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**To:** Carolina Beach Town Manager

**From:** JANT Engineering

**Date:** September 25, 2022

**Subject:** Hydrodynamic Forcing Assessment Initial Draft

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**INTRODUCTION**

The purpose of this technical memorandum is to provide a summary of findings pertaining to the hydrodynamic forcing characteristics of the project field site in Carolina Beach to designate a set of parameters to be used for structural design and analysis in our storm reduction project. These characteristics include the following:

* Wave conditions (wave height, period, direction)
* Seasonal variability of wave conditions
* 100-year storm water levels
* Sea level rise projections

The analysis considers a life expectancy of 50 years with hydrodynamic forces from 100-year storm water levels, wave parameters, and projected sea level rise.

**HYDRODYNAMIC FORCING**

1. **WAVE PARAMETERS**

Statistical wave parameters are required to design and test alternatives for functional performance and structural durability. The parameters considered are significant wave height (), peak wave period (), mean wave period (), peak wave direction (), and mean wave direction (). Data was gathered from three wave buoys off the North Carolina coast (Figure 1 in Appendix A.I). One buoy (ILM2WAVE) is maintained by the Coastal Ocean Research and Monitoring Program (CORMP), and two buoys (MASE-01 and BHI-E) are maintained by the University of North Carolina Wilmington in partnership with CORMP. Statistical wave parameters were downloaded from the CORMP database within the time frame of 22 September, 2021 to 21 September, 2022. This time frame was chosen to cover the four most recent seasons (Autumn 2021, Winter 2021-2022, Spring 2022, and Summer 2022) to have data that is accurately representative of the current wave state. The data was split according to the season it was collected. MATLAB was used to find the minimum, maximum, and mean values of the wave parameters to acquire a range and average for each season. Mean wave statistics (, ) are only available from MASE-01 and BHI-E buoys. The data for ILM2WAVE, MASE-01, and BHI-E are respectively listed in Tables 1, 2, and 3 in Appendix A.I.

1. **100-YEAR STORM WATER LEVELS**

The 100-year storm still-water level is required to test alternative designs against severe storm conditions. Storm-induced flooding must be also considered in order to limit the damage to beach profiles, transportation routes, and infrastructure on and off the beach. Astronomical tides, storm surge, wave setup, runoff, and ground elevation all influence still-water levels during a storm event. The Federal Emergency Management Agency (FEMA) provides data and reports concerning 100-year storm water levels and conditions. Transects along the New Hanover County coastline are modeled using wave conditions to find the still-water elevation for a 100-year storm (Figure 2, Appendix A.II) (FEMA, 2019). The results from this model are found in Table 4 in Appendix A.II.

1. **SEA LEVEL RISE PROJECTIONS**

Sea level rise (SLR) is on the forefront of environmental concerns and is a rapidly escalating issue for low-lying coastal areas. The state of North Carolina is planning 2 billion dollars’ worth of sea level rise solutions, including beach nourishment and flood reduction projects (“North Carolina’s Sea Level is Rising”). A summary of sea level rise and projections of sea level rise for New Hanover County are provided in Appendix A.III.

**CONCLUSION**

Based on this assessment of hydrodynamic forcing, the following parameters will be used for project design and functional analysis:

* Significant Wave Height: 3.88 [m, MLLW]
* Peak Wave Period: 34.12 [s]
* Mean Wave Period: 16.72 [s]
* Peak Wave Direction: 119.43 [deg N]
* Mean Wave Direction: 108.99 [deg N]
* 100-Year Storm Water Level: 3.2 [m, NAVD88]
* Sea Level Rise Projection: 0.761 [m, MSL]

The significant wave height, peak wave period, and mean wave period were derived by taking the highest value of that parameter from all three buoys, regardless of season. This method of selection was used since the alternatives should be designed to withstand the most severe conditions that occur at the project site. The peak wave direction and mean wave direction were derived by averaging the values across all seasons and buoys. The wave direction is relatively consistent with the dominant direction being east-southeast (ESE). The 100-year storm still-water level data ranges from 8.7 to 10.5 ft for the project area. The water level parameter was selected to be the upper value of this range in order to prevent functional and structural failure in a worst-case scenario 100-year storm. On average, sea level rises an inch every two years. With model limitations, it is challenging to derive an accurate estimate of sea level rise for the next 50 years. However, using a general rule of one inch for every two years, a Mean Sea Level (MSL) of 0.761 m was chosen.

**Appendix A. Hydrodynamic Forcing**

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1. Wave Parameters
2. 100-Year Water Levels
3. Sea Level Rise and Projections
4. References

**Appendix A. Hydrodynamic Forcing**

1. **Wave Parameters**

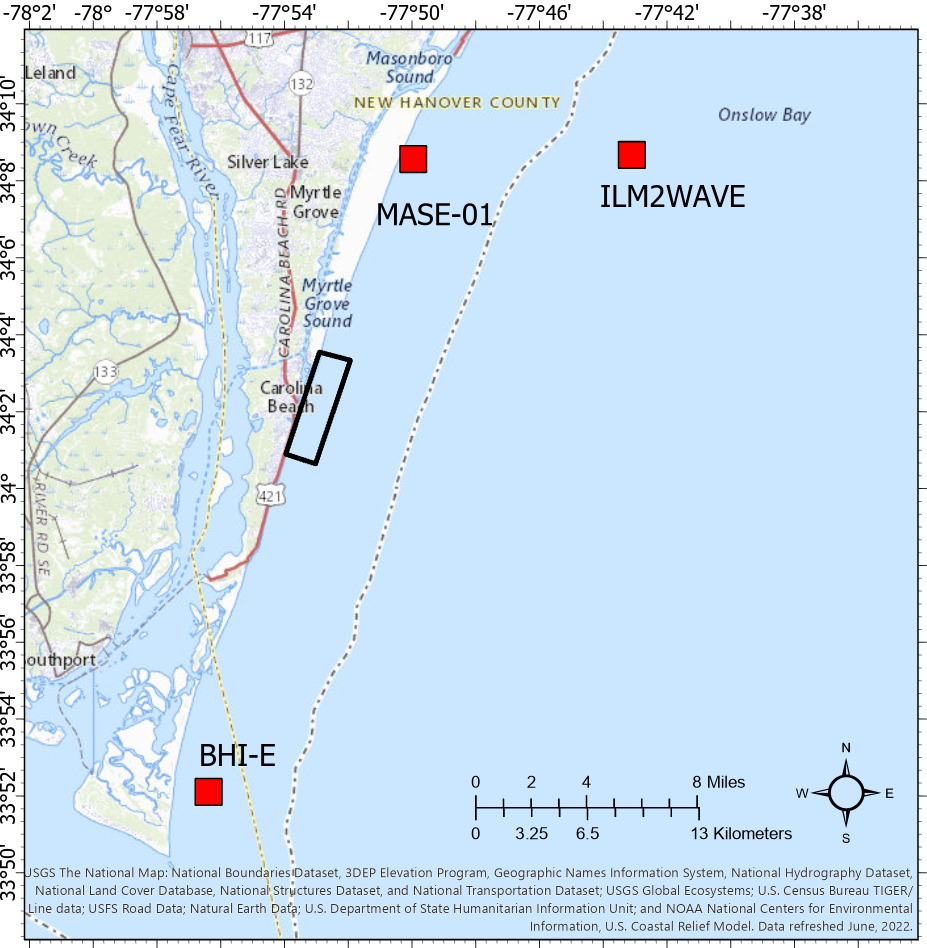


Figure 1. Wave buoys (red squares) near the field site at Carolina Beach (black box).

Table 1. Ranges and averages of wave parameters measured by the CORMP ILM2WAVE buoy from the most recent seasons (Autumn 2021 - Summer 2022). Parameters include significant wave height (), peak wave period (), and peak wave direction (). Source: [CORMP ILM2WAVE](https://cormp.org/?health=Off&quality=Off&units=Metric&duration=1%20year&maps=storm_tracks&legend=Off&forecast=Point&hti=&nhc=undefined&nhcWinds=undefined&sst=&current=&datum=MLLW&windPrediction=wind%20speed%20prediction&region=&bbox=-78.86535644531251,33.81110228864701,-77.21466064453126,34.52239858066334&iframe=null&mode=home&basemap=Streets&basemap_overlays=Bathymetry&layer_opacity=100&platform=ILM2WAVE).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Season** | **Range [m, MLLW]** | **Avg [m]** | **Range [s]** | **Avg [s]** | **Range [deg N]** | **Avg [deg N]** | **Avg [name]** |
| 2021 | Autumn | 0.26-2.95 | 0.8817 | 1.85-20 | 8.4252 | 3-358 | 118.4529 | ESE |
| 2021-22 | Winter | 0.34-3.85 | 0.9764 | 2.44-15.38 | 7.6994 | 1-360 | 123.5321 | ESE |
| 2022 | Spring | 0.37-2.84 | 0.9075 | 2.33-16.67 | 7.101 | 1-353 | 134.7554 | SE |
| 2022 | Summer | 0.33-2.01 | 0.8228 | 2.5-16.67 | 7.3339 | 20-347 | 135.0466 | SE |

Table 2. Ranges and averages of wave parameters measured by the UNCW MASE-01 buoy from the most recent seasons (Autumn 2021 - Summer 2022). Parameters include significant wave height (), peak wave period (), mean wave period (), peak wave direction () and mean wave direction (). Source: [CORMP MASE-01](https://cormp.org/?health=Off&quality=Off&units=Metric&duration=1%20year&maps=storm_tracks&legend=Off&forecast=Point&hti=&nhc=undefined&nhcWinds=undefined&sst=&current=&datum=MLLW&windPrediction=wind%20speed%20prediction&region=&bbox=-78.64837646484376,33.69235234723729,-76.99768066406251,34.40464357107097&iframe=null&mode=home&basemap=Streets&basemap_overlays=Bathymetry&layer_opacity=100&platform=MASE-01).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Season** | **Range [m, MLLW]** | **Avg [m]** | **Range [s]** | **Avg [s]** | **Range [deg N]** | **Avg [deg N]** | **Avg [name]** |
| 2021 | Autumn | 0.20-3.67 | 0.6645 | 2.22-34.12 | 8.6751 | 7.68-261.29 | 113.7310 | ESE |
| 2021-22 | Winter | 0.24-2.96 | 0.7276 | 2.76-34.12 | 7.9154 | 0.12-352.43 | 118.2000 | ESE |
| 2022 | Spring | 0.22-2.62 | 0.6879 | 2.48-25.60 | 7.4035 | 46.94-334.09 | 123.0138 | ESE |
| 2022 | Summer | 0.28-1.77 | 0.6501 | 2.56-34.12 | 7.5917 | 21.87-342.38 | 124.0367 | SE |

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| --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Season** | **Range [s]** | **Avg [s]** | **Range [deg N]** | **Avg [deg N]** | **Avg [name]** |
| 2021 | Autumn | 2.48-13.24 | 5.0992 | 51.60-235.65 | 113.0000 | ESE |
| 2021-22 | Winter | 2.90-15.74 | 5.0290 | 8.07-352.43 | 117.0384 | ESE |
| 2022 | Spring | 2.76-10.46 | 4.5970 | 69.17-170.22 | 124.5332 | SE |
| 2022 | Summer | 3.00-14.28 | 7.5917 | 78.81-126.83 | 161.9500 | SSE |

Table 3. Ranges and averages of wave parameters measured by the UNCW BHI-E buoy from the most recent seasons (Autumn 2021 - Summer 2022). Parameters include significant wave height (), peak wave period (), mean wave period (), peak wave direction () and mean wave direction (). Source: [CORMP BHI-E](https://cormp.org/?health=Off&quality=Off&units=Metric&duration=1%20year&maps=storm_tracks&legend=Off&forecast=Point&hti=&nhc=undefined&nhcWinds=undefined&sst=&current=&datum=MLLW&windPrediction=wind%20speed%20prediction&region=&bbox=-78.64837646484376,33.69235234723729,-76.99768066406251,34.40464357107097&iframe=null&mode=home&basemap=Streets&basemap_overlays=Bathymetry&layer_opacity=100&platform=BHI-E).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Season** | **Range [m, MLLW]** | | **Avg [m]** | **Range [s]** | **Avg [s]** | **Range [deg N]** | **Avg [deg N]** | **Avg [name]** |
| 2021 | Autumn | | 0.25-3.88 | 0.7378 | 2.68-34.12 | 8.8179 | 5.07-349.49 | 104.4200 | ESE |
| 2021-22 | Winter | | 0.26-2.93 | 0.8014 | 2.48-34.12 | 8.0046 | 12.65-354.19 | 107.4640 | ESE |
| 2022 | Spring | | 0.26-2.72 | 0.6960 | 2.16-34.12 | 7.7211 | 1.48-346.32 | 113.9734 | ESE |
| 2022 | Summer | | 0.28-3.76 | 0.6234 | 2.62-34.12 | 7.8746 | 38.40-350.19 | 116.4955 | ESE |

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| --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Season** | **Tm Range [s]** | **Tm Avg [s]** | **Dm Range [deg N]** | **Dm Avg [deg N]** | **Dm Avg [name]** |
| 2021 | Autumn | 2.74-14.32 | 4.9881 | 48.68-172.79 | 103.5617 | ESE |
| 2021-22 | Winter | 2.92-13.16 | 4.8935 | 8.80-107.27 | 13.1600 | NNE |
| 2022 | Spring | 2.82-15.32 | 4.5189 | 1.22-344.25 | 117.0497 | ESE |
| 2022 | Summer | 2.94-16.72 | 4.4703 | 29.05-120.56 | 120.5597 | SE |

1. **100-Year Water Levels**

A hydrodynamic analysis and 1% recurrence interval of a 100-year storm was tested by the USACE HEC-RAS computer program (FEMA, 2019). The program was calibrated using historic storm water level data and tidal gauges. Other models used were ADCIRC, CHAMP 2.0, and WHAFIS 4.0 (FEMA, 2019). The historic data records mainly consist of storm surge data and astronomical tide constituents. Cross-shore transects were identified with varying alongshore spacing around 0.2 miles along Carolina Beach, NC. The more closely spaced transects are in areas of highly variable topography where the still-water elevation is expected to differ. The further spaced transects are located in areas of more topographic uniformity. The still-water levels were determined considering analyses of wave height, wave runup, wave setup, tides, and storm surge values. For consistent initial testing conditions, the model was set to have an initial significant wave height () of 19.1 ft (5.82 m) and peak wave period () of 11.2 seconds. The model output of water level for transects 15 through 25 are listed in Table 4.

Diagram

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Figure 2. Transect map of New Hanover County used to determine still-water elevation. Transects 15 through 25 were used in analysis. Source: FEMA

Table 4. Still-water elevation range of 100-year storm transects 15 through 25. Source: FEMA

|  |  |  |
| --- | --- | --- |
| **Transect** | **Still-water Elevation**  **[ft, NAVD88]** | **Still-water Elevation**  **[m, NAVD88]** |
| 15 | 10.2 | 3.1 |
| 17 | 8.9-10.2 | 2.7-3.1 |
| 19 | 10.2-10.3 | 3.1 |
| 21 | 10.1-10.4 | 3.1-3.2 |
| 23 | 8.7-10.4 | 2.7-3.2 |
| 25 | 10.3-10.5 | 3.1-3.2 |

1. **Sea Level Rise and Projections**

In 2016, the sea level had risen 11 inches since 1950 around the New Hanover County area. This can be seen in Figure 3. In the last ten years, denoted by the red line in Figure 3, sea level has begun rising approximately one inch every two years.

Chart

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Figure 3. Sea Level Rise in New Hanover County from 1950-2016. Source: SeaLevelRise.org

The rising sea level trend relative to Mean Sea Level (MSL) for Wilmington, North Carolina (~15 miles north of Carolina Beach) can be seen in Figure 4.

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Figure 4. Relative Sea Level Trend from 1935 to 2021 at station 8658120. Source: NOAA

NOAA describes the relative sea level trend from 1935 until 2021 as an increase by 2.61 0.34 millimeters/year (0.103 0.01 inches/year). However, this is averaged from 1935. As stated previously, in the last decade, sea level rise has changed and has started increasing an inch every two years. This makes sea level rise difficult to predict in the future. Observations of the forecast for sea level rise in North Carolina indicate that there is a wide range of potential water levels in the future. Figure 5 illustrates the predicted range and mean until 2050.

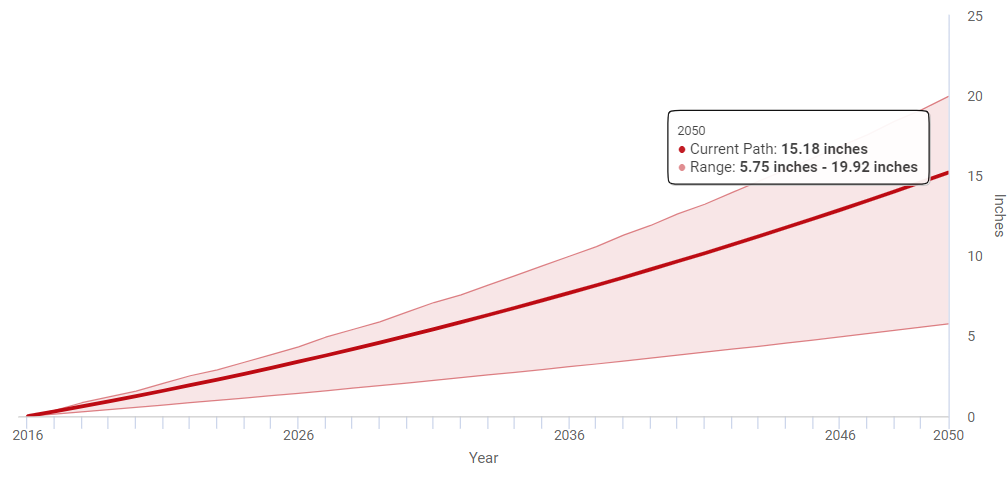


Figure 5. Sea level rise predictions from 2016-2050. Source: SeaLevelRise.org

It is challenging to predict for 50 years beyond of 2022, and current predictions are based on an average of one inch increase for every two years. For 50 years, a rise of 25 inches would be reasonably estimated based on the currently available data. Current MSL in meters as of July 2022 is 0.126 meters. With this rate of increase, an expected MSL in 50 years is 0.761 meters (current MSL plus expected rise in the next 50 years).

1. **References**

“Coastal Ocean Research and Monitoring Program.” *CORMP*, https://cormp.org/?health=Off&quality=Off&units=Metric&duration=1%20year&maps=storm\_tracks&legend=Off&forecast=Point&hti=&nhc=undefined&nhcWinds=undefined&sst=¤t=&datum=MLLW&windPrediction=wind%20speed%20prediction®ion=&bbox=-79.01092529296876,33.31905344502012,-76.4923095703125,34.68065238482746&iframe=null&mode=home&basemap=Streets&basemap\_overlays=Bathymetry&layer\_opacity=100.

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