MOTT MACDONALD

MacEachron Park Shoreline Erosion Remedies, Village of Hastings-on-Hudson, New York

Basis of Design Report

November 2021

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Introduction

The Village of Hastings-on-Hudson, NY (the "Village") is located in the town of Greenburgh, in Westchester, NY. The New York State Department of Environmental Conservation's Hudson River Estuary Program has granted funds to the village to address erosion shoreline issues at MacEachron Park. The stated purpose is to halt erosion of the shoreline, protect the utility of the park, and advance environmental sustainability through resilience.

MacEachron Park, shown in Figure 1, is a 1.3-acre waterfront park that is located on the east bank of the Hudson River. Shoreline erosion has resulted in the loss of usable parkland. In some locations, the erosion has compromised the utility of park benches. Due to the composition of the fill material which comprises the upland, the edge is easily erodible, and some plantings attempted in the park have not been able to thrive. The shoreline is subject to wave action from both storms and vessel wake, and sea level rise results in flooding during higher tides. Erosion is exacerbated by the haphazard stone revetment and lack of effective plantings. Due to the low relief of the park, it is highly unlikely that stormwater flow in the direction of the river is responsible for scarping of the shoreline edge. The location of the wrack line, or line of vegetation deposited by waves at high tide, indicates that wave erosion is the main culprit. An additional problem looming in the next few years is the timber bulkhead at the toe of the rock revetment. As this bulkhead progressively fails, the rock will tumble into the river and destabilize the shore protection.

Where possible, Mott MacDonald intends to use nature-based shoreline principles and recognizes that the Village has expressed a desire to include an evaluation of grades to allow for gentle slopes, the placement of sand, rocks and a variety of native vegetation. The purpose of this report is to document relevant conditions and provide a basis of design (BOD) for the project.

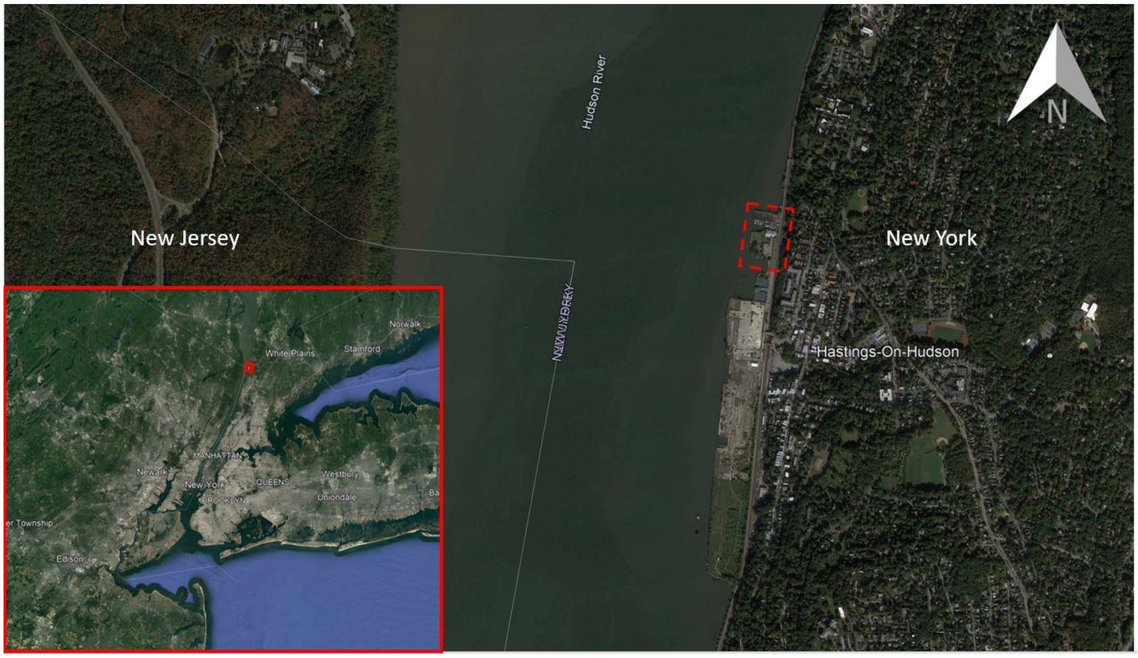

Figure 1: MacEachron Park location and extents of project site indicated by red dashed rectangle

1 Site Conditions Assessment

1.1 Tides

Tidal elevations are obtained from the National Oceanic and Atmospheric (NOAA) Station 8530095 Alpine, Hudson River, NJ (NOAA, 2004), which is located on the western side of the Hudson River, across from Hastings-on-Hudson. The station uses the NOAA Station 8518750 The Battery, NY as a control station. Tidal Elevations are provided in Table 1.

Datum	Elevation (ft NAVD88)
Mean Higher High Water (MHHW)	2.11
Mean High Water (MHW)	1.85
Mean Sea Level (MSL)	0.07
Mean Low Water (MLW)	-1.90
Mean Lower Low Water (MLLW)	-2.09

Table 1: Tidal Elevations from NOAA Station 8530095 Alpine, Hudson River, NJ (NOAA, 2004)

1.2 Extreme Water Levels

Extreme water levels were calculated as part of the USACE North Atlantic Comprehensive Study (USACE, 2015). Results from the study relevant to the project site were extracted from the USACE Coastal Hazards System webtool at AEP Point 4812 are shown in Table 2 below.

Return Period (years)	Water Surface Elevation (ft MSL)	Water Surface Elevation (ft NAVD88)
1	2.57	2.50
2	3.35	3.28
5	4.36	4.29
10	5.11	5.04
20	5.85	5.78
50	6.80	6.73
100	7.50	7.43
500	8.16	8.09

Table 2: Extreme water surface elevations at the project site from USACE NACCS (USACE, 2015)

1.3 Sea Level Rise

1.3.1 Observed Sea Level Rise

Sea level rise (SLR) is the sum of the eustatic (global) sea level change and local land elevation change. Historical sea level rise is measured at tide gages which are controlled relative to an established vertical datum. Future sea level rise is estimated by comparing historical water levels to local tide gages. Local trends are calculated by NOAA tidal gages based upon procedures found in Sea Level Variations of the United States 1854-2006 (Zervas, 2009) and published by NOAA. On a site-specific level, the observed data was taken from the nearby NOAA The Battery Station. Shown in Figure 2, the local linear trend in SLR shows a rate of 0.11 ± 0.003 in/yr (2.88 ± 0.09 mm/yr) for the project site area. When adjusted for the National Tidal Datum Epoch used in NOAA Tide predictions, the observed SLR is determined to be 0.0202 feet/year (0.242 inches/year).

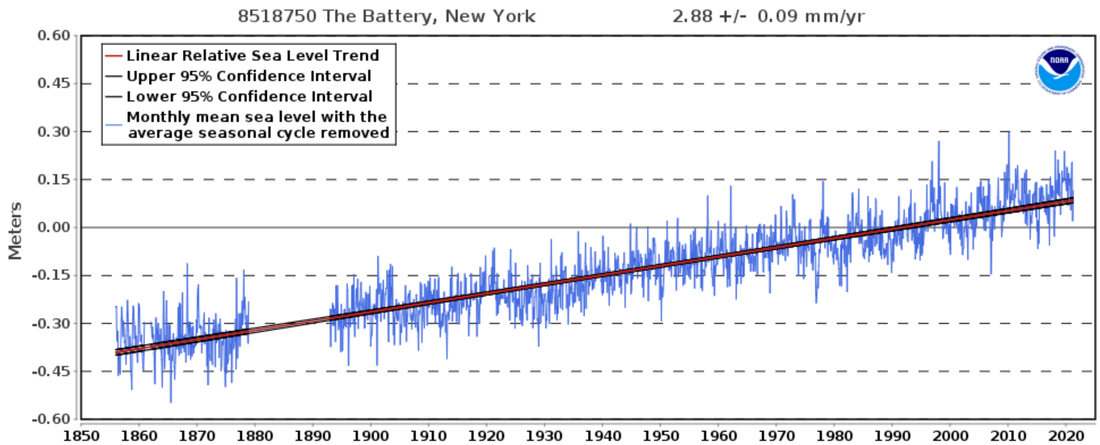

Figure 2: Relative sea level trend with a 95% confidence interval for nearby The Battery, NY (NOAA, 2020)

1.3.2 Sea Level Change Predictions

Future sea level change projections should be incorporated into planning and engineering design of civil works. The analysis presented in this report is in line with USACE guidance that recommends a multiple scenario approach when dealing with the rise in sea levels. Three different sea level rise (SLR) projections are shown in Figure 3 to assist in selecting the most appropriate SLR projection for the project: (1) USACE, (2) NOAA, and (3) Intergovernmental Panel on Climate Change (IPCC).

USACE and NOAA SLR projections (USACE, 2014) both include the high probability of accelerating global mean SLR, which is reflected on the intermediate and high curves. The amount of acceleration to include varies and generally is described as low, intermediate, or high. The USACE and NOAA low scenario is the extrapolation of the observed historical trend obtained from NOAA tidal gauges; this curve is primarily controlled by regional sea level change and contains land uplift or subsidence in the data.

IPCC (IPCC: Church, et al., 2013) recommends SLR projections which are the result of process-based models for global mean SLR. These projections are evaluated for varying future emissions and climate scenarios, referred to as RCP2.6, RCP4.5, RCP6.0, and RCP8.5. Higher RCP numbers represent more severe scenarios. Note that the IPCC values shown on Figure 3 do not account for local land elevation change.

Using the USACE/NOAA low curve for this project, and data from nearby NOAA gauge 8518750 The Battery and projecting SLR for 2071 (50 years' time), there is a projected 1.39 ft (16.68 inches) of local mean sea level rise.

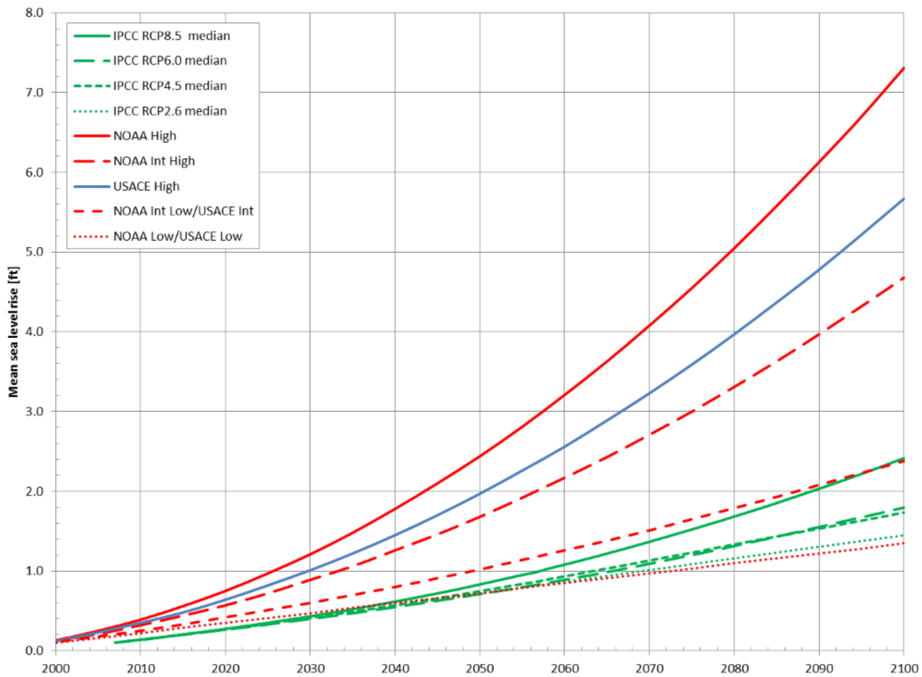

Figure 3: USACE, NOAA, IPCC (RPC2.6 median, RCP4.5 median, RCP6.0 median, RCP8.5 median not accounting for local vertical land motion) sea level rise projections

1.4 Waves

Extreme wave heights were calculated as part of the USACE North Atlantic Comprehensive Study (USACE, 2015). Results from the study relevant to the project site were extracted from the USACE Coastal Hazards System webtool at AEP Point 4812 and are shown in Table 3 below.

Return Period (years)	Significant Wave Height (ft)
1	2.54
2	2.86
5	3.25
10	3.45
20	3.65
50	3.90
100	4.13
500	4.70

Table 3: Significant wave heights at project site from USACE NACCS (USACE, 2015)

1.4.1 Vessel generated wake

The site is subject to wake generated by passing vessels. When vessels pass at high tide, the wake impacts the scarp on the upper portion of the beach, further destabilizing the easily-erodible shoreline. Wake tends to have a very short period, and steep wave height.

A wake study to determine wake heights produced from recreational and commercial vessels was performed by the Stevens Institute of Technology in conjunction with the Hudson River Sustainable Shorelines project. Four primary data parameters including wake height, boat type, vessel speed, and size, were collected at 32 sites. The data collected at the closest site location, Losee Park, Tarrytown, NY, showed the maximum wake height to be 12 in., and the average wake height to be 3 in. (Lapann-Johannessen et al., 2015). An excerpt of summary tables from the study is shown in Figure 4.

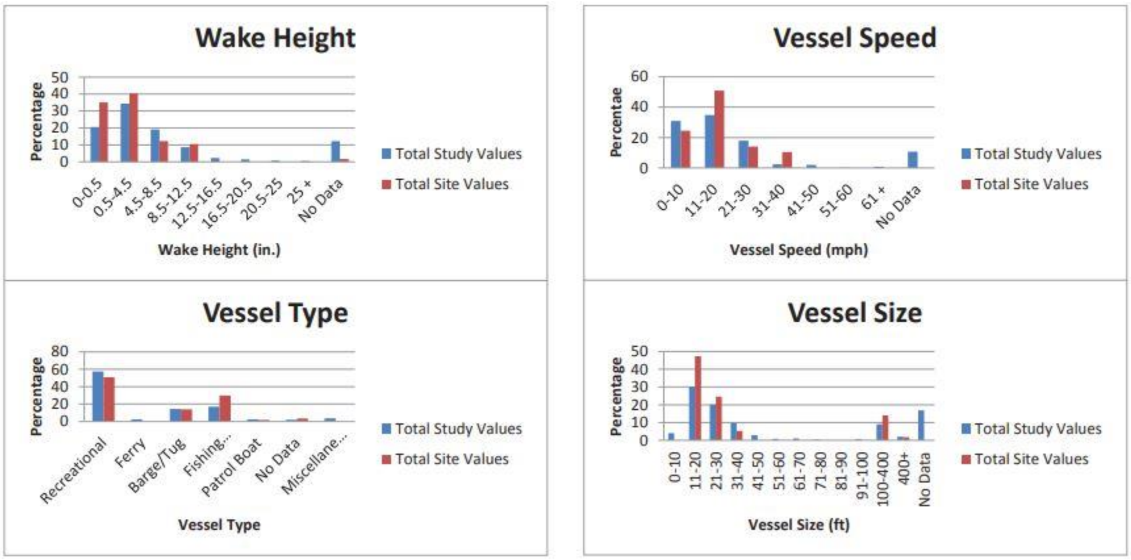

Figure 4: Vessel and Wake summary tables at Losee Park, Tarrytown, NY provided in Hudson River Wake Study (Lapann-Johannessen et al., 2015)

1.5 Salinity

During flood tides, when the tidal current is flowing inland, salt water from the Atlantic Ocean enters the Hudson River Estuary. Conversely, there is a constant flow of fresh water from runoff and precipitation that flows from the northern sections of the river south towards the Atlantic Ocean. Water that is more saline than freshwater but less saline than ocean water, known as brackish water, makes up much of southern regions of the river. At the point where the brackish water and freshwater meet a boundary called the salt front is formed. The location of Hudson River salt front varies depending on runoff and weather conditions.

The salinity levels relevant to the project site were obtained from USGS Station 01376269 Hudson River at Piermont NY. The station is approximately 3 miles north of the project site location. The salinity levels, shown in Figure 5 range from 0 psu to 15.8 psu.

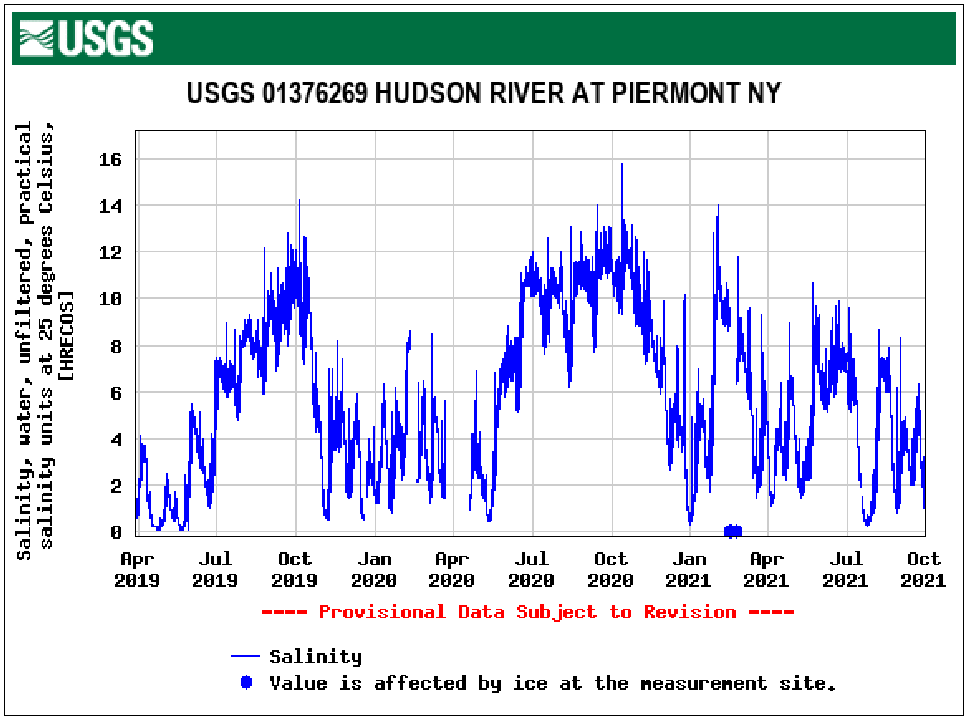

Figure 5: Salinity levels (psu) of the Hudson River from nearby USGS Station 01376269 Hudson River at Piermont NY (USGS, 2021)

1.6 Ice

The winter ice season in New York's tidal waters is a period from December 15 to the end of March when a seasonal ice field develops on the surface waters of the Hudson River Estuary. It has been shown that friction under the ice field causes significant changes to the hydrodynamics, water circulation and salinity intrusion throughout the estuary (Georgas, 2012). The ice effects increase with increasing ice concentration and ice thickness. Tidal ranges increase near the southern edge of the ice field, causing currents to increase because of tidal wave reflection due to the ice cover upstream (Georgas, 2012).

It is important to also consider the effects of seasonal ice on exposed structures and shorelines. The most critical types of forces in coastal project design are shown in Figure 7 (USACE, 2011). The magnitude of these forces depends on the point that the ice fails by crushing or splitting, which is dependent on the thickness (USACE, 2011). Ice jams resulting when the passage of ice is blocked in a river section and piles upstream are an important consideration when designing in-stream structures (Georgas, 2015). The ice loads are site specific, however, it is recommended in (Tuthill, 2008) to size the median stone diameter (D_{50}) of a shoreline revetment two to three times greater than the expected maximum winter ice thickness.

The Stevens Institute of Technology performed a study to describe the ice cover climatology of the tidal Hudson River. It was determined that ice thickness in Region 1, the region that encompasses Hastings-on-Hudson, is the least of all the 16 river regions. In this region shore-to-shore ice cover is extremely unlikely. The ice thickness 95th percentile cumulative probability, shown in Figure 6, was approximately 6 inches and ranged from 4 to 7 inches in thickness.

Additionally, it was determined that the ice occurrence percentage over the previous 11 ice seasons was approximately 15% with the most prevalent type of ice in the region being Drift Ice.

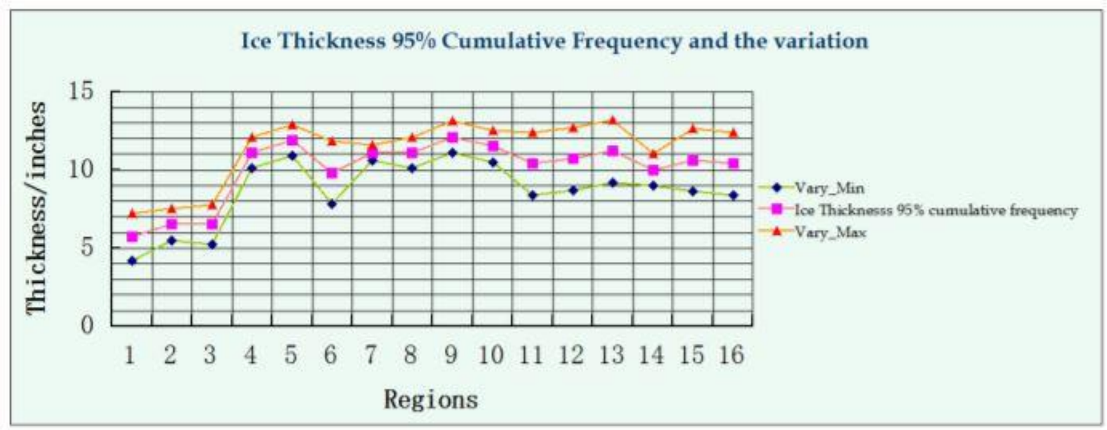

Figure 6: 95% Cumulative Probability of regional ice thickness and expected variation (Georgas, 2015)

Table VI-3-2
Ice Effects in Coastal Project Design (after Peyton (1968))

Direct Results of Ice Forces on Structures	
Horizontal forces on structures caused by:	Failure of laterally moving ice sheets by crushing.
	Failure of laterally moving ice sheets by bending.
	Impact by large floating ice masses.
	Plucking of individual armor units frozen to ice.
Vertical forces on structures caused by:	Weight of ice frozen to structure and suspended at low tide.
	Buoyancy of ice frozen to structure and submerged at high tide.
	Vertical component of ice sheet bending failure induced by ice breakers.
	Diaphragm bending forces during water level change of ice sheets frozen to structural elements.
	Weight of ice on superstructure elements caused by ice spray.
Second-order effects on structures caused by:	Movement during thawing of ice frozen to structure elements.
	Expansion during freezing of entrapped water.
	Jamming of ice rubble between structural framing members.
Indirect Results of Ice Forces on Structures	
Mooring loads caused by impingement of ice sheets on moored vessels.	
Ship impacts during mooring that are greater than normally expected.	
Abrasion and subsequent corrosion of structural elements.	
Low-Risk, But Catastrophic Considerations	
Collision by a ship caught in fast-moving, ice-covered waters.	
Collision by an extraordinarily large ice mass of very low probability of occurrence.	

Figure 7: Ice Effects in Coastal Project Design from USACE Coastal Engineering Manual VI (USACE, 2011)

1.7 River Stage

The river stages, shown in Table 4, were obtained from USGS Station 01376269 Hudson River at Piermont NY. The station is approximately 3 miles north of the project site location.

Flood Categories (in Feet relative to NAVD88)	
Major Flood Stage	7.4
Moderate Flood Stage	6.4
Flood Stage	5.4
Action Stage	6.3
Low Stage	0

Table 4: Flood categories from USGS Station 01376269 Hudson River at Piermont NY (USGS, 2021)

2 Basis of Design

2.1 Design Parameters

2.1.1 Water Level

The design water level involves quantifying the frequency of water surface elevations within a given time period. This value can often be difficult to determine because there are many factors to consider and it often has implications for the design wave height, stone size, and extent of armoring (Pile Buck International, Inc, 2014).

Wave analyses may have to be performed for extreme high and low design water levels and for one or more intermediate levels to determine critical design conditions (USACE, 1995). When determining the design water level for this project, Mott MacDonald has chosen to base the design water level off a 50-year storm event. Based on extreme water levels shown in Table 2 the design water level was chosen to be 6.73 ft NAVD88.

2.1.2 Wave Height and Period

Design wave heights and periods are chosen based upon the most critical combination of forces on a structure with due consideration of the economic life, structural integrity, and hazard for events that may exceed design conditions (USACE, 1995). Design characteristics are typically based on published wave data from NOAA tide gages, wave hindcasts and USACE wave studies. Data extracted from these methods is often unprocessed so it is important to check wave heights derived from hindcast data against the maximum breaking wave that can be supported at the site. The chosen design wave heights will be often be the smaller of the maximum breaker height or the hindcast wave height (USACE, 1995).

For stability considerations the wave height is dependent on the type of structure, rigid, semi-rigid, or flexible. Rigid structures have the potential for catastrophic failure and sometimes require design wave heights based on $H_{1.}$ Semi-rigid structures may warrant a design wave height between H_1 and $H_{10,}$ while flexible structures are usually designed for H_s or H_{10} (USACE, 1995). Yoshimi Goda (2000) recommends that the design of rubble structures be based on significant wave height at a depth equal to one-half the significant deepwater wave height if the depth is less than one-half the deepwater significant wave height.

When determining the design wave height and period, Mott MacDonald has chosen to base the design water conditions off a 50-year storm event. Based on the significant wave heights shown in Table 3 the design wave height was determined to be 3.9 ft. The peak period was interpolated from an examination of historical storms with similar wave and water level conditions and was determined to be 2.67 sec.

2.1.3 Project Design Life

A project's design life is length of time intended by the designer that the element performs satisfactorily (no damage exceeding ordinary maintenance) given its environmental conditions, before it needs replacement. Design life varies significantly according to the element considered and the conditions present. As a minimum, the design must withstand conditions which have a percent probability of being exceeded during the project's economic life. Additionally, the failure of the element during attainable maximum conditions must not result in catastrophe (i.e. loss of life or inordinate loss of property) (USACE, 1995).

Mott MacDonald has chosen a design life of 50 years for the park's shoreline. This design life accounts for routine and adequate maintenance of the structure and considers the potential for the replacement of structural components as needed.

2.1.4 Sea Level Rise

Using data from nearby NOAA gauge 8518750 The Battery, NY and the low Sea Level Rise (SLR) projection, there is an expected rate of SLR of 0.0202 feet/year (0.242 inches/year). This compares well with the projected SLR used in the Hastings on Hudson Compensatory Wetland BODR (Arcadis 2021) of 0.0175 feet/year (0.210 inches/year). Projecting SLR for the year 2071 (50 years' time), there will be the potential for 1.39 ft (16.68 inches) of local mean sea level rise. This means that MHHW in the year 2071 would be +4.5 ft NAVD 88.

There is also the likelihood that SLR may be greater than this based on the intermediate projections. Since this location is a park, and there is no critical infrastructure, the low projection is being adopted for this project. This implies a certain level of acceptable risk in the future.

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