Coastal Engineering Design in the Caribbean

A Case Study –Palisadoes Sea Defences

Smith Warner International Limited
Costal Engineering
Kingston - Jamaica

1a. Project site

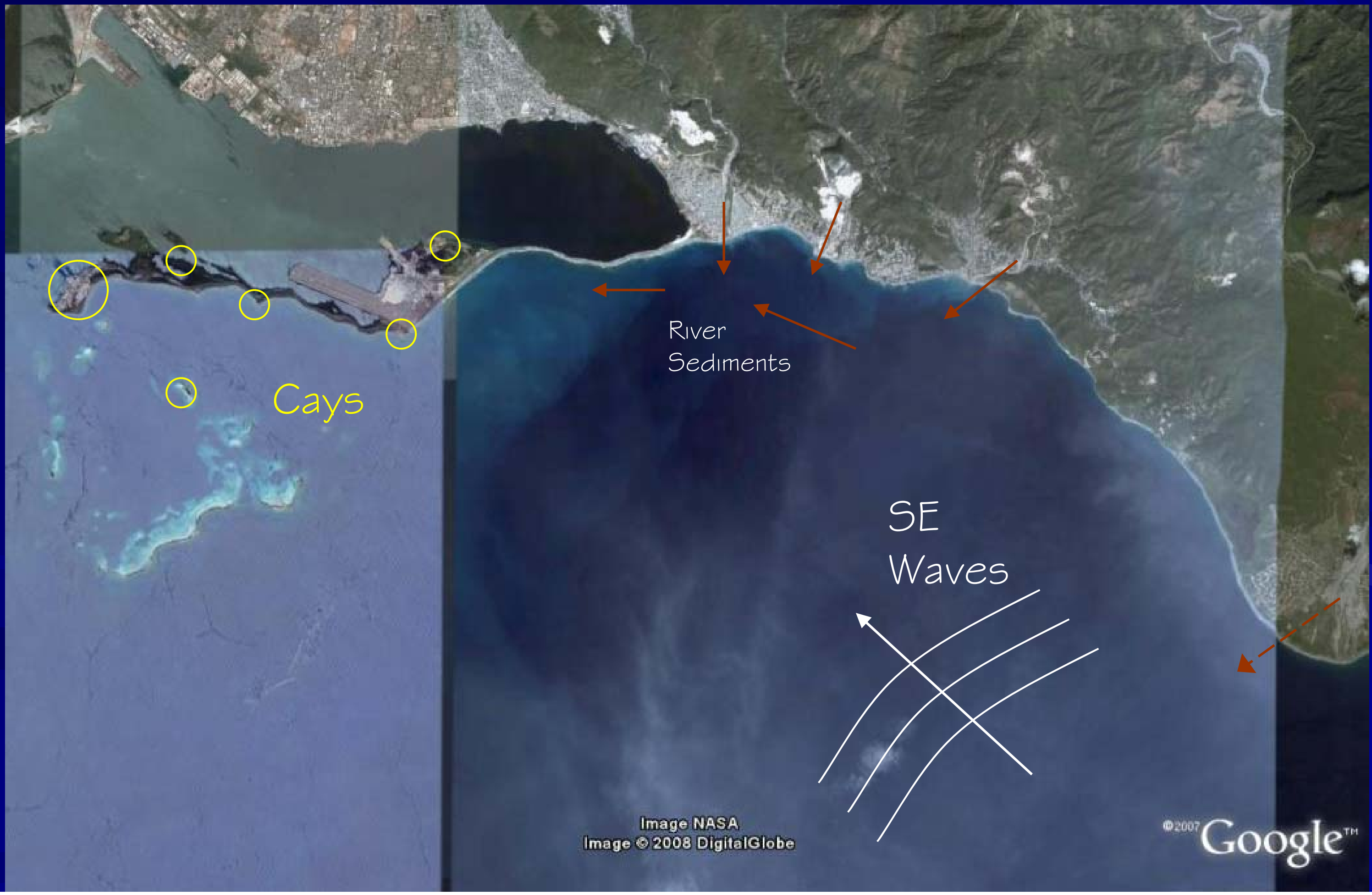
1b. Project site – Close up

Detail of the Palisadoes strip

2. Background

2.1 Understanding of Site geology

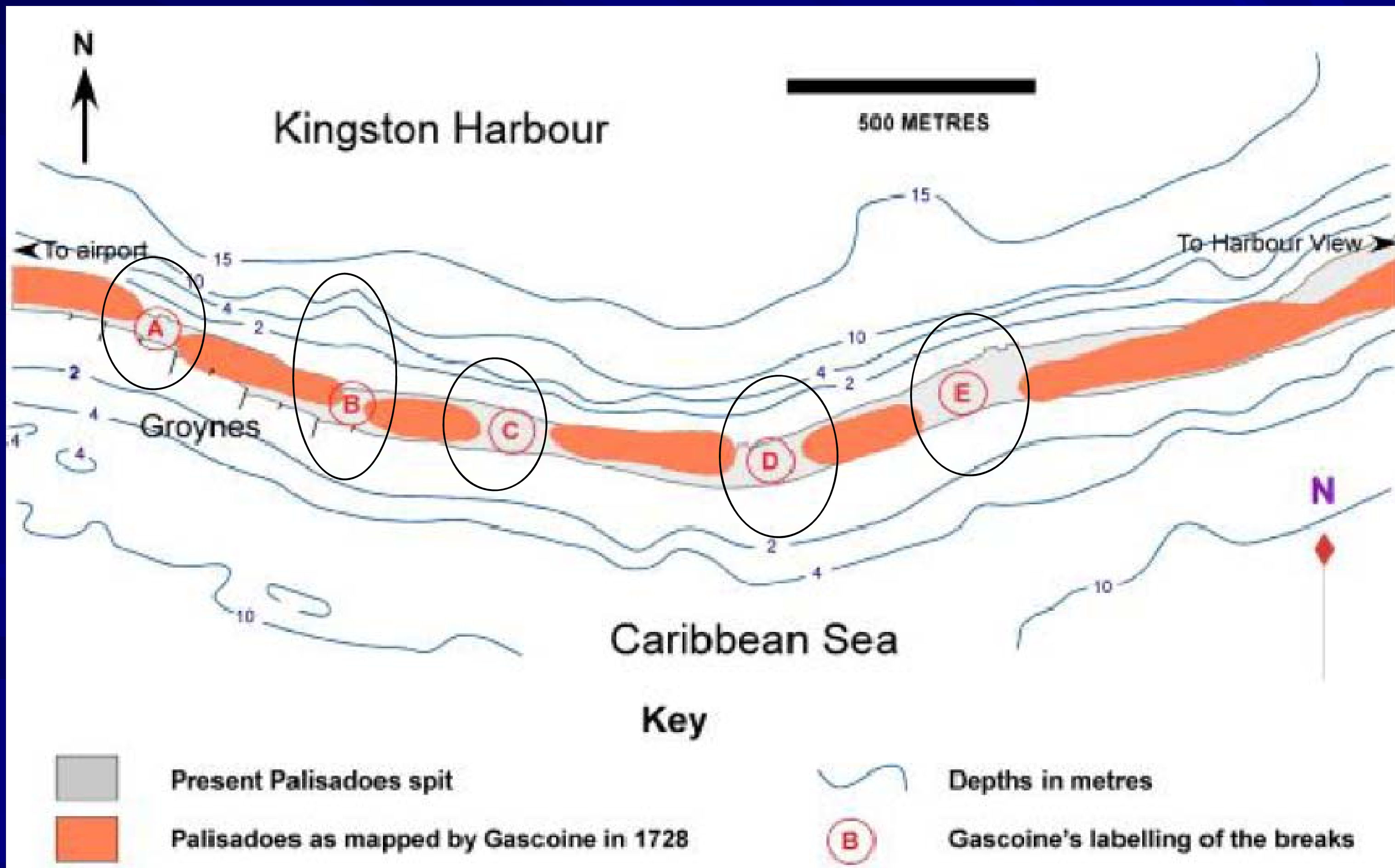
- Original date of formation unknown, ~ 4000 years
- Port Royal and relict cays were once totally separated from the mainland
- Westward longshore currents carried sediments from rivers in the east to form the Palisadoes. These Cays served as “anchor” points



2. Background

2.2 Historical natural shoreline changes

- Natural coastal processes appear to have closed the spit as early as 1722
- Hurricanes caused breaches (e.g. Mapping by Gascoine in 1728)
- However, the spit had closed completely by 1788
- In 2004 Ivan almost caused a complete breach of the spit



2. Background

2.3 History of artificial modifications

- Boulders along shoreline and other interventions of unknown date
- After Hurricane Charlie (1951), a groyne field (9 structures) was placed to stabilize 850 m of the most vulnerable section but these deteriorated over the years and …
  - were damaged by Hurricane Ivan
- A Cuban Team was comissioned to provide a design for Palisadoes sea defenses (1 in 25 year return period)
- Emergency works (1 in 5 year) placed in anticipation of final designs

Groin field - 2002

2004, post-Ivan

Emergency Works – May 2008

2. Background
2.4 Hurricane impacts

- Impact on costal areas
  - High waves
  - Storm surge
  - X-shore sediment transport
- Recently in Jamaica, Hurricanes Ivan (2004), Dean (2007), and Tropical Storm Gustav (2008) caused extensive damage

Ivan, 2004

Dean, 2007

Gustavo, 2008

2. Background

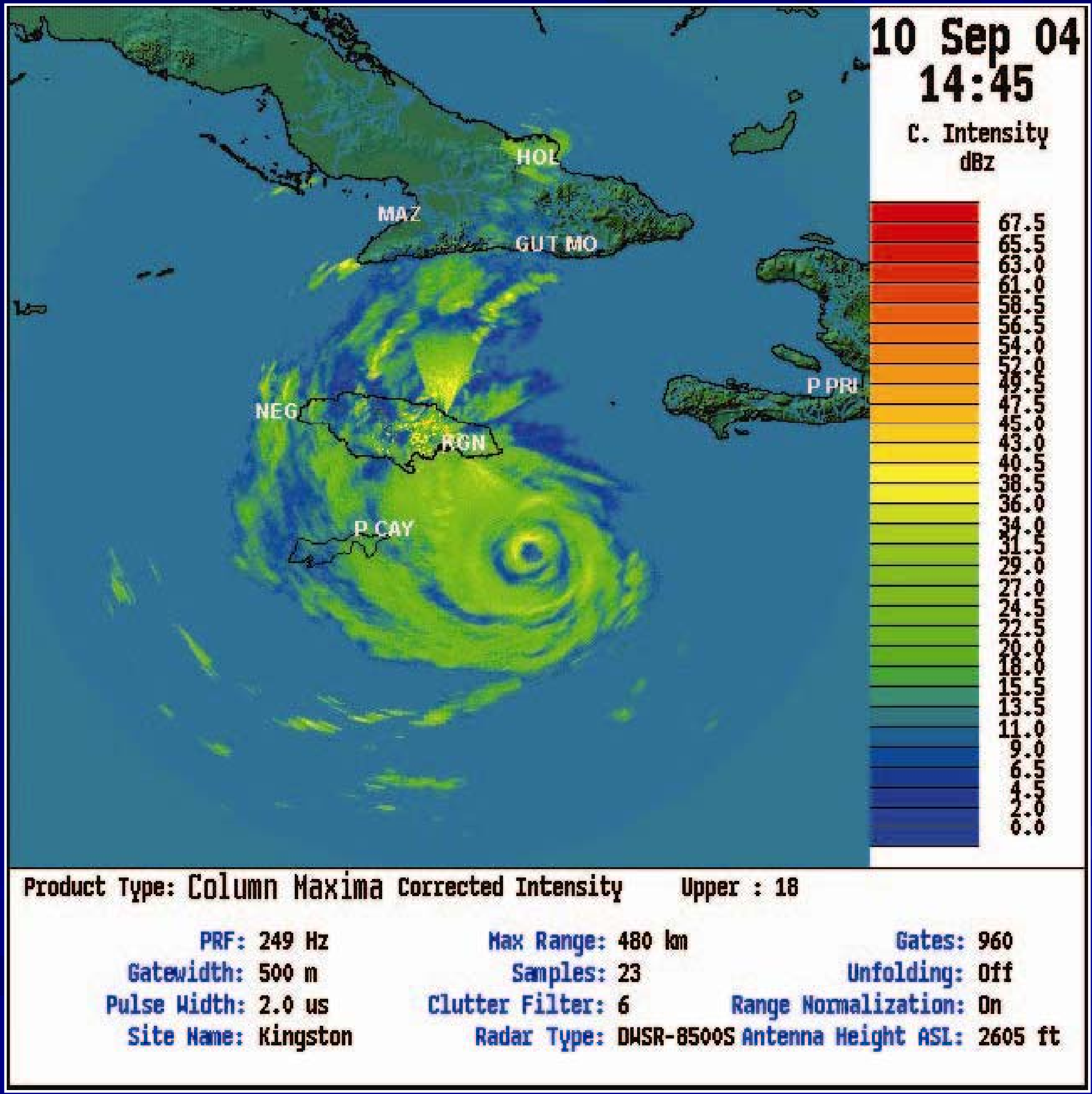
2.4 Hurricane impacts (cont'd)

The effects of Hurricanes Ivan and Dean are summarized below:

Hurricane Ivan (2004)	Hurricane Dean (2007)
Sand erosion & emergence of previously buried structures	40,000 m^3 of sand deposited onto the highway.
	Generated 2 to 3 m of storm surge at the project site.

In addition, both storms caused onshore transport of sand that was deposited at the north-eastern end of the Palisadoes, and overwashing into the bay side of the spit. Local authorities fear that if another hurricane hits the site, there is a very high risk that a breach may develop and close the highway.

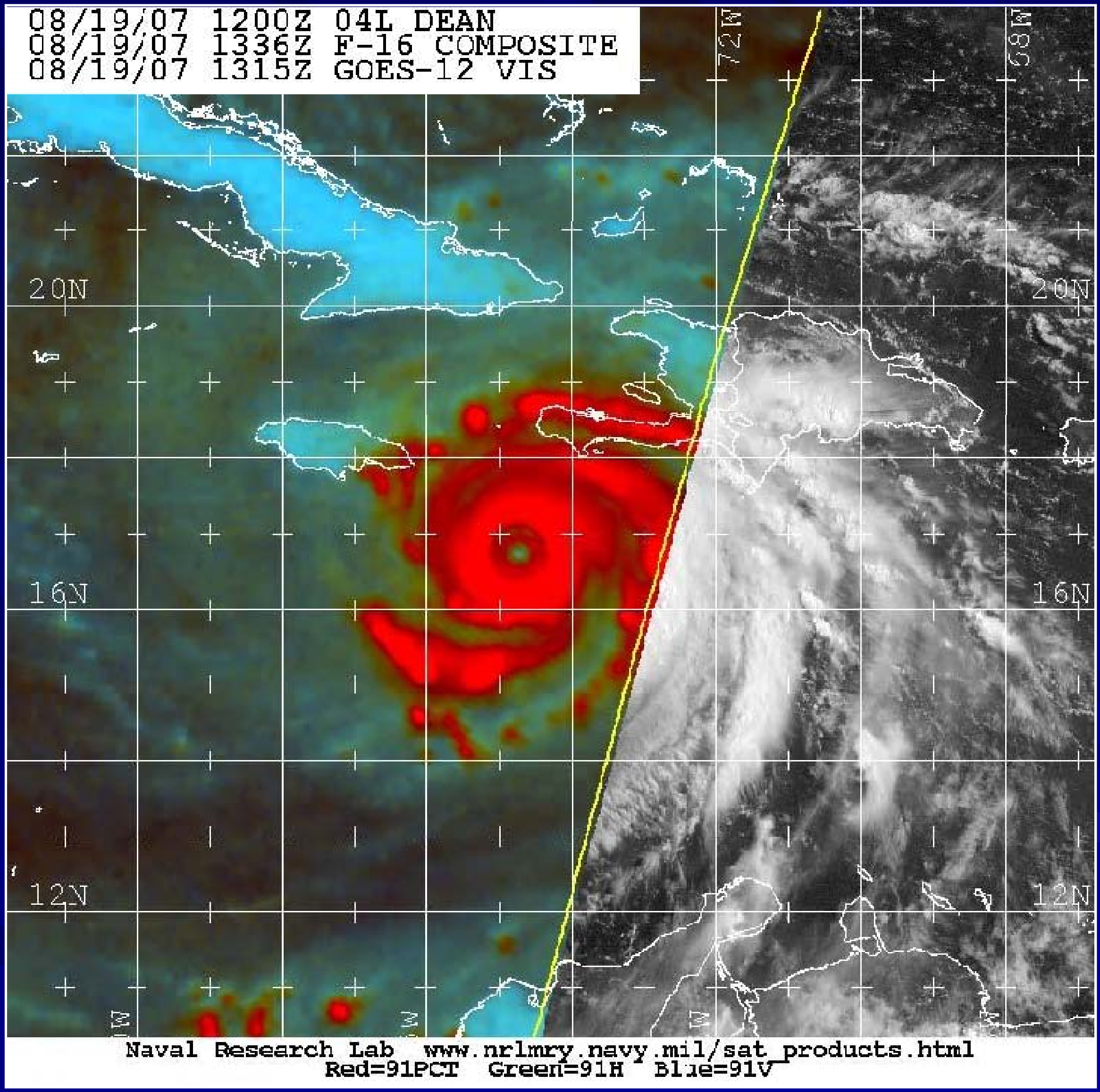
2. Background
2.4 Hurricane impacts



Satellite image of Hurricane Ivan, at 10th September 2004 (NOAA/NHC database).

2. Background

2.4 Hurricane impacts



Satellite image of Hurricane Dean, at 19th August 2007 (NOAA/NHC database).

2. Background

2.4 Hurricane impacts

2. Background

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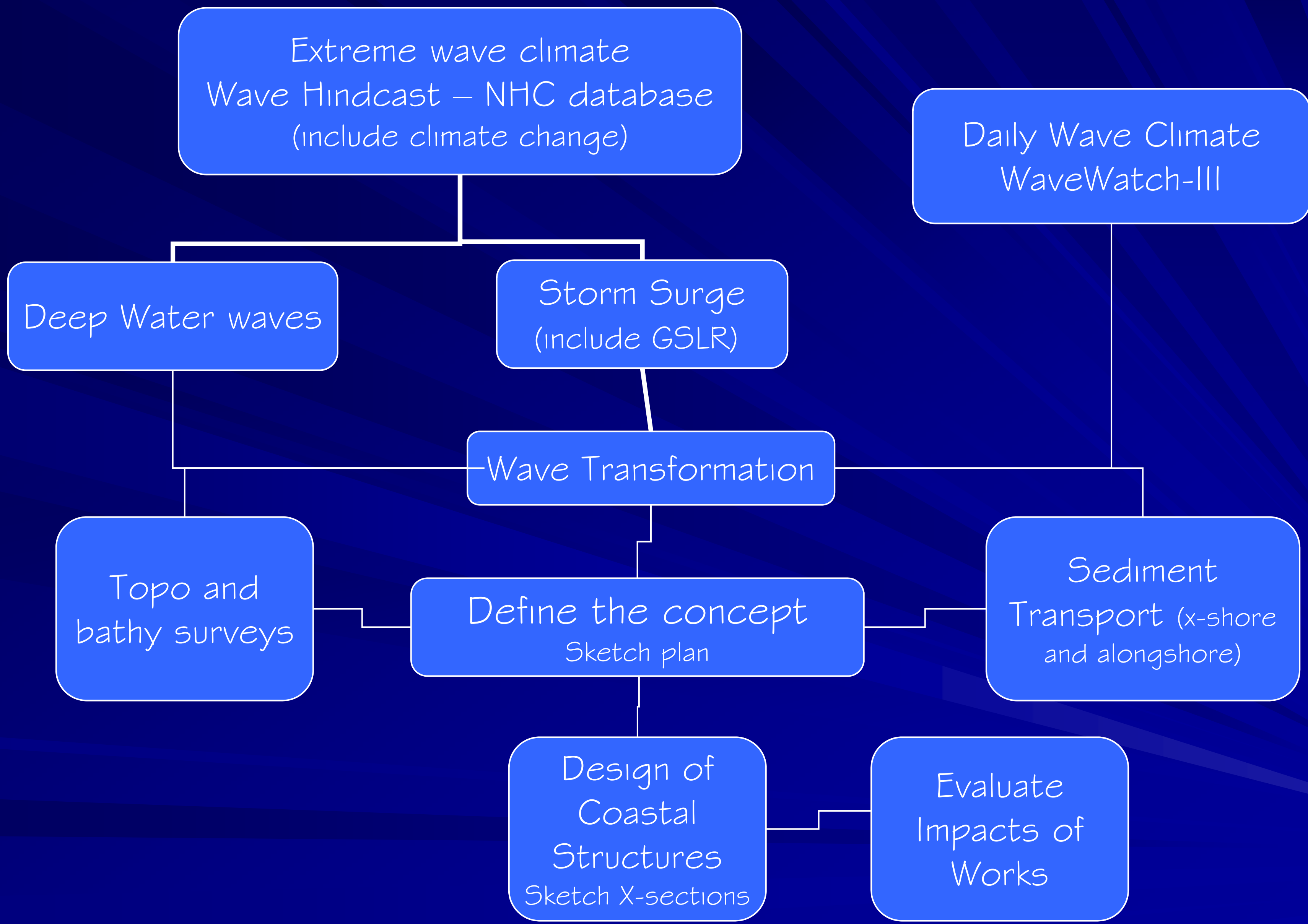
3. Problem definition and design constraints

- The dune system and the shoreline of the Palisadoes Road had suffered extensive damage and erosion, compromising the only land-based access to the NMIA and to Port Royal.
- The solution to this problem should be expected to be a combination of technically efficiency and least cost.
- The solution should seek to provide protection to the access roadway along the Palisadoes spit, for a given level of risk acceptance.
- The solution should seek to work, as much as possible, in harmony with the natural environment along this stretch of land.

Recommended Methodology

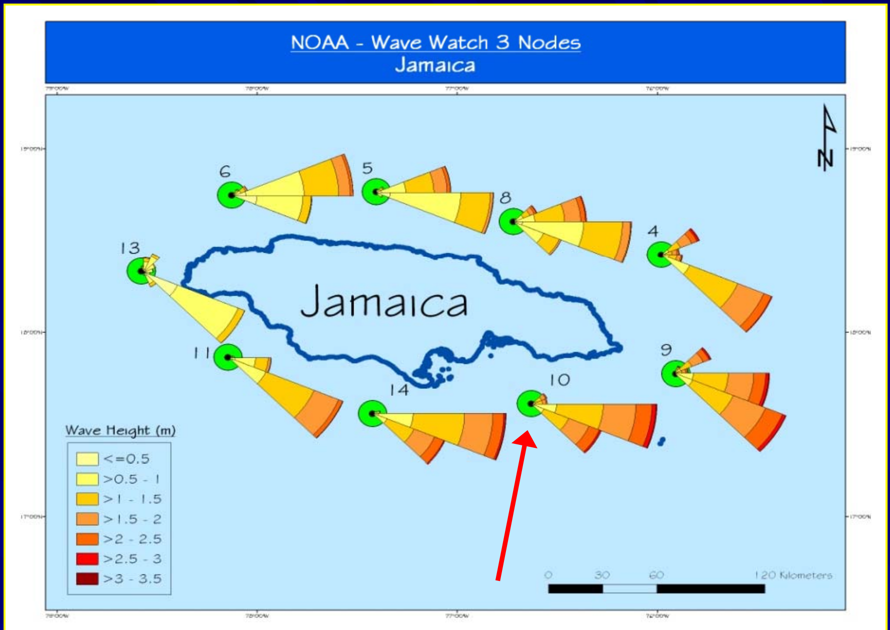


4. Coastal Processes

4.1 Daily Wave Climate

- Wave Watch III model – NOAA
- Statistical analysis probability of exceedance for directions E and SE
- Larger waves from E but shorter periods

NOAA Wave Watch III nodes for Jamaica.



Probability Exceedance Values (1% and 10%).

Direction	Probability Exceedance	Hs (m)	Tp (s)
E	1%	2.8	7.9
	10%	2.0	7.6
SE	1%	2.5	8.2
	10%	1.7	7.3

4.1 Daily Wave Conditions

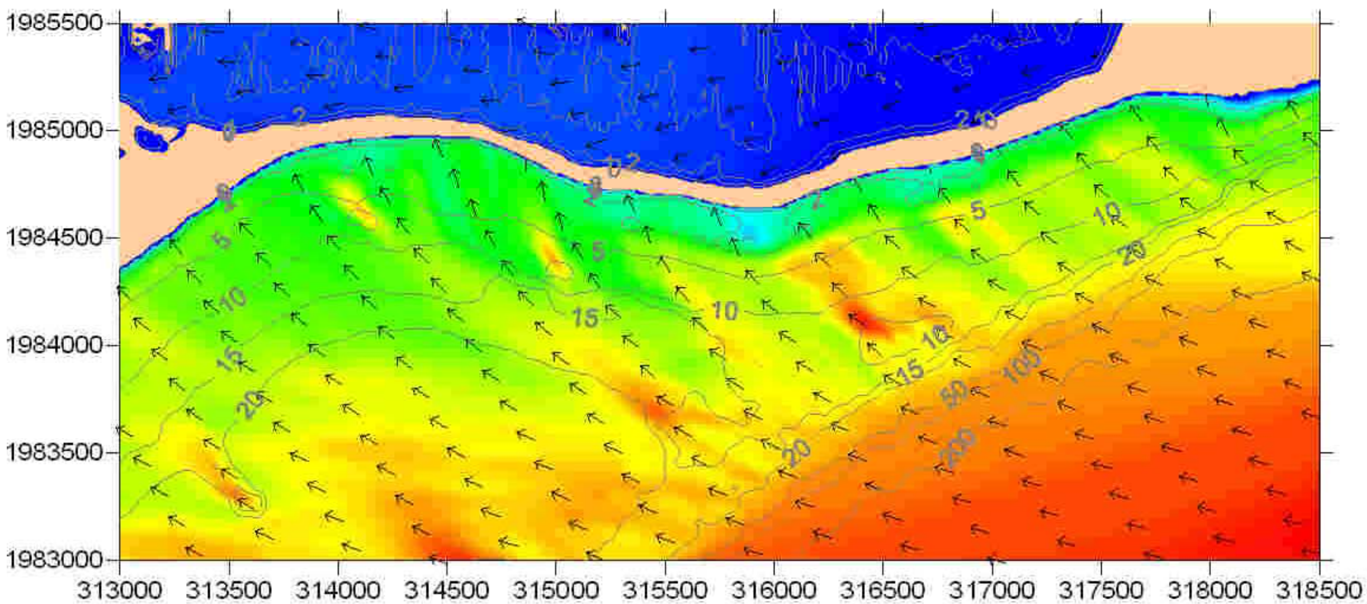
--- SWAN MODELING RESULTS ---

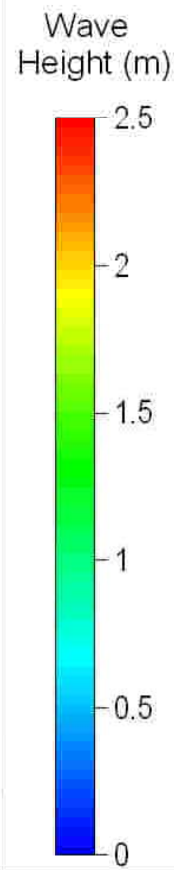
Palisadoes - 1% Exceedance from WaveWatch-III

Investigation Details:

Hs = 2.76 m
Tp = 7.94 s
Dir = E

Wind speed = 8.88 m/s
Wind direction = E





Depth countours in meters
Direction where waves are going to

Prepared by:
Gustavo Oliveira

4.1 Daily Wave Conditions

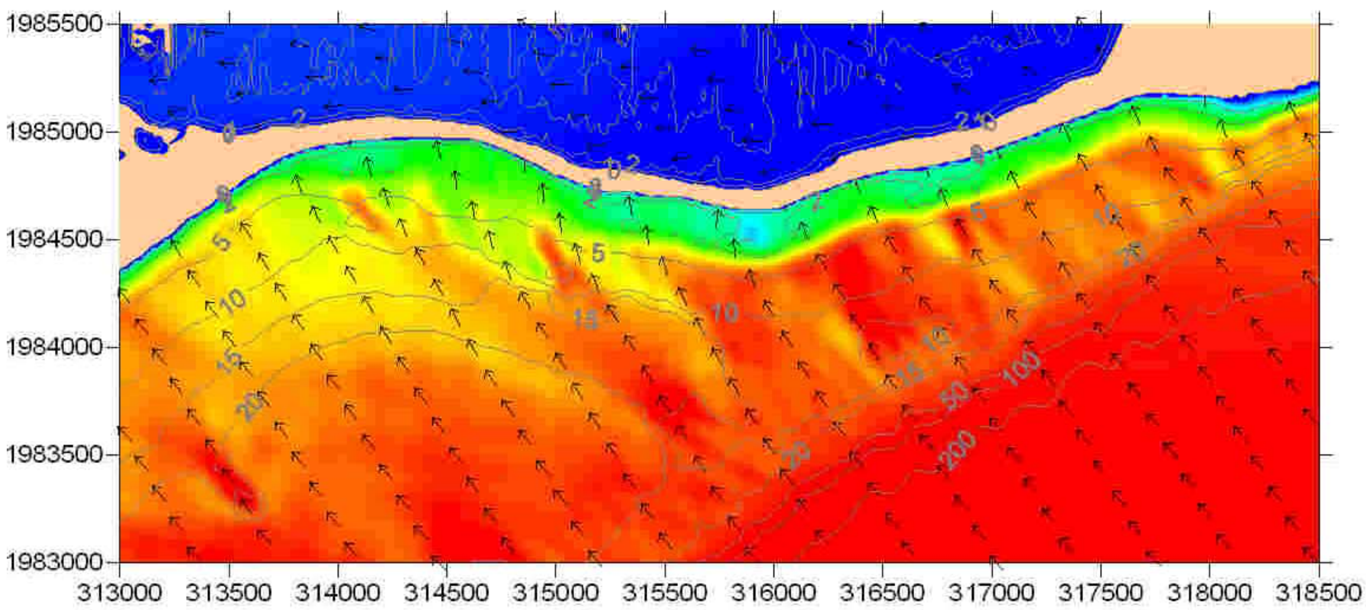
--- SWAN MODELING RESULTS ---

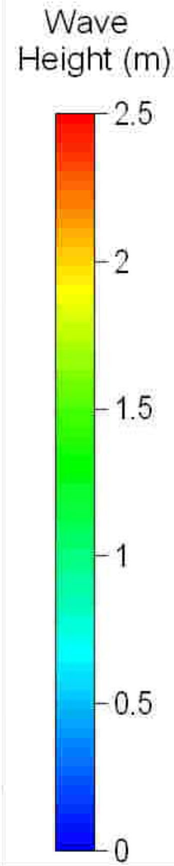
Palisadoes - 1% Exceedance from WaveWatch-III

Investigation Details:

Hs = 2.49 m
Tp = 8.23 s
Dir = SE

Wind speed = 9.38 m/s
Wind direction = SE





Depth countours in meters
Direction where waves are going to

Prepared by:
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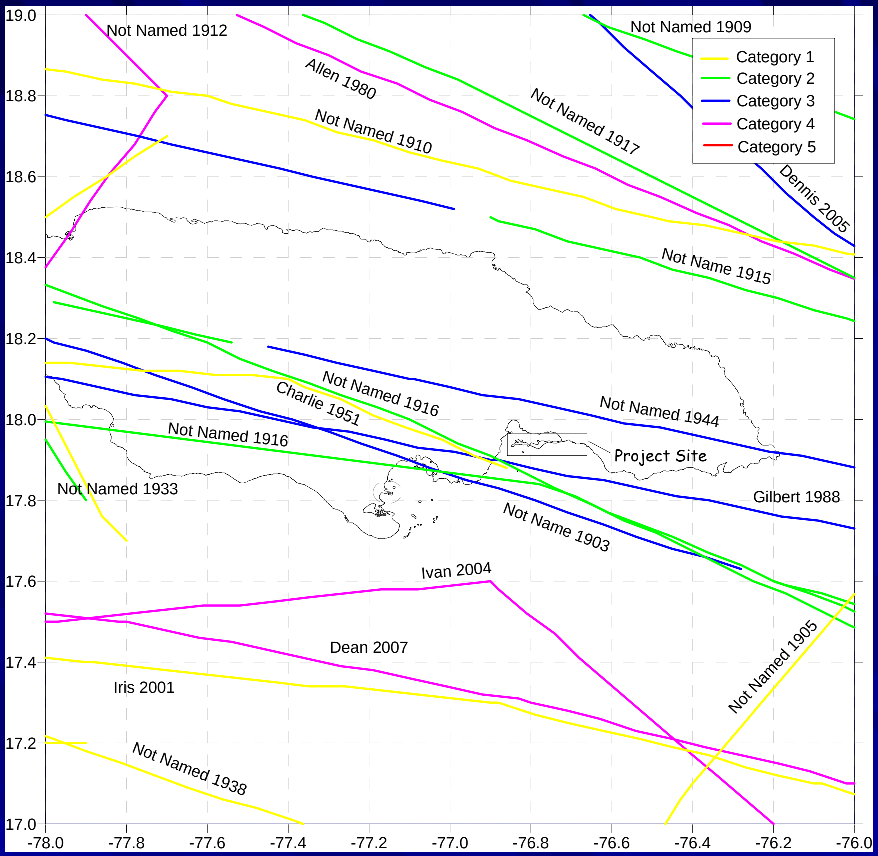
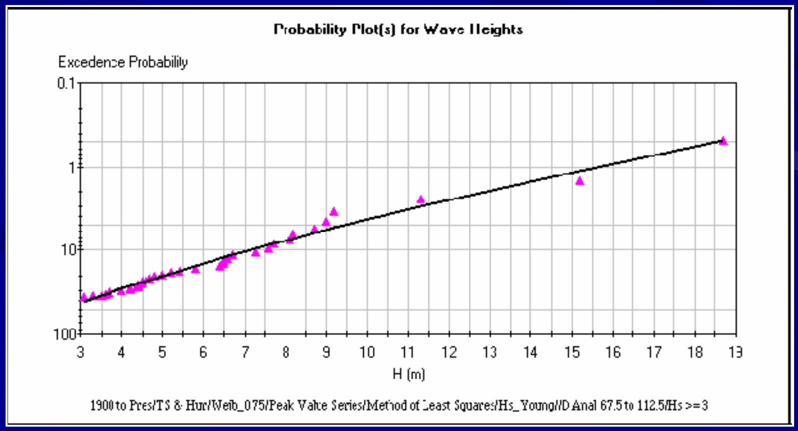
4. Coastal Processes

4.2.1 Extreme Wave Climate

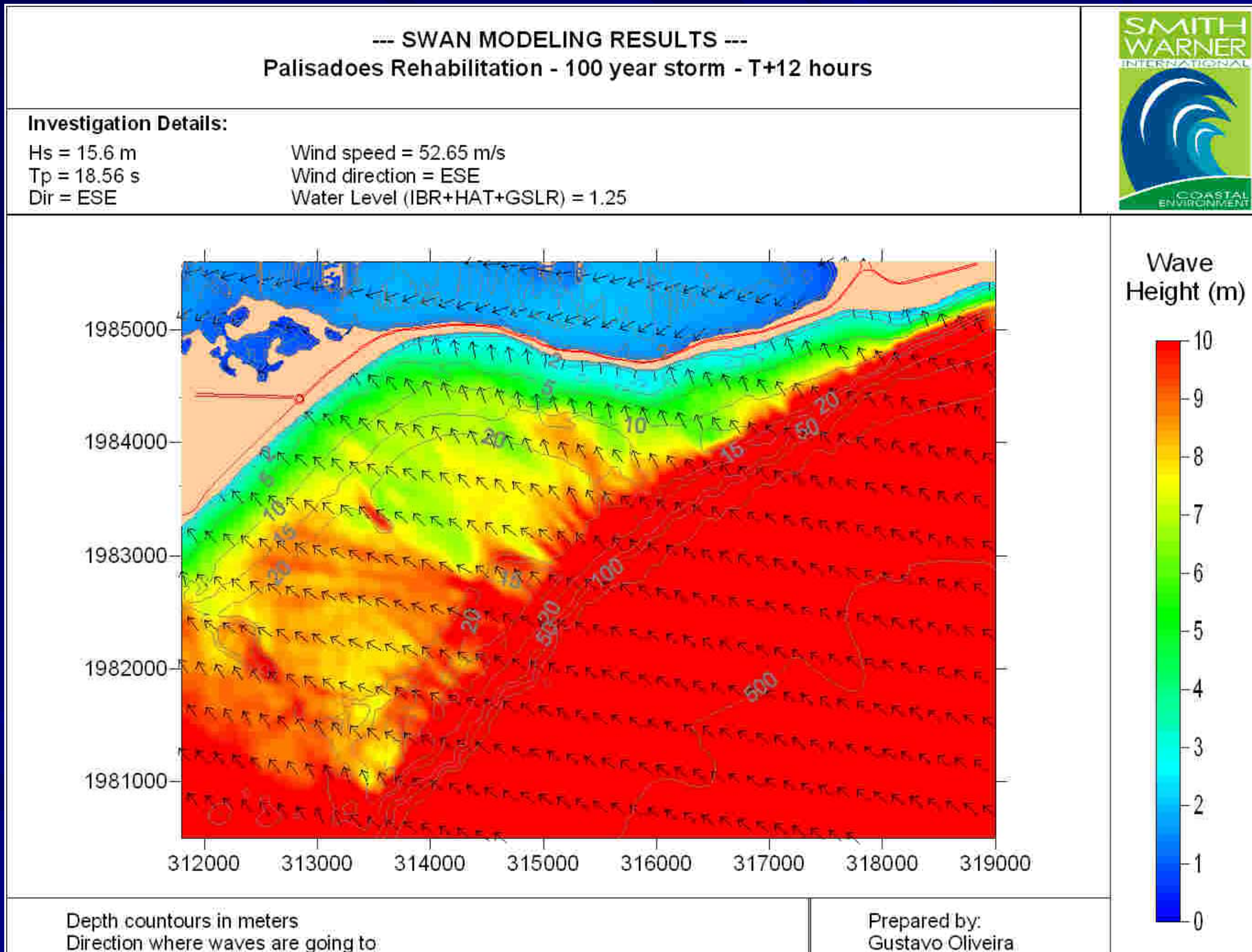
- HurWave (in-house program)
  - scans NHC database for storms within specified distance of site
  - Parametric models are used to calculate wave properties
  - Statistical distribution are fitted to exceedance probability plots
  - Return period waves are retrieved
- Wave conditions are described in terms of return periods (average time period between successive occurrences of an event being equalled or exceeded)
- The greater the return period, the larger the design significant wave height



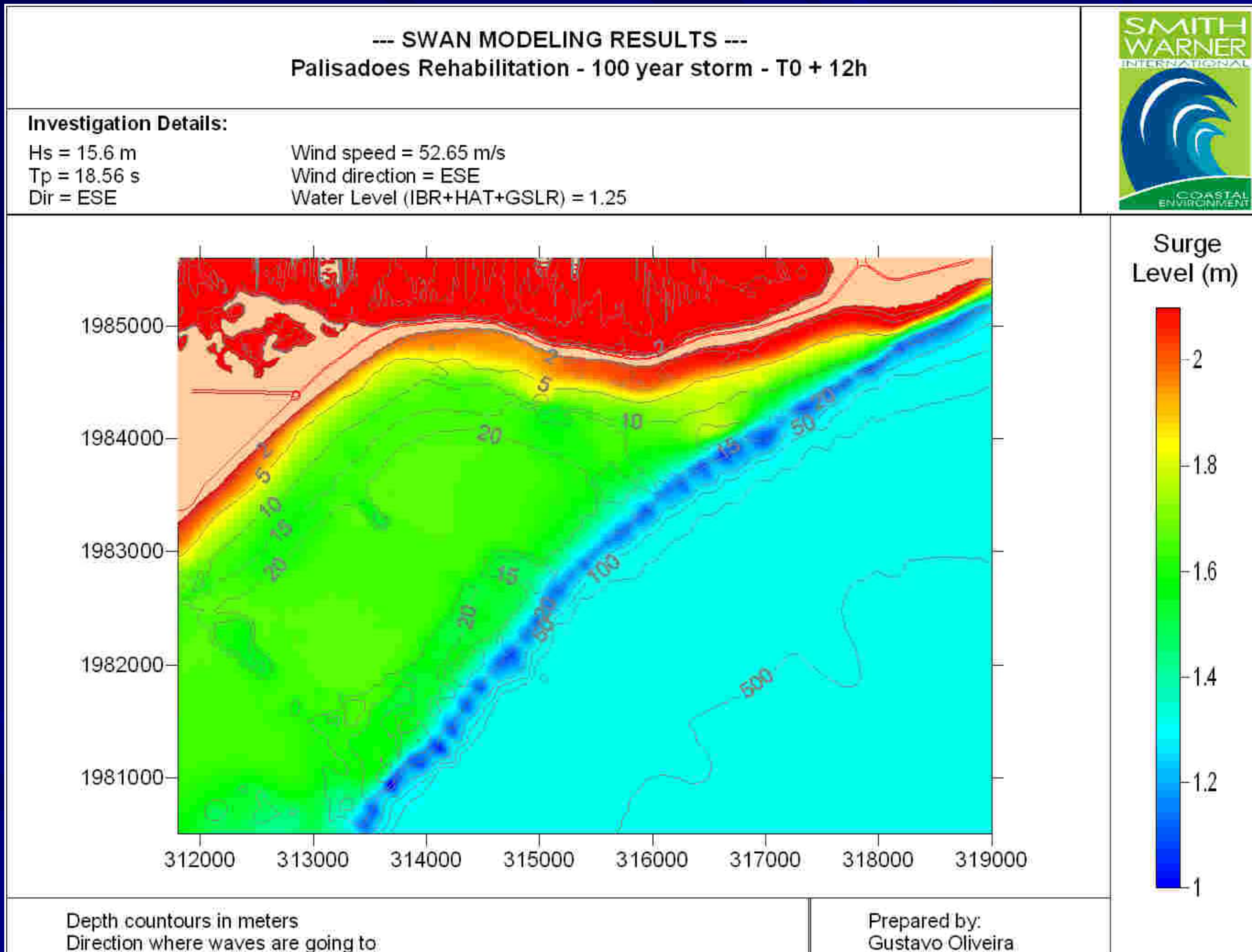
Return Period (years)	Design Life (years)		
	25	50	100
25	64%	87%	98%
50	40%	64%	87%
100	22%	39%	63%



4.2.3 Nearshore Transformation of Waves – 100 year return period



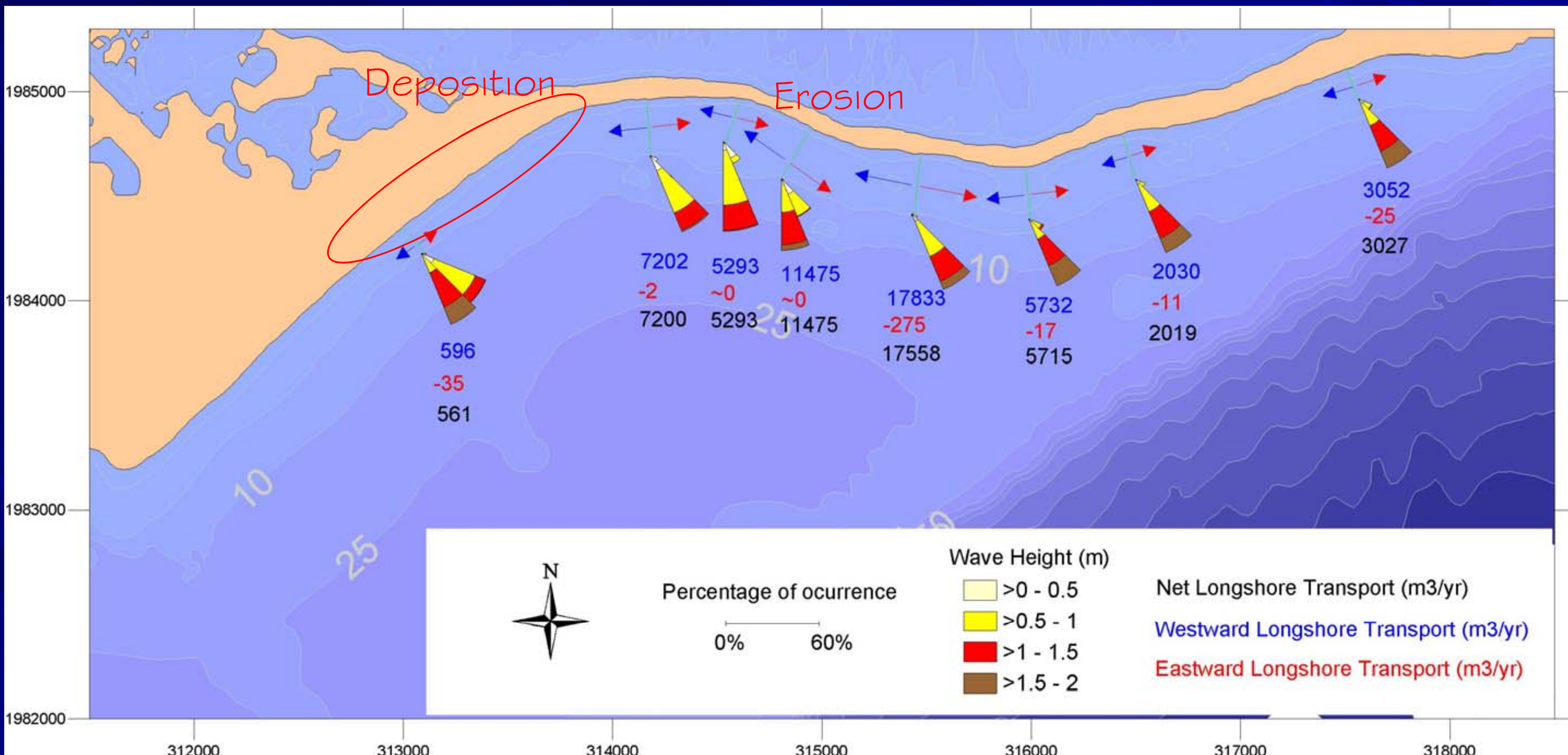
4.2.3 Nearshore Storm Surge – 100 year return period



4. Coastal Processes

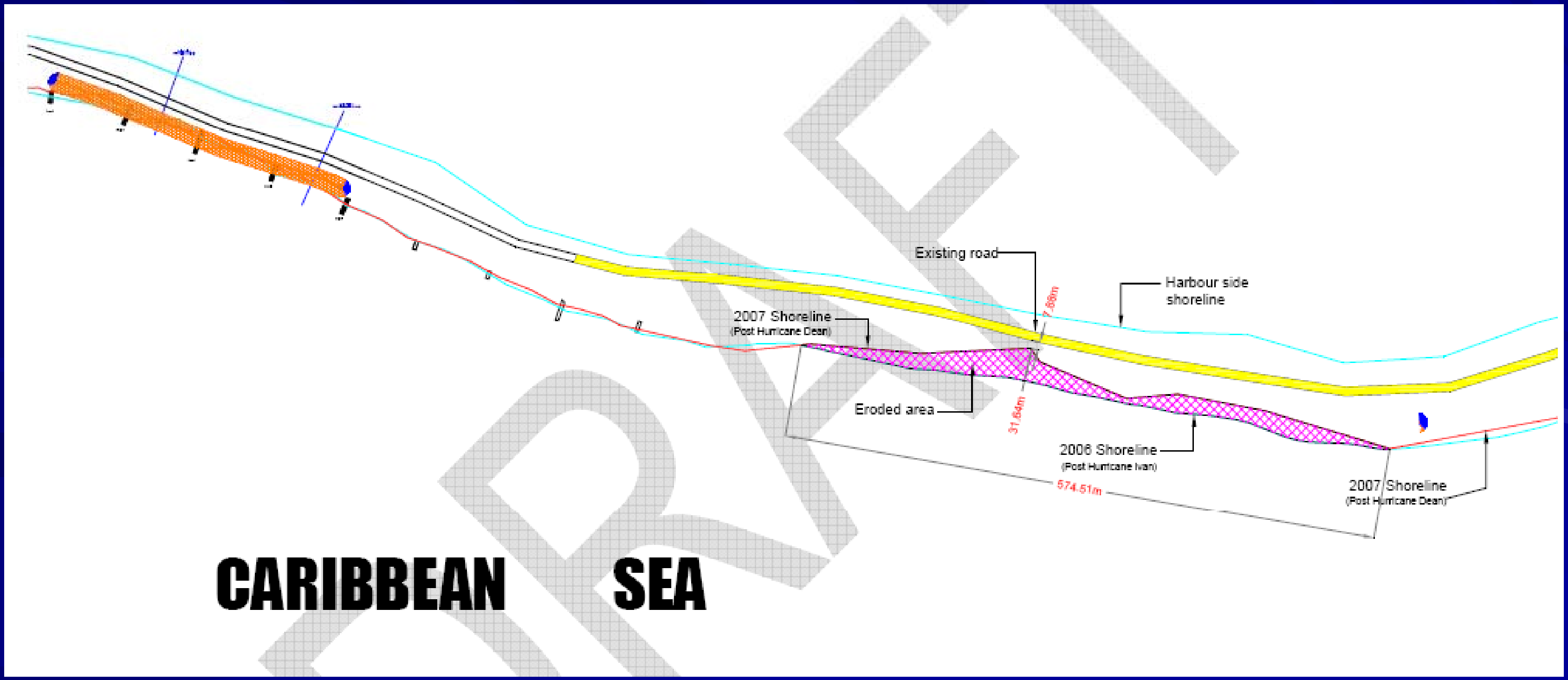
4.3 Sediment transport

- Longshore sediment transport computed (**Litdrift** - Danish Hydraulic Institute)
- The calculated net potential transport ranged from 560 to 17,600m^3/year.
- The largest transport rates are found along the most critical sector, oriented WNW-ESE.



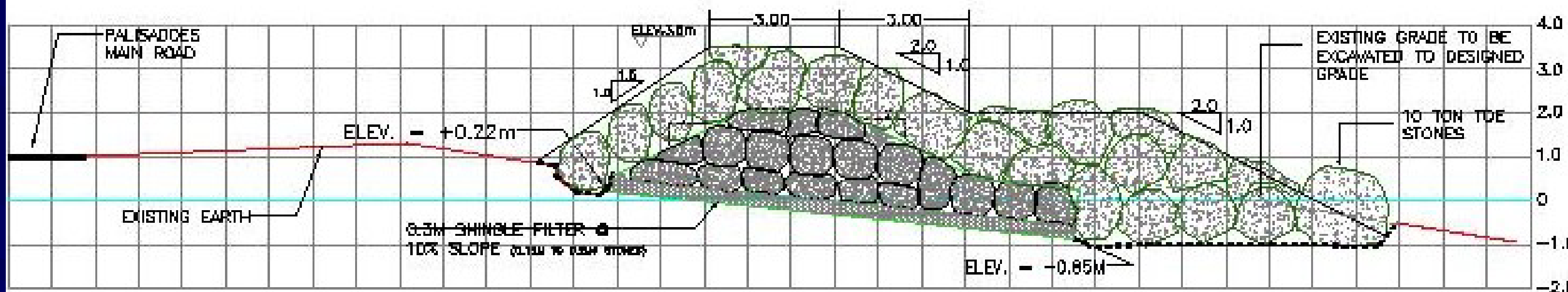
5. Re-assessing the concept

- Following Hurricane Dean, the construction of a revetment was halted in favour of an emergency works programme located along the most critical sector
  - Stones of size 1.4t – Cat 1
- The works could however, serve as the inner core for a final revetment design

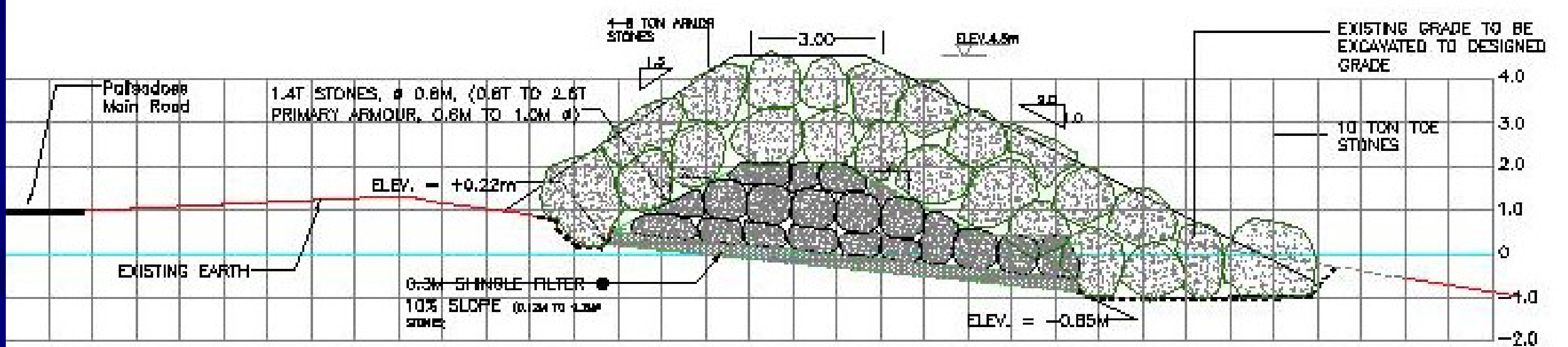


5. Design options for consideration

5.1 Shoreline revetment



BERM OPTION



NO BERM OPTION

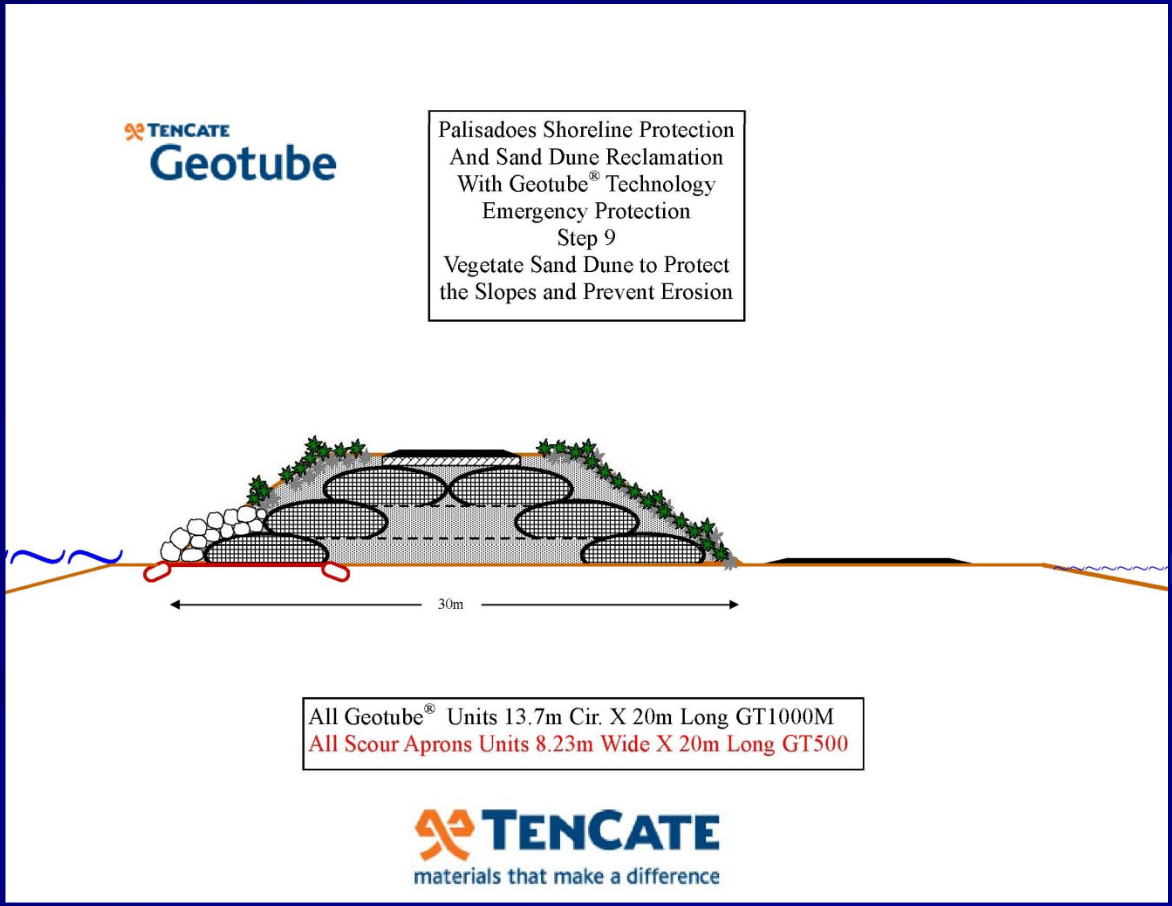
5. Design options – Site Considerations

5.1 Shoreline revetment

- In both alternatives, the emergency works serve as the inner core to the primary revetment structure, thereby reducing required materials and costs.
- However, the size of the stones in place is above what should be acceptable as the inner core, due to the potential of exaggerated wave transmission through the core.
- The entire X-Section of the structure must be properly considered, to minimise wave transmission and maximise wave energy dissipation.

5. Design options - Eco-System Based Approaches
5.2 Nourishment and dune formation

- Some consideration could be given to the re-creation of a dune system from the east end of the proposed revetment to the gypsum company pier.
- One product that could be considered in a dune/highway conceptual soft structure design for the Palisadoes strip, is "Geotube".



6. Design Confirmation - Physical Modelling

- A 2-D physical hydraulic model study of the proposed coastal woeks was tested in the Canadian Hydraulics Centre (CHC – Ottawa).

- The two hurricanes (Dean and Ivan) were used to test the preliminary design.

- In order, to represent the passage of the storms south of Jamaica, the storms were divided into 5 segments of 3 and 6 hours, for Dean and Ivan (100-year storm), respectively.

- A sub-sea profile running from deep-water up to the shoreline at the critical (erosion) sector and following the path of waves through the refraction process was used to extract the relative shoreline slope parameters.

- An appropriate scale for the model was selected, so as to minimise scale effects.

6. Physical Modelling

Frontal view of the physical model For Hurricane Dean.

Side view of the physical model for Hurricane Dean.

7. Completion of Preliminary Design