified under the microscope from 500µm sieve: algae, juvenile marsh clams (*Polymesoda floridana*) and salt crystals.

Organisms identified from 1 mm sieve: 5 juvenile costate horn snails (*Anomalocardia auberiana*), 10 juvenile half marsh clams, red algae, green algae and brown algae.

Note: very difficult to sieve due to gelatinous make-up.

Figure 22: Sample 3A 1 mm sieve



Sample 3B

- 0.5 cm red/burgundy algae, with some dark patches
- 1-4 cm brown-black
- gray sand and mud mixture

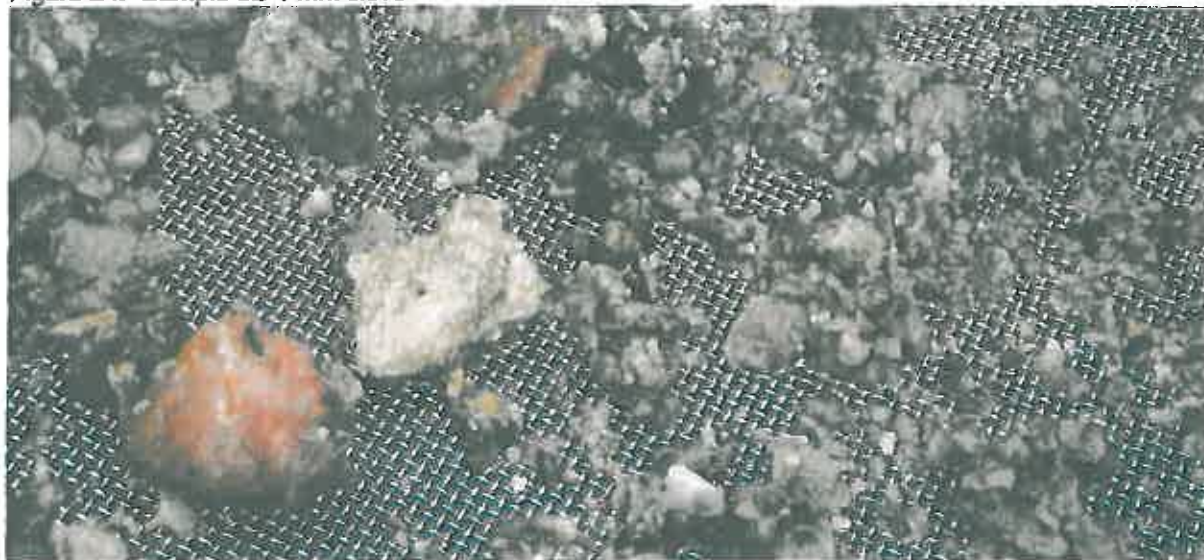
Figure 23: Sediment sample 3B



Organisms identified under the microscope from 500µm sieve: algae, juvenile marsh clams (*Polymesoda floridana*), few juvenile costate snails (*Anomalocardia auberiana*) and salt crystals.

Organisms identified from 1 mm sieve: 5 juvenile costate snails, 30 juvenile half marsh clams, pink algae, and brown algae. *Note: very difficult to sieve due to gelatinous make-up.*

Figure 24: Sample 3B 1 mm sieve



Sample 3C

- 0.5 cm red/burgundy algae, with some dark patches
- 1.5 cm brown-black
- 9 cm striated gray, tan, black-brown
- remainder is gray and sandy

Figure 25: Sediment sample 3C



Organisms identified under the microscope from 500 μ m sieve: algae, salt crystals and juvenile marsh clams (*Polymesoda floridana*).

Organisms identified from 1 mm sieve: 40 costate snails (*Anomalocardia auberiana*), 12 half marsh clams, green algae, pink algae and salt clumps. *Note: very difficult to sieve due to gelatinous make-up.*

Figure 26: Sample 3C 1 mm sieve



Little Halls Pond Cay

Little Halls Pond would rank as a hypersaline environment since its salinity falls above 50 parts per thousand. Salinity readings varied from 63 to 66‰ in the pond. Sampling occurred between approximately 10:00 and 11:00 a.m. Temperature was not scientifically recorded at Little Halls Pond as it was at the other ponds due to field equipment error. An estimated water temperature was agreed upon by field staff of 88°F (31°C) and is referenced in the results table as being approximate.

The pond was lined with limestone rock and the same mangrove composition as the other two ponds; buttonwood, silver buttonwood and white mangrove primarily. Small amounts of fuzzy finger algae were noted in the pond near the cart path crossing, most likely due to rain water draining off the path into this area. Salinity measurements were also the lowest near this cart path.



Figure 27: Little Halls Pond

Bottom sediment of Little Halls Pond was silty and soft, with rocks sporadically breaking the surface throughout the pond (Figure 27). Water depth varied from approximately 4 to 12 inches and dissolved oxygen readings varied from 3.11 to 3.42‰.

Sediment sampling results can be found below.

Sample 2A

- 0.25 cm tan, red and green- spongy striated layer
- remainder was gleyed, silty sand with many clam shells, and snails

Figure 28: Sediment Sample 2A



Organisms identified under the microscope from 500 μ m sieve:
algae, shell fragments, juvenile costate horn snails (*Anomalocardia auberiana*) and
juvenile marsh clams (*Polymesoda floridana*).

Organisms identified from 1 mm sieve: approximately 200 costate snails, 60 half marsh
clams and clumps of algae (green/brown/red).

Figure 29: Sample 2A 1mm sieve



Sample 2B

- 2 cm tan, red, green silty algae mix
- 0.5 cm blackish layer
- remainder gleyed, silty sand

Figure 30: Sediment Sample 2B



Organisms identified under the microscope from 500 μ m sieve: primarily algae with a small amount of shell fragments and juvenile marsh clams (*Polymesoda floridana*).

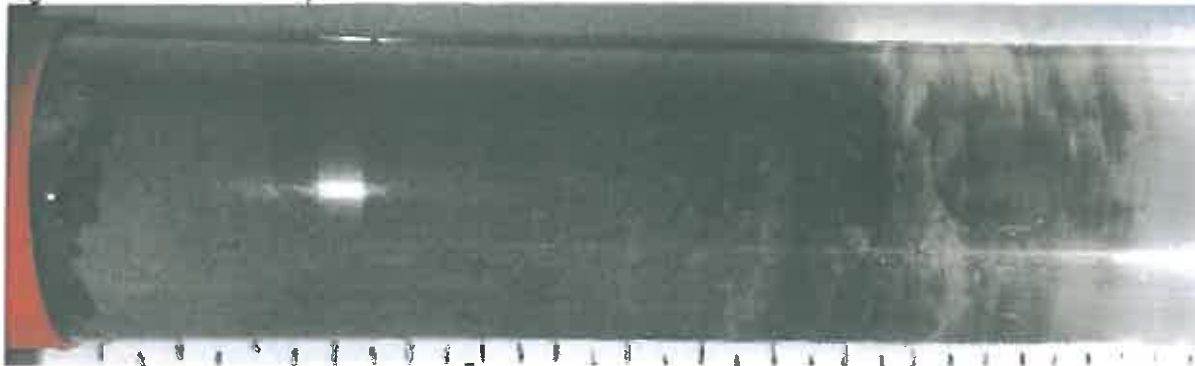
Organisms identified from 1 mm sieve: approximately 25 costate snails (*Anomalocardia auberiana*), and 18 half marsh clams.

*Note: No photo of the 1 mm sieve available due to camera malfunction at this station

Sample 2C

- 1cm yellow-brown silty algae
- 2 cm burgundy algae
- 0.5 cm light gray silt
- 0.5 cm brown silt
- 0.5 cm black silt
- 3 cm light gray silt
- remainder darker gray silty material

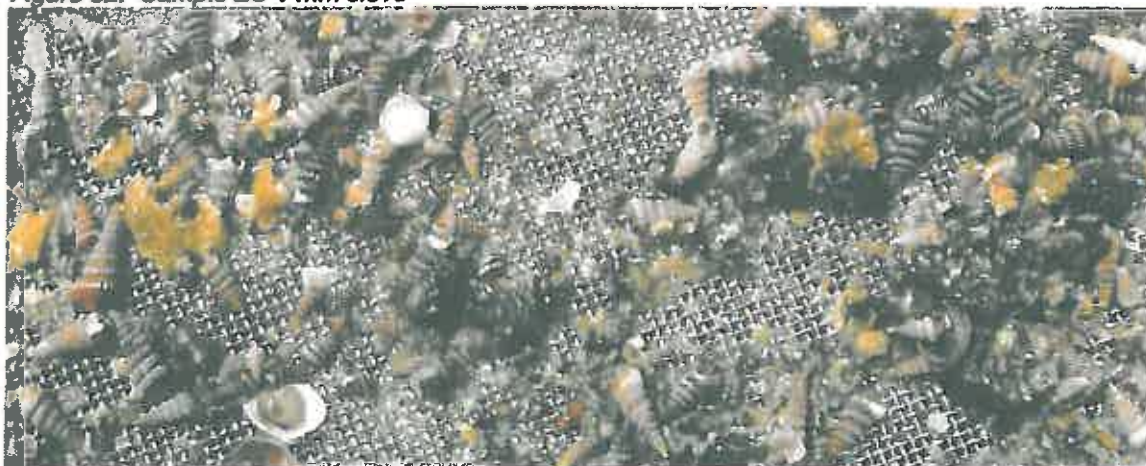
Figure 31: Sediment Sample 2C



Organisms identified under the microscope from 500 μ m sieve: primarily algae with a small amount of shell fragments, and juvenile marsh clams (*Polymesoda floridana*).

Organisms identified from 1 mm sieve: approximately 150 costate snails (*Anomalocardia auberiana*), 50 half marsh clams, and clumps of yellow-brown algae.

Figure 32: Sample 2C 1 mm sieve



Little Bell Island

The sediment sampled from Little Bell Island's pond in 2007 was very gelatinous and was comprised of green and brown algae. Brine shrimp (*Artemia sp.*) and brine shrimp eggs were also found in the pond at that time. Pond water salinity had to be diluted by 50% in order to get a reading on the refractometer. Salinity was read to be 80‰ at 50% dilution, which translates to 160‰ (or 4 times the 2009 background reading).



Figure 33: Little Bell Island pond sediment sample.

6.0 CONCLUSIONS

It is apparent from our sampling results there are direct correlations to temperature, dissolved oxygen, salinity and pH, as reported in other studies. In hypersaline conditions, as was noted in Little Halls Pond and Big Halls Pond, dissolved oxygen went down significantly to levels where most marine species would be very stressed or could not survive at all. In mesohaline environments (just below hypersaline), as was the case for Bell Island, the dissolved oxygen was within a threshold to maintain a small variety of marine life, although very little was present.

Dissolved oxygen was highest on Bell Island. A desirable dissolved oxygen level for fish would be 9.1 to 12 mg/L (Murphy, 1997), while any level below 5.0 mg/L would stress fish. Bell Island salinity averaged 42.6‰ and the dissolved oxygen averaged 5.42 mg/L. Little Halls Pond salinity averaged 64.3‰ and the dissolved oxygen averaged 3.31 mg/L. Big Halls Pond salinity averaged 293‰, which is eight times that of normal seawater, and dissolved oxygen averaged 1.10 mg/L. Little Bell Island salinity was measured at 160‰.

Of the four ponds sampled, Big Halls Pond had the most unique and hostile environment. Very little life as we know could survive in that high temperature and salinity, combined with extremely low dissolved oxygen levels. Local boat operators informed us the pond will occasionally dry up in extreme droughts. Unlike the other two ponds, this pond does not appear to have salt water transfers or freshwater input other than rainfall.

The pH of Little Halls Pond and Bell Island varied between neutral (7.0) and slightly alkaline (7.5), however we have not determined from the pHDrion paper manufacturer if the temperature correction value was needed for our readings. If pH did need correcting, then the readings would vary between 7.21 and 7.83. Big Halls Pond pH measured 7.5 consistently, +0.33 if correction was required. Seawater typically has a pH of 8.0, so the ponds measured were actually more acidic than seawater, but would still be classified as slightly alkaline.

The Bell Island pond appears to be the only pond of the four sampled which could not be considered hypersaline. A modest amount macrofaunal marine life was noted in Bell Island's pond and a very small amount was noted Little Hall's Pond, however it is not unique marine life and can be found in abundance immediately offshore. Of the four sampled, the most distinctive and intriguing environment was found on Big Hall's Pond Cay followed closely by that of Little Bell Island. Most likely life in Big Hall's Pond would be comprised of extremophiles requiring the aid of electron microscopes to view them and microbiologists to study them.

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BELL ISLAND AND TWO NEIGHBORING SALT PONDS: A STUDY OF THEIR CHARACTERISTICS
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EXHIBIT 1: SEDIMENT SAMPLING LOCATIONS

BIG HALLS POND CAY



LITTLE HALLS POND CAY



BELL ISLAND



EXHIBIT 2: ESTIMATED SALT PONDS IN THE EXUMA ISLANDS

Island Name (from N to S in chain)	# Salt Ponds	Island Name	# Salt Ponds
Little Norman's Cay	1	Big Farmers Cay	1
Norman's Cay	2	Big Galliot Cay	1
Little Wax Cay	4	Cave Cay	1
Shroud Cay	2	Rudder Cut Cay	2
Hawksbill Cay	2	Little Darby Island	2
Little Cistern	2	Darby Island	2
Waderick Wells Cay	3	Prime Cay	1
Narrow Water Cay	1	Bock Cay	1
White Bay Cay	1	Melvin/ Low Cay	1
Big Halls Pond Cay	4	Gold Ring Cay	1
Little Halls Pond Cay	1	Norman's Pond Cay	1
Cambridge Cay/ Little Bell Island	2	Leaf Cay (N of Great Exuma Island)	1
Bells Cay/ Big Bell Island	1	Lee Stocking Island	2
Compass Cay	1	Children's Cay	2
Pipe Cay	3	Rat Cay	1
Little Hattie Cay	1	Great Exuma Island	19
Sampson Cay	2	Stocking Island	1
Big Majors Spot	2	(W of Great Exuma) Duck Cay	1
Little Majors Spot	1	(W of Great Exuma) Coakley Cay	2
Staniel Cay	2	Little Exuma Island	23
Great Guana Cay	4	Hog Cay	2
Little Farmers Cay	1	Leaf Cay (SE of Little Exuma Island)	1

Total Estimated Salt Ponds within Exuma Chain: 112

Note:

The salt ponds noted were observed from Google Earth Maps and using the Explorer Chartbook of the Exuma and Ragged Islands (5th Edition), but were not field verified except as noted in this report, so numbers are only an estimate.

APPENDIX III

“RECONNAISSANCE OF PROPOSED CHANNEL AND DOCKAGE SITES: BELL ISLAND, EXUMAS”

*Reconnaissance of Proposed Channel and Dockage Sites:
Bell Island, Exumas*

22 February, 2010



eVm research & design
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Reconnaissance of Proposed Channel and Dockage Sites: Bell Island, Exumas

Introduction

eVm research & design was tasked to examine three sites near Bell Island (aka Big Bell Island), located in the central Exuma Cays. Sky conditions were partly cloudy with a north wind ~12 kts. Sea conditions were calm to a light chop and underwater visibility ~75'. Sites were examined by snorkeling on 18 Feb., 2010. Surface support was provided by the client. The sites are described in the order they were visited.

Site Descriptions & Recommendations

Yacht Basin Approach

A dredged channel is proposed leading to a yacht basin along the SE corner of Bell Island (Fig. 1). The shoreline is native limestone fringed by sloping hardground approximately 15-20' wide (Fig. 2). Beyond the hardground is a relatively flat area ~6-10' of sparse *Thalassia testudinum* (turtle grass). The sparse grass bed is tapered towards the east by an offshore sand bore. The proposed channel would breach the shoreline, cross the hardground fringe, follow the sparse grass bed and cross the sand bore in an easterly direction to a deep (~15'+) tidal channel.

Small isolated corals, sponges and gorgonians are present on the ledge along with a few "micro" patch reefs (Fig. 3a), small clumps of medium-sized coral heads (probably *Montastrea annularis* complex) that are mostly dead but have been colonized by other corals, sponges and other patch reef biota. A single colony of *Montastrea faveolata* (~0.5 m diameter) is growing very close to the shoreline just to the west of the proposed channel (Fig. 3b). A cluster of medium-sized (~1+ m diameter) coral heads was observed in the deep channel near the eastern terminus of the proposed basin approach. Most appeared to be largely dead with subsequent colonization as described above. No direct impact on these heads is anticipated.

Recommendations: Most corals in the reconnaissance area will be avoided by the proposed project as planned. It is recommended that the inshore edge of the proposed channel lie along the hardground-sand interface (Fig. 2). Thus, the dredging will primarily affect the sparse grass bed and nearby sand bore with low environmental impact.

Near the western terminus where the shoreline is to be breached, there is a micro patch reef just off of the ledge that lies within the proposed channel area. While this is not considered to be a very significant reef (many would not consider it a reef at all), it does have several species of coral, other reef biota and structure that supports a small school of French grunts (*Haemulon flavolineatum*), mahogany snapper (*Lutjanus mahogoni*), several squirrelfish (*Holocentrus adscensionis*), and other small reef species. One ~30 cm Nassau grouper (*Epinephelus striatus*) and an Indo-Pacific

lionfish (*Pterois volitans* or *miles*) were observed seeking concealment within the structure. The latter is an invasive exotic species. This micro patch reef was the most diverse observed in the immediate area. One could argue that destruction of this structure would not constitute a significant environmental loss. However, if one wanted to take the most conservative approach, it would not be technically challenging to move this micro patch reef a short distance (probably westward) out of the proposed channel footprint. There is abundant hardground to serve as substrate.

It is further recommended that care be taken during dredging operations to avoid sedimentation or collateral damage to corals close to the proposed channel.

Barge Landing Channel

This project area lies along the northwestern edge of Bell Island (Fig. 4). The northern portion of this site has a scarified hard bottom with sand-filled depressions. Very few sessile organisms, including a few small corals, were observed on exposed hard substrate. It appears that this area is heavily sand scoured and variable sedimentation has probably prevented the long-term establishment of sessile organisms. The southern portion is sandy with sparse grass.

Recommendations: No significant environmental impact is anticipated in the project area and no actions recommended.

Barge Landing

Located in a cove on the southwestern side of Bell Island (Fig. 5), most of this area is sandy bottom with two small patches of coral rubble providing some relief. A few small colonies of live hard corals were observed on the rubble but these features did not contribute enough structure to attract many other organisms. Near the existing dock is a sizable limestone outcropping in very shallow water, partially exposed to air at low tide. A few, small corals were observed but, again, few other biota were attracted to it.

The dock pilings had the most significant coral colonies in the area. Some *Porites porites* colonies are quite sizable and have grown into complex shapes. As these are on man-made structures, one could argue that they wouldn't be there naturally and are thus considered incidental taking.

Recommendations: None of the benthic features are considered significant enough to warrant moving or other mitigation. While no recommendations are made regarding the corals on the pilings, it may be of interest to the client to create a small coral nursery/artificial reef with some of the concrete pilings and corals from other pilings (to be disposed of) that would be accessible to themselves and their guests.

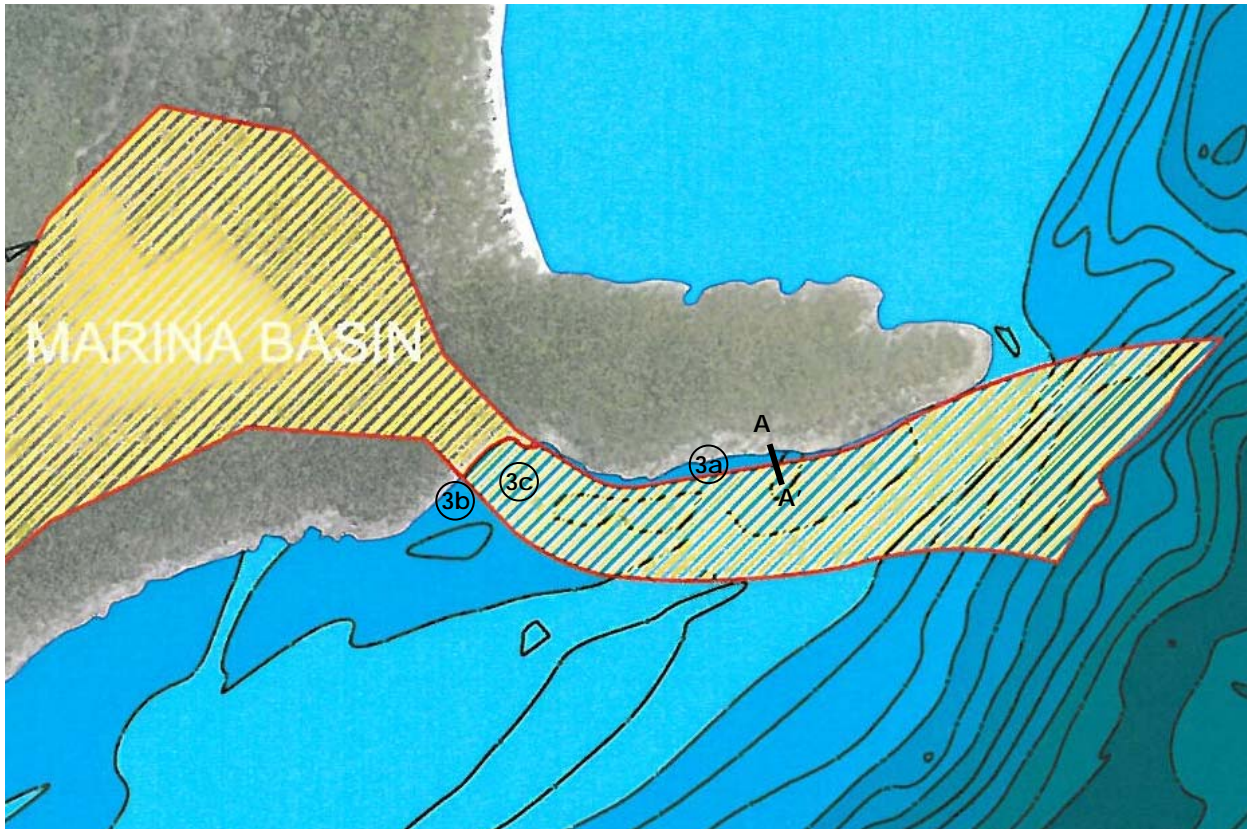


Fig. 1 – Yacht Basin Approach. Shoreline profile A-A' shown below in Fig. 2. Circles refer to Fig. 3a-c. Image provided by Turrell, Hall & Associates, Inc.

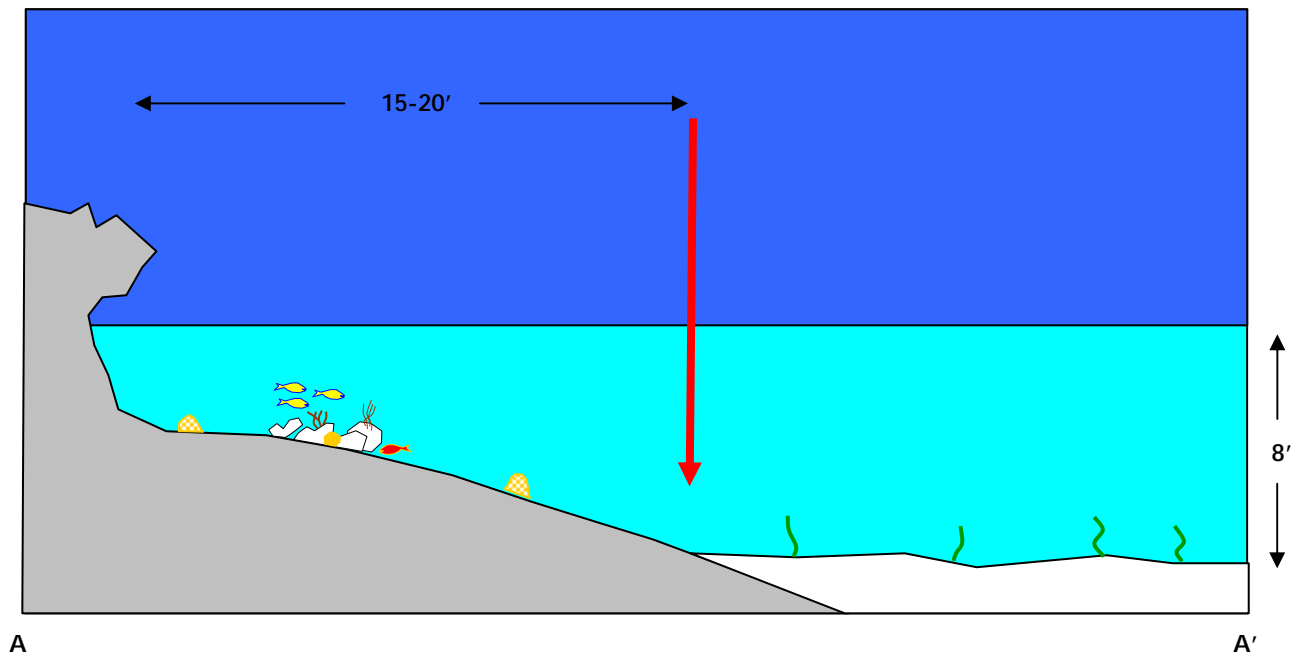


Fig. 2 – Yacht Basin Approach. Shoreline profile A-A'. Not to scale; dimensions approximate. Arrow indicates recommended inner limit of channel dredging.

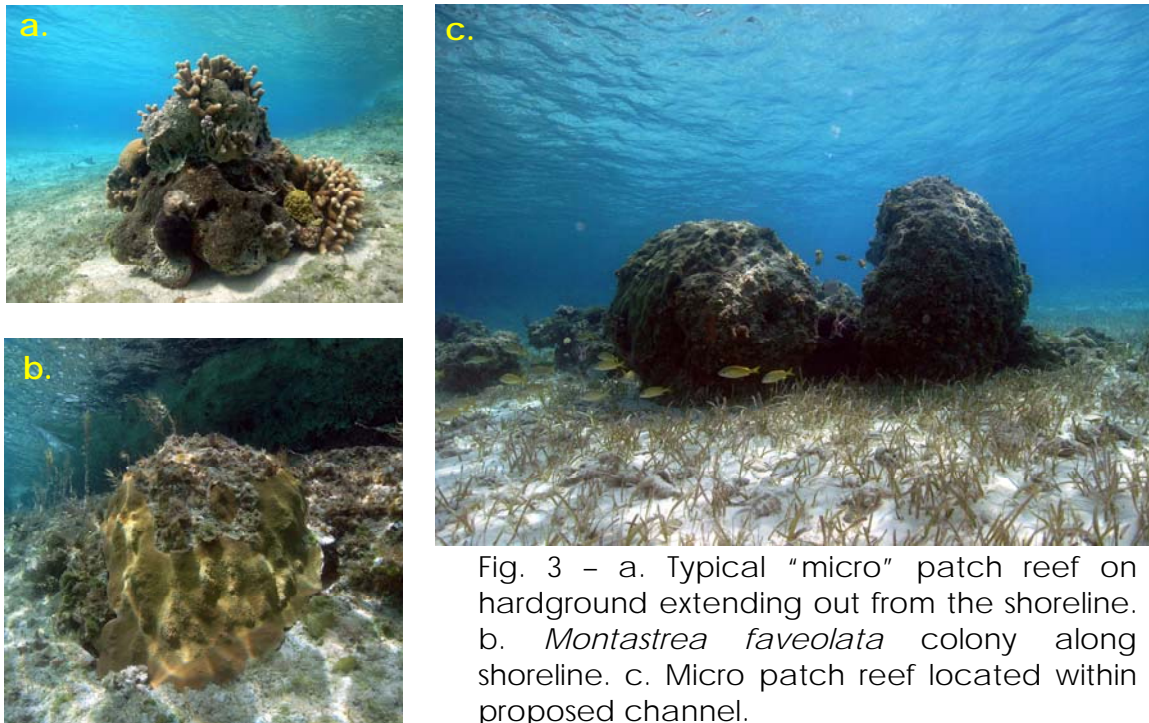


Fig. 3 – a. Typical “micro” patch reef on hardground extending out from the shoreline. b. *Montastrea faveolata* colony along shoreline. c. Micro patch reef located within proposed channel.

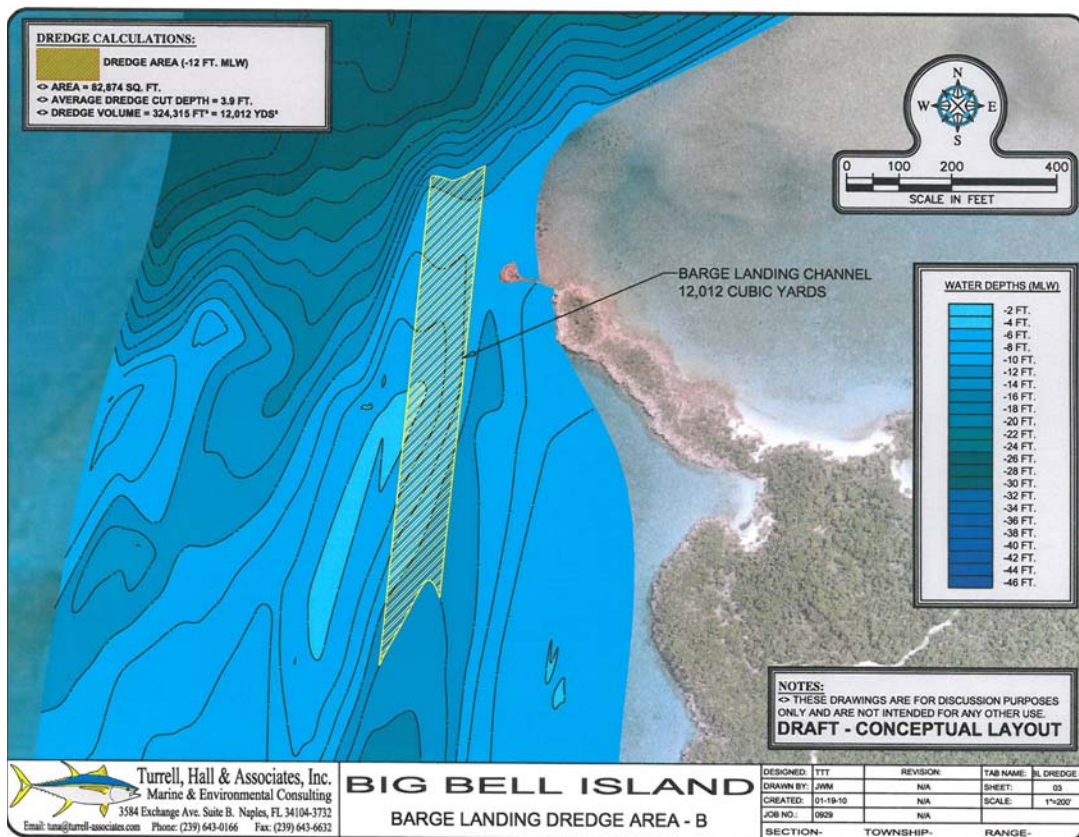


Fig. 4 – Barge Landing Channel. Image provided by Turrell, Hall & Associates, Inc.

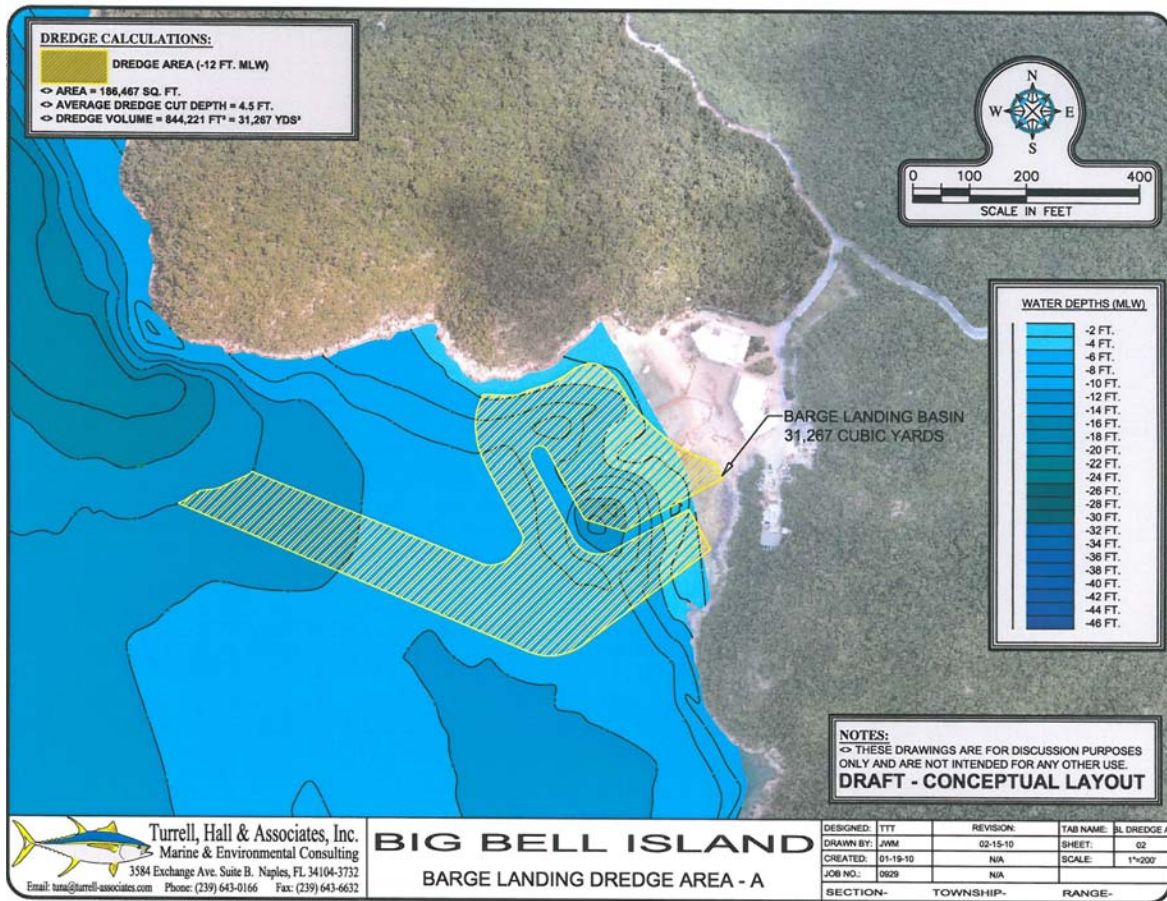


Fig. 5 – Barge Landing. Image provided by Turrell, Hall & Associates, Inc.

APPENDIX III

(SUPPLEMENT)

“RECONNAISSANCE OF PROPOSED CHANNEL AND DOCKAGE SITES: BELL ISLAND, EXUMAS”

REVISED FEB. 12, 2011

*Reconnaissance of Proposed Channel and Dockage Sites:
Bell Island, Exumas*

22 February, 2010

Revised 12 February, 2011



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Reconnaissance of Proposed Channel and Dockage Sites: Bell Island, Exumas

Revision Notes

This revision is based on changes to the proposed project scope, specifically the elimination of some dredge areas. The Yacht Basin Approach site is unchanged, the Barge Landing Basin has been modified as shown in Figure 4 and the Barge Landing Channel has been eliminated. The description of the sites has been re-ordered to reflect the changes and some text has been changed for greater clarity.

Introduction

eVm research & design was tasked to examine three sites near Bell Island (aka Big Bell Island), located in the central Exuma Cays. Sky conditions were partly cloudy with a north wind ~12 kts. Sea conditions were calm to a light chop and underwater visibility ~75'. Sites were examined by snorkeling on 18 Feb., 2010. Surface support was provided by the client. The sites are described in the order they were visited.

Site Descriptions & Recommendations

A. Yacht Basin Approach

A dredged channel is proposed leading to a yacht basin along the SE corner of Bell Island (Fig. 1). The shoreline is native limestone fringed by sloping hardground approximately 15-20' wide (Fig. 2). Beyond the hardground is a relatively flat area ~6-10' of sparse *Thalassia testudinum* (turtle grass). The sparse grass bed is tapered towards the east by an offshore sand bore. The proposed channel would breach the shoreline, cross the hardground fringe, follow the sparse grass bed and cross the sand bore in an easterly direction to a deep (~15'+) tidal channel.

Small isolated corals, sponges and gorgonians are present on the ledge along with a few "micro" patch reefs, small clumps of medium-sized coral heads (probably *Montastrea annularis* complex) that are mostly dead but have been colonized by other corals, sponges and other reef biota. Some of these are close to the proposed yacht basin approach channel (Fig. 3a) and at least one is within the proposed channel area (Fig. 3c). A single colony of *Montastrea faveolata* (~0.5 m diameter) is growing very close to the shoreline just to the west of the proposed channel (Fig. 3b). A cluster of medium-sized (~1+ m diameter) coral heads was observed in the deep channel near the eastern terminus of the proposed basin approach. Most appeared to be largely dead with subsequent colonization as described above. No direct impact on these heads is anticipated.

Recommendations: Most corals in the reconnaissance area will be avoided by the proposed project as planned. It is recommended that the inshore edge of the proposed channel lie along the hardground-sand interface (Fig. 2). Thus, the

dredging will primarily affect the sparse grass bed and nearby sand bore with low environmental impact.

Near the western terminus where the shoreline is to be breached, there is a micro patch reef just off of the ledge that lies within the proposed channel area (Fig. 3c). While this is not considered to be a very significant reef (many would not consider it a reef at all), it does have several species of coral, other reef biota and structure that supports a small school of French grunts (*Haemulon flovolineatum*), mahogany snapper (*Lutjanus mahogoni*), several squirrelfish (*Holocentrus adscensionis*), and other small reef species. One ~30 cm Nassau grouper (*Epinephelus striatus*) and an Indo-Pacific lionfish (*Pterois volitans* or *miles*) were observed seeking concealment within the structure. The latter is an invasive exotic species. This micro patch reef was the most diverse observed in the immediate area. It is recommended that this micro patch reef, along with isolated corals, be relocated a short distance (probably westward) out of the proposed channel footprint. There is abundant hardground to serve as substrate.

It is further recommended that care be taken during dredging operations to avoid sedimentation or collateral damage to any corals (i.e. Fig. 3b) and micro patch reefs (i.e. Fig 3a) close to the proposed channel.

B. Barge Landing

Located in a cove on the southwestern side of Bell Island (Fig. 4), most of this area is sandy bottom with two small patches of coral rubble providing some relief. A few small colonies of live hard corals were observed on the rubble but these features did not contribute enough structure to attract many other organisms. Near the existing dock is a sizable limestone outcropping in very shallow water, partially exposed to air at low tide. A few, small corals were observed but, again, few other biota were attracted to it. Since the reconnaissance survey, the proposed area of dredging has been reduced substantially. From the drawings provided, it appears that the limestone outcropping described above will be avoided by dredge operations.

The dock pilings had the most significant coral colonies in the area. Some *Porites porites* colonies are quite sizable and have grown into complex shapes. As these are on man-made structures, one could argue that they wouldn't be there naturally and are thus considered incidental taking.

Recommendations: None of the benthic features are considered significant enough to warrant moving or other mitigation. While no recommendations are made regarding the corals on the pilings, it may be of interest to the client to create a small coral nursery/artificial reef with some of the concrete pilings and corals from other pilings (to be disposed of) that would be accessible to themselves and their guests.

C. Barge Landing Channel - This site has been eliminated from the proposed scope of work.

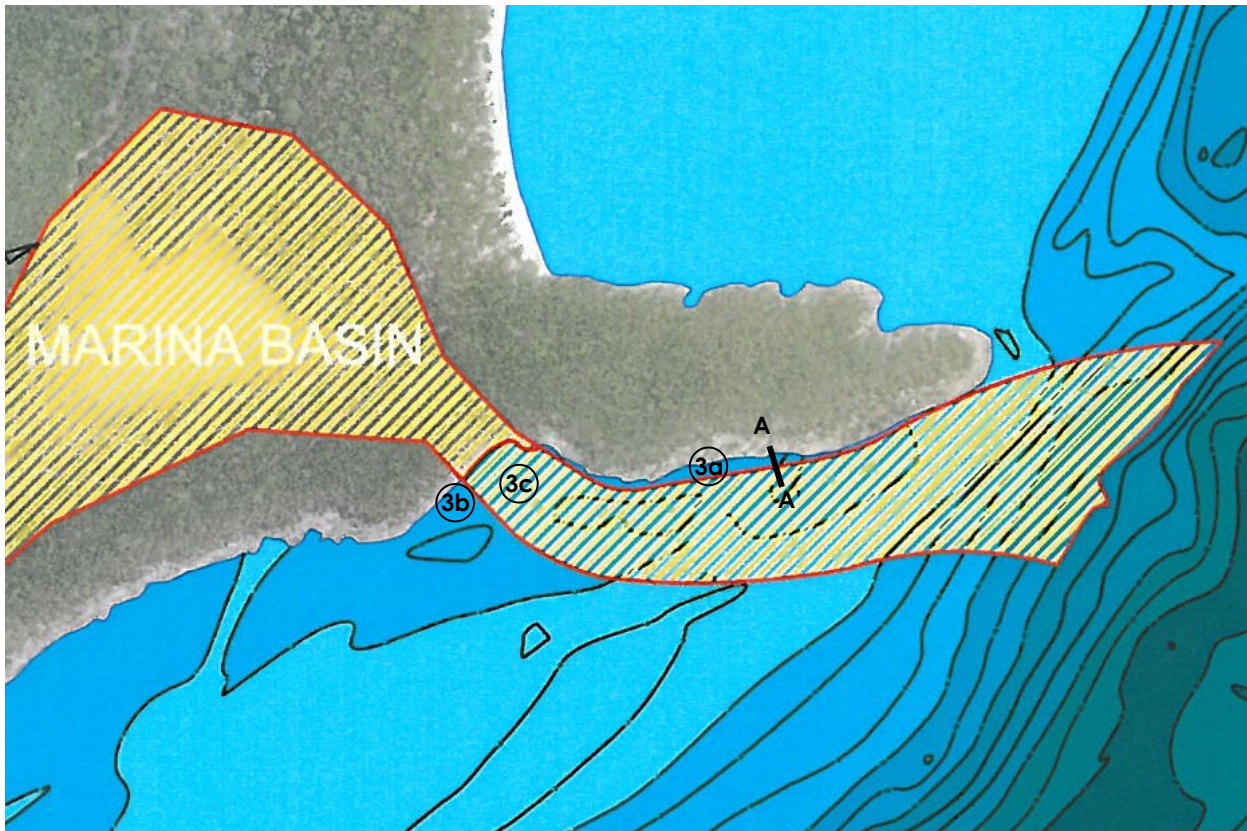


Fig. 1 – Yacht Basin Approach. Shoreline profile A-A' shown below in Fig. 2. Circles refer to Fig. 3a-c. Image provided by Turrell, Hall & Associates, Inc.

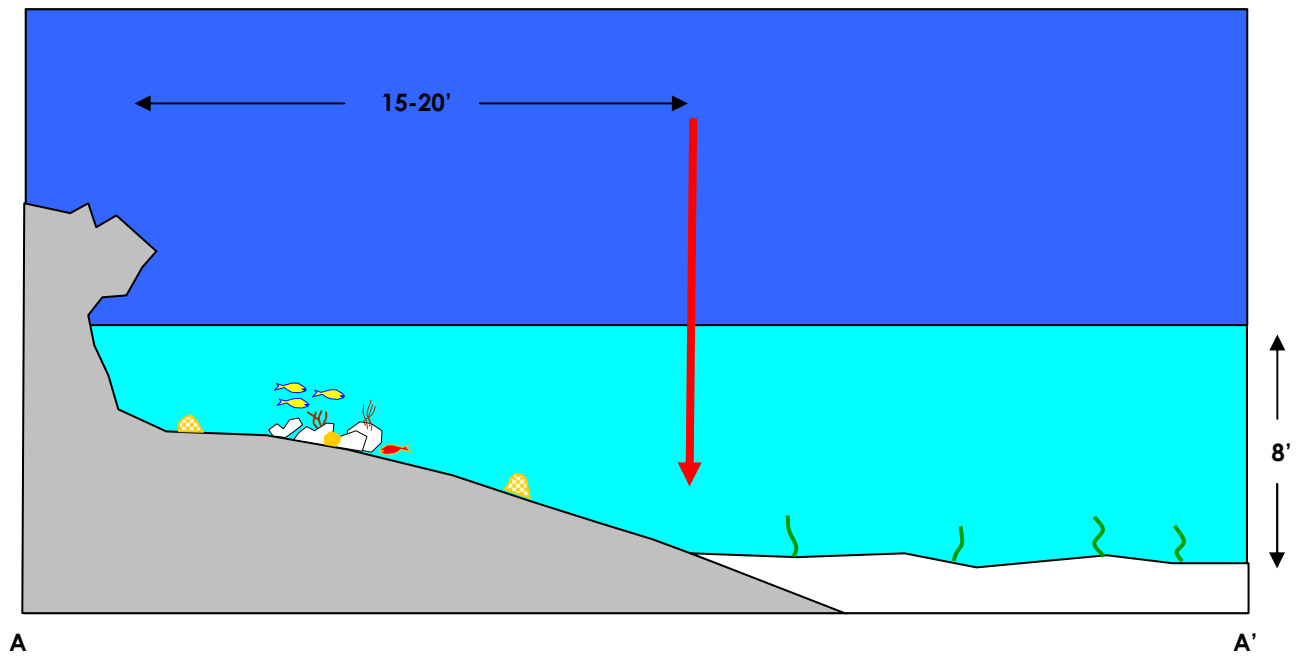


Fig. 2 – Yacht Basin Approach. Shoreline profile A-A'. Not to scale; dimensions approximate. Arrow indicates recommended inner limit of channel dredging.

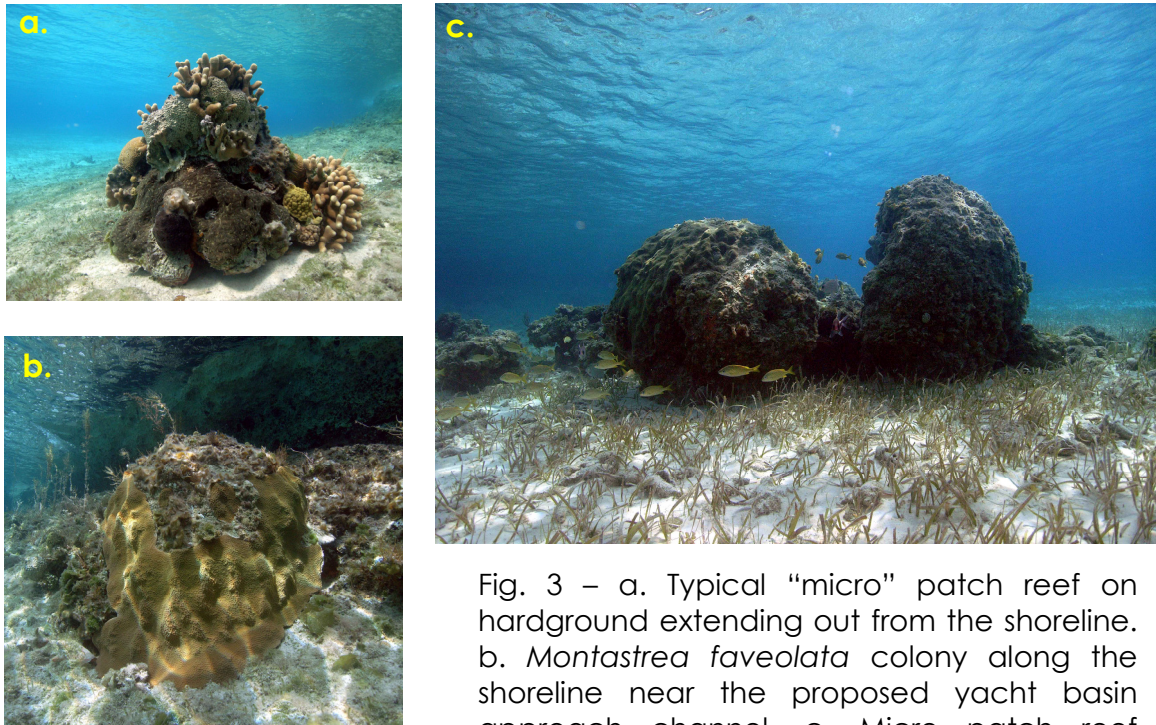


Fig. 3 – a. Typical “micro” patch reef on hardground extending out from the shoreline. b. *Montastrea faveolata* colony along the shoreline near the proposed yacht basin approach channel. c. Micro patch reef located within the proposed channel.

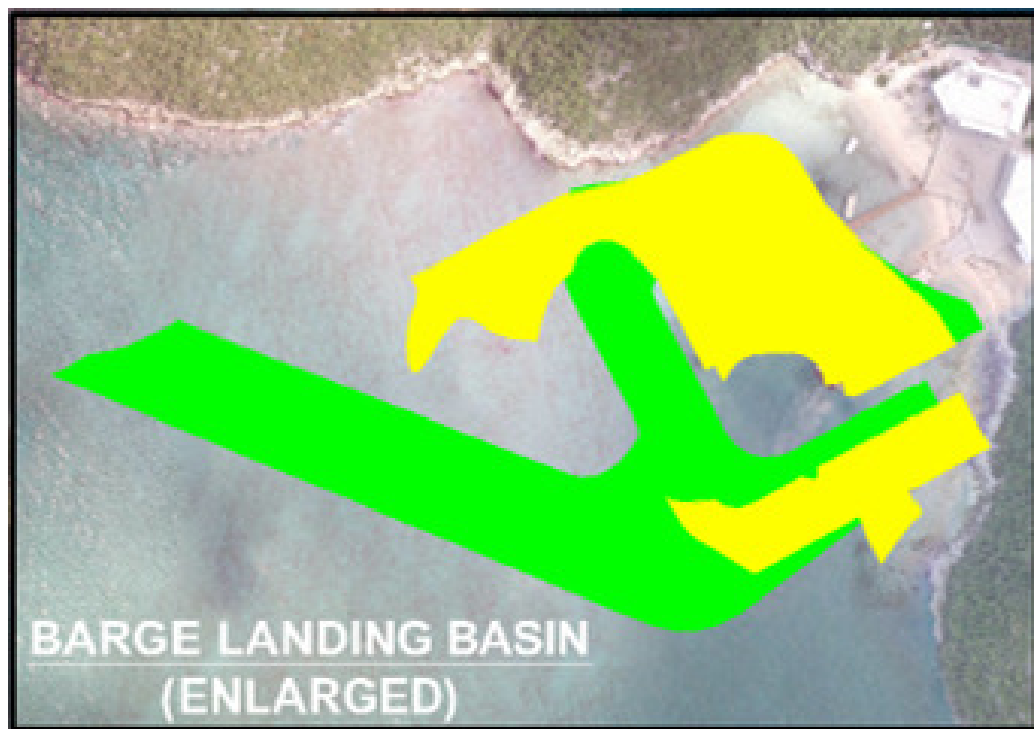


Fig. 4 – Barge Landing Basin. Original dredge area in green with revised dredge area in yellow. Image provided by Turrell, Hall & Associates, Inc.

APPENDIX IV

BAHAMIAN INVASIVE SPECIES

The Bahamas Invasive Plant Species

1. **Rosary pea** *Abrus precatorius*
2. **Asparagus fern** *Asparagus densiflorus*
3. **Poor man's Orchid, Orchid tree** *Bauhinia variegata*
4. **Australian Pine, Beef Wood** *Casuarina equisetifolia*
5. **Suckering Australian pine** *Casuarina glauca*
6. **Day jessamine** *Cestrum diurnum*
7. **Lather leaf** *Colubrina asiatica*
8. **Winged yam** *Dioscorea alata*
9. **Air potato** *Dioscorea bulbifera*
10. **Water hyacinth** *Eichhornia crassipes*
11. **Surinam cherry** *Eugenia uniflora*
12. **Azores jasmine, Brazilian jasmine** *Jasminum fluminensis*
13. **Lantana, shrub verbena, angel lips, prickly lantana,** *Lantana camara*
14. **Jumbey** *Leucaena glauca*
15. **Cat's claw vine** *Macfadyena unguis-cati*
16. **Sapodilla** *Manilkara zapota*
17. **Melaleuca, paper bark** *Melaleuca quinquenervia*
18. **Asian sword fern** *Nephrolepis multiflora*
19. **Torpedo grass** *Panicum repens*
20. **Napier grass** *Pennisetum purpureum*
21. **Scaevola, Half-flower,** *Beach naupaka,*
22. **White inkberry, Hawaiian segrape, Asian Scaevola** *Scaevola taccada*
23. **Schefflera, Queensland umbrella tree** *Schefflera actinophylla*
24. **Brazilian pepper, Bahamian holly** *Schinus terebinthifolius*
25. **Arrow head vine** *Syngonium podophyllum*
26. **Seaside mahoe, cork tree, Spanish cork** *Thespesia populnea*
27. **Wedelia** *Wedelia trilobata*
28. **Napier grass** *Pennisetum purpureum*
29. **Bay Rum** *Pimenta racemosa*
30. **Almond** *Prunus amygdalus*
31. **Castor Bean** *Ricinus communis*
32. **Mexican petunia** *Ruellia brittoniana*
33. **Schefflera, Queensland umbrella tree** *Schefflera actinophylla*
34. **Flame of the forest, African tulip tree** *Spathodea campanulata*
35. **Arrow head vine** *Syngonium podophyllum*
36. **Seaside mahoe, cork tree, Spanish cork** *Thespesia populnea*
37. **Star Jasmine** *Trachelospermum jasminoides*
38. **Wedelia, carpet daisy** *Wedelia trilobata*

The Bahamas Invasive Bird Species

- 1. Rock Dove** *Columba livia*
- 2. Shiny Cowbird** *Molothrus bonariensis*
- 3. House Sparrow** *Passer domesticus*
- 4. Eurasian Collared Dove** *Streptopelia decaocta*

The Bahamas Invasive Terrestrial Animal Species

- 1. Holstein** *Bos taurus*
- 2. Dogs all types/breeds** *Canis spp.*
- 3. Goat** *Capra hicus*
- 4. Corn snake** *Elaphe guttata*
- 5. Caribbean tree frog, common coqui** *Eleutherodactylus coqui*
- 6. Donkey** *Equus asinus*
- 7. Cats all types/breeds** *Felis catus*
- 8. Mouse** *Mus musculus*
- 9. Sheep** *Ovis aries*
- 10. Raccoon** *Procyon lotor*
- 11. Norway rat** *Rattus norvegicus*
- 12. Ship rat** *Rattus rattus*
- 13. Red imported fire ant** *Solenopsis invicta*
- 14. Pig** *Sus scrofa*
- 15. Red-eared slider** *Trachemys scripta*
- 16. Brown recluse spider** *Loxosceles reclusa*
- 17. Little fire ant** *Wasmannia auropunctatus*

The Bahamas Invasive Aquatic Species

- 1. Clown fish** *Amphiprion sp*
- 2. Brine shrimp** *Artemia cysts*
- 3. Blue crab** *Callinectes sapidus*
- 4. Dragonet** *Callionymus lyra*
- 5. Red claw** *Cherax quadricarinatus*
- 6. Banded shark** *Chiloscyllium punctatum*
- 7. Brown Bamboo shark** *Chkosoyllium piunctatum*
- 8. Sea nettle** *Chrysoara quinquechirra*
- 9. Cichild fish** *Family Cichlidae*
- 10. American oyster** *Crassostrea virgnica*
- 11. Green algae** *Dunaliella sp.*
- 12. Queensland grouper** *Epinephelus lanceolatus*
- 13. Blue-girded angelfish** *Euxiophipops navarchis*
- 14. Yellow-faced angelfish** *Euxiophipops xanthometapm*
- 15. Bamboo shark** *Hemiscylliidae*
- 16. Zebra Bullhead shark** *Heterodontus zebras*
- 17. Algae** *Nannochloropsis oculata*
- 18. Tilapia** *Oreochrommis ureblepis*
- 19. Sea anemona** *Radianthus*
- 20. Lionfish** *Pterois volitans*

APPENDIX V

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APPENDIX VI

RESUMES OF PERSONNEL INVOLVED IN THE EIA

Engineer

Todd T. Turrell, P.E.

Turrell & Associates, Inc.
3584 Exchange Ave.
Naples, FL 34104

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Summary

Todd Turrell is a licensed Ocean Engineer with over twenty years experience in design and permitting for marine and land development in southwest Florida and the Caribbean. In addition to practical and cost effective planning of waterfront projects, he offers innovative and realistic solutions to environmental issues. He is an expert on local and regional regulatory issues and with long standing collaborative relationships with agency personnel, has an outstanding success rate in project permissibility. Todd leads a diverse group of marine and terrestrial scientists and technical staff that efficiently produce the supporting data and plans for every project.

Qualifications

- 1985, M.B.A., Nova University, Fort Lauderdale, Florida
- 1981, B.S., Ocean Engineering, Florida Atlantic University, Boca Raton, Florida.
- Florida Registered Professional Engineer #39659

Capabilities

Design, engineering analysis, permitting and construction management for waterfront projects, navigation and dredging works, environmental education programs, environmental impact statements, jurisdictional analysis, Phase I Site Assessments, environmental permitting, restoration and construction related services for upland development, mitigation monitoring and design.

Representative Projects

1989 Expert witness for FDOT involving jurisdictional analysis of 20,000 acres.
1997 Permitting, construction and mitigation design of Marco Island Yacht Club
1998 Project manager for Clam Bay Restoration, restorative dredging and biological monitoring.

Special Interests

Aerial and underwater photography: Todd is a licensed pilot and incorporates aerial work into almost every project. The firm maintains an up to date inventory of video and stills cameras and SCUBA equipment in addition to standard biological survey apparatus.

Island Design: Todd provides specialized survey and design expertise for island projects including marina planning, environmental impact assessment and permitting. He has worked throughout the Bahamas and in Jamaica and the Dominican Republic.

Affiliations

- Society of Naval Architects and Marine Engineers
- Florida Marine Industries Association
- Florida Association of Environmental Professionals
- The Bahamas National Trust

- Bahamas Air Sea Rescue Association (BASRA)
- The Aircraft Owners & Pilots Association.

Ecologist

Timothy Creigh Hall

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Tim Hall is currently employed as senior biologist for the firm and specializes in terrestrial biology. Tim works closely with federal, state, and local agencies to obtain approvals for a number of marina and residential development projects. His field skills include plant and animal species identification, habitat assessments, wetland delineations, wildlife surveys, and wetland restoration.

EDUCATION

Baccalaureate Studies: Wildlife Ecology
University of Florida, 1986-1989

Masters Studies: Wildlife Ecology & Wetland Ecosystems
University of Florida, 1990-1991

PREVIOUS EXPERIENCE

- 1987-1988: University of Florida, IFAS Program – Key Deer research: collected and analyzed forage samples and used capture and release techniques to assess deer health.
- 1988-1989: Florida Cooperative Fish and Wildlife Research Unit – Alligator population research: collected, incubated, and hatched alligator eggs to assist in determination of potential repopulation rates.
- 1989: Alaska Parks – Marmot Population Study: conducted visual field survey counts of marmot burrows in remote field locations.
- 1990-1991: PMW Consulting – Wetland design and construction: Implemented studies for wetland creation/enhancement and monitoring projects in the south-eastern U.S.
- 1991-1993: Peace Corps, Guatemala - Defensores del la Naturaleza: Delineated boundaries for the Sierras de las Minas Biosphere Reserve, implemented floral and faunal surveys, taught classes on soil conservation techniques and environmental management to local villagers.
- 1993-1997: Power Corp: China, Central America, Canada, and Southern African Projects – Geologic and environmental survey: Conducted sample collection, mineral surveys, and feasibility studies in very remote locations. Produced habitat management plans and recovery / restoration plans for mining operations in Angola and Zaire.
- 1997-Present: Turrell and Associates – Senior Biologist and Project Manager: Oversee permitting efforts for a variety of projects. Conduct habitat assessments, wetland delineations, wildlife surveys, as well as create wetland restoration and habitat management plans.

ORGANIZATIONS

Naples Botanical Garden (former Director 1998-2000)
The Wildlife Society

Florida Association of Environmental Professionals

BAMAHAMIAN RELEVANT EXPERIENCE

- Key Deer research included collecting and analyzing forage samples to identify dietary components of the deer. Some of the Keys vegetative communities are very similar to Bahamian communities and many of the species identified occur in both locations.
- Conducted a preliminary review of vegetative communities and ecological linkages on development site in the Dominican Republic.
- Reviewed ecological characterizations and contributed to Environmental Assessments conducted on several Bahamian projects/sites including Winding Bay (Abaco), Club Med (Eleuthera), Cutlass Bay (Cat Island), and Albany (New Providence). Contributions included keying out and identifying photographic and botanical specimens, consideration of potential impacts to protected species, and preliminary designs of potential and proposed vegetative restoration and enhancement options.
- Consulted with Naples Botanical Gardens regarding potential of establishing Caribbean Island vegetative communities within the garden design taking into account plant compatibilities as well as ecological requirements.

ECOLOGICAL/TERRESTRIAL BIOLOGY EXPERIENCE

Floral and Faunal studies established and conducted in Alaska, Guatemala, Dominican Republic, Angola, and Zaire as well as throughout Florida. Studies conducted include species specific population surveys, vegetation density and diversity surveys, vegetation composition surveys, vegetation/ecological restoration projects

- Alaskan work focused on population studies of hoary marmots in the Denali National Park. In addition to burrow counts, ecotonal variations and transitions between vegetative communities were also noted.
- The majority of the work conducted in Guatemala focused on the "Sierras de las Minas" Biosphere Reserve. Floral and faunal surveys were designed to document existing plant and animal populations as well as identify different ecotones for future monitoring efforts. Also designed and implemented a re-forestation project on a 17-acre hillside that had been used for vegetable crop production.
- Work in the Dominican Republic consisted of a preliminary ecological assessment. Vegetative communities, vegetative health, ecological linkages and existing wildlife utilization were examined in order to determine potential enhancement and restoration opportunities for an ongoing development project.
- The primary work focus in Angola and Zaire was geared towards minimizing the potential for environmental impacts during mineral exploration activities. Habitat management plans, wildlife management plans, habitat restoration plans and strip mine reclamation plans were created, as needed for the different mine sites.
- Work in Florida has been varied and ongoing for the last eight years. Some of the specific projects completed and/or underway include;
 - Oversee the restoration efforts on a 400+ acre mangrove preserve. Approximately 50 acres died in 1995 and we designed and implemented a restoration plan geared towards

the recovery of the die-off area. To date, the work has been successful in that the area is recovering, wildlife utilization has vastly expanded, and the new mangroves have now survived two hurricanes.

- Created a mangrove and marsh mitigation peninsula in conjunction with a marina project (2002). The project to date has seen over 95% survival of the planted vegetation as well as natural recruitment of additional native vegetation and estuarine wildlife.
- Conduct wetland delineation surveys to both State of Florida and U.S. Army Corps of Engineers specifications. Delineated lines have been accepted by agency personnel and have withstood administrative challenges from outside groups.
- Conduct species-specific wildlife surveys in order to determine utilization and/or potential utilization of properties by target species. Species surveyed for include Florida panther (*Puma concolor coryi*), red-cockaded woodpecker (*Picoides borealis*), Key deer (*Odocoileus virginianus clavium*), Florida scrub jay (*Aphelocoma coerulescens*), eastern indigo snake (*Drymarchon corais couperi*), gopher tortoise (*Gopherus polyphemus*), Florida mouse (*Peromyscus floridanus*), wood stork (*Mycteria americana*), southern bald eagle (*Haliaeetus leucocephalus*), flatwoods salamander (*Ambystoma cingulatum*), Florida burrowing owl (*Speotyto cunicularia floridana*), American crocodile (*Crocodylus acutus*), as well as several others.
- Designed and permitted a Collier County Park that allowed visitor access to an approximately 80-acre preserve area with minimal impacts to the preserve.
- Design educational interpretational signage related to local plants and animals. Vegetative descriptions and potential wildlife sightings are site specific and tailored to the individual project. These signs are then located in appropriate areas around preserves, golf courses, boardwalks, etc. in order to educate facility users regarding local ecosystems and wildlife.

CURRICULUM VITAE
ERICH MUIR MUELLER

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 Maple City, Michigan 49664-8772 **E-MAIL:** evmresearch@gmail.com
 emueller@perryinstitute.org

BIRTHDATE: 19 February, 1955 **PLACE:** Sharon, CT

MARITAL STATUS: wife, Vincenza Jennifer Mueller; no children

AFFILIATIONS: International Society for Reef Studies
 Divers Alert Network
 International Society for Reef Studies

CERTIFICATIONS & LICENSES: SCUBA - Basic (YMCA), Advanced (PADI), Diving Rescue Techniques
 (NAUI), Divemaster (NAUI), Enriched Air Nitrox (PADI)
 Community CPR, Standard First Aid (Red Cross); Oxygen Provider (DAN)
 License to Operate Passenger Carrying Vessels (USCG): Master of Near Coastal
 Steam or Motor Vessels (50 tons) 1987-2005

EDUCATION

DEGREES: Florida Keys Community College 1972-1975
 A.A. Biology

Florida Atlantic University 1975-1977
 B.S. Biology

University of Miami 1979-1983
 Ph.D. Cellular and Molecular Biology

OTHER: Discovery Bay Marine Laboratory, Jamaica Summer, 1977
 Attended: "Experimental Studies on Alga-Invertebrate Symbiosis"

Florida Atlantic University Fall, 1977
 Graduate courses: Advanced Plant Physiology, Biology Seminar

University of Miami, Rosenstiel School of Marine and Atmospheric Sciences Spring, 1981
 Graduate course: Oceanography IV (Marine Geology and Geophysics)

Pilot Training - Nuytco DeepWorker 2000 submersible
 Monterey Bay Aquarium Research Institute, Moss Landing, CA Fall, 1998
 Naval Air Warfare Center, Key West, FL Summer, 1999

PROFESSIONAL EXPERIENCE & APPOINTMENTS

CURRENT:	Perry Institute for Marine Sciences, Senior Research Scientist eVm research & design, Owner	1/04 – present 6/03 - present
PREVIOUS:	Mote Marine Laboratory, Sarasota, FL Director, Pigeon Key Marine Research Center Director, Center for Coral Reef Research (Tropical Research) Adjunct Scientist University of South Alabama, Mobile, AL Coastal Res. and Dev. Institute – Assistant Professor of Research Department of Marine Sciences - Assistant Professor of Research Dept. of Biological Sciences - Adjunct Assistant Professor Marine Environmental Sciences Consortium, Dauphin Island, AL - Adjunct Faculty Observatoire Océanologique Européen, Monaco - Visiting Scientist Kinetics Marine Services, Key West, FL - Owner Tropical Sailboats, Inc., Key West, FL - Manager Marathon High/Middle School, Marathon, FL - Science Teacher Newfound Harbor Marine Institute, Big Pine Key, FL - Special Projects Coordinator Seacamp Marine Science Summer Camp, Big Pine Key, FL – Science Instructor I.P. Solar, Pty., Ltd., Sydney, Australia - Programmer Australian Institute of Marine Science, Townsville, Australia - Invited Visiting Scientist State of Florida, Dept. of Agriculture and Consumer Services, Davie, FL - Supervisor and Training Officer Florida Atlantic University, Boca Raton, FL - Laboratory and teaching assistant	9/95 - 7/99 7/99 - 6/03 7/03 – 6/04 11/89 - 10/92 10/92 - 8/95 1/94 - 8/95 1/94 - 8/95 11-12/93 7-8/94; 4-5/96 9-10/98 2-11/89 7/88 - 1/89 3-6/88 1/85 - 3/88 6-8/84 1-5/84 10-12/83 1-12/78 1-12/77

PUBLICATIONS

DISSERTATION:

Mueller, Erich, 1983. High potassium activation and β -adrenergic relaxation of the guinea pig taenia coli. University of Miami, FL. Advisor: C. van Breemen

PAPERS:

1. **Mueller, Erich** and C. van Breemen, 1979. Role of intracellular Ca^{2+} sequestration in β -adrenergic relaxation of a smooth muscle. *Nature*, 281, 682-683.
2. Cauvin, C., K. Meisheri, **E. Mueller**, K. Saida and C. van Breemen, 1984. β -adrenergic relaxation of smooth muscle and second messengers. In: *The Adrenoceptor in Asthma*, Ed. G. Morely, Academic Press: New York. (invited paper)
3. **Mueller, Erich** and Mary Sukup, 1989. Experimental planting of *Halodule wrightii* in a closed, aerated canal system on Little Torch Key, FL. *Proc. 15th Annual Conference on Wetlands Restoration and Creation*, 212-221. (non-reviewed)
4. **Mueller, Erich** and C. Steven Sikes, 1991. Polypeptide inhibitors of steel corrosion in sea water. *Corrosion*, 91, 274.
5. **Mueller, Erich** and C. Steven Sikes, 1993. Adsorption and modification of calcium salt crystallization by anionic peptides and spermine. *Calcif. Tissue Int.*, 52, 34-41.
6. Sikes, C. Steven, **Erich M. Mueller**, Jeffery D. Madura, Barney Drake and Brenda J. Little, 1993. Polyamino acids as antiscalants, corrosion inhibitors, and dispersants: atomic force microscopy and mechanisms of action. *Corrosion*, 93, 465.
7. **Mueller, E.**, C.S. Sikes and B.J. Little, 1993. Peptide interactions with steel surfaces: inhibition of corrosion and calcium carbonate precipitation. *Corrosion*, 49(10), 829-835.
8. **Mueller, Erich** and Douglas W. Haywick, 1995. Sediment assimilation and calcification by the Western Atlantic reef zoanthid, *Palythoa caribaeorum*. *Bulletin de l'Institut Océanographique de Monaco*, Special No. 14,2, 89-100.
9. Tambutté, E., D. Allemand, **E. Mueller** and J. Jaubert, 1996. A compartmental approach to the mechanism of calcification in hermatypic corals. *J. Exp. Biol.*, 199, 1029-1041.
10. Haywick, Douglas W. and **Erich Mueller**, 1997. Geological implications of encrusting *Palythoa* spp. on reefs of the Florida Keys. *Coral Reefs*, 16(1), 39-46.
11. Downs, Craig A., **Erich Mueller**, Susan Phillips, John Fauth and Cheryl L. Woodley, 2000. A molecular biomarker system for assessing the health of coral, *Montastraea faveolata*, during heat stress. *Mar. Biotechnol.*, 2, 533-544.
12. Cook, Clayton B., **Erich M. Mueller**, M. Drew Ferrier and Eric Annis, 2001. The influence of nearshore waters on corals of the Florida Reef Tract. In: *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook*. eds. J.W. Porter and K.G. Porter. CRC Press, Boca Raton, FL, 771-788.
13. Hendee, James C., **Erich Mueller**, Chris Humphrey and Trent Moore, 2001. A data-driven expert system for producing coral bleaching reports. *Bull. Mar. Sci.*, 69(2): 673-684.
14. Becker, L. and **E. Mueller**, 2001. The culture, transplantation and storage of *Montastraea faveolata*, *Acropora cervicornis* and *A. palmata*: What we have learned so far. *Bull. Mar. Sci.*, 69(2): 881-896.

PUBLICATIONS (CONT.)

PAPERS (CONT.):

15. Santavy, D.L., E. Mueller, E.C. Peters, L. MacLaughlin, J.W. Porter, K. L. Patterson and J. Campbell, 2001. Quantitative assessment of coral diseases in the Florida Keys: strategy and methodology. *Hydrobiologia*, 460: 39-52.
16. Anderson, S., R. Zepp, J. Machula, D. Santavy, L. Hansen and E. Mueller, 2001. Indicators of UV exposure in corals and their relevance to global climate change and coral bleaching. *Human and Ecological Risk Assessment*, 7(5), 1271-1282.
17. Patterson, Kathryn L., James W. Porter, Kim B. Ritchie, Shawn W. Polson, Erich M. Mueller, Esther C. Peters, Deborah L. Santavy and Garriet W. Smith, 2002. The etiology of white pox, a lethal disease of the Caribbean elkhorn coral, *Acropora palmata*. *Proc. Natl. Acad. Sci.*, 99, 8725-8730.
18. Hu, C., F.E. Muller-Karger, Z. Lee, K.L. Carder, B. Roberts, J.J. Walsh, C. Heil, P.G. Coble, K. Steidinger, G. McRae, R.H. Weisberg, R. He, E. Johns, T. Lee, B. Keller, N. Kuring, J. Cannizzaro, J. Ivey, G.A. Vargo, R.G. Zepp, J. Boyer, R. Jones, G. Kirkpatrick, R.P. Stumpf, E. Bartels, E. Mueller, R. Pierce, J. Culter and J. Hunt, 2002. Satellite images track 'black water' event off Florida coast. *EOS*, 83(26):281-285.
19. Woodley, C.M., C.A. Downs, J.E. Fauth, E. Mueller, J.C. Halas, J.A. Bemiss, Y. Ben-Haim and E. Rosenberg, 2002. A novel diagnostic biomarker system to assess the physiological status of corals. *Proc. 9th Int. Coral Reef Sym., Bali, Indonesia*, (2), 1267-1272.
20. Hawkrige, Jane M., Craig A. Downs, Richard H. Pierce and Erich Mueller, submitted. Chronic toxicity of the mosquito control pesticide, Dibrom®, to newly settled *Porites astreoides* recruits. *Mar. Poll. Bull.*
21. Pierce, R.H., M.S. Henry, T.C. Blum and E.M. Mueller, submitted. Aerial and tidal transport of mosquito control pesticides into the Florida Keys National Marine Sanctuary. *Revista de Biologia Tropical*.
22. Santavy, Deborah L., Jed Campbell, Robert L. Quarles, James M. Patrick, Linda M. Harwell, Mel Parsons, Lauri MacLaughlin, John Halas, Erich Mueller, Esther C. Peters and Jane Hawkrige, 2005. The Epizootiology of Coral Diseases in South Florida. EPA/600/R-05/146. U.S. Environmental Protection Agency, Gulf Ecology Division, Gulf Breeze, Florida. 76 pp.
23. Porter, J.W., E.K. Lipp, K.P. Sutherland, and E. Mueller. 2006 in press. The ecology of an infectious disease in the Florida Keys: From pathogen to politics." In R.S. Ostfeld and V. Eviner, Eds. *The Ecology of Infectious Disease*. Princeton University Press; Princeton, NJ.
24. Santavy, D.L., E.M. Mueller, L. MacLaughlin, E.C. Peters, R.L. Quarles, and M.G. Barron, submitted. Comparison of Coral Community Responses on Reefs near Key West and the Dry Tortugas Following Multiple Stressor Events in 1997-1998. *Bull. Mar. Sci.*

ABSTRACTS:

1. Mueller, E., K. Meisheri and C. van Breemen, 1981. Lack of $\text{Na}^+/\text{Ca}^{2+}$ exchange involvement in β -adrenergic relaxation of smooth muscle. *The Pharmacologist*, 23(3), 122. (abstract; oral presentation)
2. Mueller, Erich and Cornelis van Breemen, 1983. Reduction of high K^+ - induced calcium influx by cAMP in the guinea pig taenia coli. *Fed Proc.*, 42(3), 367. (abstract; poster presentation).
3. Mueller, Erich, 1984. Effects of a calcium channel blocker and an inhibitor of phosphodiesterase on calcification in *Acropora formosa*. *Abstracts of "Advances in Reef Science", Miami, FL*, 87. (abstract; oral presentation)

PUBLICATIONS (CONT.)

ABSTRACTS (CONT.):

4. **Mueller, Erich**, 1987. Teaching project-oriented field programs: some lessons learned. *National Science Teachers of America Area Convention, Miami Beach, FL.* (abstract; oral presentation)
5. **Mueller, E.** and **B. J. Little**, 1991. Inhibition of calcium carbonate precipitation and associated corrosion on steel surfaces by polyanionic peptides. *American Chemical Society symposium, "Biopolymers", Atlanta, GA.* (abstract; oral presentation)
6. **Mueller, Erich** and **C. Steven Sikes**, 1992. Interactions of anionic polyamino acids and polycations with hydroxylapatite and calcite crystal surfaces. *Connective Tissue Res.*, 27(2-3), 111 (abstract; poster presentation)
7. **Sikes, C.S.**, **E. Mueller** and **J.E. Donachy**, 1992. Protein and peptide binding, atomic force microscopy, and crystal growth sites of calcite and apatite. *Connective Tissue Res.*, 27(2-3), 87 (abstract; oral presentation by C.S. Sikes)
8. **Mueller, Erich**, 1992. *Palythoa caribaeorum*: an indicator of coral reef perturbation. *Proc. 7th Int. Coral Reef Symp., Guam*, 1, 72 (reviewed abstract; oral presentation).
9. **Mueller, E.M.** and **D.W. Haywick**, 1992. *Palythoa caribaeorum*: a major reservoir of fine carbonate sediment in Florida Keys reefs? *Geological Society of America Annual Meeting, Cincinnati, OH* (reviewed abstract; oral presentation by D. Haywick).
10. **Mueller, E.M.** and **D.W. Haywick**, 1992. Aspects of the biology and geology of *Palythoa caribaeorum* in the Florida Keys. *1992 Symposium on Florida Keys Regional Ecosystem, Miami, FL* (oral presentation)
11. **Mueller, Erich**, 1993. *Palythoa caribaeorum* pigmentation and populations on Florida reefs: implications for quantification of coral reef bleaching. *1993 Benthic Ecology Meeting, Mobile, AL* (abstract; oral presentation)
12. **Mueller, E.** and **D. Haywick**, 1993. Sediment assimilation and calcification by the Western Atlantic reef zoanthid, *Palythoa caribaeorum*. *Seventh Int. Symp. on Biomineralization, Monaco* (reviewed abstract; oral presentation).
13. **Haywick, Douglas W.** and **Erich M. Mueller**, 1993. An examination of sediment contained within the zoanthid *Palythoa caribaeorum*: entrapment, biomineralization and yet another possible mechanism for stromatolites in the rock record. *Geological Society of America Annual Meeting, Boston* (reviewed abstract; oral presentation by D. Haywick).
14. **Mueller, Erich M.** and **C. Steven Sikes**, 1994. Coral matrix protein fractions as inhibitors of corrosion and calcium carbonate precipitation. *American Chemical Society symposium, "Polyamino acids, the emergence of life, and industrial applications", San Diego* (abstract; opres. by C.S. Sikes).
15. **Goiran, C.**, **E.M. Mueller** and **R.P. Kiene**, 1995. Dimethylsulfoniopropionate (DMSP) and glycinebetaine (GBT) production by coral endosymbiotic dinoflagellates. *First International Symposium on DMSP and Related Sulfonium Compounds, Mobile, AL* (abstract; poster presentation by C. Goiran).
16. **Tambut  , Eric**, **Denis Allemand**, **Erich Mueller** and **Jean Jaubert**, 1995. ⁴⁵Ca transport and compartmentation in the scleractinian coral, *Stylophora pistillata*. *6th International Conference on Coelenterate Biology, The Netherlands* (presentation by J. Jaubert).
17. **Haywick, D.** and **E. Mueller**, 1995. Significance of biological particle assimilation on reef sedimentation: role of encrusting zoanthids. *1st SEPM Congress on Sedimentary Geology, "Linked Earth Systems", St. Pete Beach, FL* (reviewed abstract; oral presentation by D. Haywick).

PUBLICATIONS (CONT.)

ABSTRACTS (CONT.):

18. **Mueller, E.** and J. Bruton, 1996. Coral culture for physiological studies and practical applications. *Proc. 8th Int. Coral Reef Symp., Panama* (abstract; oral presentation).
19. **Mueller, E.M.** and R.P. Kiene, 1996. Dimethylsulfoniopropionate (DMSP) in corals and zooxanthellae and the release of methylated sulfur compounds from coral micro-colonies. *Proc. 8th Int. Coral Reef Symp., Panama* (abstract; oral presentation).
20. Cook, C.B., **E.M. Mueller** and M.D. Ferrier, 1997. Effects of Florida Bay water on reef coral growth. *Amer. Zool.*, 37(5), 11a (abstract; oral presentation by C. Cook).
21. Patterson, K.L., D.L. Santavy, J.G. Campbell, J.W. Porter, L.G. MacLaughlin, **E. Mueller** and E. Peters, 1997. Coral diseases in the Western Florida Keys, New Grounds, and the Dry Tortugas. *Amer. Zool.*, 37(5), 13a (abstract; oral presentation by K. Patterson).
22. **Mueller, Erich** and Lillian C. Becker, 1998. Principles and techniques for restoration of reef corals. *27th Benthic Ecology Meeting Abstracts, Melbourne, FL* (abstract; oral presentation).
23. Ferrier, M. Drew, Clayton B. Cook, Eric Annis and **E.M. Mueller**, 1998. The nutrient status of zooxanthellae from corals from the Florida Keys and Bahamas. *27th Benthic Ecology Meeting Abstracts, Melbourne, FL* (abstract; oral presentation by D. Ferrier).
24. Cook, Clayton B., Jose V. Lopez, Pamela Eng and **Erich M. Mueller**, 1998. Geographic variation of reef corals in the *Montastraea annularis* complex: Florida vs Panama. *27th Benthic Ecology Meeting Abstracts, Melbourne, FL* (abstract; poster presentation by C. Cook).
25. **Mueller, Erich M.**, Clayton B. Cook, M. Drew Ferrier and Eric Annis, 1998. The influence of Florida Bay on corals of the Florida reef tract. *Am. Soc. Limnol. Oceanogr. / Ecol. Soc. Amer. Ann. Meeting, St. Louis, MO.* (abstract, paper & oral presentation)
26. **Mueller, Erich** and Lillian Becker, 1998. Use of coral explants for reef restoration: a comparison of culture approaches. *Am. Soc. Limnol. Oceanogr. / Ecol. Soc. Amer. Ann. Meeting, St. Louis, MO.* (abstract; oral presentation by L. Becker)
27. **Mueller, E.**, D. Santavy and E.C. Peters, 1998. Survey and quality assurance protocols for the assessment of coral disease distribution. *Abstracts of the European Meeting, Int. Soc. for Reef Studies, Perpignan, France* (abstract; oral presentation).
28. Thornton, S., J. Feingold and **E. Mueller**, 1998. A comparison of growth rate and photoacclimation of two color morphotypes of the scleractinian coral *Porites astreoides*. *Abstracts of the European Meeting, Int. Soc. for Reef Studies, Perpignan, France* (abstract; poster presentation by S. Thornton).
29. Porter, J.W., P. Dustan, W.C. Jaap, J. Wheaton, K.G. Porter, K.L. Patterson, E.C. Peters and **E. Mueller**, 1999. Patterns of distribution and spread of coral disease in the Florida Keys. *Abstracts of Am. Soc. Limnol. Oceanogr. Aquatic Sci. Meeting, Santa Fe, NM* (abstract; presentation by J. Porter).
30. **Mueller, E.**, 1999. Coral reef restoration: science or technology? *Program and Abstracts of the Int. Conf. on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration, Ft. Lauderdale, FL*, 142 (abstract; oral presentation).
31. Becker, L. and **E. Mueller**, 1999. The culture, transplantation and storage of *Montastraea faveolata*, *Acropora cervicornis* and *A. palmata*: What we have learned so far. *Program and Abstracts of the Int. Conf. on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration, Ft. Lauderdale, FL*, 53 (abstract; manuscript;; oral presentation by L. Becker).

PUBLICATIONS (CONT.)

ABSTRACTS (CONT.):

32. Thornton, S.L., J.S. Feingold and E. Mueller, 1999. Comparison of growth rates of two color morphotypes of the scleractinian coral, *Porites astreoides*. *Program and Abstracts of the Int. Conf. on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration, Ft. Lauderdale, FL*, 192 (abstract; oral presentation by S. Thornton).
33. Hendee, James C., Erich Mueller, Chris Humphrey and Trent Moore, 1999. A data-driven expert system for producing coral bleaching reports. *Program and Abstracts of the Int. Conf. on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration, Ft. Lauderdale, FL*, 103 (abstract; manuscript; oral presentation by J. Hendee).
34. Santavy, Deborah L., Erich Mueller, Esther C. Peters, James Porter and Virginia Engle, 1999. Quality assurance measures associated with coral reef monitoring. *Program and Abstracts of the Int. Conf. on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration, Ft. Lauderdale, FL*, 170 (abstract; poster presentation by D. Santavy).
35. Santavy, Deborah L., Erich Mueller, James Porter, Esther C. Peters, Lauri MacLaughlin, Jed G. Campbell, Mel Parsons and Lillian Becker, 1999. The distribution and frequency of coral diseases in the Florida Keys and Dry Tortugas. *Program and Abstracts of the Int. Conf. on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration, Ft. Lauderdale, FL*, 170 (abstract; poster presentation by D. Santavy).
36. Downs, Craig A., Phillip Dustan, Erich Mueller, Aaron G. Downs, Susan Phillips and Cheryl M. Woodley, 1999. Oxidative stress, small heat-shock proteins and coral bleaching. *Abstracts of Cellular Responses to Oxidative and Osmotic Stress*. Egmond aan Zee, The Netherlands, 89 (abstract; poster presentation by C. Downs).
37. Santavy, Deborah L., Erich Mueller, Esther C. Peters, James W. Porter and Lauri MacLaughlin, 2000. The incidence of coral disease in the Florida Keys and Dry Tortugas. In: *Proc. 25th Annual Eastern Fish Health Workshop*. Ed: R.C. Cipriano. Nat. Fish Health Res. La., USGS, Kearneyssville, WV, 49. (abstract; oral presentation by E. Peters)
38. Downs, C.A., E. Mueller, S. Phillips, J.E. Fauth and C.M. Woodley, 2000. Assessing coral health using molecular biomarkers. In: *Proc. 25th Annual Eastern Fish Health Workshop*. Ed: R.C. Cipriano. Nat. Fish Health Res. La., USGS, Kearneyssville, WV, 52. (abstract; oral presentation by C. Woodley)
39. Anderson, S., R. Zepp, J. Machula, D. Santavy, L. Hansen, G. Cherr, and E. Mueller, Indicators of UV exposure in corals and their relevance to global climate change and coral bleaching. *EPA Symposium on Indicators in Health and Environmental Risk Assessment* NHEERL, Research Triangle Park, NC, June 2000. (abstract; oral presentation by S. Anderson)
40. Anderson, S., R. Zepp, J. Machula, D. Santavy, L. Hansen, G. Cherr and E. Mueller, 2000. Thymine dimers in coral tissue and factors affecting UV penetrations over coral reefs. *Am. Soc. Photobiology 28th Ann. Meeting / 13th Int. Cong. on Photobiology Abstracts, San Francisco, CA, July 2, 2000*. (abstract; oral presentation by S. Anderson)
41. Zepp, Richard, Eric Davis, Susan Anderson, Jana Machula, Debbie Santavy, Lara Hansen and Erich Mueller, 2000. Factors controlling UV exposure of coral assemblages in the Florida Keys. *EPA Proceedings - Coastal Intensive Sites Network (CISNet): STAR Grants 2000 Progress Review*, Narragansett, RI, 26-27 Sept., 2000, 3. (abstract; oral presentation by R. Zepp)

PUBLICATIONS (CONT.)

ABSTRACTS (CONT.):

42. **Mueller, Erich**, Denis Allemand and Jean Jaubert, 2000. Regulation of Ca^{2+} by cAMP during skeletogenesis in hermatypic corals. *9th Int. Coral Reef Symp. Abstracts, Bali, 23-27 Oct., 2000*, p. 133. (abstract; oral presentation)
43. **Mueller, E.**, D.L. Santavy, E.C. Peters, J.C. Porter, and L. MacLaughlin, 2000. The epizootiology of coral diseases in the Florida Keys. *9th Int. Coral Reef Symp. Abstracts, Bali, 23-27 Oct., 2000*, p. 283. (abstract; oral presentation)
44. Downs, C.A., **E. Mueller**, S. Phillips, J.E. Fauth and C.M. Woodley, 2000. A novel Molecular Biomarker System (MBS) to assess the physiological status of corals. *9th Int. Coral Reef Symp. Abstracts, Bali, 23-27 Oct., 2000*, p. 282. (abstract; oral presentation by C. Downs)
45. Anderson, S., R. Zepp, J. Machula, D. Santavy, L. Hansen, G. Cherr and **E. Mueller**, 2000. Indicators of UV exposure in coral: relevance to global climate change and coral bleaching. *9th Int. Coral Reef Symp. Abstracts, Bali, 23-27 Oct., 2000*, p. 372. (abstract; manuscript; poster presentation)
46. Anderson, S., R. Zepp, J. Machula, L. Hansen, G. Cherr and **E. Mueller**, 2001. Assessing UV irradiance in Caribbean reef coral and DNA damage in their coral and zooxanthellae. *Abstracts of Am. Soc. Limnol. Oceanogr. Aquatic Sci. Meeting, Santa Fe, NM, Feb., 2001*. (abstract; oral presentation by S. Anderson)
47. Santavy, D.L., **E. Mueller**, J.M. Hawkridge, L. MacLaughlin, J.W. Porter, and E.C. Peters, 2001. The prevalence of ten coral diseases in the Florida Keys and Dry Tortugas. *Assoc. Mar. Labs. Caribbean Ann. Meeting, Puerto Rico*. (abstract; oral presentation by D. Santavy)
48. Santavy, Deborah L., Jane W. Hawkridge, Robert L. Quarles, **Erich Mueller**, and Lauri MacLaughlin, 2002. The relationship between water quality and the prevalence of diseased corals in the Florida Keys. *Abstracts Volume of the ISRS European Meeting, Cambridge, U.K., 4-7 Sept., 2002*, 86. (abstract; oral presentation by J. Hawkridge)
49. Neely, Merrie Beth, Erich Bartels, Jennifer Cannizzaro, Kendall L. Carder, Paula Coble, David English, Cynthia Heil, Chuanmin Hu, Jim Ivey, Gil McRae, **Erich Mueller**, Ernst Peeples and Karen Steidinger, 2002. Florida's blackwater event summary. *Abstract book of the Xth International Conference on Harmful Algae, St. Petersburg, FL, 21-25 Oct., 2002*, 213. (abstract; poster presentation by M.B. Neely)
50. **Mueller, Erich**, 2002. Coral culture as a conservation tool for *Acropora* spp. In: *Proc. of the Caribbean Acropora Workshop: Potential Application of the U.S. Endangered Species Act as a Conservation Strategy*. A. Bruckner, ed., NOAA Technical Memorandum NMFS-OPR-24, Silver Spring, MD, 170.
51. Hawkridge, Jane M., Craig A. Downs, Art Itkins, Richard H. Pierce, and **Erich Mueller**, 2003. Chronic toxicity of the mosquito control pesticide, dibrom, to newly settled *Porites astreoides* coral recruits. *1st Int. Coral Reef Ecotoxicology and Health Workshop, Bermuda, U.K.*
52. **Mueller, Erich**, 2005. Coral model systems for physiological and health research. *Coral Reef Early Warning System (CREWS) Think Tank #3, Lee Stocking Island, Bahamas 17-22 Jan., 2005*.
53. Santavy, Deborah L., **Erich Mueller**, Lauri MacLaughlin, Robert Quarles, Jed Campbell and Esther C. Peters, 2005 The prevalence and distribution of "white coral diseases" in South Florida from 1997-2004. *Estuarine Research Federation Meeting, Norfolk, VA 16-21 Oct., 2005*.

PUBLICATIONS (CONT.)

ABSTRACTS (CONT.):

54. **Mueller, Erich**, 2008. Assessing coral resilience using a simple wounding method. Abaco Science Alliance Conference, Marsh Harbour, Bahamas (3-5 Jan., 2008).
55. **Mueller, Erich** and Catherine J. Booker, accepted. Assessment of resilience in *Montastrea faveolata* inside and outside of a marine park. 11th Int. Coral Reef Symp., Ft. Lauderdale, FL 7-11 July, 2008).

TECHNICAL REPORTS

1. Mueller, Diane Silvia and **Erich Mueller**, 1995. A phase I cultural resource assessment of 13 acres in Wetumpka, Elmore County, Alabama. Cultural Resources, Mobile, AL. Technical report for the Poarch Band of Creek Indians, 91 pp.
2. **Mueller, Erich**, 1997. Biological reconnaissance and assessment of coral growth potential in Pumpkin Harbor, Castaway (Gorda) Cay, Abacos, Bahamas and environs. Technical report for Disney Cruise Line, 18 pp.
3. Waselkov, Gregory A., Laurie Cameron Steponaitis, **Erich Mueller**, Joseph M. Herbert and George R. Abbe, 1998. Seasonality determinations from archaeological oysters shells: an experimental evaluation of incremental shell growth. Technical report of results from National Science Foundation award #9421140, Anthropological and Geographic Science Program, 202 pp.
4. **Mueller, Erich** and James K. Culter, 1999. Pumpkin Harbor, Castaway Cay, Bahamas Benthic Habitat Evaluation. Technical report to Disney Cruise Lines, 30 pp.
5. **Mueller, Erich**, 2001. Monroe County Stormwater Master Plan: Section 2.1.2 "Near-shore Marine Information" and Section 2.3.1 "Pollutant Targets". Camp, Dresser & McKee, Inc., 13 pp.
6. **Mueller, Erich**, 2001. Review of Impact Assessment Reports Associated with the *Allie-B* Grounding Site, Biscayne National Park. Moseley, Warren, Prichard & Parris, Jacksonville, Florida, 6 pp.
7. **Mueller, Erich**, 2001. Evaluation of the Cayos Cochinos Research Station, Honduras. Organization for Tropical Studies, San Jose, Costa Rica. 9 pp.
8. **Mueller, Erich**, 2003. Comparison of coral growth on materials for reef restoration. eVm research and design, Final Project Report to DECON USA, Inc.
9. **Mueller, Erich**, 2005. Benthic Survey of the Norman's Pond Cay (Exuma, Bahamas) Integrated Coral Observing Network (ICON) Site. eVm research & design, Final Project Report to the NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, FL. 17 pp.

PUBLICATIONS (CONT.)

MISCELLANEOUS PUBLICATIONS:

1. **Mueller, Erich.** *The Natural Keys.* Monthly column in *The Island Navigator*, Island Navigator Corporation: Big Pine Key, FL, April, 1987 to Nov., 1989; Jan., 1996.
2. **Mueller, Erich,** 1988. Artificial reefs study. *NAUI Diving Association News*, March/April, pp. 45-46.
3. **Mueller, Erich,** 1988. Work Study Program: Diving students at Florida's Seacamp gather data on state artificial reefs. *Underwater USA*, 5 (1), p. 24.
4. **Mueller, Erich** and George O. Winston, 1991. Geologic History of the Florida Keys. In: *The Monroe County Environmental Story*, Ed., J. Gato. Monroe County Environmental Education Task Force, 4-11. (reviewed non-anonymously)
5. **Mueller, Erich,** 1996. When are Algae Seaweeds? or What the Heck are Algae Anyway? Article in the *Monroe County Environmental Education Advisory Council newsletter*. Sept., 1996.
6. **Mueller, Erich,** 1997. Coral Research at Mote's Pigeon Key Marine Research Center. *Mote News*. 42(1), 12-14.
7. **Mueller, E.,** E.C. Peters and L. MacLaughlin, 1997. Guide to Coral Diseases of the Western Atlantic Region. *The Nature Conservancy* (underwater identification card).
8. **Mueller, Erich** and George O. Winston, 1997. Geologic History of the Florida Keys. In: *The Florida Keys Environmental Story*, Ed., D. Gallagher. Monroe County Environmental Education Advisory Council (note: revised edition of Mueller & Winston, 1991).
9. Viele, John, 2001. *Florida Keys, Volume III: The Wreckers.* Maps produced by **E. Mueller.**
10. **Mueller, Erich,** 2001. Coral diseases in the Florida Keys. *Sounding Line*, Newsletter of the Florida Keys National Marine Sanctuary. Summer/Autumn issue, 5.
11. **Mueller, Erich,** 2003. Fighting the Decline of Coral Reefs. *Mote Marine Laboratory Annual Report 2002*, 4.
12. **Mueller, Erich,** 2005. Coral Reefs – Rainforests of the Sea. *Perry Currents*, 3 (1), p.1. Newsletter of the Perry Institute for Marine Science.
13. **Mueller, Erich,** 2005. The Coral Gardens at Lee Stocking Island. *Perry Currents*, 3 (1), p. 5. Newsletter of the Perry Institute for Marine Science.
14. Withington, Dawn (artist) and **Erich Mueller** (layout and text), 2006. Elkhorn Coral – *Acropora palmata*, PIMS Poster Series #4.

RESEARCH SUPPORT

CURRENT:

46. Marine Management Area Project (co-PI): Effect of Marine Protected Areas on Coral Resilience (PI). Conservation International, 2006-2008. \$125,000.

PREVIOUS:

1. Comparison of fish populations on natural and artificial reefs of the Florida Keys. The Max and Victoria Dreyfus Foundation, 1987. \$7,500.00 (PI)
2. Looe Key National Marine Sanctuary Reef Fair. NOAA, Marine and Estuarine Management Division, 1987-1988. \$20,000.00 (PI)
3. The primary structure of organic matrix from CaCO_3 biomineral and some mechanisms of matrix/crystal interactions. NSF/EPSCoR Program, 1988-1991. \$205,062.00 (Research Associate, 1990; Co-PI, 1991)
4. Properties and commercial applications of polyamino acids as water treatment chemicals and dentrifice additives. Alabama Research Institute, 1991. \$150,000.00 (Co-PI)
5. *Palythoa caribaeorum* as a primary bleaching indicator: preliminary survey of Key Largo National Marine Sanctuary Bank Reefs. NOAA, National Undersea Research Program, NURC/UNCW 1991. Logistic support (PI)
6. The primary structure of organic matrix from CaCO_3 biomineral and some mechanisms of matrix/crystal interactions. NSF, Biochemistry Program, 1990-1992. \$140,000.00 (Co-PI)
7. The distribution and pigmentation of *Palythoa caribaeorum* on certain reefs in the Looe Key and Key Largo National Marine Sanctuaries. University of South Alabama Research Committee, 1991-1992. \$7,173.00 including in-kind support from the National Marine Sanctuary Program and departmental matching funds (PI)
8. Establishment of an imaging and graphics system in the Mineralization Center. University of South Alabama Research Committee, 1992-1993. \$2,550.00 (PI)
9. Polypeptide inhibitors of corrosion from marine organisms. Mississippi - Alabama Sea Grant Consortium, 1991-1993. \$67,770.00 (Co-PI)
10. Scientific visualization using an IBM RISC 6000 graphics workstation. Alabama NSF EPSCoR Equipment Matching Grant Program, 1994. \$90,370.00 (Co-PI)
11. Photosynthesis and calcification in corals and coccolithophorids. NSF/EPSCoR Program, 1992-1995. \$432,479.00 (PI) [C.S. Sikes (Co-PI), USA; T. Sherman (Co-PI), USA; V. Fabry (Co-PI, California State University)]
12. Production of dimethylsulfoniopropionate (DMSP) and related compounds by reef corals. University of South Alabama Research Committee, 1995-1996. \$2,562.00 (PI) [R.P. Kiene (co-PI), USA]

RESEARCH SUPPORT (CONT.)

PREVIOUS (cont.):

13. Control of coral skeleton physical characteristics for use in reconstructive bone surgery. Mississippi-Alabama Sea Grant Consortium, 1995-1996. \$37,626.00 (PI) [C. J. Damien (Associate Scientist), Intermedics Orthopedics™, Inc./ Denver; D. Haywick (Associate Scientist), USA]
14. The use of reef corals and their symbiotic zooxanthellae as indicators of past nutrient exposure. EPA Water Quality Protection Program for the Florida Keys National Marine Sanctuary, 1995-1996. \$65,000.00 (Co-PI) [Clay Cook (PI), Harbor Branch Oceanographic Institution / M. Drew Ferrier (co-PI), Hood College]
15. Seasonality determinations from archaeological oyster shells: an experimental evaluation of incremental shell growth. NSF / Archaeology, 1995-1997. \$113,024.00 (Co-PI) [G. Waselkov (PI), USA; L. Steponaitis (Co-PI), UNC Chapel Hill; G. Abbe (Co-PI), Academy of Natural Sciences Benedict Estuarine Research Laboratory]
16. Biological Reconnaissance and Assessment of Coral Growth Potential in Pumpkin Harbor, Castaway (Gorda) Cay, Abacos, Bahamas and Environs. Disney Cruise Line, 1997. \$4,792.00 (PI).
17. Coral Culture at Lee Stocking Island: A Feasibility Study. NURP - Caribbean Marine Research Center. \$3,500.00 - logistic support only. (PI).
18. Effects of mosquito control measures on non-targeted organisms. EPA Water Quality Protection Program for the Florida Keys National Marine Sanctuary, 1997-1998. \$70,000.00 (Co-PI) [Richard Pierce (PI), Mote Marine Laboratory].
19. Etiology and distribution of coral diseases in the Florida Keys National Marine Sanctuary. EPA Water Quality Protection Program for the Florida Keys National Marine Sanctuary, 1997-1998. \$50,000.00 (PI) [Esther C. Peters (co-PI), Tetra Tech. Inc. / James W. Porter, Karen G. Porter (co-PI's), University of Georgia].
20. Calcification by hermatypic corals: regulation of the calcium pathway. NSF / Biological Oceanography, 1995-1999. \$197,625.00 (PI)
21. Optimization strategies for reef restoration using cultured hermatypic corals. NSF / Environmental Biology (Special Competition for Basic Research in Conservation and Restoration Biology), 1995-1999. \$141,365.00 (PI)
22. The incidence of coral diseases on reefs Near Lee Stocking Island, Bahamas. Caribbean Marine Research Center, Program Development Grant, 1999-2000. \$1,450.00 (on-island support) (PI).
23. Florida Keys coral disease survey. U.S. EPA. Office of Research and Development, 1999. \$12,799.00 (PI).
24. Florida Keys coral disease survey. U.S. EPA, Office of Research and Development, 2000. \$7,877.06 (PI).
25. Detection and assessment of episodic reef events: the MEERA (Marine Ecosystem Event Response and Assessment) Project. NOAA Sanctuaries and Reserves Division, 1999-2001. \$40,000.00 (PI).
26. Exxon Corporation, Houston, TX. General Support. 2000. \$10,000.00 (PI).
27. Restoration of the *Voyager* Grounding Site: A Pilot Training Project for the Community-Based Reef Medic Program. NMFS Office of Habitat Conservation - Restoration Center. 1999-2000. \$39,162.00 (PI).
28. Impact of Coral Diseases on Reefs of the Florida Keys and Bahamas. Disney Conservation Fund, 1999-2000. \$34,641.00 (PI).

RESEARCH SUPPORT (CONT.)

PREVIOUS (cont.):

29. Exxon Corporation, Houston, TX. Center for Tropical Research, General Support. 2001. \$10,000.00 (PI).
30. Monroe County Stormwater Master Plan. Monroe County, Florida. 1999-2000. \$8,296.00 (subcontractor to Camp, Dresser & McKee, Inc.).
31. Florida Keys coral disease survey. U.S. EPA, Office of Research and Development, 2001. \$16,188.00 (PI).
32. Environmental stressors and coral disease: determining the causes of reef decline. Royal Caribbean Ocean Fund, 2001-2002. \$20,000 (PI)
33. Impact of Coral Diseases on Reefs of the Florida Keys and Bahamas. Disney Wildlife Conservation Fund, 2001-2002. \$20,000 (PI).
34. Florida Keys coral disease survey. U.S. EPA, Office of Research and Development, 2002. \$5,000.00 (PI).
35. 2002 SW Florida "Black water" Event: Assessment and Potential Impacts to Essential Fisheries Habitats. NOAA/NMFS, 2002. \$20,000 (PI).
36. Mote/FMRI Cooperative Red Tide Research Program. Florida Wildlife Conservation Commission, 2000-2003. \$2,600,000 (co-PI; R. Pierce, PI)
37. Penetration of ultraviolet light in reef waters: implications for coral bleaching. U.S. EPA, Office of Research and Development, 2001-2004. \$49,200 (co-PI).
38. Training program for the community-based Reef Medics Program. NMFS, Community-Based Restoration Program. 2001-2003. \$32,025 (PI).
39. Coral Culture for Reef Restoration and Coral Research. NOAA/NMFS, 2002-2004. \$43,713 (PI).
40. Community-Based Reporting and Response to Events in our Coastal Marine Environment. U.S. Fish & Wildlife Service, 2002-2003. \$40,000 (PI).
41. Coral Culture at the Caribbean Marine Research Center. Perry Institute for Marine Sciences, 2003-2004. \$15,895 (PI).
42. Coral Disease Survey, NOAA, FKNMS, 2003. \$2,700 (Senior Scientist).
43. Evaluation of Materials as Substrates for Stony Corals. DECON, Inc., 2003. \$6,775 (PI).
44. Coral Culture for Research. Perry Institute for Marine Science, 2004-2005. \$4,350 (PI).
45. Coral Culture for Research at Lee Stocking Island. Perry Institute for Marine Science. 2005-2006. \$16,810 (PI).
47. Important Species of the Wider Caribbean Poster Series: *Acropora palmata* – Elkhorn Coral. Mote Marine Laboratory "Protect Our Reefs Fund," 2006. \$12,500 (co-PI).

RESEARCH CRUISE EXPERIENCE

R/V *Lady Basten*, Australian Institute of Marine Science, 1-15 Nov., 1983. Townsville, Qld. to Rib and Myrmidon Reefs. Role: Scientist.

O.S.V. *Peter W. Anderson*, U.S. Environmental Protection Agency.

1-8 June, 1997. Key West to Dry Tortugas. Role: Scientist.

6-14 Sept., 1997. Key West to Dry Tortugas. Role: Scientist.

14-26 June, 1999. Biscayne National Park to Dry Tortugas. Role: Scientist.

10-17 Aug., 2000. Looe Key to Dry Tortugas. Role: Scientist.

5-12 Sept., 2001. Key West to Dry Tortugas. Role: Scientist.

M.V. *Whisker*, Suncoast Seabird Sanctuary.

20-26 May, 1998. Biscayne National Park to Key West. Role: Chief Scientist.

10-14 Aug., 1998. Biscayne National Park to Key West. Role: Chief Scientist.

Sustainable Seas Expeditions, Dr. Sylvia Earle, Project Director

18-20 Aug., 1999. NOAA Ship *Ferrel*, National Oceanic and Atmospheric Administration. Dry Tortugas area. Role: Principal Investigator and Submersible Pilot

11-15 Sept., 2000. NOAA Ship *Gordon Gunter*, National Oceanic and Atmospheric Administration. Dry Tortugas area. Role: co-Chief scientist and Submersible Pilot

3-6 July., 2001. NOAA Ship *Gordon Gunter*, National Oceanic and Atmospheric Administration. Tortugas Ecological Reserve. Role: Principal Investigator and Submersible Pilot

R/V *Eugenie Clark*, Mote Marine Laboratory. 29 June - 3 July, 2001. Tortugas Ecological Reserve. Role: Chief Scientist

M/V *Tiburon*. 18-20 Sept., 2001. Tortugas Ecological Reserve. Role: Chief Scientist

R/V *Dante Fascell*, National Oceanic and Atmospheric Administration. 23 Aug. - 4 Sept., 2002. Dry Tortugas to Key Largo. Role: Scientist.

NOAA Ship *Nancy Foster*, National Oceanic and Atmospheric Administration.

23-29 Aug., 2003. Key West area. Role: Senior Scientist.

16-28 August, 2005. Florida Keys. Role: Principal Investigator

6-14 September, 2006. Florida Keys. Role: Principal Investigator

22-30 September, 2007. Florida Keys. Role: Principal Investigator

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Education

- 1998 Ph.D. North Carolina State University (Major: Marine Science; Minor: Biostatistics)
1994 University of North Carolina at Wilmington (Major: Marine Biology).
1991 B.A. College of William and Mary (Major: International Studies)

Professional Experience

- 2004-present Senior Research Scientist, Perry Institute for Marine Science, Lee Stocking Island, Bahamas
2001-2004 Director of Scientific Operations, Perry Institute for Marine Science/Caribbean Marine Research Center, Lee Stocking Island, Bahamas
2000-2001 Fisheries Director, Perry Institute for Marine Science/Caribbean Marine Research Center, Tequesta FL and Lee Stocking Island, Bahamas
1998-2000 Post-Doctoral Fellowship, Marine Protected Areas Program, Center for Marine Conservation, Washington DC
1997-1998 Earthwatch Project Leader. Caribbean Marine Research Center, Lee Stocking Island, Bahamas
1994-1998 Research Assistant. UNC Wilmington, Department of Biological Sciences/NC State University, Department of Marine Earth and Atmospheric Sciences, Raleigh, NC.
1993-1994 Laboratory Instructor. "Introduction to Biology" UNC Wilmington, Wilmington, NC
1992-1994 Research Associate. NOAA/NURP National Undersea Research Center-UNC Wilmington, Wilmington, NC
1992 Research Technician, Bimini Biological Field Station, Bimini, Bahamas
1991 Fisheries Technician, Idaho Panhandle National Forest, Priest Lake, ID

Appointments and Awards

- 2003-present Scientific Assessment Team Member for The Nature Conservancy and Bahamas National Trust's Parks Partnership Program
2000-present Bahamas Marine Protected Area Advisory Committee
2000-present Perry Institute for Marine Science – Dive Control Board
2000-2001 The Island School - Student Research Advisor
2000 Caribbean Marine Research Center – Scientific Advisory Board
1999-2005 NOAA's Caribbean Fishery Management Council - Science and Statistical Committee Member

- 1998 National Geographic's Sustainable Seas Expedition - Education Advisory Committee
- 1993-1994 University of North Carolina at Wilmington, Center for Marine Science Research - Graduate Fellowship Award

Publications

- Haley, V. **C.P. Dahlgren** and C. Layman. In prep. Seasonal migration of bonefish to pre-spawning and spawning aggregations.
- Haley, V., **C.P. Dahlgren** and C. Layman. In prep. Managing Bonefish in The Bahamas: A case study of Andros Island.
- Harborne A.R., P.J. Mumby, C.V. Kappel, **C.P. Dahlgren**, F. Micheli, K.E. Holmes, and D.R. Brumbaugh. 2008. Tropical coastal habitats as surrogates of fish community structure, grazing, and fisheries value. *Ecological Applications*.
- Harborne, A.R., P.J. Mumby, C.V. Kappel, **C.P. Dahlgren**, F. Micheli, K.E. Holmes, J.N. Sanchirico, K. Broad, I.A. Elliott, and D.R. Brumbaugh. 2008. Reserve effects and natural variation in coral reef communities. *Journal of Applied Ecology* 45: 1010-1018.
- Dahlgren, C.P.**, J. Shenker, and R. Mojica. 2007. Ecology of bonefish during the transition from late larvae to early juveniles. Pp. 155-178 in Ault, J. (ed.) *Biology and Management of the world tarpon and bonefish fisheries*. CRC Press. 441 pp.
- Mumby, P.J., A.R. Harborne, J. Williams, C.V. Kappel, D.R. Brumbaugh, F. Micheli, K.E. Holmes, **C.P. Dahlgren**, C.B. Paris, and P.G. Blackwell. 2007. Trophic cascade facilitates coral recruitment in a marine reserve. *Proceedings of the National Academy of Sciences* 104(20): 8362-8367.
- Dahlgren, C.P.** and F Staine. 2006. Spatial and Temporal patterns of Caribbean spiny lobster, *Panulirus argus*, puerulus settlement to the Belize lagoon system. *Proceedings of the 59th Gulf and Caribbean Fisheries Institute*. Belize City, Belize. Pp. 325-336.
- Dahlgren, C.P.** and F. Staine. 2006. Growth and survival of Caribbean spiny lobster, *Panulirus argus*, raised from puerulus to adult size in captivity. *Proceedings of the 59th Gulf and Caribbean Fisheries Institute*. Belize City, Belize. Pp. 337-346.
- Mumby, P.J., **C. P. Dahlgren**, A. R. Harborne, F. Michel, C. Kappel, D. Brumbaugh, S. Box, J. M. Mendes, K. Broad, J. Sanchirico, K. Buch and K. Holmes (2006). Fishing, trophic cascades, and the process of grazing on coral reefs. *Science* 311:98-101.
- Harborne A.R., P.J. Mumby, D. Brumbaugh, **C.P. Dahlgren**, P. Kramer and F. Micheli. 2006. The functional value of Caribbean reef habitats to ecosystem processes. *Advances in Marine Biology* 48:59-190.
- Layman, C.A., **Dahlgren, C.P.**, G.T. Kellison, A.J. Adams, B.M Gillanders, M.S. Kendall, J.A. Ley, I. Nagelkerken, and J.E. Serafy. 2006. Marine nurseries and effective juvenile habitats. Reply comment. *Marine Ecology Progress Series* 318: 307-308.

- Dahlgren, C.P.**, T. Kellison, A. Adams, B. Gillanders, M. Kendall, C. Layman, J. Ley, I. Nagelkerken, J. Serafy. 2006. Marine nurseries and effective juvenile habitat: concepts and applications. *Marine Ecology Progress Series* 312:291-295.
- A. Adams, **C. P. Dahlgren**, T. Kellison, M. Kendall, C. Layman, J. Ley, I. Nagelkerken, J. Serafy. 2006. The nursery function of back reef systems. *Marine Ecology Progress Series* 318:287-301.
- Sobel, J. and **C.P. Dahlgren**. 2004. Marine Reserves: A Guide to Science, Design and Use. Island Press, Washington, DC 336 pp.
- Eggleston, D.B., **C.P. Dahlgren** and E. G. Johnson. 2004. Habitat mapping and reef fish abundance in tropical back-reef habitats: Key West National Wildlife Refuge, USA. *Bulletin of Marine Science* 75:175-204.
- Dahlgren, C.P.** and J. Marr. 2004. Back reef systems: important but overlooked components of tropical marine ecosystems. *Bulletin of Marine Science* 75:145-152.
- Dahlgren, C.P.** 2002. Marine Protected Areas in the Bahamas. *Bahamas Journal of Science* 9(2): 41-49.
- Dahlgren, C. P.**, and D. B. Eggleston. 2001. Spatiotemporal variability in abundance, distribution and habitat associations of early juvenile Nassau grouper. *Marine Ecology Progress Series* 217:145-156.
- Eggleston, D.B. and **C.P. Dahlgren**. 2001. Distribution and abundance of *Panulirus argus* in the Key West National Wildlife Refuge: relationship to habitat features and impact of an intensive recreational fishery. *Marine and Freshwater Research* 52:1567-1576.
- Dahlgren, C.P.**, and D.B. Eggleston. 2000. Ecological processes underlying ontogenetic habitat shifts in a coral reef fish. *Ecology* 81(8):2227-2240.
- Dahlgren, C.P.** and J. Sobel. 2000. Designing a Dry Tortugas Ecological Reserve: how big is big enough...to do what? *Bulletin of Marine Science* 66(3):707-719.
- Dahlgren, C.P.**, J. Sobel and D.E. Harper. 2000. Assessment of the reef fish community, habitat, and potential for larval dispersal from the proposed Tortugas South Ecological Reserve. *Proceedings of the 52nd Gulf and Caribbean Fisheries Institute*. 700-712.
- Eggleston, D., W. Elis, L. Etherington, **C. Dahlgren**, M. Posey. 1999. Organism response to habitat fragmentation and diversity: habitat colonization by estuarine macrofauna. *Journal of Experimental Marine Biology and Ecology* 236:107-132.
- Dahlgren, C.P.**, M.H. Posey, and A.W. Hulbert. 1999. The effects of bioturbation on the infaunal community adjacent to an offshore hardbottom reef. *Bulletin of Marine Science* 64:21-34.
- Dahlgren, C.P.** 1999. Replenishing Marine Populations. *Science* 284:49.
- Dahlgren, C.P.** 1999. The biology, ecology and conservation of Nassau grouper, *Epinephelus striatus*, in the Bahamas. *Bahamas Journal of Science* 7:6-12.
- Dahlgren, C.** 1999. Replenishing Marine Populations. *Science* 284: 49
- Dennis, G.D., **C. Dahlgren**, S. Ratchford. 1998. Occurrence of the toadfish, *Opsanus phobetrion*, in the Exuma Cays, Bahamas. *Bahamas Journal of Science*. 6(1): 31-34.

Technical Reports and other Publications

- Dahlgren, C.** 2007. Assessment of Micronesia's spiny lobster stocks. Unpublished report to SeaArk. 12 pp.
- Layman, C., G. Moore, **C. Dahlgren** and P. Kramer. 2006. Grenada and Grenadines Wetlands Assessment. Report to The Nature Conservancy. 40 pp.
- Heinemann, D., R. Appeldoorn, and **C. Dahlgren**. 2004. Expedition Report: 2003 joint Ocean Conservancy-CORALINA Rapid Ecological Assessment of the Northern Banks of the Archipelago of San Andres and Old Providence. *Report to the Corporation for Sustainable Development of the Archipelago of San Andrés, Old Providence, and Santa Catalina (CORALINA)*. 50 pp.
- Crosby, M., **C.P. Dahlgren**, S. Archibald, J. Mitchell, and C. Morral. 2003. Report on the Eastern Caribbean States Partnership Program's MPA Assessment Research Cruise in Antigua and Grenada. *Report to the Organization of Eastern Caribbean States and the Eastern Caribbean States Partnership Program's Steering Committee*.
- Dahlgren, C.P.**, K. Buch, and E. Rechisky. 2003. Report on the status of reef and reef fish resources in the Exuma Cays Land and Sea Park. *Report to the Bahamas National Trust*.
- Dahlgren, C.P.**, E. Arboleda, K.L. Buch, J.P. Caldas, S. Posada, M. Prada. 2003. Characterization of reef-fish diversity, community structure, distribution and abundance on three Southwestern Caribbean atolls: Quitasueño, Serrana, and Roncador Banks (Seaflower Biosphere Reserve), Archipelago of San Andrés and Providencia, Colombia. *Report to The Ocean Conservancy and the Corporation for Sustainable Development of the Archipelago of San Andrés, Old Providence, and Santa Catalina (CORALINA)*.
- Hendee, J., G. Liu, A. Strong, J. Sapper, D. Sasko and **C. Dahlgren**. 2002. Near real-time validation of satellite sea surface temperature products at Rainbow Gardens reef, Lee Stocking Island, Bahamas. *Proceedings of the Seventh International Conference, Remote sensing for Marine and Coastal Environments, Miami, FL 20-22 May 2002*.
- Eggleston, D. B., **C. P. Dahlgren**, and E. G. Johnson. 2000. Fish and Caribbean spiny lobster distribution and abundance patterns in the Key West National Wildlife Refuge: an initial assessment in the Lakes and Marquesas regions. *Report to the U.S. Fish and Wildlife Service*. 71pp.
- Dahlgren, C. P.** and D. B. Eggleston. 2000. Preliminary Assessment of Reef Fish and Invertebrate Recruitment into the Key West National Wildlife Refuge. *Report to the U.S. Fish and Wildlife Service*. 28 pp.
- Dahlgren, C.P.** 2000. Marine Protected Area Research in the Bahamas: Fisheries Benefits and Design Considerations. *Report to the Bahamas Environment Science and Technology Commission*.
- Dahlgren, C. P.** and J. A. Sobel. 1999. Characterization of reef fish communities upstream of the Key West National Wildlife Refuge and Great White Heron National Wildlife Refuge. *Report to the U.S. Fish and Wildlife Service*. 19 pp.
- Stoner, A. W., M. A. Hixon, and **C. P. Dahlgren**. 1999. Scientific review of the marine reserve network proposed for the Commonwealth of the Bahamas by the Bahamas

Department of Fisheries. *Report to the Bahamas Ministry of Agriculture and Fisheries*. 59 pp.

Current and Past Research Grants

- 2010 Disney Wildlife Foundation: "Evaluating Nassau grouper Management in The Bahamas" \$25,000/12 mos. PI.
- 2009 USFWS Wildlife Without Borders-Latin America and Caribbean: "Managing MPA's in The Bahamas: Bonefish Pond National Park and Central Andros Marine Parks" \$35,000/12 mos./PI
- 2009 NOAA International Coral Reef Conservation Program: "Managing MPA's in The Bahamas: Bonefish Pond National Park and Central Andros Marine Parks" \$75,000/18 mos. PI
- 2008 Disney Wildlife Foundation: "Ensuring Nassau grouper's Future IV" \$20,000/12 mos. PI.
- 2007 The Ocean Fund: "Marine Protected Areas in the Bahamas: Evaluation for improved management" \$30,000/12 mos. PI
- 2007 Disney Wildlife Foundation: "Ensuring Nassau grouper's Future III" \$20,000/12 mos. PI.
- 2006 Kerzner Marine Foundation: "Developing an evaluation program for the Andros Island National Park" \$300,000/3 years PI.
- 2006 NOAA's International Program Office - Coral Reef Conservation Grant Program: "Evaluating Marine Protected Areas in the Bahamas and Belize" \$73,385/18 mos. PI
- 2006 Disney Wildlife Foundation: "Ensuring Nassau grouper's Future II" \$20,000/12 mos. PI.
- 2006 The Curtis and Edith Munson Foundation: "Developing a Caribbean Fisheries Research Program" \$20,000/12 mos. PI
- 2005 National Fish and Wildlife Foundation: "Evaluating Coral reef Marine protected areas" \$47,000 12 mos. PI.
- 2005 Disney Wildlife Foundation: "Protecting Nassau grouper" \$20,000/12 mos. PI.
- 2005 Darden Environmental Trust: "The potential for spiny lobster aquaculture in Belize" \$47,000/12 mos. PI.
- 2004 NOAA's International Program Office - Coral Reef Conservation Grant Program: "Understanding movement of Caribbean coral reef fishery species: Improving the design of marine reserves in the Caribbean" \$30,000/18 mos. PI
- 2004 Darden Environmental Trust: "The ecology and fisheries productivity of the Caribbean spiny lobster, *Panulirus argus* in the Bahamas and Belize" \$90,000/12 mos. PI.
- 2004 Disney Wildlife Conservation Fund: "Marine Conservation in the Bahamas" \$10,000/12 mos. PI.
- 2004 The Nature Conservancy RJ Kose Grant Award: "Developing indicators for conservation and restoration of critical wetland nursery habitats in the tropical western Atlantic" 100,000/12 mos. (co-PI with Phil Kramer, The Nature Conservancy)

- 2004 NOAA's Undersea Research Program: "Spatial Patterns of marine biodiversity and their implications for the design of MPA networks in coral reef ecosystems" \$45,000/12 mos. (co-PI with D. Brumbaugh, American Museum of Natural History)
- 2004 NOAA's Undersea Research Program: "Marine Reserves and the spillover effect: seascape-scale movements of grouper and snapper" \$98,000/24 mos. (co-PI with M. Hixon, Oregon State University)
- 2003 Darden Environmental Trust – "Increasing productivity of Caribbean spiny lobster in the Bahamas and Belize: aquaculture, stock enhancement or habitat enhancement?" \$100,000/12 mos. PI.
- 2003 Disney Wildlife Conservation Fund: "Marine Reserves in the Bahamas" \$6,500/12 mos. PI.
- 2003 National Fish and Wildlife Foundation: "Protecting coral reef ecosystems II" \$47,500/12 mos. PI.
- 2002 Disney Wildlife Conservation Fund: "Monitoring and building support for marine reserves in the Bahamas" – \$16,000/12 mo. P.I.
- 2002 NOAA's Undersea Research Program "Marine Reserves and the Spillover Effect: movements of coral-reef grouper and snapper at multiple scales" – 98,689/2 yr. (co-PI with M. Hixon, Oregon State University)
- 2002 NOAA's Undersea Research Program "Connectivity and the Spatial Dynamics of a Nassau Grouper Metapopulation in the Bahamas: Fulfilling urgent, key information needs for conservation" – \$127,074/2 yr. (co-PI with D. Eggleston, North Carolina State University)
- 2002 National Fish and Wildlife Foundation – "Marine reserves for protecting coral reef ecosystems: efficacy, design and stakeholder participation" – \$37,000/12 mos. PI.
- 2002 NOAA's Undersea Research Program – "Site assessment of proposed Bahamian Marine Protected Areas: Research cruise aboard the R/V F.G. Walton Smith" \$70,000/12 mos. PI.
- 2002 The Ocean Fund: "Research and education in support of marine protected areas in the Bahamas" \$31,250/12 mos. PI.
- 2001 Darden Environmental Trust: "Increasing productivity of Caribbean spiny lobster: stock enhancement or habitat enhancement?" - \$51,625/12 mo., PI
- 2001 Disney Wildlife Conservation Fund: "Designing, monitoring, and building support for a marine reserve in the Bahamas II" – \$20,000/12 mo., PI.
- 2001 National Science Foundation: "Coupled natural and human dynamics in coral reef ecosystems: the effects of marine reserve network design and implementation on fisheries, biodiversity and humans" – \$2,500,000/5 yr. (with D. Brumbaugh, American Museum of Natural History; \$200,000 to C. Dahlgren)
- 2001 PADI AWARE: "Marine science teacher's enhancement initiative: Coral reefs" - \$1,000/12 mos. PI
- 2000 US Fish and Wildlife Service: "Coral reef fish habitat, connectivity, and recruitment study: Part II" - \$70,000/12 mo., PI.

- 2000 NOAA's Undersea Research Program: "Spawning aggregations of Nassau grouper: Essential habitat, population structure, and fish movement patterns" - \$49,000/2 yr. (co-P.I. with D. Eggleston, North Carolina State University)
- 2000 Disney Wildlife Conservation Fund: "Designing, monitoring, and building support for a marine reserve in the Bahamas". – \$19,800/12 mo., PI.
- 2000 National Science Foundation (FSML): "FSML- Analytical Laboratory at the Caribbean Marine research Center facility at Lee Stocking Island, Bahamas" - \$113,837/12 mo. (co-PI with J. Marr, Perry Institute for Marine Science)
- 2000 National Science Foundation (Biocomplexity): "Development of an integrated research plan for analyzing the viability of a marine reserve network" - \$100,000/12 mo. (co-PI with Rob DeSalle, American Museum of Natural History)
- 1999 US Fish and Wildlife Service: "Coral reef fish habitat, connectivity, and recruitment study" - \$70,000/12 mo., PI.
- 1996 Sigma Xi Grant in Aid of Research: "Mechanisms underlying ontogenetic habitat shifts in juvenile Nassau grouper, *Epinephelus striatus*" - \$800/12 mo., PI

Presentations

Contributed: Marine Benthic Ecology Meetings (1994, 1995, 1997, 1998), Mote International Symposium on Essential Fish Habitat and Marine Reserves (1998), Gulf and Caribbean Fisheries Institute (2000), International Bonefish and Tarpon Symposium (2003). International Coral Reef Symposium (2004)

Invited: UNC Wilmington (1994, 1997), EPA Marine and Estuarine Shallow Water Science and Management Conference (1996), NC State University (1998), BREEF, Marine Reserves for the Bahamas Workshop (1998, workshop leader); Scientific Review of the Marine Reserve Network proposed by the Bahamas Department of Fisheries (1999), NOAA/NURP review of the Caribbean Marine Research Center (2000), Association of Marine Laboratories of the Caribbean Meeting (2000), US Coral Reef Task Force, Workshop on Marine Protected Areas for Coral Reefs (2000), Bahamas Environment, Science and Technology Commission, Workshop on Issues Related to the Bahamian Marine Environment (2000, workgroup facilitator), Bahamas Department of Fisheries: Marine Reserves Planning Workshop (2001), Back Reef Habitats: Ecological Analysis, and Characterization Workshop (2002), Bahamas Department of Fisheries Nassau Grouper Workshop (2002), Bahamas National Trust Environmental Partnership Symposium (2002).

Popular Literature/Media

Hanging in the Balance – Documentary featuring my research on the use of marine protected areas for marine conservation (2004).

The Exuma Sentinel – Regular contributor of articles on marine life and marine research for local newspaper (2002-2003).

Future Storm – Discovery Channel Europe program highlighting current research on climate change and environmental stresses to coral reefs in the Bahamas (aired Fall 2002).

Past and current research featured in articles appearing in *National Fisherman*, *Sea Technology* and other marine publications.

Research Expeditions

- 2007 Spiny Lobster Stock Assessment of the Federated States of Micronesia.
- 2003 The Ocean Conservancy and CORALINA's Expedition to the Northern Cays of the San Andrés Archipelago of Colombia: Quitasueño, Roncador and Serrana Banks (M/V Spree; D. Heinemann, P.I.; C. Dahlgren, Fish Assessment Team Leader).
- 2002 Eastern Caribbean Partnership Program: Grenada Research Cruise (R/V Suncoaster; M. Crosby, P.I., C. Dahlgren Co-P.I.)
- 2002 Eastern Caribbean Partnership Program: Antigua Research Cruise (R/V Suncoaster; M. Crosby, P.I., C. Dahlgren Co-P.I.)
- 2002 Bahamas MPA Site Assessment Research Cruise (R/V F.G. Walton Smith, C. Dahlgren P.I.)
- 1999 Center for Marine Conservation Tortugas/Riley's Hump Research Cruise (M/V Spree, C. Dahlgren, P.I.)
- 1994 Spiny lobster survey – Exuma Sound (R/V Shadow, R. Lipcius, P.I.)
- 1993 Benthic Chemical Ecology Research Cruise (R/V Columbus Islan; W. Fenical, P.I.)
- 1992 Effects of Hurricane Andrew on the Great Bahama Bank (R/V Calanus; C. Neuman, P.I.)

Professional Activities and Societies

Reviewer: Journal of Marine and Freshwater Research, Marine Ecology Progress Series, Bulletin of Marine Science, Fishery Bulletin, National Undersea Research Program, National Sea Grant College Program, Coral Reefs.

Education/Outreach activities: Organizer of RECON training workshop for recreational divers to participate in coral reef condition assessments in the Bahamas; Organizer of REEF training workshop for recreational divers to participate in reef fish assessments in the Bahamas; contributor to environmental education program for 5th and 6th grade students in the Bahamas; scientific advisor for the Cape Eleuthera Island School (high school) student research projects

Membership to Professional Societies: Ecological Society of America, International Society for Reef Studies, Gulf and Caribbean Fisheries Institute, American Academy of Underwater Sciences

Certifications: SCUBA – PADI: Open Water, Advanced Open Water; NAUI: Nitrox, Dry Suit; International Association of Nitrox and Technical Divers: Nitrox; Divers Alert Network Oxygen provider, First Aid, Advanced First Aid, CPR

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APPENDIX VII

“HABITAT MAPPING AND BIOLOGICAL ASSESSMENT OF MARINE RESOURCES AROUND BELL ISLAND, BAHAMAS”

BY:

CRAIG DAHLGREN, PHD

Habitat Mapping and Biological Assessment of Marine Resources around Bell Island, Bahamas

Craig Dahlgren, PhD
1/27/2011

Introduction

This report reflects a rapid assessment of habitats and biological resources around Bell Island. Based on time constraints and priorities related to the proposed dredging activities, efforts were focused on the areas proposed for dredging (Barge Landing Basin and Yacht Channel) and an impact zone encompassing all marine areas within 250m of the center of proposed dredging activities. Within these areas, objectives were to (1) map habitats and (2) assess biological resources including corals, seagrass, and other benthic organisms, as well as fish and economically and ecologically important invertebrates such as conch, crawfish and the long-spined sea urchin *Diadema antillarum*. Detailed habitat mapping and quantitative biological surveys within representative habitats were conducted within these areas. In addition, qualitative surveys of habitats and biological resources were conducted out to 1km of dredging operations within Estimated Turbidity Zones, areas in which suspended sediments and particulates from dredging operations might be transported by tidal currents.

Habitat Mapping

To gain a better understanding of the marine resources likely to be impacted by the proposed dredging activities at Bell Island, marine habitats have been mapped within a 250m radius “Impact Zone” around each proposed dredging site and within an “Estimated Turbidity Zone” which includes areas within 1km of the proposed dredging site that may be impacted by sediment plumes due to transport in tidal currents. A description of the field portion of mapping is presented below.

Methods

To rapidly characterize marine habitats within 250 meters of the proposed dredged areas on Bell Island (see Figure Bell Island Turbidity map), we employed a towed diver survey, whereby a snorkeler was slowly towed behind a boat and signaled the habitat type under the boat throughout the towed survey. On the boat, the habitat type was recorded and a waypoint marked approximately every 20 m. The diver was towed in a grid pattern that ran transects across the survey area with the distance between transects ranging from approximately 20-50m. Because the boat could not safely and effectively survey close to the shoreline, surveys within 30 m of the shoreline were conducted by snorkeling. Additional data points were collected from spot checks on features that appeared interesting from an aerial photograph of the area and from biological surveys conducted in seagrass areas. This resulted in habitat type data being collected for over 560 points within both dredge impact zones and in adjacent Estimated Turbidity Zones. Habitats were classified into 6 main habitat groups and 3 unique habitats that occurred in specific

Habitats

1. ***Sparse – Medium Density Seagrass*** – This habitat occurs in sandy substrate, with occasional rubble pieces throughout the survey areas. The dominant seagrass species is usually *Thalassia testudinum*, but occasionally *Syringodium filiforme* (e.g., off the beach in the Barge Landing Basin Dredge area) and/or *Halodule wrightii* (adjacent to the sand bar in the Yacht Channel Dredge area and off the beach north or there within the 250 m radius area) are also present, either mixed with the *Thalassia* or on their own. Occasional algae (e.g., *Caulerpa*, *Laurencia*, *Halimeda*) are also present). Seagrass shoot densities range from 20 to 100 per m².



Typical Sparse Seagrass Habitat within the Barge Landing Basin Dredge Impact Zone. Seagrass densities throughout both impact zones varied somewhat over short (<30m) distances.

2. ***Dense Seagrass*** – This habitat occurs in patches in the survey area. *Thalassia testudinum* typically dominates this habitat. Within dense seagrass patches, sand was rarely visible and seagrass shoot densities exceed 100 per m².

3. **Hardbottom** – Hardbottom habitats in the survey area typically occur along rocky shorelines and are characterized by a relatively low relief hard substrate covered primarily by macroalgae, including a mix of *Batophora*, *Cladophora*, *Microdictyon* and algal turf, occasionally with patches of *Laurencia*, *Sargassum* and other algae. Rubble may be present, particularly at the interface between this habitat and adjacent sandy areas. Small corals (e.g., *Favia fragum*, *Porites astreoides*, *Porites porites*, *Siderastrea radians*, *Manicina aereolata*) and sponges (several encrusting and boring sponges, *Aplysina fistularis*) are occasionally found in this habitat, but they occupy a small amount of space within the habitat and do not provide much relief for fish and mobile invertebrates to use as a refuge.

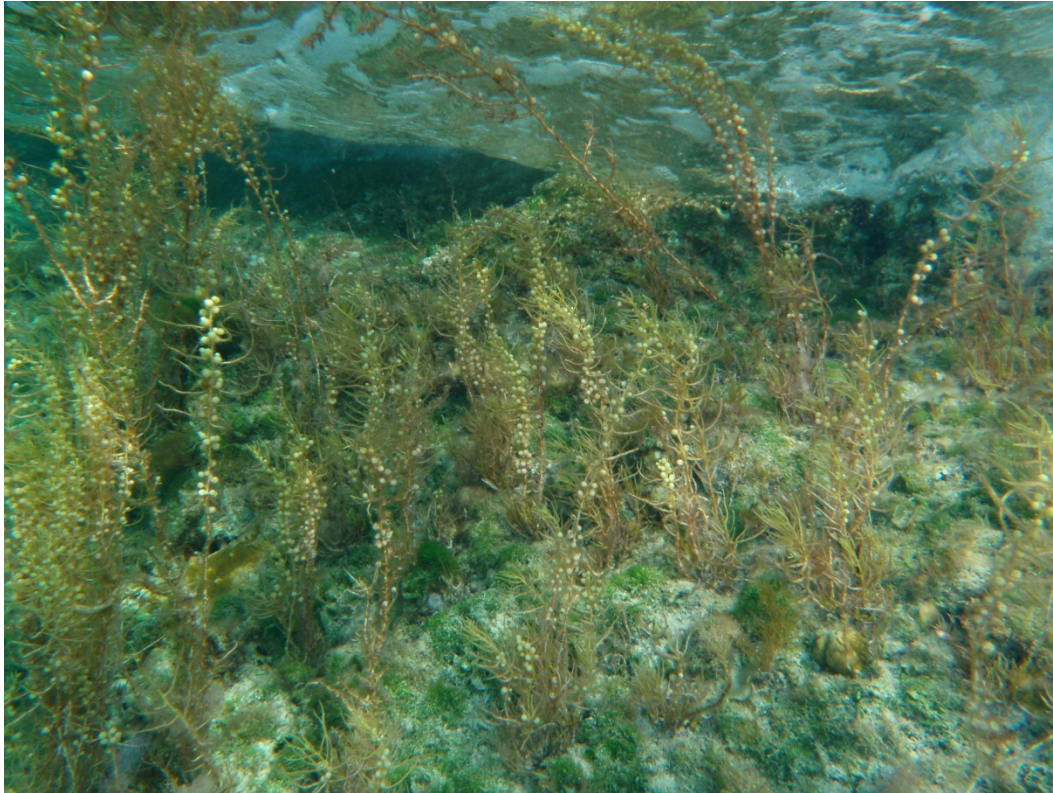
A.



B.

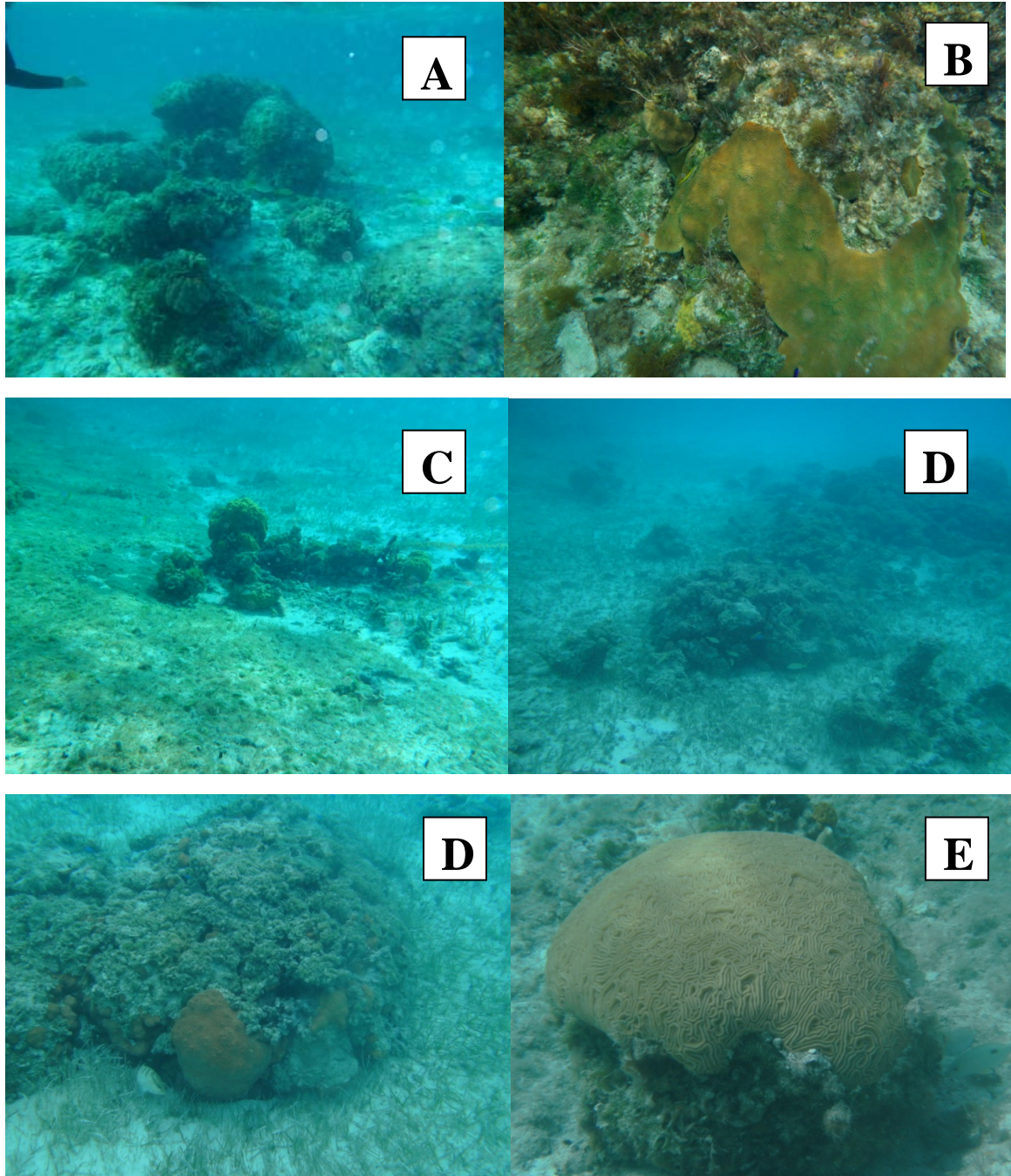


C.



Various examples of Hardbottom Habitats along rocky shorelines of Bell Island. Note that all are dominated by macroalgae. (A) is from the rocky shoreline along the Barge Landing Basin Dredging Impact Zone and is typical of low current Hardbottom habitats. (B) is typical of most Hardbottom Habitat within somewhat higher current areas, including most of the Yacht Channel Dredging Impact Zone and South Shoreline of Bell Island. (C) is in the highest current areas towards the Southeastern tip of Bell island within the Yacht Channel Dredging Impact Zone and other areas of high current and/or wave exposure.

4. **Patch Reef** - The Patch Reef habitat type includes areas of unconsolidated, often widely scattered living and dead coral heads surrounded by either hard or soft substrates. The key feature that separates this habitat type from hardbottom habitats is the three dimensional structure that living and dead coral colonies provide and the value of this structure for supporting diverse fish and invertebrate communities. Individual coral colonies may range in size from 30 cm to 10m in diameter and may be comprised of 100% living coral to colonies with <10% cover by live coral tissue. Most of the reef framework is comprised of living or dead *Montastraea* (boulder coral), *Diploria* (brain coral) and other massive corals, but other coral species frequently colonize areas where the primary structure producing coral has died off. These habitats typically also include high cover by algae as well as some sponge and gorgonian (soft coral) cover. Because of the scattered nature of coral heads within a patch reef, it is difficult to delineate the edges of the reef or measure the total reef area during rapid assessments. From a habitat perspective, the area in between corals may also be important foraging areas or serve other purpose for the diverse fish communities refuging in the structure provided by the coral heads.



Examples of Patch Reefs from the Yacht Channel Dredging Impact Zone (A-C) and the Barge Landing Basin Dredging Impact Zone (D-F). Photos A-C are within the proposed dredging area for the Yacht Channel. The reefs in Photo A are the largest structure in the area and extend approximately 20 m from the shoreline. Live coral cover is low, but there are still significant amounts of live coral on each head. Photo B is from the shoreline in the same area, where coral communities are patchily distributed, but have high coverage of live coral locally, particularly in places where the shoreline is undercut and in places where there are seeps of water coming up through the rocks (presumably nutrient rich water from the inland pond). Photo C shows coral heads towards the edge of the patch reef zone. Photo D shows an overview of patch reefs immediately adjacent to the southern dredge area within the Barge

Landing Basin. Photo E shows a closer view of a typical coral head in this area (approximately 3 m diameter). While live coral cover is generally low, there are several healthy coral colonies (or fragments of the original colony) on each head and fish life is abundant. Photo F is of a *Diploria labyrinthiformes* head from patch reefs farther to the South along the shoreline within the Barge Landing basin Dredging Impact Zone

5. **Channel Reef** – Channel reef habitats are similar to patch reefs in that much of the structure is provided by scattered coral heads of varying species and sizes. They are somewhat unique, however, due to the fact that their location within high flow channel environments often causes them to be dominated by gorgonians (soft corals such as sea fans and plumes) and sponges as well as hard corals. Channel reefs around Bell Island are relatively low relief (1.5-2m high) reefs compared to others in the Exuma Park (e.g., Jeep Reef), but they harbor the most diverse fish and benthic communities of any habitats around Bell island.



Photos of the Channel Reef Habitat Type. Both photos highlight the scattered distribution of coral heads and the abundance of gorgonians and sponges within the benthic community.

6. **Sand** – Areas in which seagrass, other vegetation or hard substrate was noticeably absent. Sand areas included areas of high current energy, such as shifting ooid sand bars like the one in the proposed Yacht Basin dredging area, and shallow areas in which wave energy prevents vegetation from gaining a foothold. Sand patches were also noted in protected embayments typically dominated by sparse seagrass. Sand was also a major habitat in

deeper parts of the Barge Basin Dredging Impact Zone, Barge Basin Dredging Impact Zone, perhaps due to prop-wash from the Mail Boat and larger vessels using this area.

7. ***Rubble and Sand*** – This habitat type was limited to a few small areas. While sand dominated these areas, there were also extensive rubble (small pieces of hard substrate) areas. Rubble was bare or had only small amounts of turf and/or macroalgae.
8. ***Sparse Seagrass and Algae*** – This habitat is similar to the Sparse Seagrass habitat type except the seagrass and other substrate also have high cover of macroalgae, frequently *Batophora*.



Photo of sparse *Thalassia* habitat in which the algae, *Batophora* comprises a significant portion of bottom coverage.

9. ***Seagrass Detritus*** – There were a few areas where dead seagrass and other detritus had accumulated and were noted. As with the Rubble and Sand habitat, this was not a major habitat within any of the impact zones.

Of the Habitat classes found around Bell Island, The Patch Reef and Channel Reef Habitats are the ones that support the greatest fish and benthic diversity, species of interest such as corals and commercially important species (e.g., grouper, snapper, crawfish), and biomass of fish. Because the species that create the structure in these habitats (corals, gorgonians, sponges) are all sensitive to changes in turbidity and other water quality parameters, these habitats are most sensitive to impacts from dredging activities, even if they are outside of the immediate dredging area. While some of these impacts may be minimized in Channel Reefs and in some Patch Reef areas due to high currents present in these areas, the re-suspension of sediments may interfere with photosynthesis (in the case of corals) and/or feeding in these organisms and have a negative impact on them and the communities that they support. For this reason, these habitats should be considered of primary concern with respect to dredging activities.

Although seagrass meadows may be less sensitive to the impacts of nearby dredging, seagrass meadows are not completely free from impacts. Prolong changes in turbidity and sediment grain size as a result of dredging may impact seagrass growth. Similarly Queen conch and other species commonly found in seagrass bed may be sensitive to changes in sediments characteristics as a result of dredging.

Biological Surveys

In addition to Habitat Mapping, this study included Biological Surveys of fish and benthic communities as well as conch populations within some of the sensitive habitat areas. Understanding what biological resources are present in various habitats that may be affected by the proposed dredging operations will allow for actions to lessen dredging impacts on these resources and monitoring potential impacts. The quantitative surveys conducted were designed to assess representative areas of some of the more significant habitats that may be affected by dredging – Seagrass, Patch Reefs and Channel Reefs. In addition to quantitative assessments, qualitative observations during the habitat mapping were used to supplement this information. Further surveys may be necessary for monitoring or habitat transplanting efforts.

Methods

Biological surveys methods used to assess and monitor biological resources in the Exuma Park and other parts of the Bahamas were followed with some adaptations to allow for time constraints of this project and unique features of the habitats present in the survey area. Fish and mobile invertebrate communities were assessed using 30m x 2 m belt transects in which all fish and select mobile invertebrates (Queen conch, Caribbean spiny lobster, long-spined sea urchins) were identified, their size was estimated and counted. Along the same transect, substrate type and benthic organism cover was assessed at 50 cm intervals (60 points per transect). For analyses, substrates were divided into soft and hard substrates and hard substrate benthic organisms were grouped taxonomically into broad categories – Algae, Hard Coral, Gorgonians (soft corals), Sponges. In seagrass beds, the number of shoots for each species (*Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrighti*) and blade length for 10 shoots chosen haphazardly was assessed within a 25 cm x 25 cm area at 10 m intervals along each transect (4 surveys per transect). In both reef habitats, the species, number, size and percent living tissue of coral colonies larger than 5 cm was assessed within the same belt transect used for assessing fish. It is important to note that many larger coral colonies were mostly dead and fragmented into small pieces of living tissue. When it was easy to determine whether scattered fragments of live

tissue were part of the same colony they were considered as part of that colony (i.e., their living tissue was expressed as a % of the larger colony). For patch reef habitats, coral colonies were assessed throughout the entire 30 m x 2 m belt transect. High number of corals in the Channel Reef habitat (and difficult survey conditions due to currents) resulted in corals only being surveyed in a 15m x 2 m area.

A total of 3 patch reefs and 1 channel reef were sampled around Bell Island. The channel reef was in the main channel adjacent to the Yacht Channel Dredge area (18 R 342934 2688561). One patch reef surveyed was within the Yacht Channel Dredge area (18 R 342687 2688532), one was just outside the 250m impact zone for the Yacht Channel Dredge area (18 R 342475 2688434) and the last patch reef was along the shoreline at the edge of the southern Barge Landing Basin Dredge area (18 R 341572 2688548). Because of the small size of the patch reefs present in this survey, only one 30m x 2m transect was conducted at patch reefs in the Barge Landing Basin area and just outside the 250m impact zone for the Yacht Channel area. Three surveys were conducted for patch reefs within the Yacht Channel Dredge area. Only 2 transects were conducted at the Channel Reef habitat due to high current conditions.

In seagrass areas, one transect was conducted at each of 6 seagrass sites (3 within the 250m radius impact zone for each dredge site). In addition, 4 transects were conducted at one site within the 250m radius impact zone for the Barge Landing Basin due to the high density of juvenile conch observed at this site. In addition, the edges of the conch nursery area were mapped out during extensive snorkeling surveys within the area. This area was also identified as a nursery by Stoner and colleagues over 20 years ago. It is important to that juvenile conch movement may expand the boundaries of this nursery from what was mapped out on January 26, 2011. The high density of juvenile conch reported at this site in 2011 and previously indicate that it is a significant area for juvenile conch and impacts to the site should be monitored and minimized.

Benthic Surveys

One measure of benthic communities and the amount of coral on a reef is the % cover that various benthic organisms occupy. In our surveys of Patch Reefs and the Channel Reef, the scattered nature of the coral heads allowed for soft substrate communities (bare sand or sand covered by seagrass) occupied a significant percentage of points along the survey transects, so percent cover results are presented with soft substrate communities included and then with soft substrate areas excluded. For Patch reefs, algae represented the hard substrate organism that had the highest cover. Coral coverage in hard substrate areas was less than 10% in most cases, with the one exception being the patch reef just outside the 250m radius impact zone for the Yacht Channel Dredge area. That Patch Reef was dominated by a single large *Montastraea annularis* colony that had many living fragments, as well as several *Diadema* that removed algae over extensive areas of the reef. Sponges were present on all patch reefs, but their total coverage was low. No soft corals were included in percent cover surveys for patch reefs. The channel reef was similar in that it had extensive soft substrate areas, but had much greater sponge and gorgonian coverage. This is typical of areas of high current flow like channel reefs.

Site	Total % Cover					Hard Substrate % Cover			
	Algae	Coral	Soft Substrate	Sponge	Gorgonian	Algae	Coral	Sponge	Gorgonian
Yacht Channel Patch Reef	76.1	2.8	18.3	2.8	0.0	93.2	3.4	3.4	0.0
Bell Patch Reef 1	28.3	11.7	56.7	3.3	0.0	65.4	26.9	7.7	0.0
Channel 1	5.8	2.5	70.8	11.7	9.2	20.0	8.6	40.0	31.4
Barge Patch Reef	45.0	5.0	43.3	6.7	0.0	79.4	8.8	11.8	0.0

Assessing the species distribution, number, and size of corals per belt transect may be a better way of determining the need to take action to minimize dredging impacts to corals and monitoring the health of coral communities in these habitats. Coral densities in belt transects ranged from 22 to 42 colonies per 60m² on patch reefs and 27 colonies per 30m² for the channel reef habitat. The highest number of coral colonies for patch reefs was within the Yacht Channel Dredge area and the lowest was in the Barge Landing Basin impact area. This result is somewhat different from the percent cover data, and is the result of the Yacht Channel Patch Reef having a large number of smaller coral colonies present. All sites had an average of 10 coral species per belt transect. Multiple transects at the Yacht Channel Dredge site, however, were varied and a total of 14 species were observed at this site. In addition to having more coral colonies on a per area basis, the channel reef site had a higher coral diversity with 17 species reported.

On patch reefs the size and species distribution varied between reefs. All patch reefs had at least one large *Montastraea* sp. colony (2 m diameter or larger), that had little live coral remaining; however these large heads provided the most structure for fish habitat. Numerically, *Porites* spp. Dominated at the Yacht Channel Dredge site and Barge Landing Basin site, but *Montastraea* spp.colonies had somewhat higher abundance at the site outside the 250m Yacht Channel Impact zone (Bell Patch Reef 1).

Benthic surveys of seagrass areas showed that most sites had more than one species of seagrass present. *Thalassia* was always the most common/abundant species, but *Syringodium* was present at all but two sites and *Halodule* was present at one site in the Barge Landing Basin impact zone and two of three sites at the Yacht Channel area, both of which were in the channel within or immediately adjacent to the proposed dredge site. Seagrass lengths (*Thalassia* only) typically ranged from less than 5 cm to 10 cm or more. Overall Seagrass densities ranged from 22 shoots per square meter to over 90 per square meter.

Waypoint	Area	UTM 18 coordinates		Shoot density (no/m ²)			Size Range
		East	North	<i>Thalassia</i>	<i>Syringodium</i>	<i>Halodule</i>	
268	Barge	341439	2688457	84	0	0	3-10 cm
269	Barge	341424	2688572	13	9	0	7-10 cm
270	Barge	341280	2688496	91	0	0	4-10 cm
271	Barge	341523	2688367	61	5	11	5-14 cm
273	Yacht	342858	2688461	56	10	8	3-12 cm
274	Yacht	342680	2688459	35	10	17	n/a
275	Yacht	342822	2688651	45	5	0	3-9 cm

Fish and Key Invertebrate Surveys

Surveys of Patch Reefs and the Channel Reef habitat included 47 species of fish. Species diversity within transects ranged from 17-26 species per transect. As with coral surveys, the greatest diversity was at the Patch Reef site within the Yacht Channel Dredge area. Total fish abundance, however was greatest (99 individuals per transect) at the patch reef just outside of the Yacht Channel Dredge 250m Impact Zone (Bell Patch Reef 1) and the Yacht Channel patch reef had the lowest fish abundance (52 individuals per transect). The high abundance at Bell Island Patch Reef 1 was largely due to the high number of grunts (primarily French grunt, *Haemulon flavolineatum*) residing around the large *Montastraea* colony that dominated the site. The Patch Reef within the Yacht Channel Dredge area was dominated by wrasses (e.g., *Thalassoma bifasciatum*, bluehead wrasse; *Halichoeres bivittatus*, yellowhead wrasse). The Patch Reef in the Barge Landing Basin area had the lowest diversity, but it was home to the greatest number of juvenile Nassau grouper (*Epinephelus striatus*, 5 per 60m²). This site also had 1 lionfish observed in the transect

The Channel reef had slightly higher fish diversity (29 species) and similar overall abundances. Wrasses (e.g., *Thalassoma bifasciatum*) dominated at this site. Of the 29 species observed at this site, over one third (n=11) were not observed at Patch Reef sites. One lionfish was observed at this site.

Species	Channel 1	Barge Patch Reef	Yacht Channel Patch Reef	Bell Patch Reef 1	Species	Channel 1	Barge Patch Reef	Yacht Channel Patch Reef	Bell Patch Reef 1
<i>Abudefduf saxatilis</i>	0.0	0.0	0.3	4.0	<i>Halichoeres maculipinna</i>	0.0	1.0	0.3	0.0
<i>Acanthurus bahianus</i>	0.5	0.0	0.0	11.0	<i>Halichoeres pictus</i>	13.0	0.0	6.7	0.0
<i>Acanthurus chirurgus</i>	0.0	1.0	0.3	1.0	<i>Halichoeres poeyi</i>	0.0	0.0	0.0	1.0
<i>Acanthurus coeruleus</i>	0.5	2.0	0.7	0.0	<i>Halichoeres radiatus</i>	0.0	0.0	0.3	0.0
<i>Aulostomus maculatus</i>	0.5	0.0	0.0	0.0	<i>Holacanthus ciliaris</i>	2.0	0.0	0.0	0.0
<i>Bodianus rufus</i>	0.5	0.0	0.0	0.0	<i>Holacanthus tricolor</i>	1.0	0.0	0.0	0.0
<i>Canthidermis sufflamen</i>	1.0	0.0	0.0	0.0	<i>Holocentrus rufus</i>	2.0	3.0	3.0	6.0
<i>Canthigaster rostrata</i>	2.0	0.0	0.0	0.0	<i>Lutjanus apodus</i>	0.0	0.0	0.3	1.0
<i>Caranx ruber</i>	0.0	0.0	0.3	0.0	<i>Microspathodon chrysurus</i>	0.0	0.0	0.0	1.0
<i>Cephalopholis cruentatus</i>	0.5	0.0	0.3	1.0	<i>Pterois volitans</i>	0.5	1.0	0.0	0.0
<i>Cephalopholis fulvus</i>	0.5	1.0	0.0	0.0	<i>Scarus iserti</i>	5.0	2.0	5.0	0.0
<i>Chaetodon ocellatus</i>	1.0	2.0	0.3	2.0	<i>Serranus tigrinus</i>	0.5	0.0	0.0	0.0
<i>Chromis cyanea</i>	17.0	21.0	1.7	13.0	<i>Sparisoma atomarium</i>	1.0	0.0	0.0	0.0
<i>Dasyatis americana</i>	0.5	0.0	0.0	0.0	<i>Sparisoma aurofrenatum</i>	1.0	0.0	0.7	0.0
<i>Diadema sp_</i>	0.0	0.0	0.3	0.0	<i>Sparisoma rubripinne</i>	0.0	0.0	0.3	0.0
<i>Epinephelus guttatus</i>	0.0	2.0	0.0	0.0	<i>Sparisoma viride</i>	0.5	0.0	0.3	0.0
<i>Epinephelus striatus</i>	1.5	5.0	1.0	1.0	<i>Stegastes diencaeus</i>	1.0	0.0	0.0	0.0
<i>Gobiosoma genie</i>	0.0	0.0	0.7	0.0	<i>Stegastes fuscus</i>	0.0	0.0	0.0	1.0
<i>Gramma loreto</i>	2.5	0.0	0.0	0.0	<i>Stegastes leucostictus</i>	1.0	7.0	5.3	0.0
<i>Haemulon album</i>	0.0	0.0	0.0	1.0	<i>Stegastes partitus</i>	4.0	2.0	0.3	0.0
<i>Haemulon flavolineatum</i>	0.0	15.0	9.0	47.0	<i>Stegastes planifrons</i>	1.5	1.0	0.0	3.0
<i>Haemulon plumieri</i>	0.0	0.0	0.0	2.0	<i>Stegastes variabilis</i>	2.5	0.0	0.3	0.0
<i>Haemulon sciurus</i>	0.0	0.0	0.3	1.0	<i>Thalassoma bifasciatum</i>	41.5	9.0	16.3	3.0
<i>Halichoeres bivittatus</i>	0.0	4.0	12.7	1.0	Total Fish per transect	72.5	72.0	52.0	99.0
<i>Halichoeres garnoti</i>	7.5	2.0	1.0	1.0	No. species	29.0	17.0	26.0	19.0

Other observations of significance included sightings of several spotted eagle rays and a hawksbill turtle within channels adjacent to Cambridge Cay (Little Bell Island) within the 1000m radius Estimated Turbidity Zone. Channel Reefs within the Estimated Turbidity Zone to the Northeast of the Yacht Channel Dredge area also were found to have several large mutton snapper and other commercial/subsistence fishery species. Several patch reefs observed during the Mapping Surveys appeared to have relatively high densities of grunts, wrasses and damselfish. Several juvenile Nassau grouper were also observed at these patch reefs and several gray snapper (*Lutjanus griseus*) were observed on Patch Reefs in the Estimated Turbidity Zone to the northwest of the Barge Landing Dredge Channel area.

Surveys of fish and key invertebrates within seagrass areas revealed very low diversity (0-1 species present per site) and low abundance of fish. Only one site had conch present. This site (Waypoint 271) was within the 250m Impact zone for the Barge Landing Basin Dredge site and had such juvenile conch densities (88 individuals per 60m² on the initial transect) that multiple transects were conducted in different directions to determine the extent of the nursery area. The extent of this conch nursery was then mapped using snorkeling and towed diver surveys. While this nursery did not have conch densities as high as the bank on the southern side of the channel south of the Yacht Channel Dredge Impact Zone (outside of the 250m radius area), nor did it cover as extensive an area, it represents a significant conch nursery for the Bell Island area and dredging impacts should be monitored in this area.

UTM 18 coordinates				Species observed (no. per 30 x 2 m transect)			
Waypoint	Area	East	North	Queen Conch	Slippery dick	Rosy Razorfish	Bandtail Puffer
268	Barge	341439	2688457	0	1	0	0
269	Barge	341424	2688572	0	0	3	0
270	Barge	341280	2688496	0	0	0	1
271	Barge	341523	2688367	80*	0	0	0
273	Yacht	342858	2688461	0	0	0	0
274	Yacht	342680	2688459	0	0	0	0
275	Yacht	342822	2688651	0	0	0	0

*average of 4 transects (88, 33, 88, 110)

While conch densities were not quantified in other locations using transect surveys, high concentrations of early juvenile conch were found within the 250m impact zone for the Yacht Channel Dredge area along the rocky shore at both the north and south edged of the bay just north of the Dredge Channel area. Conch densities of 200-300 early juvenile conch were observed along relatively small areas (60-80m²) of the Hardbottom margin of the rocky shore. Another area where (larger) juvenile conch appeared to be abundant was the dense seagrass area at the far margin of the NW Estimated Turbidity Zone for the Barge Landing Basin. While there are no major conch habitats in the proposed dredging area, and the most significant conch nursery in the area is across the channel from the Yacht Channel Dredging area, making it unlikely to be impacted by dredging activities, biological surveys conducted as part of this study have indicated that there is a significant conch nursery within 250 m and the Estimated Turbidity Zone for the Barge Landing Basin area and there are small pockets of high density juvenile

conch along the rocky shorelines immediately adjacent to both ends of the beach to the north of the Yacht Channel area.

Based on biological surveys, patch reefs and channel reefs within the 250m radius impact zones and in the Estimated Turbidity zones contain some of the biological resources that are most likely to be impacted by dredging activities. Live corals in reef areas within dredging zones should be relocated, and live corals on reefs that are likely to see high sedimentation from dredging should also be relocated. It is important to note that while relocation of living corals can minimize loss of reef building corals, it is likely that reef structure (i.e., fish habitat) may still be lost since much of the structure within patch reef habitats at present is dead coral heads, which may be difficult to relocate based on their size and the fact that boring organisms may have weakened the reef framework and cause it to fall apart if moved. In these cases options that will minimize dredging impacts (e.g., reducing sediment loads reaching these sites) might be more effective at maintaining the ecosystem than transplanting corals. If reef structure is to be removed from an area, large rubble pieces from the dredging operation may provide similar structure for fish and, if positioned properly and colonized by corals, may supplement transplanting efforts by filling a similar function to patch reefs. For transplanting corals, several suitable areas (e.g., areas with similar environmental conditions to where corals are currently growing in the impact zones) exist around Bell Island but specific sites should be examined in a bit more detail prior to translocation efforts. Patch reefs and Channel reefs in impact areas and estimated turbidity zones affected by dredging activities should be monitored and changes on these reefs compared to nearby control reefs to assess impacts of dredging activity on biological resources in these areas.

Conch should be removed from the immediate dredging areas prior to dredging and during dredging operations. There are many suitable relocation sites nearby to dredging areas. The conch nursery near the Barge Landing basin Dredging area is one that should be monitored to ensure that the habitat remains suitable for conch and that conch continue to persist in this area.

APPENDIX VII
(SUPPLEMENT)

HABITAT ANALYSIS EXHIBITS FOR
IMPACT AREAS
FOR
CRAIG DAHLGREN, PHD

FEB. 18, 2011

HABITAT ANALYSIS EXHIBITS FOR IMPACT AREAS
FOR
CRAIG DAHLGREN, PhD
FEB. 18, 2011

The information contain in this supplement dated February 18th 2011 draws on information provided in the main body of the Dalhgren report dated January 27, 2011, and provided as Appendix VII. The table and exhibits to follow were prepared to assist in the description of the marine resources observed in the vicinity of the Yacht Basin and Barge Landing dredge areas of the Bell Island project. The exhibits illustrate individual locations of corals and conch habitat with corresponding photographs; while the table further describes the attributes of each of these locations. The table directly relates to the locations identified in the Yacht Basin Dredge Impact exhibit and the Barge Basin Dredge Impact exhibit.

The data presented in the table is an excerpt from the information on the following pages:

- Pages 5-8 discuss the various habitats present. This information can be found on the exhibit through the pictures represented.
- Pages 11-12 discuss the Benthic communities and the percent of coral reef colonies
- Page 4 explains Sea Grass Habitat - Spares to Medium density depicted as BL4a, 4b and 5
- Page 5 discusses Hardbottom Habitat shown as BL6 and YB4
- Page 6 describes Patch Reef Habitat illustrated as BL 2 and YB 2

PHOTO #	MAJOR SPECIES OBSERVED	GPS (UTM-WGS 1984 datum, Zone 18 North, Meter)		% COVER LIVE CORAL	VIABILITY	MEAN SIZE	ACTION TO BE TAKEN
		X	Y				
YB 1	<i>Montastraea annularis</i> , <i>Montastraea faveolata</i> , <i>Porites astreoides</i> , <i>Porites porites</i>	342672.523	2688530.5322	9	87%	13 cm	Relocation (to included prominent corals where the channel is to cut into the basin)
YB 2	<i>Montastraea annularis</i>	342474.4707	2688433.6699	27	80%	42 cm	Preservation
YB 3	<i>Montastraea faveolata</i> , <i>Porites astreoides</i> , <i>Porites porites</i>	342646.3256	2688515.3483	2	92%	13 cm	Relocation
YB 4	<i>Porites astreoides</i> , <i>Montastraea annularis</i> , <i>Porites porites</i> , <i>Siderastrea siderea</i> , <i>Diploria labyrinthiformes</i> .	342708.1514	2688530.0086	2	94%	13 cm	Relocation
BL 1	<i>Montastraea annularis</i> , <i>M. faveolata</i>	341581.1025	2688559.8838	9	83%	26 cm	Relocation
BL 2	<i>Diploria labyrinthiformes</i>	341606.3265	2688459.0207	5	80%	30 cm	Preservation
BL 3	<i>Siderastrea siderea</i>	341570.5925	2688524.6868	5	83%	26 cm	Relocation
BL 6	<i>Manicina areolata</i>	341512.2619	2688663.3736	1	95%	5 cm	Relocation
SEAGRASS HABITATS				% COVER	SHOOT COUNT	BLADE LENGTH	
BL 4a	<i>Thalassia testudinum</i>	341402.9577	2688589.3022	5-10	66/m ²	3-10 cm	Part of Conch Relocation Plan
BL 4b	<i>Thalassia testudinum</i>	341545.3684	2688560.4092	5-10	66/m ²	3-10 cm	Lost
BL 5	<i>Thalassia testudinum</i> , <i>Strombus gigas</i>	341441.3193	2688472.1539	20	72/m ²	5-15	Part of Conch Relocation Plan

CORALS – VIABILITY = Mean % Living Tissue on Individual Colonies
MEAN SIZE = Mean diameter of Individual Colonies

2

1

1 ALTERNATE VIEW

Montastraea annularis, *Montastraea faveolata*, *Porites astreoides*,
Porites porites

(4)

3

2

Montastraea annularis

BELL ISLAND

YACHT BASIN DREDGE IMPACT



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BARGE LANDING DREDGE

250 METER RADIUS



Montastraea spp.



Diploria labyrinthiformes



Siderastrea siderea and others



Thalassia testudinum



Thalassia testudinum, Strombus gigas



small corals e.g., Manicina areolata

BELL ISLAND

BARGE LANDING DREDGE IMPACT



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DATE:	02-17-2011		
SCALE:	N/A		
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