OECS Regional Engineering Workshop
September 29 – October 3, 2014

Coastal Erosion and Sea Defense: Sandy Bay and Darkview

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OBJECTIVE

• To provide an overview of the design process used in developing shoreline protection and stabilisation options for these two locations

TOPICS

• Project Settings
• Data Collection and Analysis
  – Topography
  – Bathymetry
  – Beach Profiles
  – Historical Imagery
• Wave Climate Analysis
  – Daily Wave Climate
  – Extreme Wave Climate
• Shoreline Morphology/response to wave attack
• Implications of Analyses
• Development of Options
CHARACTERIZING THE PROJECT SETTINGS

• Site Visits
• Stakeholder consultations/interviews
• Prepare Inception Report
  – Physical and Geomorphological conditions
  – Coastal Vulnerabilities (storm, cyclic seasonal damages)
  – Available data and identification of data gaps
  – Socio-economics issues
  – Institutional framework relevant to CZM
  – Environmental and Ecological issues
• Develop Project Settings
  – Assessment of vulnerability resulting from wave damage, storm surge and cliff erosion
  – Identify positive impacts from implementation of slope stabilization and sea defense initiatives
**Dark View**

- Four separate communities
- ENE-WSW trending shoreline
- Very narrow coastal zone
- Steeply rising terrain behind the coastal flat area
- Coastal zone susceptible to flooding from storm surge and to damage from wave action
• **SANDY BAY**

- NNW-SSE trending shoreline
- Fully Exposed to waves coming from the Atlantic Ocean
• **TOPOGRAPHY**

Data provided by the St-Vincent Survey Department

(1) Digital Elevation Model (DEM) with 5-meter grid spacing
Source: Lidar Surveys
(2) Contours digitized from aerial photography
• **Bathymetry and Beach Profiles**

- Boat Based Bathymetric Survey using Echo-Sounder and GPS

- Beach profiles from back of the beach to the 1.5m water depth contour taken at 5m intervals perpendicular to shore

- Additional contours and spot elevation from Map Source
- Beach Profiles
- Bathymetry
- Topography

Merged

Base maps of the project sites
**HISTORICAL SHORELINE COMPARISON**

Sources
- Aerial Photography
- Topographical maps
- Satellite imagery

Sandy Bay (9 Years)
- 2003
- 2007
- 2012

Sandy Bay north, retreat ≈ 18m in 9 years
Old Church foundation, retreat ≈ 13m in 9 years
South of Karo point, retreat ≈ 30m in 9 years
North of London accretion ≈ 10m in 5 years

Erosion rate as much as 3m/year
Alongshore ST likely
Southern headland, limited bypassing
Dark View (10 Years)
- Smaller shoreline fluctuations
- Erosion at Dark View
- Accretion at Rose Bank

- Shoreline Stable under Daily condition
- Erosion during storms
- Cross Shore movement of sand
• **Wave Climate Analysis**

(1) Operational Wave Climate= Day to Day, Seasonal winter swells, results in Long-term morphological change
(2) Extreme wave climate= Hurricanes “Short”-term morphological change

Design of Coastal Defense Scheme
(1) Structure Layout, ST Analysis, long-term
(2) Structural Stability, Storm Waves and Inundation Level
• **OPERATIONAL WAVE CLIMATE**

ARCHIVED RESULTS
NOAA WW3 MODEL
GLOBAL WAVE FORECAST
30KM GRID SPACING (0.25 DEGREE)

WW3 applied on spatial scales (grid increments) larger than 1 to 10km outside the surf Zone

Directional Distribution
8 years wave height data base
• **Nearshore wave climate using the MIKE 21 spectral wave model**

Mike 21 developed by the Danish Hydraulic Institute

Model Domain defined with Flexible Mesh

Seabed Depth from offshore to nearshore

The mesh describes the spatial relationship between all the computation points, and is principally governed by the water depth.

Wave energy movement is highly dependent on the direction of wave travel and the depth contours encountered on the approach path.
• **RESULTING ANNUAL WAVE ROSE DISTRIBUTION**

Leeward side of St Vincent
- 0.25 to 0.5m waves throughout the year
- Occasional maximum up to 1.25m

Windward side of St Vincent
- 1 to 2m waves throughout the year
- Occasional maximum above 2m
Percentage of Annual Wave Climate

- **0.1 to 0.25m**: 70-80% of the time
- **0.3 to 0.5m**: 7-15% of the time
- **1 to 2m**: 5-15% of the time
- **0.75 to 1.25m**: 60% of the time
- **1.3 to 2m**: 30% of the time
- **Over 2m**: 9% of the time

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### Percentage of Annual Wave Climate at Dark View

<table>
<thead>
<tr>
<th>Wave Height Bin (m)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>33%</td>
</tr>
<tr>
<td>0.25</td>
<td>35%</td>
</tr>
<tr>
<td>0.5</td>
<td>15.4%</td>
</tr>
<tr>
<td>1</td>
<td>9.8%</td>
</tr>
<tr>
<td>1.5</td>
<td>4.3%</td>
</tr>
<tr>
<td>2</td>
<td>1.5%</td>
</tr>
<tr>
<td>2.5</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

### Percentage of Annual Wave Climate at Sandy Bay

<table>
<thead>
<tr>
<th>Wave Height Bin (m)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.1%</td>
</tr>
<tr>
<td>0.75</td>
<td>18%</td>
</tr>
<tr>
<td>1.25</td>
<td>17%</td>
</tr>
<tr>
<td>1.75</td>
<td>31%</td>
</tr>
<tr>
<td>2.25</td>
<td>32%</td>
</tr>
<tr>
<td>2.75</td>
<td>6.8%</td>
</tr>
<tr>
<td>3.25</td>
<td>7.3%</td>
</tr>
</tbody>
</table>

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*Graphs showing wave height distribution at Dark View and Sandy Bay.*
• **Hurricane Wave Climate**

- Database of storm tracks obtained from National Hurricane Centre (NHC)
- In house program HurWave uses the database of storm tracks
- Statistical Analysis of data set for relevant directional sectors
- Data fitted to an extremal distribution and correlation done to find the best-fit distribution

Data Fitted to the east directional sector
HurWave results: deep water wave and water level conditions
100, 150 Year return period input to MIKE 21 coupled wave-hydrodynamic model

Water Level Inputs
- IBR from HurWave
- MHW, High Tide Above MSL
- GSLR (Climate Change)

Overall Result: Mapping of wave height and storm surge in the nearshore of Sandy Bay and Dark View

<table>
<thead>
<tr>
<th>Direction</th>
<th>Wind Speed (m/s)</th>
<th>Wave Height (m)</th>
<th>Wave Period (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100-yr</td>
<td>150-yr</td>
<td>100-yr</td>
</tr>
<tr>
<td>N</td>
<td>16.3</td>
<td>17.4</td>
<td>7.7</td>
</tr>
<tr>
<td>NE</td>
<td>20.7</td>
<td>22.6</td>
<td>9.8</td>
</tr>
<tr>
<td>E</td>
<td>22.6</td>
<td>24.4</td>
<td>10.7</td>
</tr>
<tr>
<td>SE</td>
<td>20.3</td>
<td>22.6</td>
<td>9.6</td>
</tr>
<tr>
<td>S</td>
<td>15.4</td>
<td>17.3</td>
<td>7.3</td>
</tr>
<tr>
<td>SW</td>
<td>10.9</td>
<td>11.7</td>
<td>5.2</td>
</tr>
<tr>
<td>W</td>
<td>13.4</td>
<td>14.3</td>
<td>6.4</td>
</tr>
<tr>
<td>NW</td>
<td>15.5</td>
<td>16.9</td>
<td>7.4</td>
</tr>
</tbody>
</table>
-GSLR (Climate Change)
Waves, Water levels computed at hourly intervals for each directional sector
Statistical analyses for maximum wave height and water levels over the model domain

- Waves
  1 to 5m Dark View
  1 to 7m Sandy Bay

- Static Surge
  2.4m Dark View
  2.6m Sandy Bay
- Hurricanes, Track Results
- Extracted from NOAA database

- Storm Parameters
  - Time (hr)
  - Latitude (deg)
  - Longitude (deg)
  - Maximum wind speed (m/s)
  - Radius to maximum wind speed (km)
  - Central Pressure (KPa)
  - Ambient Pressure (KPa)

- Track information converted to time-varying wind speed and pressure map
- 15min time step to minimize errors associated with interpolations
• **Ivan on Sandy Bay**

1 to 5m wave height
Static surge at MHW = 2.2m
1 to 3.75m waves
Static surge due to wave set up = 0.5m

Waves and surge generated kilometers away from the track of the storm
**Total Inundation Level (Static Surge + Wave Run-up)**

Wave Run-up = Dynamic component of storm surge
Waves Break & remaining wave energy runs up the beach
Smooth Impermeable Beach = Higher run-up
Rough armour stone slope = Lower run-up

Static and Dynamic Components of Storm Surge

During a storm
Beach undergoes erosion
Change in beach profile = implication on level of run-up
HURRICANE IMPACTS – INUNDATION AND SHORELINE DAMAGE
HURRICANE IMPACTS – BEFORE AND AFTER
HURRICANE IMPACTS – BEFORE AND AFTER
• **USE OF SBEACH (US ARMY CORE OF ENGINEERS)**

Models cross-shore movement of sediment
Prediction of wave overtopping over existing and proposed shoreline features

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**Final Inundation Mapping**

<table>
<thead>
<tr>
<th>Project Sites</th>
<th>1 in 150-Year Storm</th>
<th>Hurricane Lenny</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Final Inundation</td>
<td>Maximum Erosion</td>
</tr>
<tr>
<td></td>
<td>Level (m)</td>
<td>(m)</td>
</tr>
<tr>
<td>Rose Bank</td>
<td>+7.4</td>
<td>-3.5</td>
</tr>
<tr>
<td>South of Dark View</td>
<td>+5.6</td>
<td>-2.75</td>
</tr>
<tr>
<td>North of Dark View</td>
<td>+5.5</td>
<td>-2.5</td>
</tr>
<tr>
<td>Petit Bordel</td>
<td>+7.3</td>
<td>-3.5</td>
</tr>
<tr>
<td>North of Sandy Bay</td>
<td>+6.8</td>
<td></td>
</tr>
</tbody>
</table>
- **LONG TERM SEDIMENT TRANSPORT USING LITDRIFT MODULE FROM THE LIPTACK SUITE (DEVELOPED BY DHI)**

  Movement of sediment across nearshore profile
  Analysis of Alongshore ST only
  No morphology

  **Depth of Closure 50m**

  **Depth of Closure 200m**
Difference in sediment transport capacity

*Alongshore net transport dominant to the southwest*
Alongshore net transport dominant to the south
Sediment by-passes the central headland
At Big Sands ST Capacity remains the same
Potential for erosion
To the south sediment does not bypass the headland
**IMPLICATIONS**

**Petit Bordel**  
Wave Sheltering from Spit  
No Significant Erosion  
Gentle back of beach slope= inland inundation  
Sediment Movement to the South

**Evacuation Jetty built towards the northern end of the beach**

**Dark View**  
Erosion from Hurricane Waves and Storm Surge  
Leeward Highway in direct threat  
Run up to +5.6m for the 1 in 150 Year Storm  
Erosion 3.5m at the base of the Cliff

**Protective Revetment**  
**Protective Breakwater**

**Rose Bank**  
Vulnerable to inundation

**House relocation plan**

**Warf Bay**  
Heritage Value

**Eco-Tourism, management of Land Access to site**

**Sandy Bay**  
Damage from Storm Surge  
Aggressive Wave environment on daily basis

**Hard Coastal Protection Structure**  
**Protection of Roadway**  
**Land Reclamation**  
**Manual Labor (Economic Benefits)**
### Shoreline Change with Implementation of Design

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<td></td>
<td>Level (m)</td>
<td>(m)</td>
</tr>
<tr>
<td>Dark View Existing</td>
<td>+5.6</td>
<td>-2.75</td>
</tr>
<tr>
<td>Dark View Proposed option 1</td>
<td>+6.5</td>
<td>-1.5</td>
</tr>
<tr>
<td>Dark View Proposed option 2</td>
<td>+5.3</td>
<td>-0.8</td>
</tr>
<tr>
<td>Sandy Bay Existing</td>
<td>+6.8</td>
<td></td>
</tr>
<tr>
<td>Sandy Bay Proposed option</td>
<td>+7.4</td>
<td></td>
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![Diagram showing computed maximum run-up and beach erosion](image_url)