	CALCULATION COVER SHEET	CALC. NO. 1 REV. 2 PAGE 1 of 17

Title:	Rubble Mound Breakwater (Sill) Armor Stone Stability Calculation	**Project: Weaver Cove Boat Ramp Protection** **Project No.: 03.0034944.00**

Item	**Calculation Status**	**Yes**	**No**
	Preliminary	☐	☒
	Final	☒	☒
	Revision	☐	☒

Purpose:

The Weaver Cove Boat Ramp is located in Narragansett Bay on the western shore of Portsmouth, Rhode Island. The project site is located on the southern end of Weaver Cove, directly north of a tidal estuary, with an inlet/outlet to Narragansett Bay.

The Weaver Cove Boat Ramp includes: a new concrete boat ramp; a new timber pier; and rubble mound, shore-perpendicular granite quarrystone breakwater (sill). The primary purpose of the rubble mound breakwater, which will be parallel and adjacent to the ramp and pier, is to attenuate wave energy within the ramp area. A secondary purpose of the rubble mound breakwater is to trap longshore sand from depositing within the ramp area.

The purpose of this Calculation is to evaluate the internal stability of the breakwater and establish the armor stone size and distribution (D_{50} and gradation) required for the 50-year annual recurrence probability coastal flood under current sea level.

Revisions: Rev 2

Revised breakwater (sill) crest elevation to 4.8 feet NAVD88.

(Print Name and Sign)	
Originator: Michael Gardner	**Date:** 11/10/2022
Consultant/Reviewer: Daniel Stapleton	**Date:** 11/10/2022
PIC or PE: Russell Morgan	**Date:** 11/10/2022

	CALCULATION REVISION STATUS SHEET	CALC. NO. 1
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CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
2	11/10/2022	Issued Final

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
5,6,9, 10	2		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.

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Calculation Review:

Calculation review includes verification of:

- Approach
- Methodology
- Design Inputs
- Results
- Conclusions

Consultant/Reviewer: Daniel Stapleton	**Date: 11/10/2022**

Calculation Review Summary:

Approach, methodology and design inputs appear appropriate.

The armor stone weight is calculated for a mean value. Van der Meer predicted an 18% coefficient of variation for the Hudson Formula (reference Coastal Engineering Manual VI-5-64. Using this coefficient of variation and the calculated values, an upper bound = the mean plus two standard deviations would result in an upper bound W50 of about 1,590 lbs and an associated cubic diameter of about 2.1 feet.

Based on the above summary and comment resolution, the Calculation is determined to be acceptable.

Consultant/Reviewer: Daniel Stapleton	**Date: 11/10/2022**
Others:	**Date:**

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APPENDICES

LIST OF FIGURES

1.0 PURPOSE AND SCOPE

The purpose of this Calculation is to evaluate the internal stability of the breakwater and establish the armor stone size and distribution (D_{50} and gradation) required for annual recurrence probability coastal floods ranging from 1-year to 50-years under current sea level.

The Weaver Cove Boat Ramp is located in Narragansett Bay on the western shore of Portsmouth, Rhode Island. The project site is located on the southern end of Weaver Cove, directly north of a tidal estuary, with an inlet/outlet to Narragansett Bay.

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Not included in the calculation:

- Net longshore drift and sediment capture by the proposed breakwater (sill).

2.0 SUMMARY OF RESULTS AND CONCLUSIONS

GZA performed this Calculation to evaluate the internal stability of the breakwater and establish the armor stone size and distribution (D_{50} and gradation) required for annual recurrence probability coastal floods ranging from 1-year to 50-years under current sea level.

Waves within Narragansett Bay and in the vicinity of the Weaver Cove Boat Ramp are generally due to wind-generated waves along fetches within Narragansett Bay. The prevailing winds during the summer months are from the south-southwest. The prevailing winds during the winter months are from the northwest. The south-southwest wave direction has the largest exposed fetch making it the design wave direction, with waves at the breakwater approaching from the west-southwest. Waves propagating from the northwest are expected to be similar in height for higher frequency flood events (on the order of 1 to 1.5 feet for a 1-year recurrence interval) and smaller for the 100-year recurrence interval event (2 to 3 feet). (see **Reference B**).

The stability and armor stone size was determined for a condition of: 1) south-southwest wave (propagation direction to the north-northeast, normal to breakwater alignment). The results indicate that:

1. The proposed breakwater will be a randomly-placed rubble mound quarry stone breakwater with 2 layers of angular armor stone over a 8-inch minus angular stone core and base (minimum base thickness of 8-inches), with a 4-foot crest width and a crest elevation of 6.9 feet MLW (4.8 feet NAVD88). Side slopes range from 1.5H:1V to 3H:1V.
2. Overtopping is predicted at peak flood during the 1-year and greater interval floods. These flood events are expected to occur with 1-minute sustained wind speeds on the order of 35 mph and significant and maximum wave heights of up to about 2.5 feet and 4.1 feet, respectively.
3. Wave run-up will result in result in overtopping between 2-year and 5-year flood events. These flood events are expected to occur with 1-minute sustained wind speeds on the order of 35 mph to 40 mph and significant and maximum wave heights of up to about 2.5 feet to 2.9 feet and 4.1 feet to 4.7 feet, respectively.
4. The recommended 50-year recurrence interval design armor stone:

   W_{50} = 1,090 lbs

   Gradation:
   - W_{max} = 4,360 lbs
   - W_{50} = 1,090 lbs
   - W_{min} = 146 lbs

   Size Gradation (assumed cubic shape):
   - D_{max} = 3 feet
   - D_{50} = 2 feet
   - D_{min} = 1 foot

3.0 REFERENCES

- Appendix A – Concept Drawing: Weaver Cove Boat Ramp and Pier Improvement - Portsmouth, Rhode Island
- Appendix B - Metocean Data Analysis - Proposed Weaver Cove Boat Ramp Improvements
- Hudson and van der Meer Formulas – Coastal Engineering Manual (CEM) VI-5-65 through VI-5-67
- Armor Stone Gradation - Coastal Engineering Manual (CEM) 1110-2-1100, Part VI (Dated 28 Sep 11) for riprap

4.0 ASSUMPTIONS

No assumptions

5.0 DESIGN INPUT

Design input includes: 1) geometry and location of the proposed breakwater (sill); 2) breakwater type; 3) hydrologic inputs; and 4) calculation input variable values.

Breakwater (Sill) Locations and Dimensions:

Appendix A presents the proposed site plans and sections. The proposed structure geometry includes:

- The proposed breakwater alignment is to the northwest.
- The breakwater length, measured from toe of slope to toe of slope, is approximately 108 feet.
- The crest width is 4 feet.
- Slopes range from 1.5H:1V (on the ramp side) to 3H:1V on the wave-facing side. Armor stone size was conservatively estimated assuming a 1.5H:1V slope.
- Crest Elevation of 6.9 feet MLW (4.8 feet NAVD88).
- A seaward toe elevation of -3 feet MLW (-5.1 feet NAVD88) and a landward toe elevation of 2 feet MLW (-0.1 feet NAVD88.

Breakwater (Sill) Type:

The proposed breakwater will be a randomly-placed rubble mound quarry stone breakwater with 2 layers of angular armor stone over a 8-inch minus angular stone core and base (minimum base thickness of 8-inches).

Hydrologic Input:

Hydrologic inputs include: design wave height (H_{10}) and period; wave direction; and associated water levels. The hydrologic inputs were developed based on a metocean data analyses performed by GZA and presented in **Appendix B** "Metocean Data Analysis - Proposed Weaver Cove Boat Ramp Improvements".

The hydrologic inputs represent a range of recurrence interval floods under current sea level conditions, up to the 50-year recurrence interval flood. $H_{10} = 1.27\ H_s$ (Rayleigh Distribution). Representative environmental conditions include:

- Design Stillwater Elevation (Peak Flood):
  - 1-year: 3.6 feet NAVD88
  - 2-year: 4.2 feet NAVD88
  - 5-year: 5.0 feet NAVD88
  - 10-year: 5.8 feet NAVD88
  - 50-year: 7.2 feet NAVD88
- Design Wave Height (H_{10}) and Period:
  - 1-year: 2.2 feet; 2.3 seconds
  - 2-year: 2.9 feet; 2.5 seconds
  - 5-year: 3.7 feet; 2.7 seconds
  - 10-year: 4.2 feet; 2.9 seconds
  - 50-year: 5.8 feet; 3.2 seconds
- Design Wave Height (H_s) and Period:
  - 1-year: 1.7 feet; 2.3 seconds
  - 2-year: 2.3 feet; 2.5 seconds
  - 5-year: 2.9 feet; 2.7 seconds

- 10-year: 3.3 feet; 2.9 seconds
- 50-year: 4.6 feet; 3.2 seconds

- Design Wave Direction: South-Southwest (wave propagation direction is normal to wall)

Calculation Variables:

- wave duration: 6 hours
- g = gravitational constant = 32.2 lb/s^2
- $\gamma_s = \rho_s g$ = unit weight of rock = 165 lb/cf
- ρ_s/ρ_w = s, the specific gravity for rock = 2.7
- K_D is the Hudson stability coefficient = 2 (breaking) and 4 (non-breaking) for rough angular stone
- $\cot\alpha$ = slope = 1.5
- number of layers: 2
- percent damage: 0 to 5%
- permeability = 0.6

6.0 METHODOLOGY

The condition of the breakwater (sill) ranges from non-overtopping to low-crested. The associated methods to evaluate breakwater stability and armor stone size include:

- Hudson Method per Coastal Engineering Manual (CEM) version 1 June 06, VI-5-64 (Table VI-5-22)
- Van der Meer Method per Coastal Engineering Manual (CEM) VI-5-65 (Table VI-5-23)

General Equations:

$$W_{50} = \gamma_r(H/\Delta N_s)^3$$

$$W_{50} = \gamma_r D_{50}^3$$

$$r = n k_\Delta D_{50}$$

$$B_{crest} = 3k_\Delta D_{50}$$

Where:

- g = gravitational constant
- $\gamma_s = \rho_s g$ = unit weight of rock
- ρ_s/ρ_w = s, the specific gravity for rock
- $\Delta = (\rho_s/\rho_w - 1)$
- K_D is the stability coefficient
- $\cot\alpha$ = slope
- H_{10} = design wave
- Ns = stability parameter = $H/\Delta D_{50}$
- k_Δ = layer coefficient

Equations (Hudson for Two layered Armored Non-Overtopped Slopes):

$$\frac{H}{\Delta D_{n50}} = (K_D \cot\alpha)^{1/3} \quad \text{or} \quad M_{50} = \frac{\rho_s H^3}{K_D \left(\frac{\rho_s}{\rho_w} - 1\right)^3 \cot\alpha}$$

where

H	Characteristic wave height (H_s or $H_{1/10}$)
D_{n50}	Equivalent cube length of median rock
M_{50}	Medium mass of rocks, $M_{50} = \rho_s D_{n50}^3$
ρ_s	Mass density of rocks
ρ_w	Mass density of water
Δ	$(\rho_s/\rho_w) - 1$
α	Slope angle
K_D	Stability coefficient

Equations (Van der Meer for Two-Layered Armored Non-Overtopped Slopes):

$$\frac{H_s}{\Delta D_{n50}} = 6.2 \cdot S^{0.2} P^{0.18} N_z^{-0.1} \xi_m^{-0.5} \qquad \text{Plunging waves}: \xi_m < \xi_{mc} \qquad \text{(VI-5-68)}$$

$$\frac{H_s}{\Delta D_{n50}} = 1.0 \cdot S^{0.2} P^{-0.13} N_z^{-0.1} (\cot\alpha)^{0.5} \xi_m^P \qquad \text{Surging waves}: \xi_m > \xi_{mc} \qquad \text{(VI-5-69)}$$

$$\xi_m = s_m^{-0.5} \tan\alpha \qquad \xi_{mc} = \left(6.2\, P^{0.31} (\tan\alpha)^{0.5}\right)^{1/(P+0.5)}$$

where

H_s	Significant wave height in front of breakwater
D_{n50}	Equivalent cube length of median rock
ρ_s	Mass density of rocks
ρ_w	Mass density of water
Δ	$(\rho_s/\rho_w) - 1$
S	Relative eroded area (see Table VI-5-21 for nominal values)
P	Notional permeability (see Figure VI-5-11)
N_z	Number of waves
α	Slope angle
s_m	Wave steepness, $s_m = H_s/L_{om}$
L_{om}	Deepwater wavelength corresponding to mean wave period

Equations (Van der Meer for Two-Layered Armored Overtopped but not Submerged Low Crested Slopes):

van der Meer (1991) suggested that the van der Meer stability formulae for non-overtopped rock slope, Eqs VI-5-68 and VI-5-69, be used with $f_i D_{n50}$ substituted for D_{n50}. The reduction factor f_i is given as

$$f_i = \left(1.25 - 4.8 \frac{R_c}{H_s} \sqrt{\frac{s_{op}}{2\pi}}\right)^{-1} \qquad \text{(VI-5-71)}$$

where R_c is the freeboard, $s_{op} = H_s / L_{op}$, and L_{op} is deepwater wavelength corresponding to the peak wave period. Limits of Eq VI-5-71 are given by

$$0 < \frac{R_c}{H_s} \sqrt{\frac{s_{op}}{2\pi}} < 0.052$$

Gradation

The maximum and minimum armor stone gradation was calculated using the CEM 1110-2-1100, Part VI (Dated 28 Sep 11) for riprap. Those equations are as follows:

Maximum: $W_{max} = 4*W_{50}$
Minimum: $W_{min} = 0.125*W_{50}$

7.0 CALCULATIONS

An Excel spreadsheet is utilized to perform the calculations. The values were checked at peak flood (non-breaking) and mid flood elevations (breaking wave).

The calculated values are summarized below:

1-year:

- Overtopping at peak flood
- No Submergence
- Hudson Formula
- W_{50} = 119 lbs
- D_{50} (assumed cubic) = 0.9 foot

2-year:

- Overtopping at peak flood
- No Submergence
- Hudson Formula:
  - W_{50} = 136 lbs
  - D_{50} (assumed cubic) = 0.9 foot

5-year:

- Overtopping
- Submergence
- Hudson:
  - W_{50} = 110 lbs
  - D_{50} (assumed cubic) = 0.9 foot

10-year:

- Overtopping
- Submergence
- Hudson
  - W_{50} = 201 lbs
  - D_{50} (assumed cubic) = 1.1 foot

50-year:

- Overtopping
- Submergence
- Hudson (assuming non-overtopped):
  - W_{50} = 1,090 lbs
  - D_{50} (assumed cubic) = 1.85 foot

50-year (lower water level during storm to result in breaking wave):

- Overtopping
- Submergence
- Hudson (assuming non-overtopped):
  - W_{50} = 1,020 lbs
  - D_{50} (assumed cubic) = 1.81 foot

50-year recurrence interval design armor stone:

- W_{50} = 1,090 lbs
- Gradation:
  - W_{max} = 4,360 lbs
  - W_{50} = 1,090 lbs
  - W_{min} = 140 lbs
- Size Gradation (assumed cubic shape):
  - D_{max} = 3 feet
  - D_{50} = 2 feet
  - D_{min} = 1 foot

Appendix A

WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT PROJECT

BURMA ROAD
PORTSMOUTH, RHODE ISLAND

PERMIT SET
SEPTEMBER 7, 2022

PREPARED FOR:

TOWN OF PORTSMOUTH
2200 EAST MAIN ROAD
PORTSMOUTH, RHODE ISLAND

DESIGNED BY:

GZA GEOENVIRONMENTAL, INC.
188 VALLEY ST. SUITE 300
PROVIDENCE RHODE ISLAND, 02909

PROJECT LOCUS MAP

0 1000' 2000' 4000' 6000'
SCALE IN FEET 1" = 2000'

SOURCE:
BASE MAP FROM THE FOLLOWING USGS QUADRANGLE MAP: GEORGIAVILLE, RI (2018), BLACKSTONE, MA (2018)

DIGITAL TOPOGRAPHIC MAPS PROVIDED BY USGSSTORE.GOV.
CONTOUR ELEVATIONS REFERENCE NAVD 88,
CONTOURS ARE SHOWN IN FEET AT 10 FOOT INTERVALS

QUADRANGLE LOCATION

PROJECT VICINITY MAP

0 1000' 2000' 4000' 6000'
SCALE IN FEET 1" = 2000'

SOURCE: AERIAL MAP DEVELOPED FROM BING AERIAL IMAGERY ACCESSED ON JUNE 11, 2021

INDEX OF DRAWINGS

SHEET NUMBER	SHEET TITLE
1	COVER SHEET AND INDEX OF DRAWINGS
2	EXISTING CONDITIONS PLAN AND PROFILE
3	EXISTING SECTION
4	PROPOSED REMOVALS AND EROSION CONTROL PLAN
5	PROPOSED CONDITIONS PLAN
6	PROPOSED PROFILES
7	PROPOSED SECTION AND DETAILS
8	MISCELLANEOUS DETAILS

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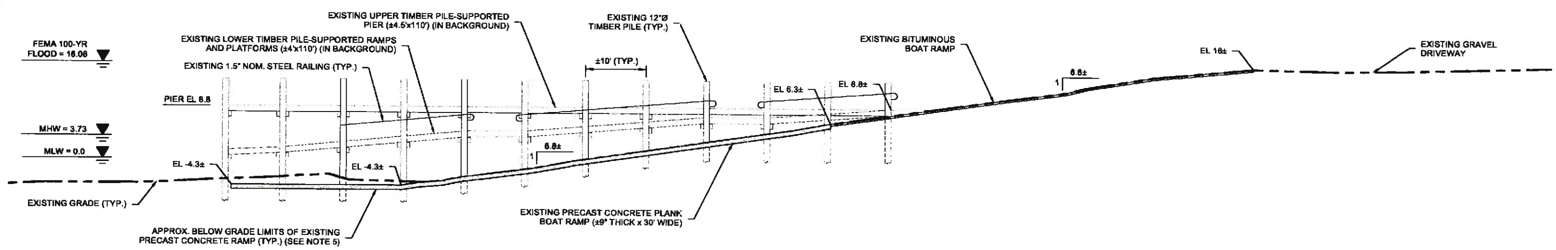
P.E. STAMP:
RUSSELL J. MORGAN
PROFESSIONAL ENGINEER (CIVIL)
9/6/22



EXISTING PROFILE A - A'

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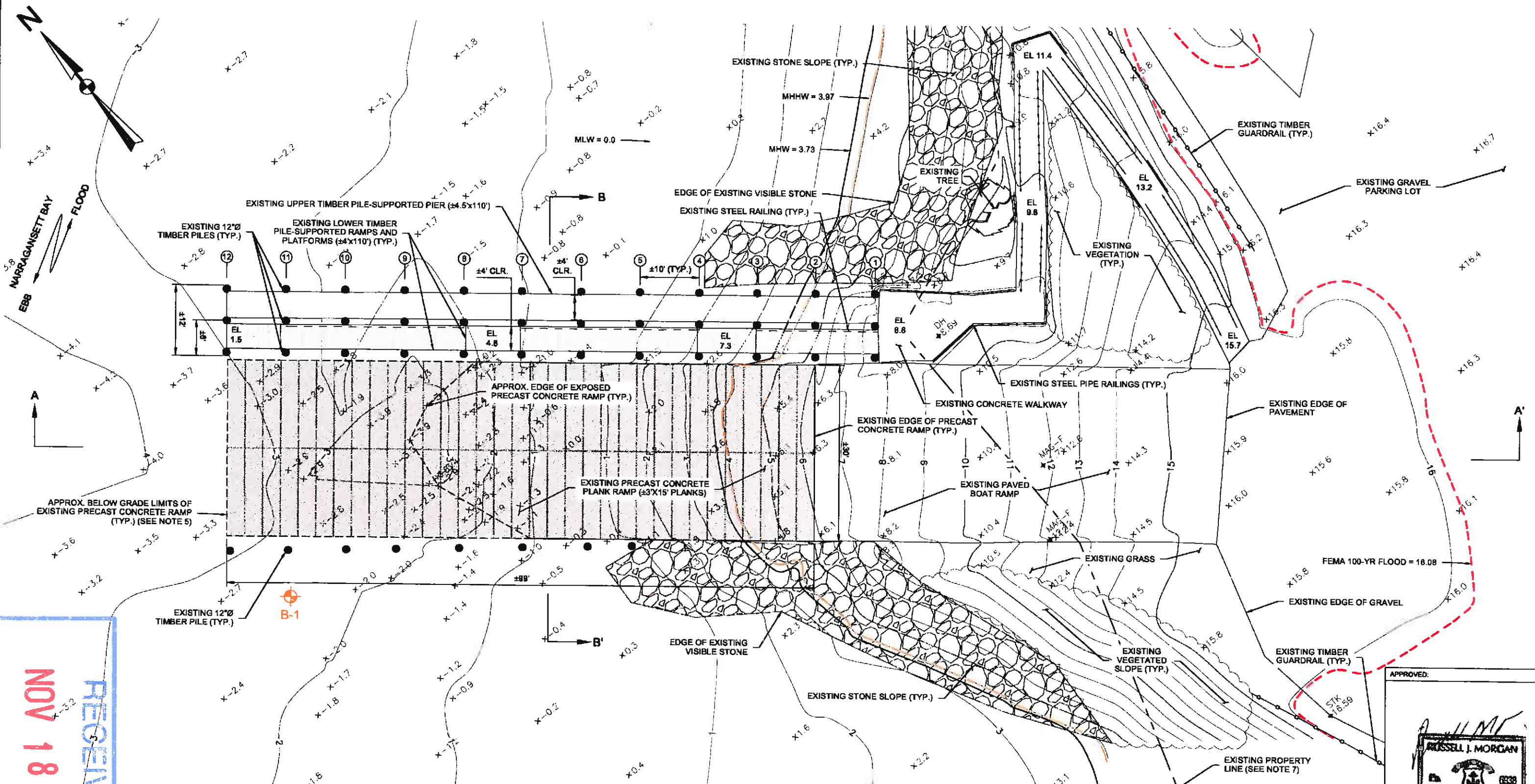


EXISTING CONDITIONS PLAN

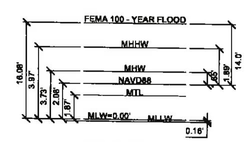
SCALE 1" = 10'

GENERAL NOTES

1. ELEVATIONS ARE IN FEET AND REFERENCE MEAN LOW WATER (MLW) DATUM: MLW=0.0', MLLW= -0.16', NAVD88=2.06', MTL=1.87', MHW=3.73', MHHW=3.97', FEMA 100-YEAR FLOOD ZONE VE=16.08'.
2. TIDAL DATUM REFERENCED TO THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) STATION ID 8452555, NAVY PIER, PRUDENCE ISLAND, RHODE ISLAND.
3. VERTICAL DATUM CONVERSION TAKEN FROM NOAA'S VERTICAL DATUM CONVERSION WEBSITE ACCESSED ON AUGUST 9, 2021.
4. LIMITED TOPOGRAPHIC AND BATHYMETRIC SURVEY PERFORMED BY GZA GEOENVIRONMENTAL, INC., ON AUGUST 4, 2021 AND REPRESENTS CONDITIONS AT THE TIME OF THE SURVEY.
5. APPROXIMATE BELOW GRADE LIMITS OF THE EXISTING PRECAST CONCRETE BOAT RAMP BASED ON PLAN TITLED "AS-BUILT SITE PLAN - BOAT RAMP AREA WEAVER COVE", PREPARED BY JOHN P. CAITO CORPORATION, DATED DECEMBER 12, 1996.
6. BORING LOCATION DETERMINED IN THE FIELD BY GZA GEOENVIRONMENTAL, INC. BASED ON TAPE MEASUREMENTS FROM EXISTING SITE FEATURES.
7. PARCEL DATA WAS OBTAINED FROM THE TOWN OF PORTSMOUTH, RI WEBGIS MAPPING SERVICE AND SHOULD BE CONSIDERED ACCURATE TO THE METHOD USED TO DEVELOP BY THE SOURCE.

LEGEND

- EXISTING CONTOUR MAJOR
- EXISTING CONTOUR MINOR
- MEAN LOW WATER [MLW]
- MEAN HIGH WATER [MHW]
- MEAN HIGHER HIGH WATER [MHHW]
- FEMA 100-YR FLOOD ELEVATION
- APPROXIMATE PROPERTY LINE
- EXISTING TIMBER GUARDRAIL
- EXISTING STEEL RAILINGS
- APPROXIMATE EXISTING VEGETATION
- EXISTING EXPOSED STONE
- EXISTING PRECAST CONCRETE RAMP
- APPROXIMATE BELOW GRADE LIMITS OF EXISTING PRECAST CONCRETE RAMP (SEE NOTE5)
- B-1 INDICATES BORINGS PERFORMED BY NEW ENGLAND BORING CONTRACTORS OF DERRY, NEW HAMPSHIRE ON AUGUST 10, 2021. OBSERVED AND LOGGED BY GZA PERSONNEL.
- ① BENT ROW DESIGNATION NUMBER



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APPROVED:

RUSSELL J. MORGAN
No. 6638
REGISTERED PROFESSIONAL ENGINEER (CIVIL)
9/6/22

WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT
PORTSMOUTH, RHODE ISLAND

EXISTING CONDITIONS PLAN AND PROFILE

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: TOWN OF PORTSMOUTH 2200 EAST MAIN ROAD PORTSMOUTH, RHODE ISLAND	
PROJ MGR: RKT	REVIEWED BY: RJM	CHECKED BY: MJP	DRAWING
DESIGNED BY: RKT	DRAWN BY: ADD	SCALE: AS SHOWN	2
DATE: SEPTEMBER 2022	PROJECT NO. 03.0034944.00	REVISION NO. -	SHEET NO. 2 OF 8

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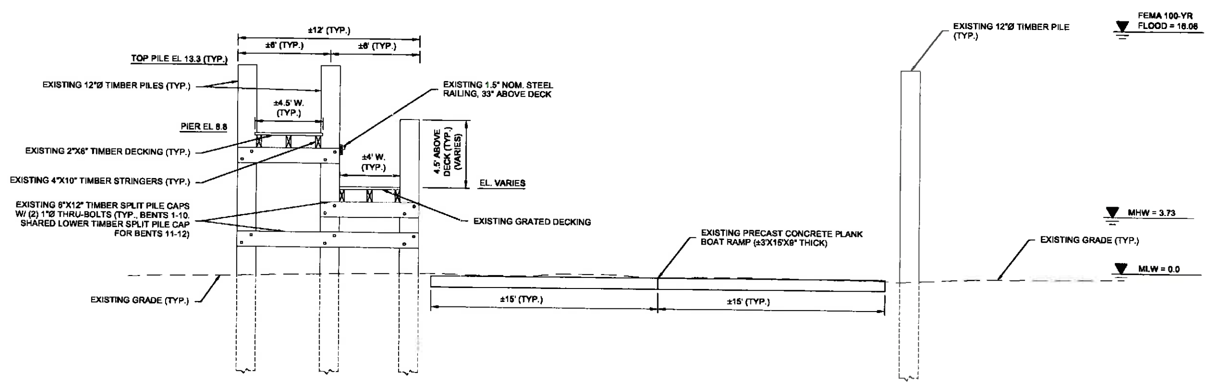

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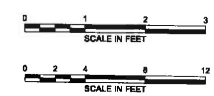

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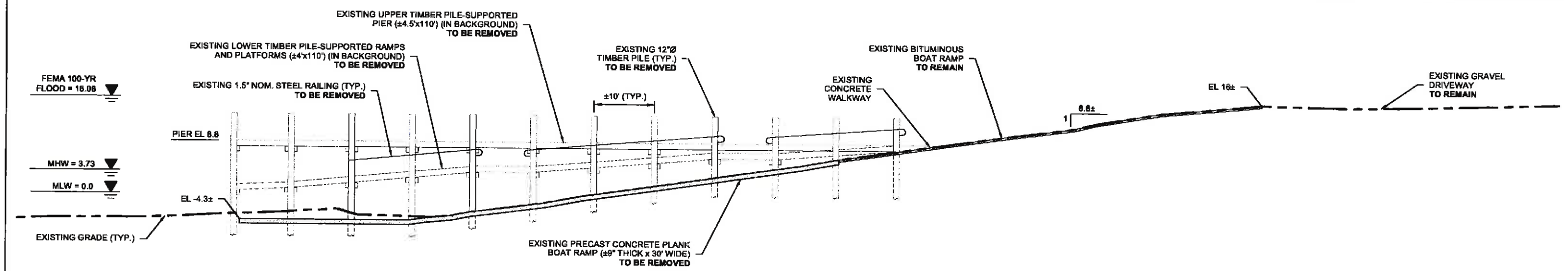
APPROVED:

RUSSELL J. MORGAN 6638 REGISTERED PROFESSIONAL ENGINEER (CIVIL) 9/6/22

WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT
PORTSMOUTH, RHODE ISLAND

EXISTING SECTION

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: TOWN OF PORTSMOUTH 2200 EAST MAIN ROAD PORTSMOUTH, RHODE ISLAND	
PROJ MGR: RKT	REVIEWED BY: RJM	CHECKED BY: MJP	DRAWING
DESIGNED BY: RKT	DRAWN BY: AD	SCALE: AS SHOWN	3
DATE: SEPTEMBER 2022	PROJECT NO. 03.0034944.00	REVISION NO. -	SHEET NO. 3 of 8



PROPOSED REMOVALS PROFILE

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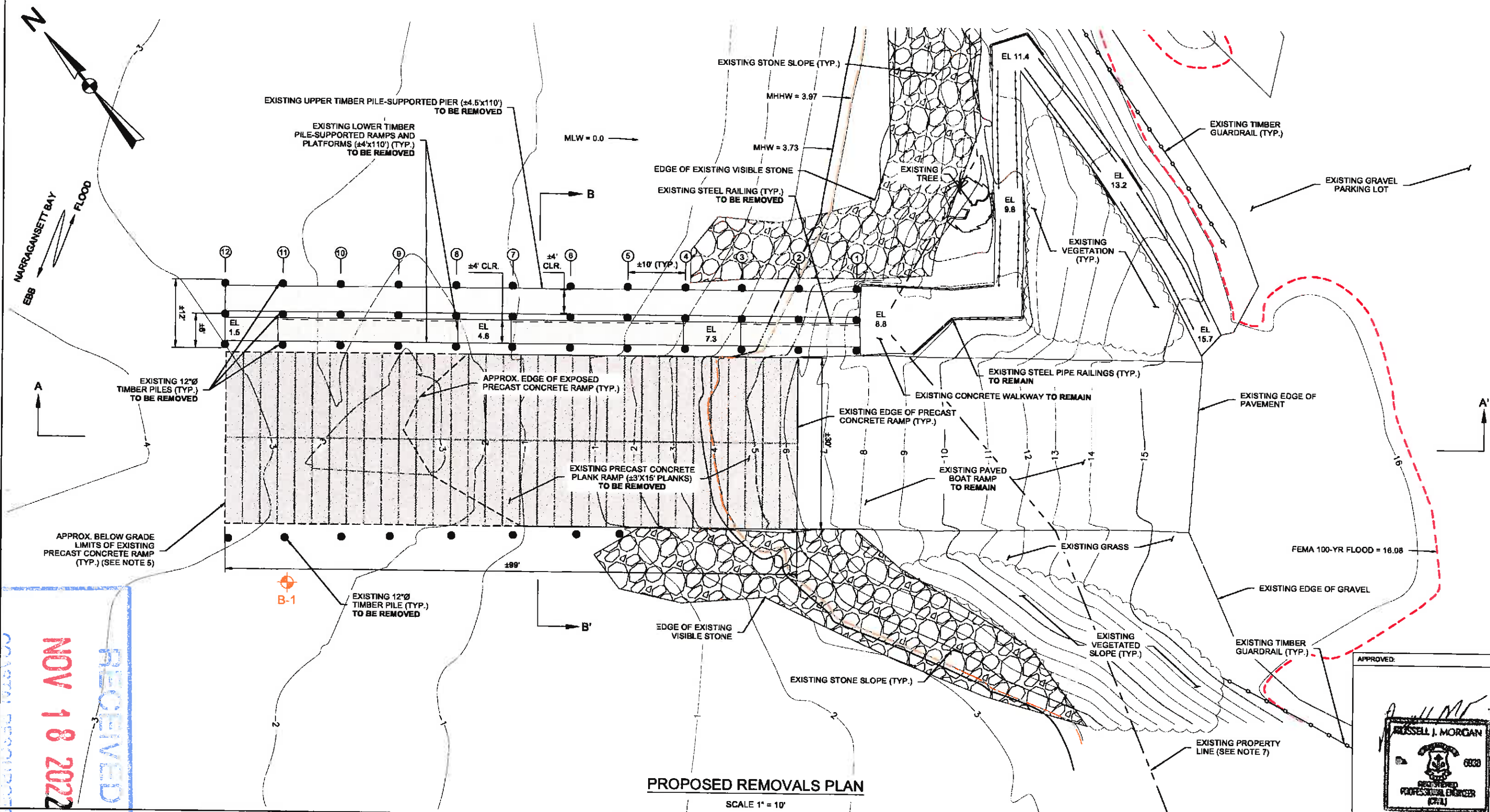

PROPOSED REMOVALS PLAN

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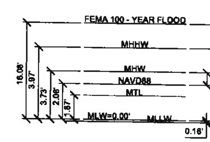


DATUM RELATIONSHIP
NOT TO SCALE

0 5 10 20 30
SCALE IN FEET

PERMITTING ONLY
NOT FOR CONSTRUCTION

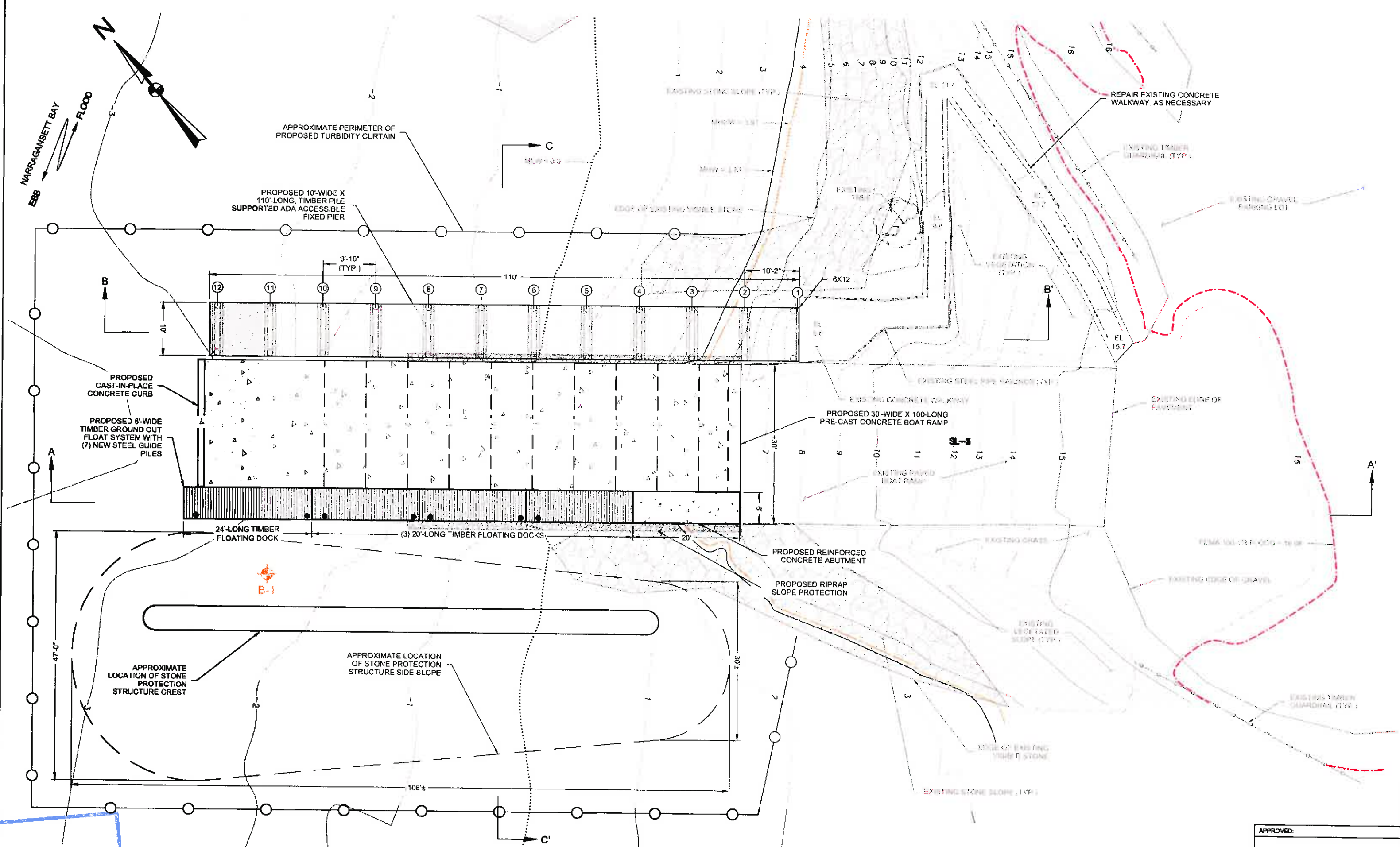
APPROVED:

RUSSELL J. MORGAN 6838 REGISTERED PROFESSIONAL ENGINEER (CIVIL) 9/6/22

WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT
PORTSMOUTH, RHODE ISLAND

PROPOSED REMOVALS AND EROSION AND SEDIMENTATION CONTROL PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: TOWN OF PORTSMOUTH 2200 EAST MAIN ROAD PORTSMOUTH, RHODE ISLAND	
PROJ MGR: RKT	REVIEWED BY: RJM	CHECKED BY: MJP	DRAWING
DESIGNED BY: RKT	DRAWN BY: ADO	SCALE: AS SHOWN	4
DATE: SEPTEMBER 2022	PROJECT NO. 03.0034944.00	REVISION NO. -	SHEET NO. 4 OF 8



PROPOSED CONDITIONS PLAN

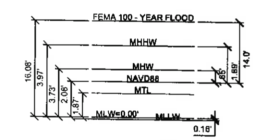
SCALE 1" = 10'

GENERAL NOTES

1. ELEVATIONS ARE IN FEET AND REFERENCE MEAN LOW WATER (MLW) DATUM: MLW=0.0', MLLW= -0.16', NAVD88=2.06', MTL=1.87', MHW=3.73', MHHW=3.97', FEMA 100-YEAR FLOOD ZONE VE=16.08'.
2. TIDAL DATUM REFERENCED TO THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) STATION ID 8452555, NAVY PIER, PRUDENCE ISLAND, RHODE ISLAND.
3. VERTICAL DATUM CONVERSION TAKEN FROM NOAA'S VERTICAL DATUM CONVERSION WEBSITE ACCESSED ON AUGUST 9, 2021.
4. LIMITED TOPOGRAPHIC AND BATHYMETRIC SURVEY PERFORMED BY GZA GEOENVIRONMENTAL, INC., ON AUGUST 4, 2021 AND REPRESENTS CONDITIONS AT THE TIME OF THE SURVEY.
5. APPROXIMATE BELOW GRADE LIMITS OF THE EXISTING PRECAST CONCRETE BOAT RAMP BASED ON PLAN TITLED "AS-BUILT SITE PLAN - BOAT RAMP AREA WEAVER COVE", PREPARED BY JOHN P. CATO CORPORATION, DATED DECEMBER 12, 1996.
6. BORING LOCATION DETERMINED IN THE FIELD BY GZA GEOENVIRONMENTAL, INC. BASED ON TAPE MEASUREMENTS FROM EXISTING SITE FEATURES.
7. PARCEL DATA WAS OBTAINED FROM THE TOWN OF PORTSMOUTH, RI WEBGIS MAPPING SERVICE AND SHOULD BE CONSIDERED ACCURATE TO THE METHOD USED TO DEVELOP BY THE SOURCE.

LEGEND

- EXISTING CONTOUR MAJOR
- EXISTING CONTOUR MINOR
- MEAN LOW WATER [MLW]
- MEAN HIGH WATER [MHW]
- MEAN HIGHER HIGH WATER [MHHW]
- FEMA 100-YR FLOOD ELEVATION
- APPROXIMATE PROPERTY LINE
- EXISTING TIMBER GUARDRAIL
- EXISTING STEEL RAILINGS
- APPROXIMATE EXISTING VEGETATION
- EXISTING EXPOSED STONE
- EXISTING PRECAST CONCRETE RAMP
- APPROXIMATE BELOW GRADE LIMITS OF EXISTING PRECAST CONCRETE RAMP (SEE NOTE5)
- B-1 INDICATES BORINGS PERFORMED BY NEW ENGLAND BORING CONTRACTORS OF DERRY, NEW HAMPSHIRE ON AUGUST 10, 2021. OBSERVED AND LOGGED BY GZA PERSONNEL.
- ① BENT ROW DESIGNATION NUMBER



DATUM RELATIONSHIP
NOT TO SCALE

0 5 10 20 30
SCALE IN FEET

PERMITTING ONLY
NOT FOR CONSTRUCTION

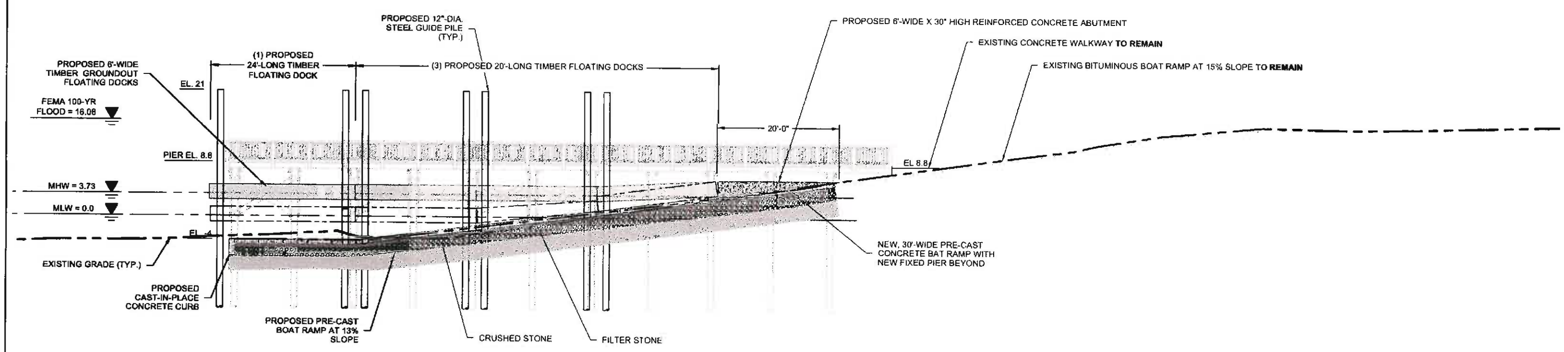
APPROVED:

RUSSELL J. MORGAN No. 6938 REGISTERED PROFESSIONAL ENGINEER (CIVIL) 9/6/22

WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT
PORTSMOUTH, RHODE ISLAND

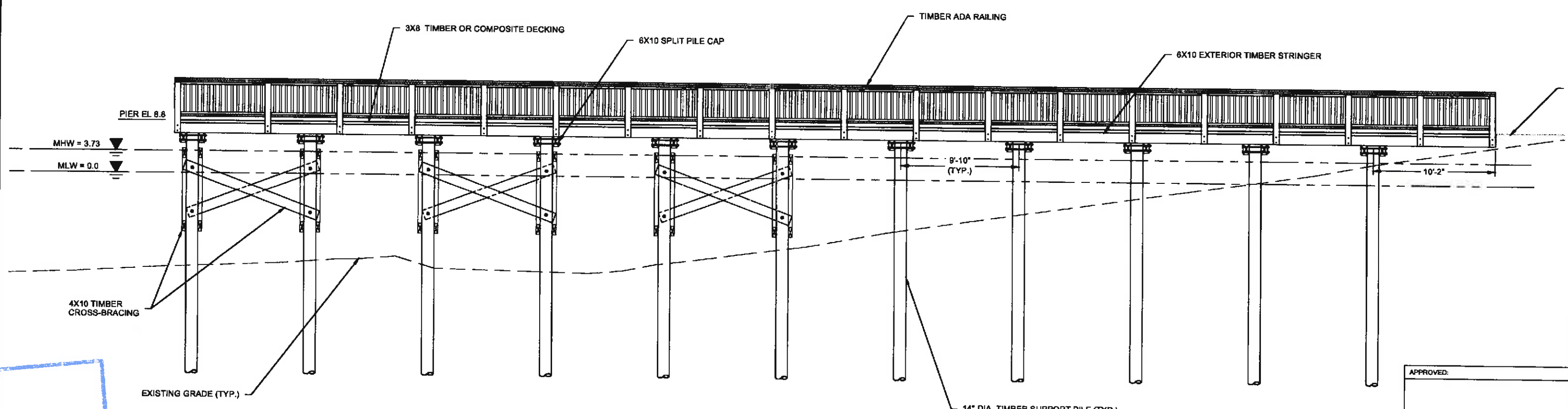
PROPOSED CONDITIONS PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: TOWN OF PORTSMOUTH 2200 EAST MAIN ROAD PORTSMOUTH, RHODE ISLAND	
PROJ MGR: RKT	REVIEWED BY: RJM	CHECKED BY: MJP	DRAWING
DESIGNED BY: RKT	DRAWN BY: AD	SCALE: AS SHOWN	5
DATE: SEPTEMBER 2022	PROJECT NO. 03.0034944.00	REVISION NO. -	SHEET NO. 5 OF 8



PROPOSED PROFILE A - A'

SCALE 1" = 10'



PROPOSED PROFILE B - B'

SCALE 1" = 5'

GENERAL NOTES

1. ELEVATIONS ARE IN FEET AND REFERENCE MEAN LOW WATER (MLW) DATUM: MLW=0.0', MLLW= -0.16', NAVD88=2.08', MTL=1.87', MHW=3.73', MHHW=3.97', FEMA 100-YEAR FLOOD ZONE VE=16.06'.
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7. PARCEL DATA WAS OBTAINED FROM THE TOWN OF PORTSMOUTH, RI WEBGIS MAPPING SERVICE AND SHOULD BE CONSIDERED ACCURATE TO THE METHOD USED TO DEVELOP BY THE SOURCE.

0 5 10 20 30
SCALE IN FEET

PERMITTING ONLY
NOT FOR CONSTRUCTION

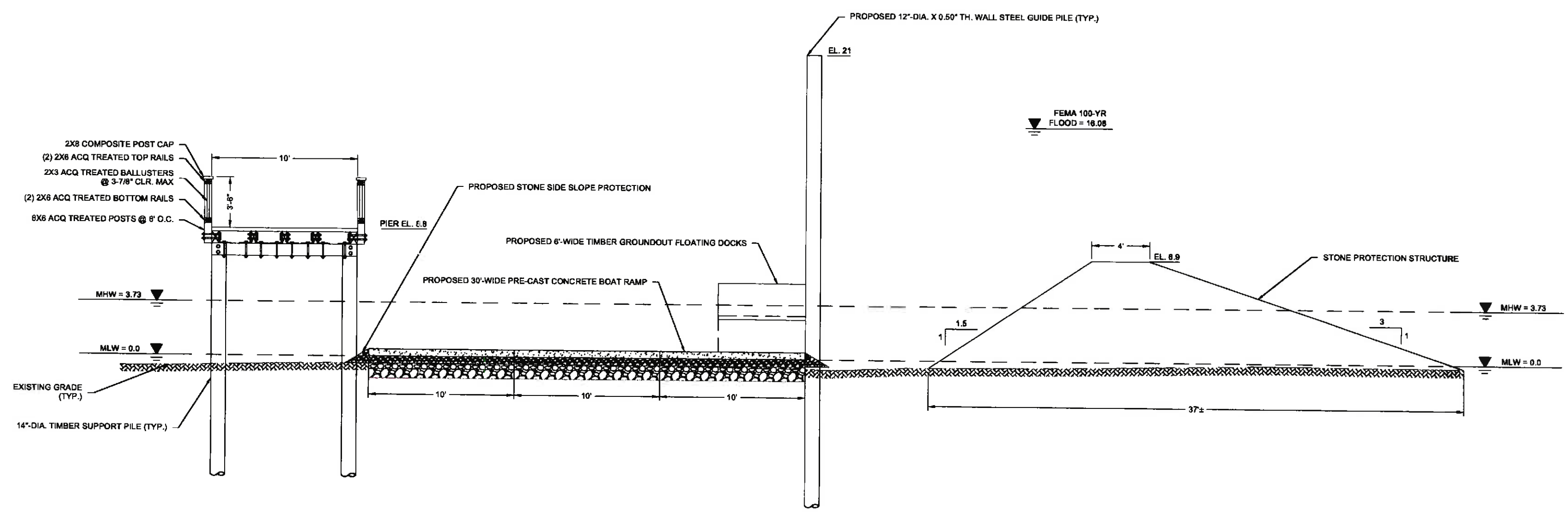
APPROVED:

RUSSELL J. MORGAN No. 6838 REGISTERED PROFESSIONAL ENGINEER (CIVIL)
9/6/22

WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT
PORTSMOUTH, RHODE ISLAND

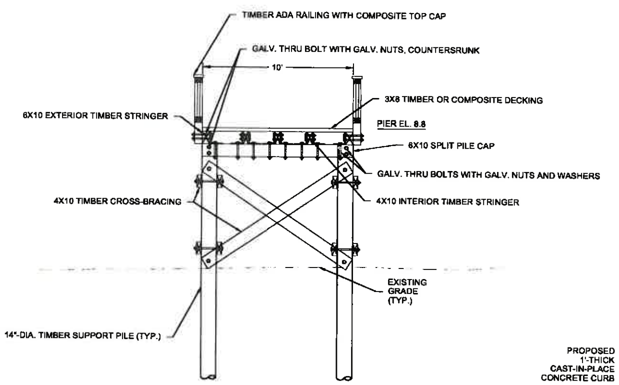
PROPOSED PROFILES

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: TOWN OF PORTSMOUTH 2200 EAST MAIN ROAD PORTSMOUTH, RHODE ISLAND	
PROJ MGR: RKT	REVIEWED BY: RJM	CHECKED BY: MJP	DRAWING
DESIGNED BY: RKT	DRAWN BY: ADD	SCALE: AS SHOWN	6
DATE: SEPTEMBER 2022	PROJECT NO. 03.0034944.00	REVISION NO. -	SHEET NO. 6 OF 8



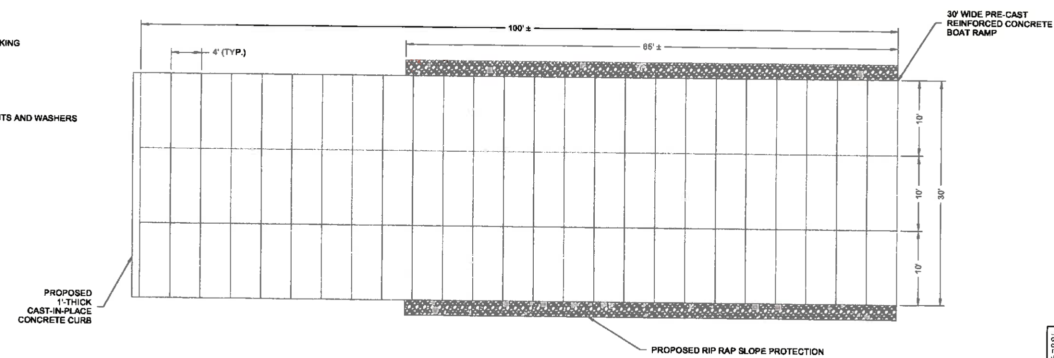
PROPOSED SECTION C-C'

SCALE 1" = 4'



PROPOSED PIER SECTION

SCALE 1" = 4'



PROPOSED RAMP DETAIL

SCALE 1" = 4'

0 5 10 20 30
SCALE IN FEET

PERMITTING ONLY
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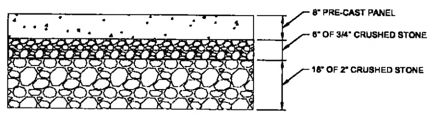
APPROVED:

RUSSELL J. MORGAN 6938 REGISTERED PROFESSIONAL ENGINEER (CIVIL)
9/6/22

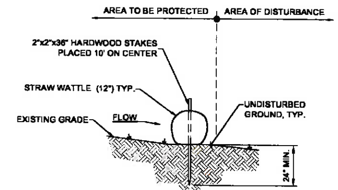
WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT
PORTSMOUTH, RHODE ISLAND

PROPOSED SECTION AND DETAILS

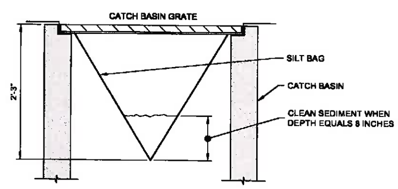
PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: TOWN OF PORTSMOUTH 2200 EAST MAIN ROAD PORTSMOUTH, RHODE ISLAND	
PROJ MGR: RKT	REVIEWED BY: RJM	CHECKED BY: MJP	DRAWING
DESIGNED BY: RKT	DRAWN BY: ADD	SCALE: AS SHOWN	7
DATE: SEPTEMBER 2022	PROJECT NO. 03.0034944.00	REVISION NO. -	SHEET NO. 7 OF 8



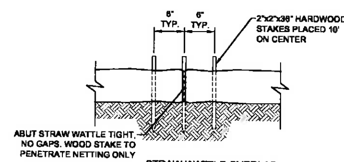
PRE-CAST RAMP SECTION
NOT TO SCALE



FILTREXX SOXX DETAIL
NOT TO SCALE



SILT SACK DETAIL
NOT TO SCALE



STRAW WATTLE OVERLAP
NOT TO SCALE

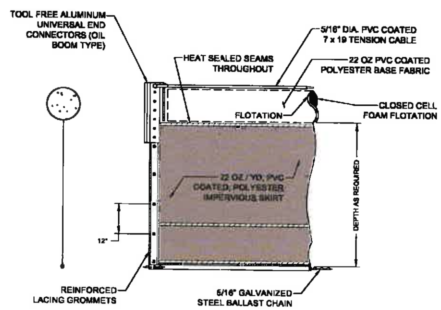
NOTES:

1. ALL MATERIAL TO MEET STRAW WATTLE SPECIFICATIONS.
2. FILTER MEDIA (TM) FILL TO MEET APPLICATION REQUIREMENTS.
3. COMPOST MATERIAL TO BE DISPERSED ON SITE AS APPROVED BY ENGINEER.

STRAW WATTLE SEDIMENT CONTROL DETAIL
NOT TO SCALE

NOTES:

1. SEDIMENT BAG INLET PROTECTION TO BE SILT SACK MANUFACTURED BY ATLANTIC CONSTRUCTION FABRICS INC. RICHMOND, VA OR APPROVED EQUAL.
2. STORMWATER CATCH BASINS OR DRAINS SHALL BE PROTECTED FROM MATERIALS RUN-OFF. CONTRACTOR SHALL SHALL INSTALL SILT SACKS WITHIN EACH CATCH BASIN IN THE VICINITY OF ANY WORK AREAS IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS. CONTRACTOR SHALL USE ALL BMP'S NECESSARY TO PROTECT THESE INLETS FROM SEDIMENT AND DEBRIS.



TURBIDITY CURTAIN
NOT TO SCALE

NOTES:

1. ANCHOR CURTAIN ENDS AT DAM FACE.
2. ANCHOR CURTAIN AT INTERMEDIATE POINTS WITH CONCRETE ANCHOR BLOCKS.

0 1 2 3
SCALE IN FEET

0 2 4 8 12
SCALE IN FEET

PERMITTING ONLY
NOT FOR CONSTRUCTION

APPROVED:

RUSSELL J. MORGAN
No. 6936
REGISTERED PROFESSIONAL ENGINEER (CIVIL)
9/6/22

WEAVER COVE BOAT RAMP AND PIER IMPROVEMENT
PORTSMOUTH, RHODE ISLAND

MISCELLANEOUS DETAILS

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: TOWN OF PORTSMOUTH 2200 EAST MAIN ROAD PORTSMOUTH, RHODE ISLAND	
PROJ MGR: RKT	REVIEWED BY: RJM	CHECKED BY: MJP	DRAWING
DESIGNED BY: RKT	DRAWN BY: AD	SCALE: AS SHOWN	8
DATE: SEPTEMBER 2022	PROJECT NO. 03.0034944.00	REVISION NO. -	SHEET NO. 8 OF 8

Appendix B

MEMORANDUM

To: Rebecca Thormann, P.E. (GZA)

From: Michael Gardner (GZA)
Daniel Stapleton, P.E. (GZA)

Date: January 24, 2022

File No.: 03.0034944.00

Re: Metocean Data Analysis
Proposed Weaver Cove Boat Ramp Improvements
Portsmouth, Rhode Island

GZA GeoEnvironmental, Inc. (GZA) completed a metocean data analysis and wave evaluation for the following project.

- Weaver Cove Boat Ramp located on the west shore of Portsmouth, Rhode Island in Narragansett Bay. See **Figures 1** and **2** for the project site location. The proposed project includes the construction of either: 1) a quarry stone sill/ breakwater; or 2) a floating dock/breakwater, to reduce wave action and sediment accretion at the Weaver Cove Boat Ramp.

This memorandum presents the results of GZA's analysis and is subject to the Limitations presented in **Attachment 1**. A glossary of terms is presented in **Attachment 2**.

PURPOSE

The purpose of GZA's metocean data analysis is to characterize the environmental conditions to be used for the project evaluation and design, specifically including:

- Bathymetry and Topography
- Wind Intensity and Direction
- Tidal Datums
- Relative Sea Level Rise
- Extreme (Coastal Storm Tide) Water Levels
- Wind-Generated Waves
- Shoreline Change

METHODOLOGY

Bathymetry and Topography

GZA developed bathymetric and topographic data for the project area based on the following.

- Lidar and Bathymetric Data available via NOAA Digital Coast
- NOAA Nautical Chart
- GZA Bathymetric Survey

The bathymetric and topographic source details are presented in **Attachment 3**.

Wind Intensity and Direction

GZA has developed wind intensity and direction for the project area for the purpose of estimating wave characteristics. GZA's wind analysis is based on statistical analysis of recorded wind data from:

- The Rhode Island T. F. Green International Airport in Warwick, Rhode Island Providence

GZA's statistical wind data are also compared with the ASCE 7-16, 3-second gust wind speeds at 10 meters elevation.

The results are presented in **Attachment 4**.

Water Levels: Tidal Datums

Prevailing water levels were established for the project area based on tidal datums form the NOAA tide station located at:

- NOAA Quonset, RI Tide Station [8454049]

Tidal datums are presented in **Attachment 5.**

Water Levels: Relative Sea Level Rise

Relative sea level rise (RSLR) projections were developed for the project area using NOAA 2017 and the USACE sea level rise tool for:

- NOAA Newport, RI Tide Station [8452660]

RSLR projections are presented in **Attachment 6**.

Water Levels: Extreme Water Levels (Coastal Storm Surge)

Extreme (coastal storm tide) water levels for multiple annual exceedance probabilities were developed for the project area based on:

- The effective FEMA Flood Insurance Study and Coastal Transect(s); and
- The USACE North Atlantic Coast Comprehensive Study (NACCS) Save Point(s).

Extreme water levels are presented in **Attachment 7**.

Wind-Generated Waves

Wind-generated waves characteristics were developed for the project site based on:

- The USACE North Atlantic Coast Comprehensive Study (NACCS) Save Point(s).
- Analytical calculation based on wind and wave fetch and methods presented in the USACE Coastal Engineering Manual. Calculation input.

Wave details are presented in **Attachment 8**.

Shoreline Change

GZA reviewed aerial photos depicting sediment change at the site. Overall, the area appears to be accreting sediment at a rate of 0.1 to 0.5 feet/ year with a sediment influx coming from a tidal marsh outflow to the south of the boat ramp.

Shoreline change details are presented in **Attachment 9**.

RESULTS

Coastal Setting

The Weaver Cove Boat Ramp is located in Narragansett Bay on the western shore of Portsmouth, Rhode Island. The project site is located on the southern end of Weaver Cove, an approximately 5,000 long by 1,300 feet deep cove. The southern end of Weaver Cove is defined by a promontory, which affects transformation of waves from the south, southwest and southeast. The Weaver Cove Boat Ramp is located directly north of Lawton Brook. Lawton Brook is a tidal estuary, with an inlet/outlet to Narragansett Bay via two bridges (railway and roadway).

The tidal outlet significantly affects alongshore sediment transport in the vicinity of the Weaver Cove Boat Ramp. Net longshore drift has not been determined as part of this study. The depth of closure was not calculated as part of this study; however, based on site bathymetry and breaking wave heights associated with coastal storms, longshore sediment transport is expected to occur predominantly within the zone between the shoreline and approximately 290 feet cross-shore.

Construction of the proposed sill/breakwater will likely affect sediment transport, shoreline change and localized scour in the vicinity of the boat ramp.

Water Levels

The mean tidal range is 3.7 feet. The MHHW is 1.87 feet NAVD88 and the MLLW is (-)2.24 feet NAVD88. Mean sea level (MSL) is (-)0.37-foot NAVD88. The highest observed and astronomical tides are 5.08 feet and 3.18 feet NAVD88, respectively.

Recommended extreme water levels (stillwater elevation) were developed for multiple recurrence intervals utilizing multiple data sources and are presented in **Table 1**.

Waves

Recommended wave heights were developed for prevailing conditions and for extreme conditions (multiple recurrence intervals) utilizing multiple data sources and are presented in **Table 2**. Waves within Narragansett Bay and in the vicinity of the Weaver Cove Boat Ramp are generally due to wind-generated waves along fetches within Narragansett Bay. The prevailing winds during the Summer months are from the south-southwest. The prevailing winds during the Winter months are from the northwest. The south-southwest wave direction has the largest exposed fetch making it the design wave direction, with waves at the breakwater approaching from the west-southwest. Waves propagating from the northwest are expected to be similar in height for higher frequency flood events (on the order of 1 to 1.5 feet for a 1-year recurrence interval) and smaller for the 100-year recurrence interval event (2 to 3 feet). 1 and 2-minute sustained wind speeds at 10-meters, utilized for GZA's wave calculation are presented in **Table 2.**

Sediment Transport

Sediment transport in particular in the vicinity of the tidal mouth outflow is expected to be a significant issue and should be considered in site design.

Additional Work

Given the complexity of sediment transport in the vicinity, additional analysis and modeling is warranted if more specific design input is required. GZA's current analysis did not consider sea level rise on the flood hazard. This can be provided if requested.

Tables

TABLE 1: RECOMMENDED EXTREME WATER LEVELS

Recurrence Event Probability	Water Level (feet, NAVD88)
Prevailing	1.6 (MHW)
1-Year	3.6 (NACCS)
2-Year	4.2 (NACCS)
5-Year	5.0 (NACCS)
10-Year	5.8 (FEMA)
50-Year	9.1 (FEMA)
100-Year	11.5 (FEMA)

TABLE 2: RECOMMENDED DESIGN WAVE CONDITIONS

Recurrence Event Probability	GZA 1-minute Wind Speed (SSW, mph)	Significant Wave Height (Hs, feet)	Max 10% of Wave Heights* (H_{10}, feet)	Maximum Wave Height* (H_{max}, feet)	Design Wave Period (seconds)	NACCS Point 10256 Significant Wave Height (feet)
Prevailing	14	0.9	1.1	1.7	1.8	N/A
1-Year	25	1.7	2.2	3.2	2.3	2.6
2-Year	33	2.3	2.9	4.1	2.5	3.1
5-Year	40	2.9	3.7	4.7	2.7	3.6
10-Year	45	3.3	4.2	5.3	2.9	3.9
50-Year	59	4.6	5.8	7.8	3.2	4.6
100-Year	66	5.2	6.6	9.8	3.3	4.8

*Calculated using: H_{10} = 1.27*Hs; H_{max} = 1.86*Hs; or as a depth limited, breaking wave (Hb) = 0.78*depth

Figures

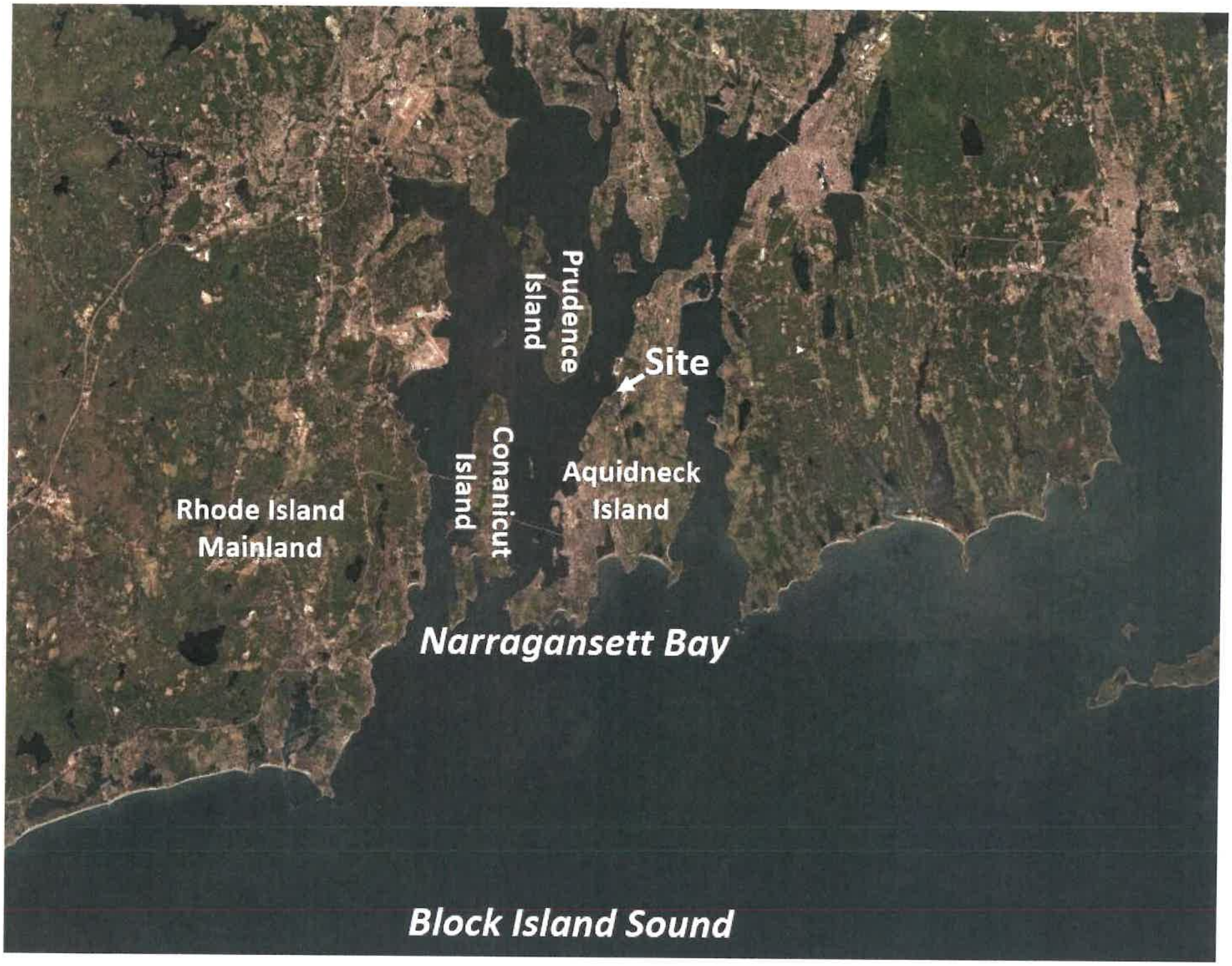


Figure 1: Site Locus

Figure 2: Site Locus

Attachment 1
Limitations

USE OF REPORT

1. GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of the Client for the stated purpose(s) and location(s) identified in the Report. Use of this Report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not identified in the agreement, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

STANDARD OF CARE

2. Our findings and conclusions are based on the work conducted as part of the Scope of Services set forth in the Report and/or proposal and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. Conditions other than described in this report may be found at the subject location(s).

3. The interpretations and conclusions presented in the Report were based solely upon the services described therein, and not on scientific tasks or procedures beyond the scope of the described services. The work described in this report was carried out in accordance with the agreed upon Terms and Conditions of Engagement.

4. GZA's metocean data analysis and wave evaluation were performed in accordance with generally accepted practices of qualified professionals performing the same type of services at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made. The findings of the risk characterization are dependent on numerous assumptions and uncertainties inherent in the risk assessment process. The findings of the flood evaluation are not an absolute characterization of actual risks, but rather serve to highlight potential sources of risk at the site(s).

5. Unless specifically stated otherwise, the flood evaluations performed by GZA and associated results and conclusions are based upon evaluation of historic data, trends, references, and guidance with respect to the current climate and sea level conditions. Future climate change may result in alterations to inputs which influence flooding at the site (e.g. rainfall totals, storm intensities, mean sea level, etc.). Such changes may have implications on the estimated flood elevations, wave heights, flood frequencies and/or other parameters contained in this report.

RELIANCE ON INFORMATION FROM OTHERS

6. In conducting our work, GZA has relied upon certain information made available by public agencies, Client and/or others. GZA did not attempt to independently verify the accuracy or completeness of that information. Any inconsistencies in this information which we have noted are discussed in the Report.

COMPLIANCE WITH CODES AND REGULATIONS

7. We used reasonable care in identifying and interpreting applicable codes and regulations necessary to execute our scope of work. These codes and regulations are subject to various, and possibly contradictory, interpretations. Interpretations with codes and regulations by other parties are beyond our control.

ADDITIONAL INFORMATION

8. In the event that the Client or others authorized to use this report obtain information on conditions at the site(s) not contained in this report, such information shall be brought to GZA's attention forthwith. GZA will evaluate such information and, on the basis of this evaluation, may modify the opinions stated in this report.

9. The Phase I study was performed using the NOAA SLOSH model, which has limited model resolution in the site vicinity. Additional analyses are required to refine the flood-frequency curves at the project site(s) and to include wave effects and to define flood hydrographs and flow velocities.

ADDITIONAL SERVICES

10. GZA recommends that we be retained to provide services during any future investigations, design, implementation activities, construction, and/or property development/ redevelopment at the Site. This will allow us the opportunity

to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.

Attachment 2
Glossary of Terms and Notation

BASE FLOOD

A flood having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the "100-year flood." The base flood is the national standard used by the National Flood Insurance Program (NFIP) and all Federal agencies for the purposes of requiring the purchase of flood insurance and regulating new development. Base Flood Elevations (BFEs) are typically shown on Flood Insurance Rate Maps (FIRMs).

BASE FLOOD ELEVATION (BFE)

The elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year. The BFE is shown on the Flood Insurance Rate Map (FIRM) for zones AE, AH, A1–A30, AR, AR/A, AR/AE, AR/A1– A30, AR/AH, AR/AO, V1–V30 and VE.

COASTAL HIGH HAZARD AREAS

Special Flood Hazard Areas (SFHAs) along the coasts that have additional hazards due to wind and wave action. These areas are identified on Flood Insurance Rate Maps (FIRMs) as zones V, V1-V30 and VE.

HIGHEST ASTRONOMICAL TIDE (HAT)

The elevation of the highest predicted astronomical tide expected to occur at a specific tide station over the National Tidal Datum Epoch.

MEAN HIGHER HIGH WATER (MHHW*)

The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.

MEAN HIGH WATER (MHW)

The average of all the high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.

DIURNAL TIDE LEVEL (DTL)

The arithmetic mean of mean higher high water and mean lower low water.

MEAN TIDE LEVEL (MTL)

The arithmetic mean of mean high water and mean low water.

MEAN SEA LEVEL (MSL)

The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch. Shorter series are specified in the name; e.g. monthly mean sea level and yearly mean sea level.

MEAN LOW WATER (MLW)

The average of all the low water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.

MEAN LOWER LOW WATER (MLLW*)

The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.

LOWEST ASTRONOMICAL TIDE (LAT)

The elevation of the lowest astronomical predicted tide expected to occur at a specific tide station over the National Tidal Datum Epoch.

GREAT DIURNAL RANGE (GT)

The difference in height between mean higher high water and mean lower low water.

MEAN RANGE OF TIDE (MN)

The difference in height between mean high water and mean low water.

MEAN DIURNAL HIGH WATER INEQUALITY (DHQ)

One-half the average difference between the two high waters of each tidal day observed over the National Tidal Datum Epoch. It is obtained by subtracting the mean of all the high waters from the mean of the higher high waters.

MEAN DIURNAL LOW WATER INEQUALITY (DLQ)

One-half the average difference between the two low waters of each tidal day observed over the National Tidal Datum Epoch. It is obtained by subtracting the mean of the lower low waters from the mean of all the low waters.

GREENWICH HIGH WATER INTERVAL (HWI)

The average interval (in hours) between the moon's transit over the Greenwich meridian and the following high water at a location.

GREENWICH LOW WATER INTERVAL (LWI)

The average interval (in hours) between the moon's transit over the Greenwich meridian and the following low water at a location.

MAX TIDE

Highest Observed Tide

The maximum height reached by a rising tide. The high water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions.

MIN TIDE

Lowest Observed Tide

The minimum height reached by a falling tide. The low water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions.

STATION DATUM

A fixed base elevation at a tide station to which all water level measurements are referred. The datum is unique to each station and is established at a lower elevation than the water is ever expected to reach. It is referenced to the primary bench mark at the station and is held constant regardless of changes to the water level gauge or tide staff. The datum of tabulation is most often at the zero of the first tide staff installed.

NATIONAL TIDAL DATUM EPOCH

The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years. Tidal datums in certain regions with anomalous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch.

Attachment 3
Bathymetry and Topography

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NOAA DIGITAL COAST DATA DIGITAL ELEVATION MODEL (DEM)

The NOAA Data Access Viewer (DAV) was used to establish bathymetry and topography for the project area. The NOAA DAV is a national repository for available elevation (LiDAR), imagery and land cover data for the coastal U.S. and its territories. The data, hosted by the NOAA Office for Coastal Management, is customized to a selected area and provided as a downloadable a csv file. GZA converted the data to a topobathymetric digital elevation model (TBDEM)., expressing elevations relative to the NAVD88 datum. The specific data sources used by GZA to create the DEM include:

- The USGS Coastal National Elevation Database (CoNED) Applications Project. The CoNED Project integrates disparate light detection and ranging (LiDAR) and bathymetric data sources into a common database aligned both vertically and horizontally to a common reference system. Database attributes include:
    - Data Source: Raster Digital Elevation Model
    - Note: Composite data set of the best available high-resolution elevation through 2016. Accuracy is spatially variable.
    - Cell size (m): 1.00
    - Vertical Accuracy (cm): 50 - Not tested
    - Vertical Datum: NAVD88
    - Tide controlled: No

Attachment 3 Figure 1 presents the TBDEM for the project area.

NOAA NAUTICAL CHART

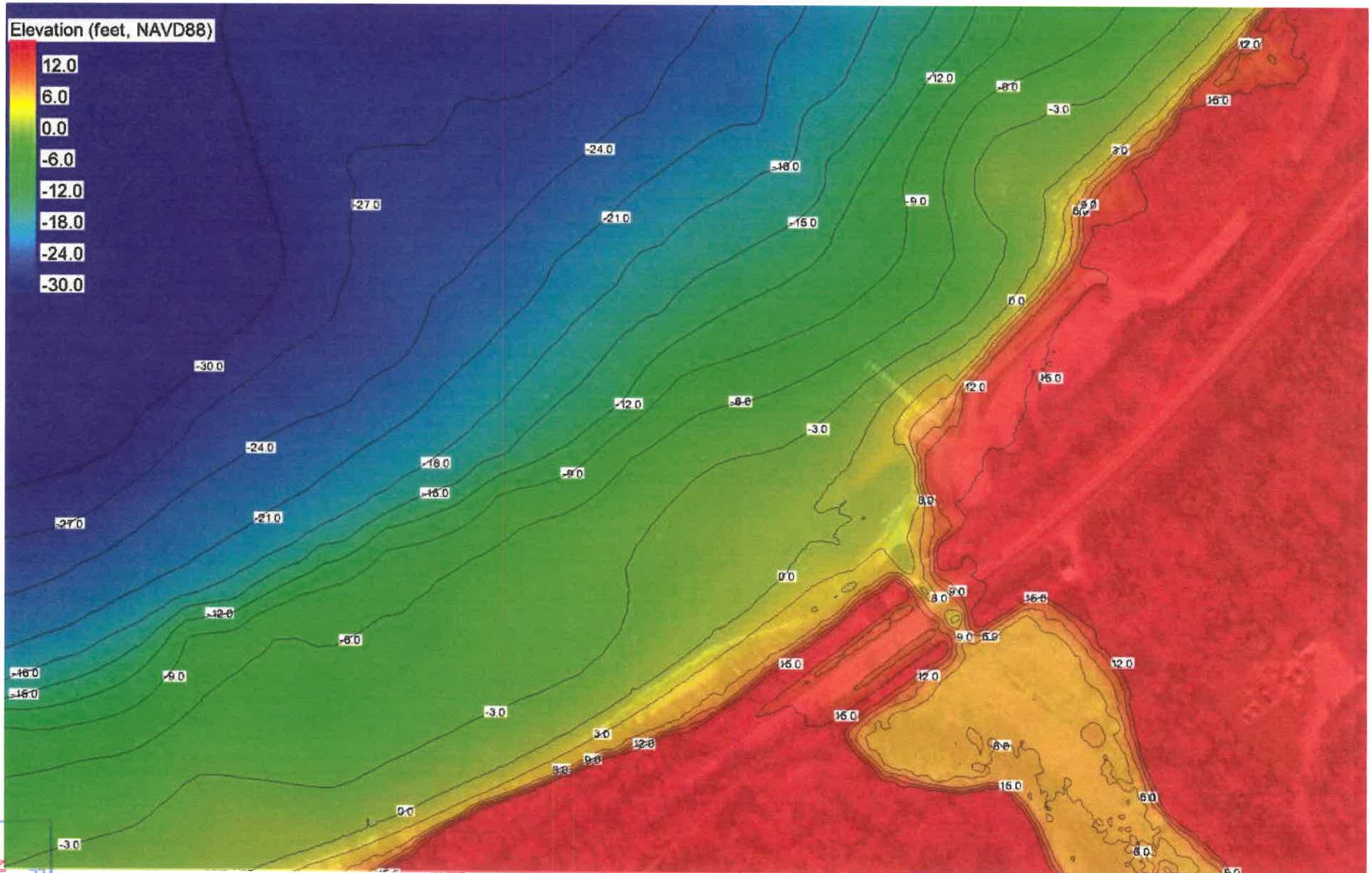
Additional bathymetric data is indicated on the NOAA Navigation Chart for the site vicinity, indicated depth in feet below the Mean Lower Low Water (MLLW) datum.

NOAA's Office of Coast Survey maintains the nation's nautical charts and publications for U.S. coasts and the Great Lakes. They use hydrographic surveys to collect depth measurements for nautical charts to provide safe and efficient navigation.

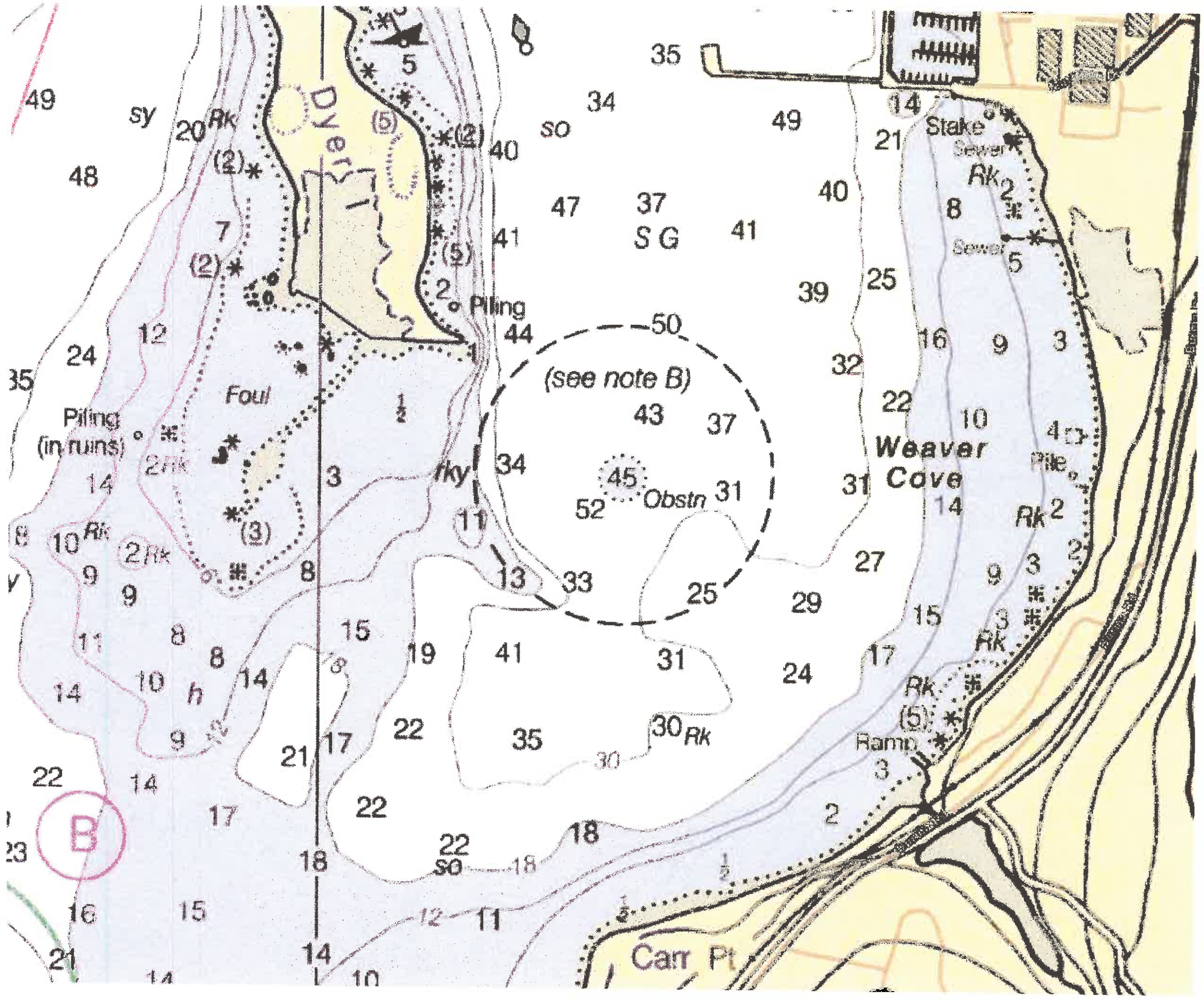
Attachment 3 Figure 2 presents the NOAA Nautical Chart segment for the project area.

GZA BATHMEYRIC SURVEY

GZA completed a bathymetric survey of the project area. The details are presented elsewhere. Bathymetry is presented on GZA's **Attachment 3 Figure 1**.



Attachment 3 Figure 1: Topobathymetric Digital Elevation Model (TBDEM) for the Project Area. Relative to NAVD88 datum in feet.



Attachment 3 Figure 2: NOAA Nautical Chart for the Project Area. Relative to MLLW datum in feet.

Attachment 4
Wind Characteristics

GZA WIND ANALYSIS

PVD Wind Data Summary

Hourly wind data at the T. F. Green Airport was downloaded from the National Centers for Environmental Information (NCEI). The record covers 1942, 1943 and 1948 through present, a total of 74 years, from two separate datasets provided by NCDC.

USAF-WBAN ID	Station Name	Lat (deg)	Long (deg)	Elevation (ft)	Period of Record
725070-14765	Theodore F Green State Airport	41.722	-71.433	18.3	1942, 1943, 1973 through present
999999-14765	Providence T F Green ARPT	41.722	-71.433	18.9	1948 through 1972

GZA Evaluation (Updated 08/2019):

GZA compiled and analyzed wind data from the T.F. Green Airport (PVD). GZA conducted statistical analysis of the wind data representing both the prevailing and extreme conditions. The data source is: NOAA's National Centers for Environmental Information (formerly the National Climatic Data Center (NCDC), data accessible at https://www.ncdc.noaa.gov/). The available wind record at T. F. Green International Airport (PVD) includes a 74-year record (1942, 1943, and 1948 – 2019) of hourly wind data of speed and direction (10-meter, 1 and 2-minute averaging duration).

The wind information includes:

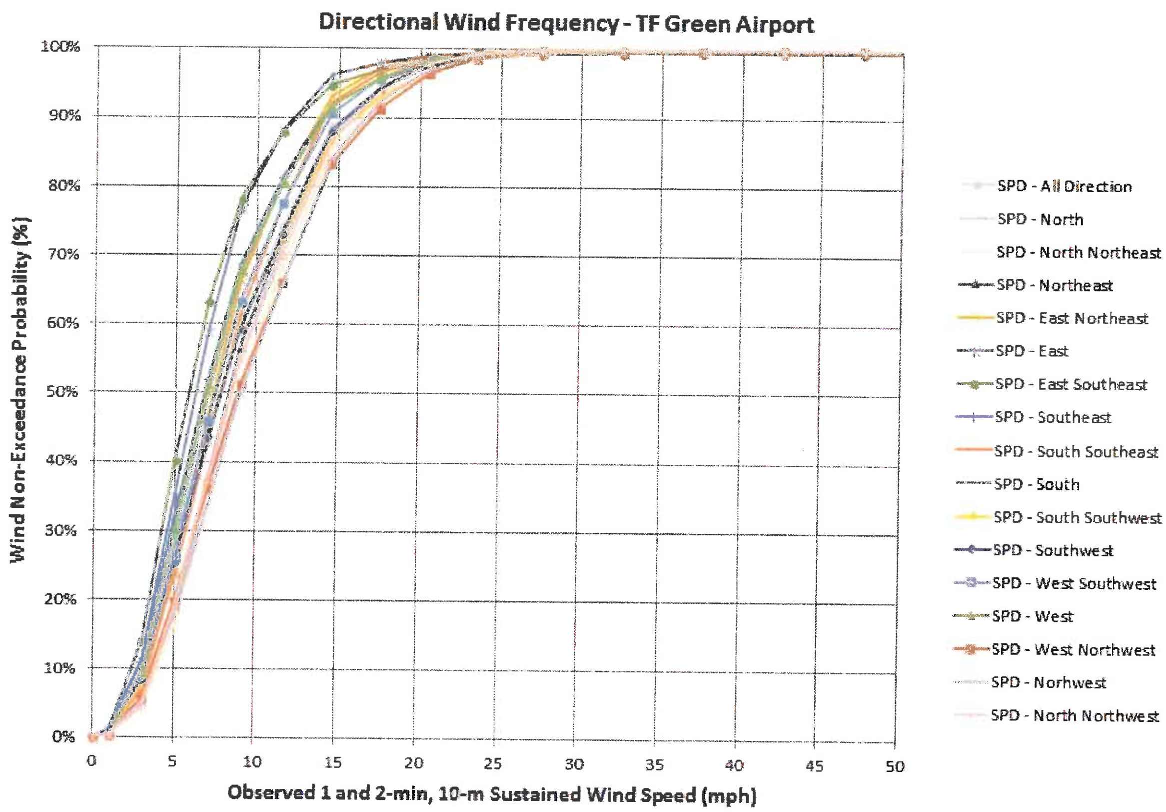
- Prevailing Winds: The prevailing wind is the wind that blows most frequently across a particular region. Specifically, it is the dominant, non-storm wind that blows most frequently across a particular region. GZA's prevailing wind figure indicates the 1 and 2-minute, 10-meter sustained wind speed cumulative non-exceedance probability (in percent and miles per hour) of the complete wind dataset, analyzed by 22.5-degree directional bins and cumulatively for all directions. Directions are presented as clockwise from true north and indicate the direction from which the winds blow.
- Wind Roses: A wind rose is a graphic tool that presents a succinct view of how wind speed and direction are typically distributed at a particular location. Presented in a circular format, the wind rose shows the frequency of winds blowing from particular directions over a specified period. The length of each "spoke" around the circle is related to the frequency that the wind blows from a particular direction per unit time. Each concentric circle represents a different frequency, emanating from zero at the center to increasing frequencies at the outer circles. Wind roses typically use 16 cardinal directions, such as north (N), NNE, NE, etc., although they may be subdivided into as many as 32 directions. In terms of angle measurement in degrees, North corresponds to 0°/360°, East to 90°, South to 180° and West to 270°. The information presented includes: 1) the entire wind data set; 2) seasonally-binned wind data (i.e., spring, summer, fall, winter); and 3) intensity-binned wind data (six categories of magnitude from winds 0-10 mph to winds greater than 50 mph). The results presented include the 1 and 2-minute, 10-meter sustained wind speed in mph.
- Extreme Winds: Extreme Winds include those wind events that exceed typical prevailing winds and are typically associated with tropical depressions and cyclones, extratropical cyclones such as Nor'easters and convective and non-convective events including tornados and thunderstorms. GZA performed statistical analysis of the observed 1 and 2-minute, 10-meter sustained monthly maximum wind data extracted from the data set, using the Generalized Extreme Value (GEV) distribution and the MathWorks© software (MATLAB). The three cases covered by the GEV distribution are often referred to as the Types I, II, and III. Each type corresponds to the limiting

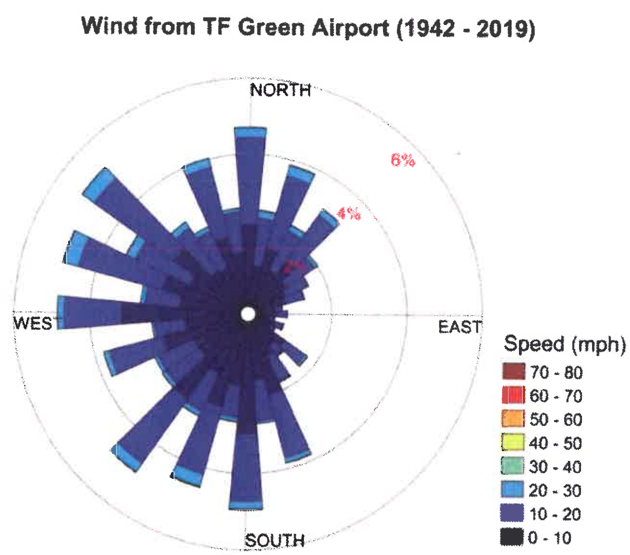
distribution of block maxima from a different class of underlying distributions. Statistical analyses were performed for the complete wind dataset for all-direction and for eight directional 45-degree data bins (i.e., North, Northeast, East, Southeast, South Southwest, West, and Northwest). GZA's Extreme Wind Frequency results include the Best Fit of the 1 and 2-minute, 10-meter sustained wind speed annual exceedance probability (in terms of recurrence interval in years and wind speed in miles per hour). Directions are presented as clockwise from true north and indicate the direction from which the winds blow.

Limitations

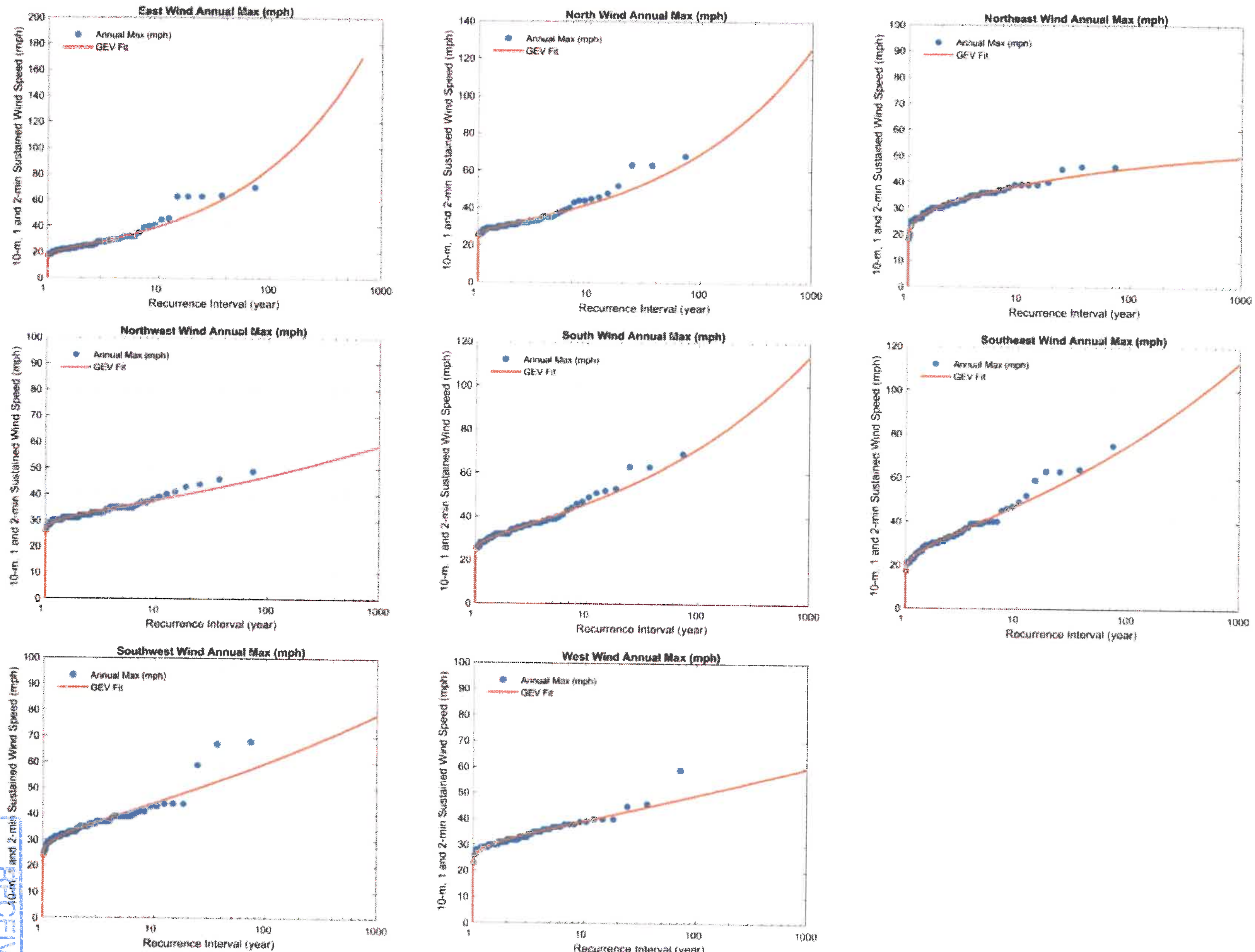
The period of record does not include certain significant wind events (e.g., the Hurricane of '38), which inclusion may significantly influence the statistical analysis. Wind speed recommendations presented in ASCE 7 should be reviewed and compared for consistency. The limited data set analyzed in the directional wind analysis may result in significant analysis uncertainty. The selection of wind speeds for design is based on available data and engineering judgement.

More detailed, directional wind analyses that is based on locally observed wind data are recommended for final design.

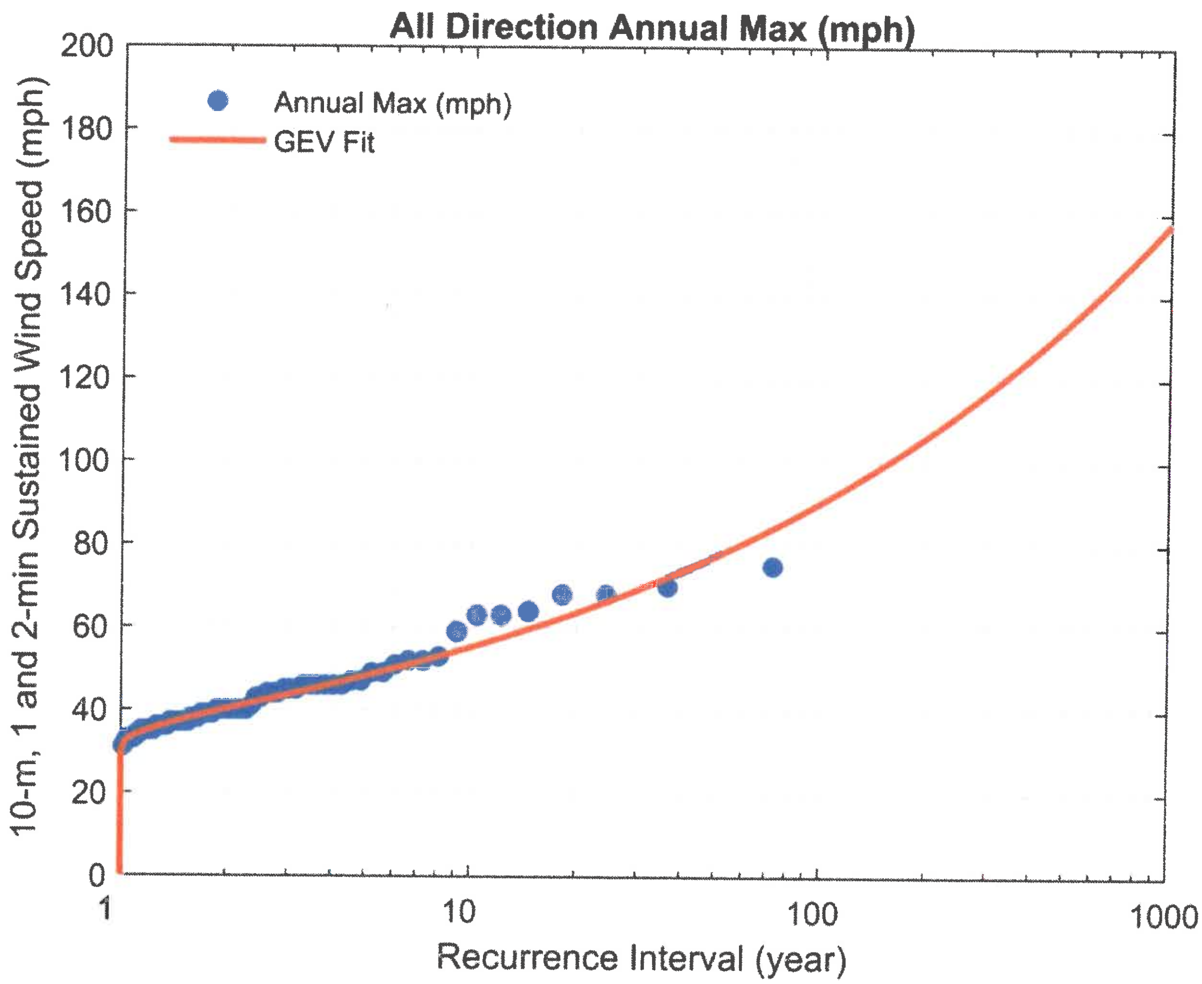




Attachment 4 Figure 1: Prevailing Winds based on GZA Statistical Analysis



Attachment 4 Figure 2: Directional Extreme Wind Intensity based on GZA Statistical Analysis



Attachment 4 Figure 3: All-Direction Extreme Wind Intensity based on GZA Statistical Analysis

ASCE 7-16

ASCE 7-16 3-second gust wind speeds at 10 meters elevation were utilized as a comparison with GZA wind data to verify GZA's statistical wind analysis results. ASCE 7 winds represent the ultimate wind speed factored for allowable stress design over an ASCE Exposure C terrain scenario (roughly open terrain). The ASCE 7-16 3-second gusts were adjusted to overwater exposure wind speeds, for time averaging (duration required for the wave to be fetch-limited over the transects evaluated) and for fetch characteristics in accordance with the USACE Coastal Engineering Manual (CEM) Part II. The ASCE 7-16 3-second gust wind speed at 10 meters for the 100-year recurrence interval wind event is 107 mph. This value is based on linear interpolation between contours in accordance with the 7-16 Standard. The site is located in a predominantly hurricane prone region as defined in ASCE/SEI 7-16 Section 26.2 (Data Source: ASCE/SEI 7-16, Fig. 26.5-1A and Figs. CC.2-1–CC.2-4, and Section 26.5.2).

Wind Details

Wind Speed	119 Vmph
10-year MRI	76 Vmph
25-year MRI	88 Vmph
50-year MRI	101 Vmph
100-year MRI	107 Vmph

For comparison with the GZA airport wind analysis, the ASCE wind was converted to the 1-2-minute wind using the World Meteorological Organization (WMO) guidelines presented in the table below for an In-Land, Roughly open terrain exposure scenario. The ASCE 100-year wind for a 1- and 2-minute reference period is 72 and 69 mph, respectively. This is generally consistent with the observed wind speeds at the 100-year recurrence interval, analyzed form the airport data.

Exposure at +10 m		Reference Period	Gust Factor G_{τ,T_o}				
			Gust Duration τ (s)				
Class	Description	T_o (s)	*3*	*60*	*120*	*180*	*600*
In-Land	Roughly open terrain	3600	1.75	1.28	1.19	1.15	1.08
		600	1.66	1.21	1.12	1.09	1.00
		180	1.58	1.15	1.07	1.00	
		120	1.55	1.13	1.00		
		60	1.49	1.00			
Off-Land	Offshore winds at a coastline	3600	1.60	1.22	1.15	1.12	1.06
		600	1.52	1.16	1.09	1.06	1.00
		180	1.44	1.10	1.04	1.00	
		120	1.42	1.08	1.00		
		60	1.36	1.00			
Off-Sea	Onshore winds at a coastline	3600	1.45	1.17	1.11	1.09	1.05
		600	1.38	1.11	1.05	1.03	1.00
		180	1.31	1.05	1.00	1.00	
		120	1.28	1.03	1.00		
		60	1.23	1.00			
At-Sea	> 20 km offshore	3600	1.30	1.11	1.07	1.06	1.03
		600	1.23	1.05	1.02	1.00	1.00
		180	1.17	1.00	1.00	1.00	
		120	1.15	1.00	1.00		
		60	1.11	1.00			

Attachment 5
Tidal Datums

NOAA TIDAL STATION DATUMS

NOAA's Tides and Currents website, developed and supported by the Center for Operational Oceanographic Products and Services (CO-OPS)

NOAA tidal datums are local datums referenced to fixed points (known as benchmarks). The present National Tidal Datum Epoch is from 1983-2001. The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years. Tidal datums in certain regions with anomalous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch. Tidal datums descriptions are presented in **Attachment 2**.

Tidal datums that are applicable to the project area were developed for the following NOAA tide station:

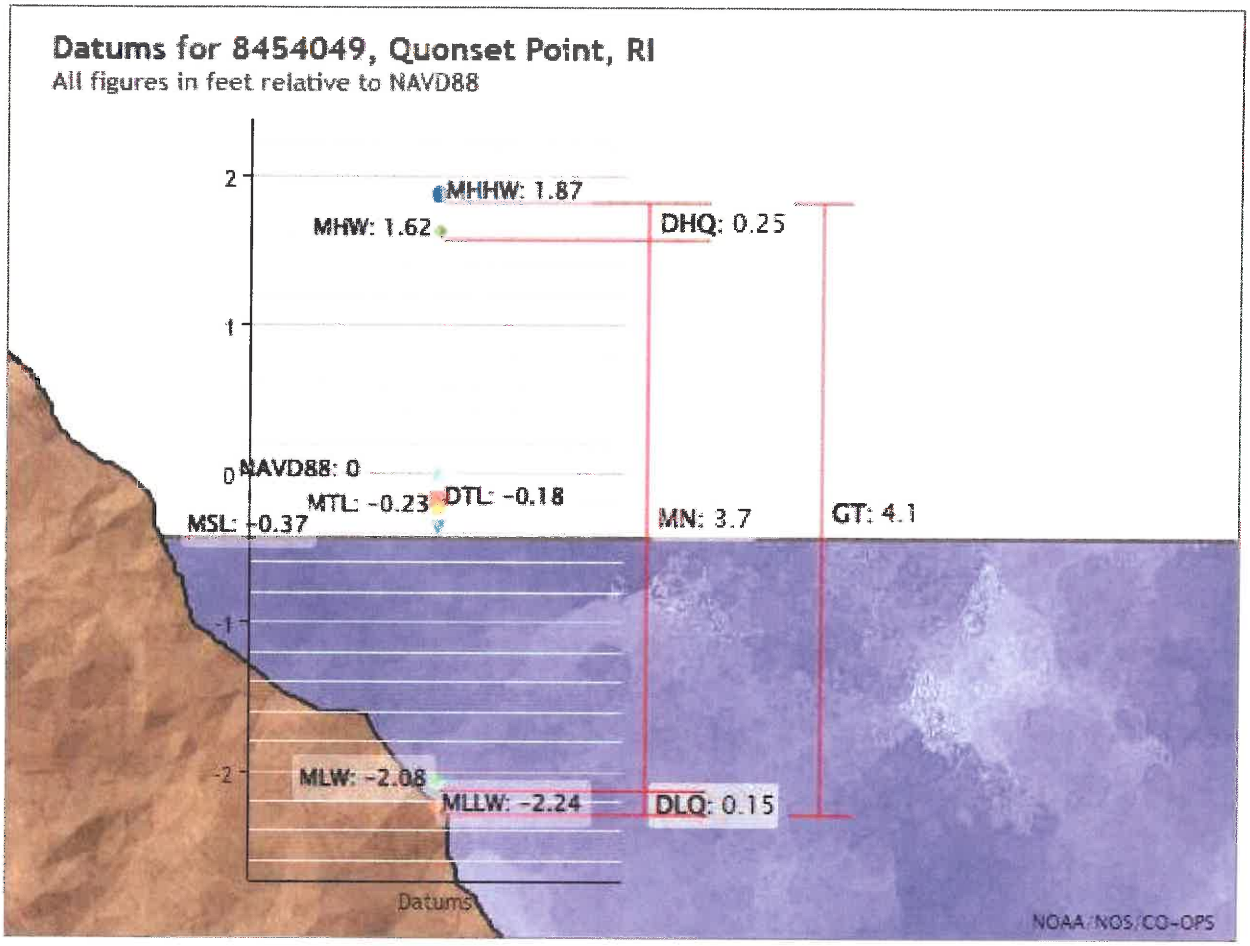
- The NOAA Quonset, RI tide station (845049), Location in **Attachment 5 Figure 2**

Elevations on NAVD88

Station: 8454049, Quonset Point, RI
Status: Accepted (May 22 2020)
Units: Feet
Control Station: 8452660 Newport, RI

T.M.: 75
Epoch: 1983-2001
Datum: NAVD88

Datum	Value	Description
MHHW	1.87	Mean Higher-High Water
MHW	1.62	Mean High Water
MTL	-0.23	Mean Tide Level
MSL	-0.37	Mean Sea Level
DTL	-0.18	Mean Diurnal Tide Level
MLW	-2.08	Mean Low Water
MLLW	-2.24	Mean Lower-Low Water
NAVD88	0.00	North American Vertical Datum of 1988
STND	-25.25	Station Datum
GT	4.10	Great Diurnal Range
MN	3.70	Mean Range of Tide
DHQ	0.25	Mean Diurnal High Water Inequality
DLQ	0.15	Mean Diurnal Low Water Inequality
HWI	0.37	Greenwich High Water Interval (in hours)
LWI	5.88	Greenwich Low Water Interval (in hours)
Max Tide	5.08	Highest Observed Tide
Max Tide Date & Time	04/16/2007 11:12	Highest Observed Tide Date & Time
Min Tide	-4.96	Lowest Observed Tide
Min Tide Date & Time	02/11/2001 21:06	Lowest Observed Tide Date & Time
HAT	3.18	Highest Astronomical Tide
HAT Date & Time	10/16/1993 12:54	HAT Date and Time
LAT	-3.27	Lowest Astronomical Tide
LAT Date & Time	03/09/1993 06:36	LAT Date and Time



Attachment 5 Figure 1: Tidal Datums - NOAA Station 8454049, Quonset Point

Attachment 5 Figure 2: NOAA Station 8454049, Quonset Point, RI (North); NOAA Station 8452660, Newport, RI (South)

Attachment 6
Relative Sea Level Rise

RELATIVE SEA LEVEL RISE

Observed Relative Sea Level Rise

NOAA has observed and recorded the rate of mean sea level rise or fall has been determined for 117 long-term water level stations. Monthly mean sea level data were used to obtain the linear trend, the average seasonal cycle, and the interannual variations. The linear trend at a coastal location is primarily a combination of the global sea-level rise and any local vertical land movement. The seasonal cycle and interannual variations are caused by fluctuations in coastal ocean temperatures, salinities, winds, atmospheric pressures, and currents. The interannual variations for many Pacific stations are closely related to the El Nino/Southern Oscillation. Assuming no change in trend, the time series of interannual variations are extended up to the latest month, and maps are created to show the regional extent of anomalously high or low water levels.

Observed RSLR from the following NOAA tide station is applicable to the project area:

- NOAA Newport, Rhode Island Tide Station (8452660)

Graphed observed RSLR are presented in **Attachment 6 Figure 1**.

Projected Future Relative Sea Level Rise

The National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) developed global and regional sea level rise scenarios, presented in NOAA Technical Report NOS CO-OPS 083 " Global and Regional Sea Level Rise Scenarios for the United States". The report articulates the linkages between scenario-based and probabilistic projections of future sea levels for coastal-risk planning and management of long-lived critical infrastructure.

During 2015 to 2018, the Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force, jointly convened by the U.S. Global Change Research Program (USGCRP) and the National Ocean Council (NOC): 1) updated scenarios of global mean sea level (GMSL) rise; 2) integrated the global scenarios with regional factors contributing to sea level change for the entire U.S. coastline; and 3) incorporated these regionally appropriate scenarios within coastal risk management tools and capabilities deployed by individual agencies in support of the needs of specific stakeholder groups and user communities. Gridded relative sea level (RSLR), which includes both ocean-level change and vertical land motion) projections for the United States associated with an updated set of GMSL scenarios were produced.

GMSL rise and associated RSL change were quantified from the year 2000 through the year 2200 (on a decadal basis to 2100 and with lower temporal frequency between 2100 and 2200). The 0.3 m-2.5 m GMSL range for 2100 was discretized by 0.5-m increments and aligned with emissions-based, conditional probabilistic storylines and global model projections into six GMSL rise scenarios: a Low, Intermediate-Low, Intermediate, Intermediate-High, High and Extreme, which correspond to GMSL rise of 0.3 m, 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m, respectively. These GMSL rise scenarios were used to derive regional RSL responses on a 1-degree grid covering the coastlines of the U.S. mainland, Alaska, Hawaii, the Caribbean, and the Pacific Island territories, as well as at the precise locations of tide gauges along these coastlines. GMSL was adjusted to account for key factors important at regional scales, including: 1) shifts in oceanographic factors such as circulation patterns; 2) changes in the Earth's gravitational field and rotation, and the flexure of the crust and upper mantle, due to melting of land-based ice; and 3) vertical land movement (VLM; subsidence or uplift) due to glacial isostatic adjustment (GIA, which also changes Earth's gravitational field and rotation, as well as the overall shape of the ocean basin), sediment compaction, groundwater and fossil fuel withdrawals, and other non-climatic factors.

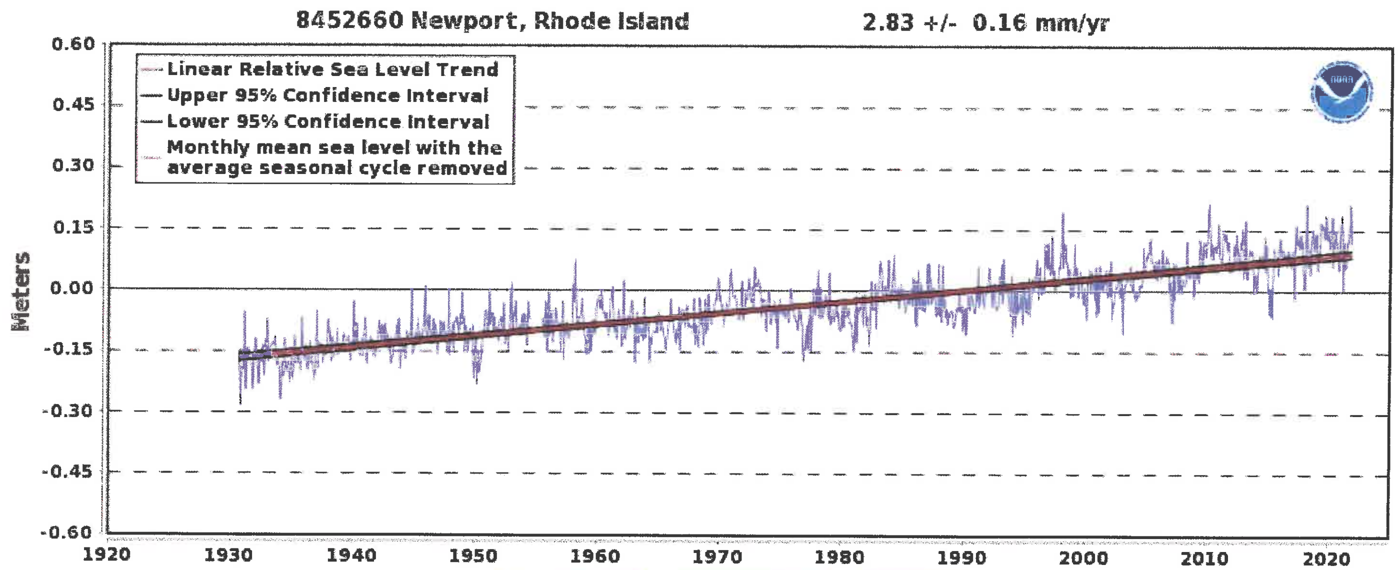
The "2017 US Global Change Research Program" RSLR projections (NOAA 2017) are available for NOAA tide stations using the USACE Sea Level Calculator. The Sea Level Rise Calculator provides a way to visualize the USACE and other authoritative sea level rise scenarios for any tide gauge that is part of the NOAA National Water Level Observation Network (NWLON).

RSLR projections were developed for the project using the USACE Sea Level Rise Calculator and NOAA 2017 projections for the following NOAA tide station:

- NOAA Newport, Rhode Island Tide Station (845260)

Tabulated and graphed projections are presented in **Attachment 6 Figure 2**.

Relative Sea Level Trend
8452660 Newport, Rhode Island



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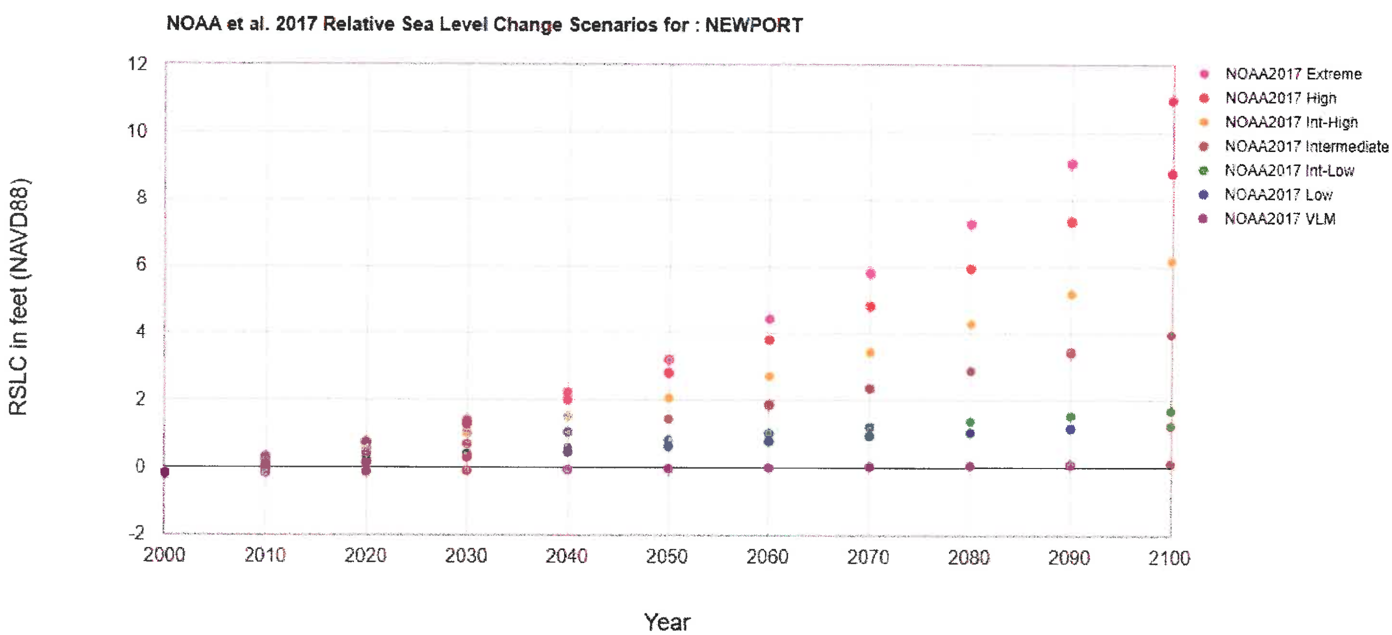
The relative sea level trend is 2.83 millimeters/year with a 95% confidence interval of +/- 0.16 mm/yr based on monthly mean sea level data from 1930 to 2020 which is equivalent to a change of 0.93 feet in 100 years.

Attachment 6 Figure 1: Observed Relative Sea Level Rise Projections based on NOAA Newport, RI Tide Station

Scenarios for NEWPORT
NOAA2017 VLM: 0.00322 feet/yr
All values are expressed in feet

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
2000	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
2010	-0.17	-0.04	-0.00	0.10	0.19	0.26	0.29
2020	-0.14	0.13	0.19	0.39	0.55	0.75	0.72
2030	-0.10	0.29	0.39	0.69	1.01	1.28	1.38
2040	-0.07	0.46	0.59	1.05	1.51	2.00	2.23
2050	-0.04	0.62	0.82	1.44	2.06	2.82	3.21
2060	-0.01	0.78	1.01	1.87	2.72	3.80	4.43
2070	0.03	0.95	1.21	2.36	3.44	4.82	5.80
2080	0.06	1.05	1.38	2.88	4.30	5.94	7.28
2090	0.09	1.18	1.54	3.44	5.18	7.35	9.09
2100	0.12	1.24	1.70	3.97	6.17	8.79	10.96



Attachment 6 Figure 1: Relative Sea Level Rise Projections based on NOAA 2017 Scenarios

Attachment 7
Extreme Water Levels

NOAA TIDAL STATION EXTREME WATER LEVELS

NOAA provides exceedance probability statistics on extreme water levels, including annual and monthly exceedance probability levels for select CO-OPS water level stations with at least 30 years of data. When used in conjunction with real time station data, exceedance probability levels can be used to evaluate current conditions and determine whether a rare event is occurring. This information may also be instrumental in planning for the possibility of dangerously high or low water events at a local level. The NOAA Technical Report, "Extreme Water Levels of the United States 1893-2010" describes the methods and data used in the calculation of the exceedance probability levels.

The extreme levels measured by the CO-OPS tide gauges during storms are called storm tides, which are a combination of the astronomical tide, the storm surge, and limited wave setup caused by breaking waves. They do not include wave runup, the movement of water up a slope. Therefore, the 1% annual exceedance probability levels shown here do not necessarily correspond to the Base Flood Elevations (BFE) defined by the Federal Emergency Management Administration (FEMA). The 1% annual exceedance probability levels on this website more closely correspond to stillwater elevations (SWEL) developed by FEMA and the USACE NACCS. The peak levels from tsunamis, which can cause high-frequency fluctuations at some locations, have not been included in this statistical analysis due to their infrequency during the periods of historic record.

Attachment 7 Figure 1 presents NOAA annual exceedance probability curves with 95% confidence intervals indicating the highest water levels as a function of return period in years. The dots indicate the annual highest or lowest water levels after the Mean Sea Level trend was removed, which were used to calculate the curves. The levels are in meters relative to the MHHW datums established by CO-OPS (1 foot = 0.3 meters). The horizontal position of the rightmost dot indicates the number of years of data used in the calculation.

NOAA also provides a listing of the Top Ten Highest Water Levels at 110 long-term stations as a table in meters or a table in feet above MHHW. No adjustment has been made for the rates of sea level rise or fall at each station. An inferred level indicates that missing data at the peak water level were filled in. A high-water mark is a physical mark near the station that can indicate the maximum elevation of a storm event. See **Attachment 7 Table 1.**

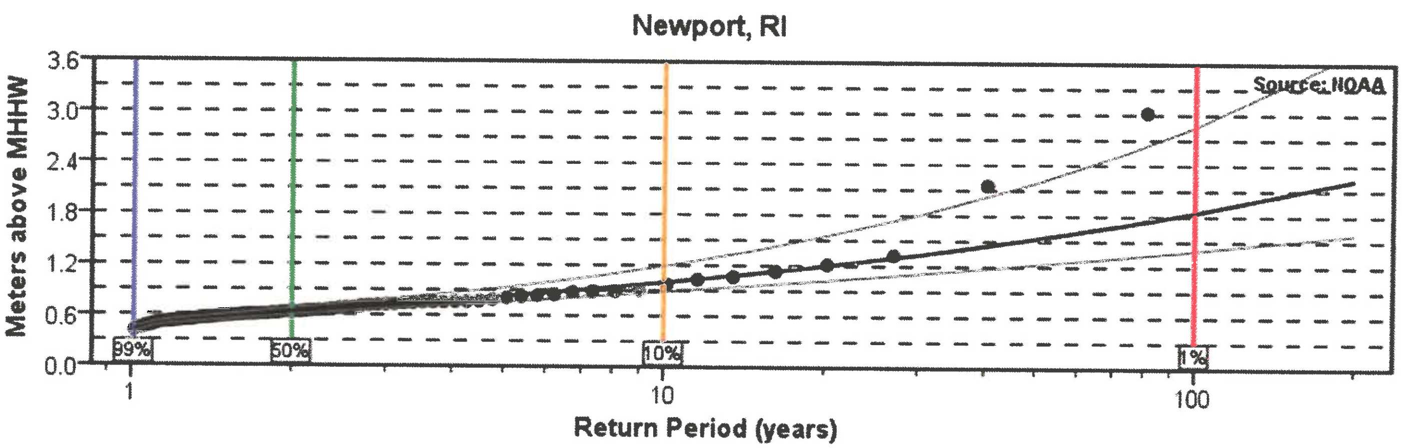
Attachment 7 Figure 2 presents plots showing the monthly highest and lowest water levels with the 1%, 10%, 50%, and 99% annual exceedance probability levels in red, orange, green, and blue. The plotted values are in meters relative to the MHHW datum established by CO-OPS (1 foot = 0.3 meters). On average, the 1% level (red) will be exceeded in only one year per century, the 10% level (orange) will be exceeded in ten years per century, and the 50% level (green) will be exceeded in fifty years per century. The 99% level (blue) will be exceeded in all but one year per century, although it could be exceeded more than once in other years.

Top Ten Highest Water Levels for long-term stations in feet above MHHW (as of 4/2018)

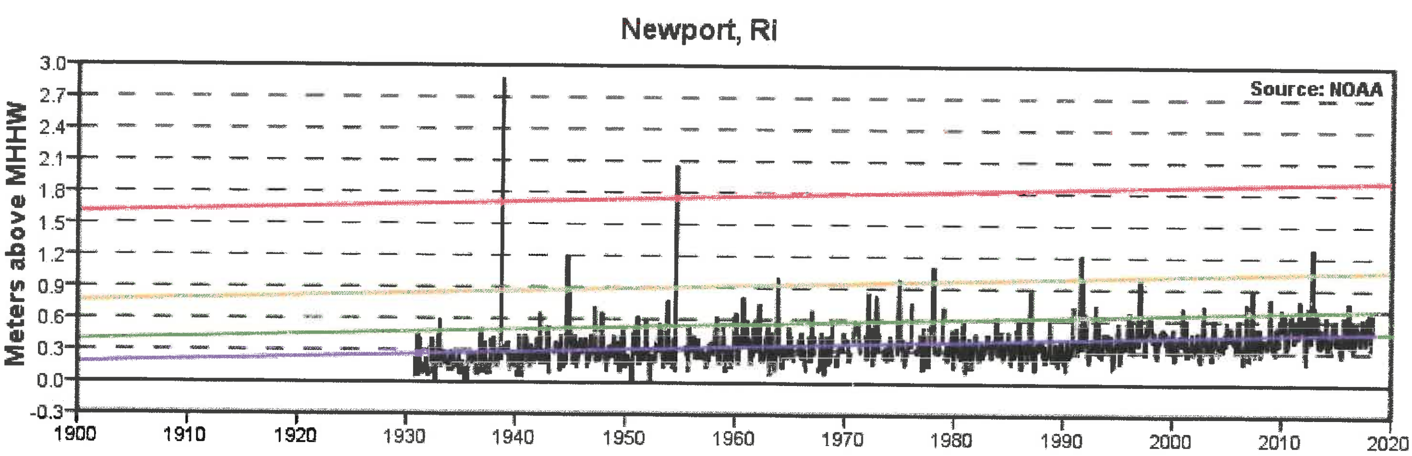
* --- Inferred Level   & --- Last Recorded Level   # --- High Water Mark

Station Number	Station Name	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth
8452660	Newport, RI (since 1930)	9/21/1938 # 9.46	8/31/1954 * 6.76	10/29/2012 4.21	8/19/1991 3.98	9/14/1944 # 3.96	1/9/1978 3.60	10/31/1991 3.26	2/7/1978 3.25	11/30/1963 3.25	12/2/1974 3.24

Attachment 7 Table 1: Top Ten Highest Water Levels at NOAA Newport Tide Station



Attachment 7 Figure 1: NOAA annual exceedance probability curves with 95% confidence intervals



Attachment 7 Figure 2: NOAA annual exceedance probability curves with 95% confidence intervals

USACE NORTH ATLANTIC COAST COMPREHENSIVE STUDY (NACCS)

The North Atlantic Coast Comprehensive Study (NACCS) was completed by the US Army Corps of Engineers (USACE) after Hurricane Sandy to address coastal storm and flood risk to vulnerable populations, property, ecosystems, and infrastructure. The study was conducted to provide information for computing the joint probability of coastal storm environmental forcing parameters for the U.S. North Atlantic Coast (NAC) coastal regions from Virginia to Maine.

The NACCS wave and water level modeling goals included simulating an efficient number of storms representing a sufficient range of storm characteristics in order to accurately describe the statistical nature of coastal storm response over the entire region. NACCS included the application of a suite of high-fidelity numerical models within the Coastal Storm Modeling System (CSTORM-MS). Representative synthetic tropical and historical extratropical storms were strategically selected to characterize the regional storm hazard. CSTORM-MS was then applied with the wave generation and propagation model WAM, providing offshore, deep-water waves to apply as boundary conditions to the nearshore steady-state wave model STWAVE. The circulation model ADCIRC was used to simulate the surge and circulation response to the storms. STWAVE to provide nearshore wave conditions including local wind -generated waves.

The statistical analysis of the response of the 1,150 simulated storms (1,050 tropical cyclones and 100 extra-tropical cyclones) was conducted at nearly 19,000 save point locations to produce response statistics including AEP and average recurrence interval (ARI). In addition, epistemic uncertainty was quantified and represented as confidence limits (CLs).

The NACCS JPA model employs the joint probability method with optimal sampling (JPM-OS) scheme for the statistical analysis of tropical cyclones. The JPM considers all possible combinations of tropical cyclone meteorological parameters (i.e., track location, heading direction, translational speed, central pressure deficit, and radius of maximum winds) along with their associated probabilities and the storm responses generated by each combination of parameters. Each of these combinations constitutes a synthetic tropical cyclone. The probabilities of the tropical cyclones are combined by means of the JPM multidimensional integral in order to compute the AEP of each storm response.

For analysis of extratropical cyclones, NACCS utilized the following general methodology. The most significant historical extratropical cyclones were sampled from water level stations throughout the study area using the Peak Over Thresholds (POT) statistical method. The selected storms were simulated using climatological and hydrodynamic numerical simulation. Hindcast wind and pressure fields were used to drive high-fidelity storm surge and wave hydrodynamic models. The simulated water level responses were fitted with a parametric distribution model (typically the Generalized Pareto Distribution (GPD)). The best estimates of the distribution parameters can be obtained using fitting approaches such as using the maximum likelihood method (MLM).

Storm Set Simulations: Four sets of storm simulations were performed within NACCS:

- The first set of extratropical and tropical simulations (TCS1, XCS1) represents the base condition, modeled on mean sea level with wave effects but without astronomical tides or long-term SLC.
- The second set of extratropical and tropical simulations (TCS2, XCS2) consisted of the same base condition as in the first set but with each storm modeled on a unique, randomly selected tide phase.
- The third set of extratropical and tropical simulations (TCS3, XCS3) was the same as the second set except that it was modeled with a static water level adjustment of 1.0 m to simulate a future GSLC scenario of the same magnitude.
- A tide-only suite of 96 simulations was also run where each simulation had a random phase selected from historical tides occurring in September 2010.
- A fourth tropical cyclone set (TCS4) of results was developed by linear superposition of 96 tide-only simulations with the base condition set (TSC1).

Data access is provided via the USACE Coastal Hazards System (CHS), a national, coastal, storm-hazard data storage and mining system.

NACCS Project Data

GZA has utilized the results of USACE UCHS (NACCS) study output (NACCS save point data) that are applicable to this project. The data utilized includes:

- <u>Flood-Frequency Relationships:</u>
  - Response statistics representing the total water level flood frequency including 13 ARI values representing 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, and 10000 years
  - Uncertainty: expected value, 68%, 90%, 95% confidence intervals
- <u>Nearshore Wave Height Frequency Relationships:</u>
  - Response statistics representing the significant wave height (Hs) frequency including 13 ARI values representing 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, and 10000 years
  - Uncertainty: expected value, 68%, 90%, 95% confidence intervals

NACCS save point **10256** was utilized to develop representative water level flood frequency and wave frequency conditions for the project site. **Attachment 7 Figure 3** presents the NACCS save point locations. **Attachment 7 Figure 4** presents flood-frequency relationships for save point 10256.

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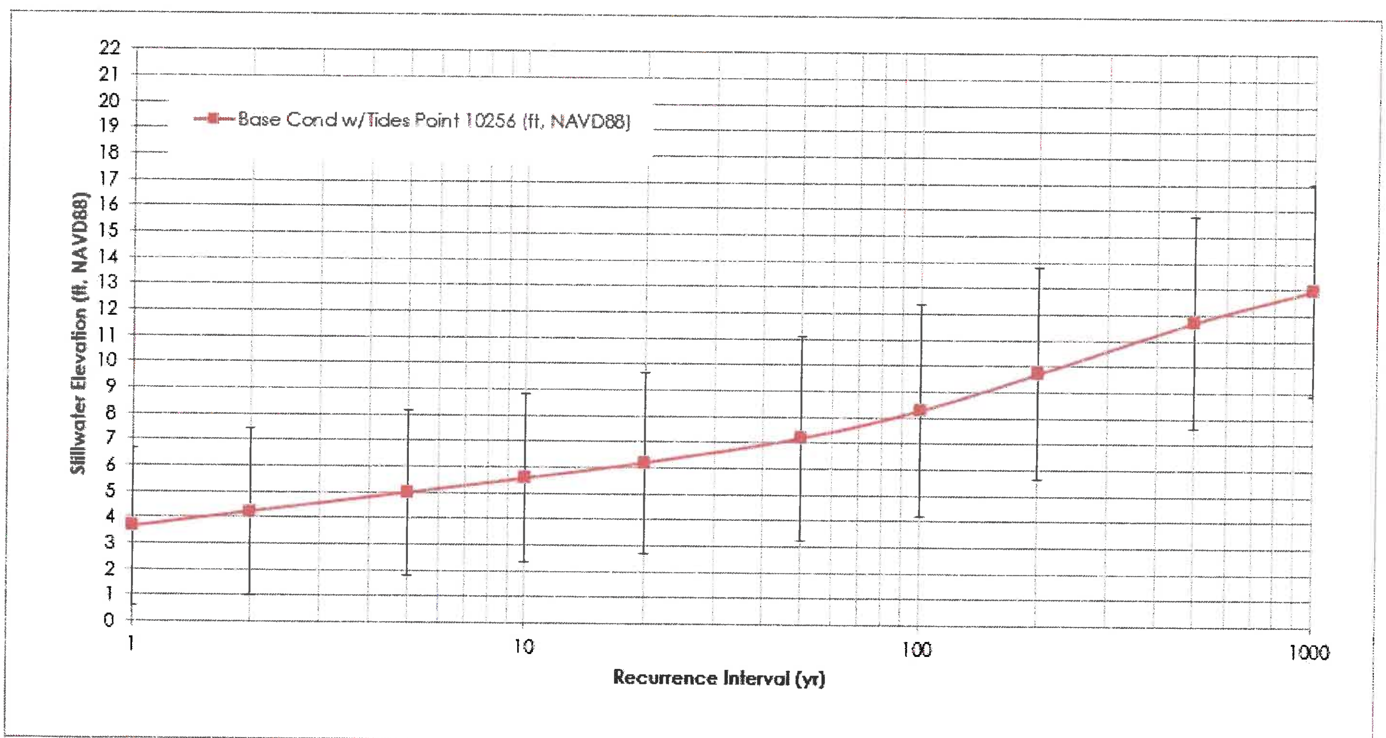
Attachment 7 Figure 3: USACE NACCS Save Points at Project Site



Attachment 7 Figure 4: USACE NACCS Save Point Flood Frequency Relationship at Project Site

FEMA FLOOD INSURANCE STUDY AND FLOOD INSURANCE RATE MAP

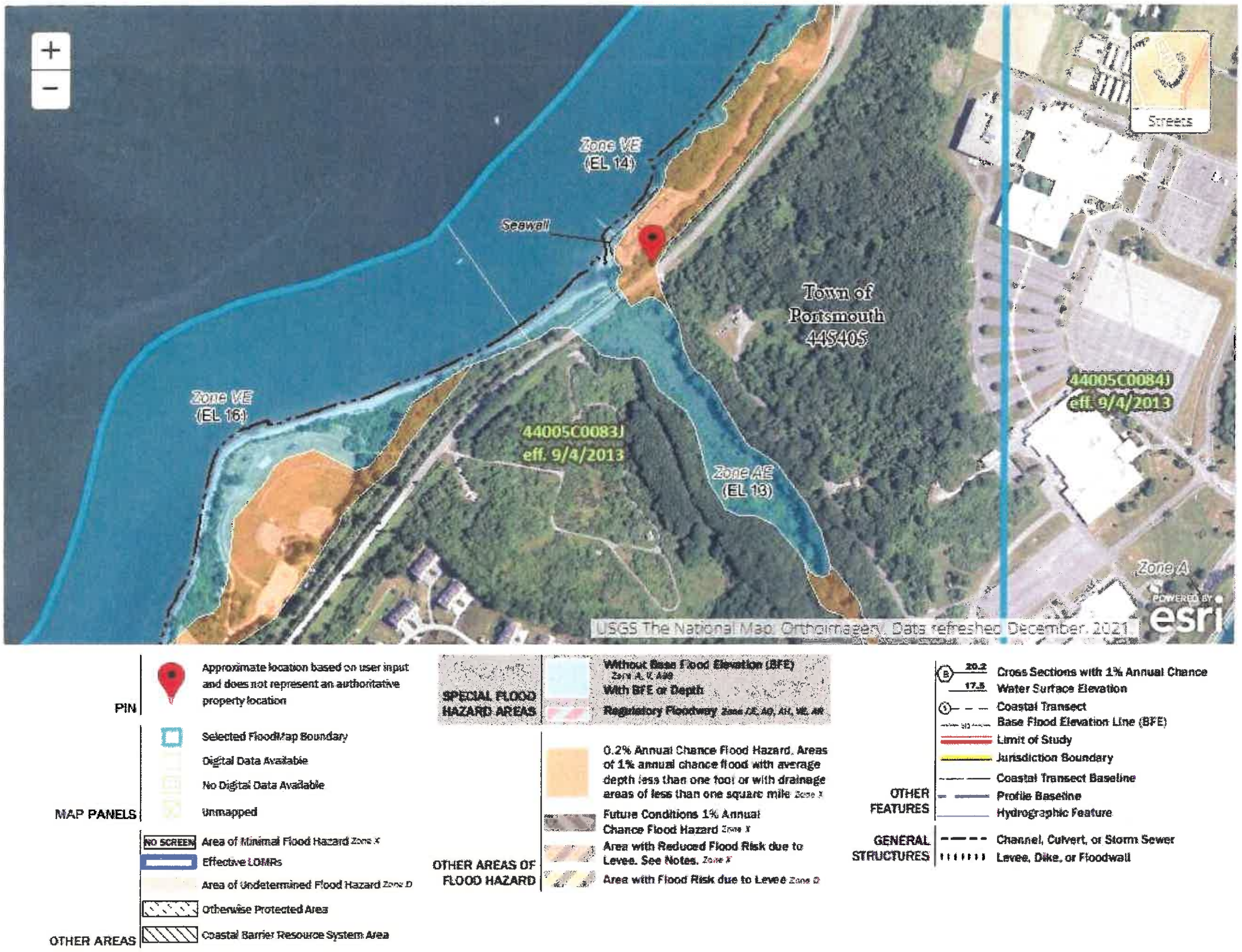
FEMA Flood Insurance Rate Maps (FIRMS) and Flood Insurance Studies (FIS) present flood-frequency information for the project area. The FIS and FIRM used for this study include:

- FEMA Flood Insurance Study, Newport County, Rhode Island; Revised July, 2021
- FEMA Flood Insurance Rate Map Panel 44005C0083j; effective date 9/1/2013 (including Coastal Transects 24, 35 and 36)

For the areas of Newport County that are impacted by coastal flooding processes, coastal flood hazard analyses were performed to provide estimates of coastal Base Flood Elevations (BFEs). Coastal BFEs reflect the increase in water levels during a flood event due to extreme tides and storm surge as well as overland wave effects. Regional frequency analysis were performed using L-moments with interpolation to establish stillwater flood-frequency. The statistical analyses utilized recorded water level data from 5 NOAA tide stations: Providence, Quonset Point, Newport, New London and New Bedford. Wave heights were determined using the numerical wave model STWAVE.

Attachment 7 Figure 5 presents FEMA flood hazard zones at the project site and vicinity.

Attachment 7 Figure 6 presents flood-frequency relationships at FEMA coastal transects. Coastal Transects 24, 35 and 36 represent the project area.



Attachment 7 Figure 5: FEMA Flood Insurance Rate Map Flood Hazard Zones in Project Vicinity

Flood Source	Coastal Transect	Starting Wave Conditions for the 1% Annual Chance		Starting Stillwater Elevations (ft NAVD88) Range of Stillwater Elevations (ft NAVD88)				
		Significant Wave Height H_s (ft)	Peak Wave Period T_p (sec)	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Narragansett Bay	18	*	*	6.1	*	9.5	12.1	22.8
Narragansett Bay	19	*	*	6.1	*	9.5	12.0	22.7
Narragansett Bay	20	*	*	5.9	*	9.2	11.7	22.2
Narragansett Bay	21	*	*	5.8	*	9.0	11.5	21.7
Narragansett Bay	22	*	*	5.9	*	9.2	11.7	22.1
Narragansett Bay	23	*	*	6.0	*	9.3	11.9	22.4
Narragansett Bay	24	*	*	5.8	*	9.1	11.5	21.8
Narragansett Bay	25	*	*	6.1	*	9.5	12.0	22.7
Narragansett Bay	32	*	*	6.0	*	9.4	11.9	22.5
Narragansett Bay	33	*	*	6.0	*	9.3	11.8	22.3
Narragansett Bay	34	*	*	5.9	*	9.2	11.7	22.1
Narragansett Bay	35	*	*	5.8	*	9.1	11.5	21.8
Narragansett Bay	36	*	*	5.7	*	8.9	11.3	21.3
Narragansett Bay	37	*	*	5.4	*	8.5	10.8	20.4
Narragansett Bay	38	*	*	5.4	*	8.4	10.7	20.2

*Not calculated for this Flood Risk Project

Attachment 7 Figure 6: FEMA Flood Insurance Rate Map Coastal Transect Flood-Frequency

Attachment 8
Nearshore Waves

USACE NORTH ATLANTIC COAST COMPREHENSIVE STUDY (NACCS)

See **Attachment 7** for description of the USACE NACCS. Nearshore Wave Height Frequency Relationships include:

- Response statistics representing the significant wave height (Hs) frequency including 13 ARI values representing 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, and 10000 years
- Uncertainty: expected value, 68%, 90%, 95% confidence intervals

The following NACCS save points were utilized to develop representative total water level flood frequency and wave frequency conditions for the project site: 10256

Attachment 8 Figure 1 presents USACE NACCS predicted significant wave heights (Hs) at save point 10256.

GZA WAVE CALCULATION

GZA has completed a wave analysis of the project site to predict wind-generated waves in accordance with methodology presented in the USACE Coastal Engineering Manual. Wave characteristics were evaluated over multiple transects representing different wind fetches, extending out from the project site to the regions of greatest fetch exposure **Attachment 8 Figure 2**. The fetch representing the condition resulting in the largest waves at the site was selected for project design input (GZA Transect 3).

Wind intensity and direction was developed for input to GZA's wave calculation. See **Attachment 4**. As part of the wave calculation, wind speeds were transformed for: 1) overwater exposure wind speeds; 2) time averaging (duration required for the wave to be fetch-limited over the transects evaluated); and 3) fetch characteristics in accordance with the USACE Coastal Engineering Manual (CEM) Part II.

As an example, the adjusted design wind speed across the Transect 3 design fetch from the GZA wind analysis is 56.9 mph. Wind speeds are presented in the following table. For wave calculations, the adjusted design wind speeds were assumed to be all directional.

Adjusted Wind Speed at 10-meter standard level (U_{10}):	66.0	mph	(Eq. II-2-8, CEM 2015)
Adjusted Wind Speed for fetch-limited duration (U_{10}):	52.72	scaling factor	(CEM Figure II-2-1)
Adjusted Wind Speed for Over Water ( ):	63.3		(CEM Figure II-2-20)
Adjusted Wind Speed for Stability (sea-air temp. difference):	1.0		Assumed value of 1
Adjusted Wind Speed for Fetch ( ):	56.9		

Wave characteristics were developed for the most extreme representative wave:

- Transect 3: South-Southwesterly fetch, resulting in an approximate a 100-year recurrence interval significant wave height (Hs) of 5.2 feet propagating from the South-Southwest. The associated peak wave period is about 3.5 seconds.

For comparison, the nearest FEMA Coastal Transects (Transect 24, 35 & 36) have input significant wave heights (Hs) of 7.6, 7.0 & 7.9 feet with periods of 5.6, 5 & 5.6 seconds, respectively. The nearest USACE NACCS save point (Point 10256) estimates a 100-year recurrence chance wave of 4.8 feet.

The water depths assumed for project area waves were developed based on: 1) bathymetry (see **Attachment 3**); 2) tidal water levels (see **Attachment 5**); 3) relative sea level rise (see **Attachment 6**); and 4) extreme water levels (see **Attachment 7**)

Attachment 8 Figure 2 presents the fetch transects evaluated. **Attachment 8 Table 1** through **Table 3** present GZA-estimated wave heights for a range of wave recurrence intervals across 3 representative transects.

Attachment 8 Table 1: Transect 1: 41,130 feet, West

Recurrence Event Probability	Water Level (feet, NAVD88)	GZA 1-minute Wind Speed (West, mph)	Wave Height Transect 1 (feet)	Wave Period Transect 1 (seconds)
Prevailing	1.6 (MHW)	11	0.7	1.8
1-Year	3.6 (NACCS)	25	1.8	2.4
2-Year	4.2 (NACCS)	32	2.3	2.6
5-Year	5.0 (NACCS)	36	2.7	2.7
10-Year	5.8 (FEMA)	39	2.9	2.8
50-Year	9.1 (FEMA)	46	3.6	3.0
100-Year	11.5 (FEMA)	49	3.8	3.1

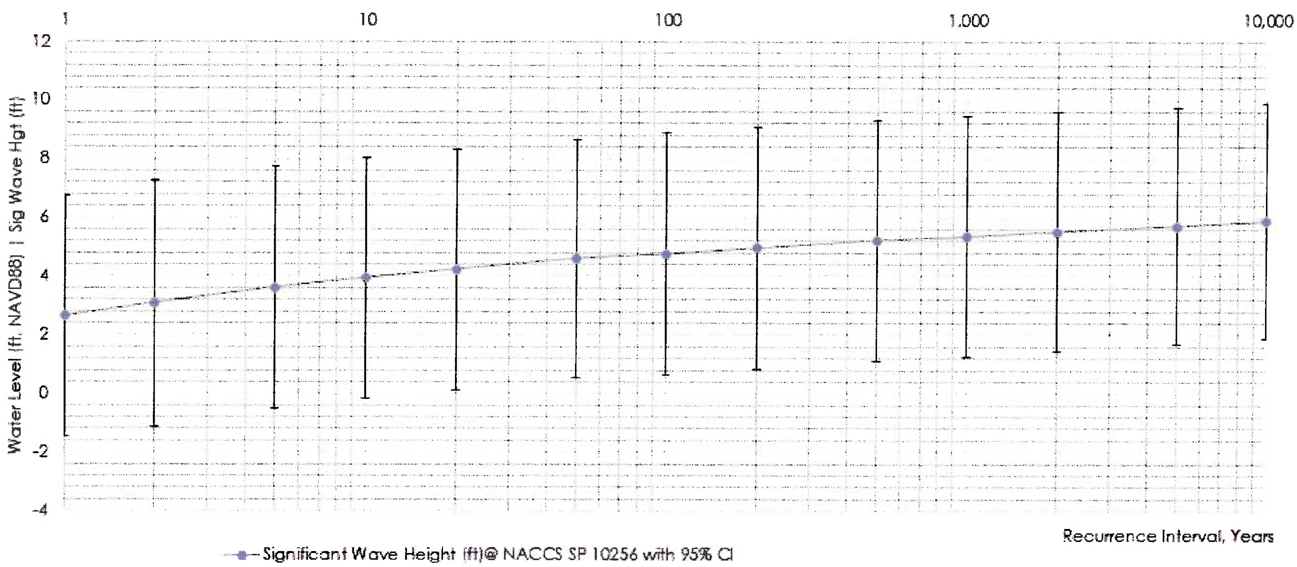
Attachment 8 Table 2: Transect 2: 23,220 feet, Southwest

Recurrence Event Probability	Water Level (feet, NAVD88)	GZA 1-minute Wind Speed (SW, mph)	Wave Height Transect 2 (feet)	Wave Period Transect 2 (seconds)
Prevailing	1.6 (MHW)	13	0.7	1.5
1-Year	3.6 (NACCS)	25	1.3	2.0
2-Year	4.2 (NACCS)	33	1.8	2.2
5-Year	5.0 (NACCS)	40	2.3	2.3
10-Year	5.8 (FEMA)	44	2.5	2.4
50-Year	9.1 (FEMA)	55	3.3	2.6
100-Year	11.5 (FEMA)	60	3.7	2.7

Attachment 8 Table 3: Transect 3: 37,308 feet, South Southwest

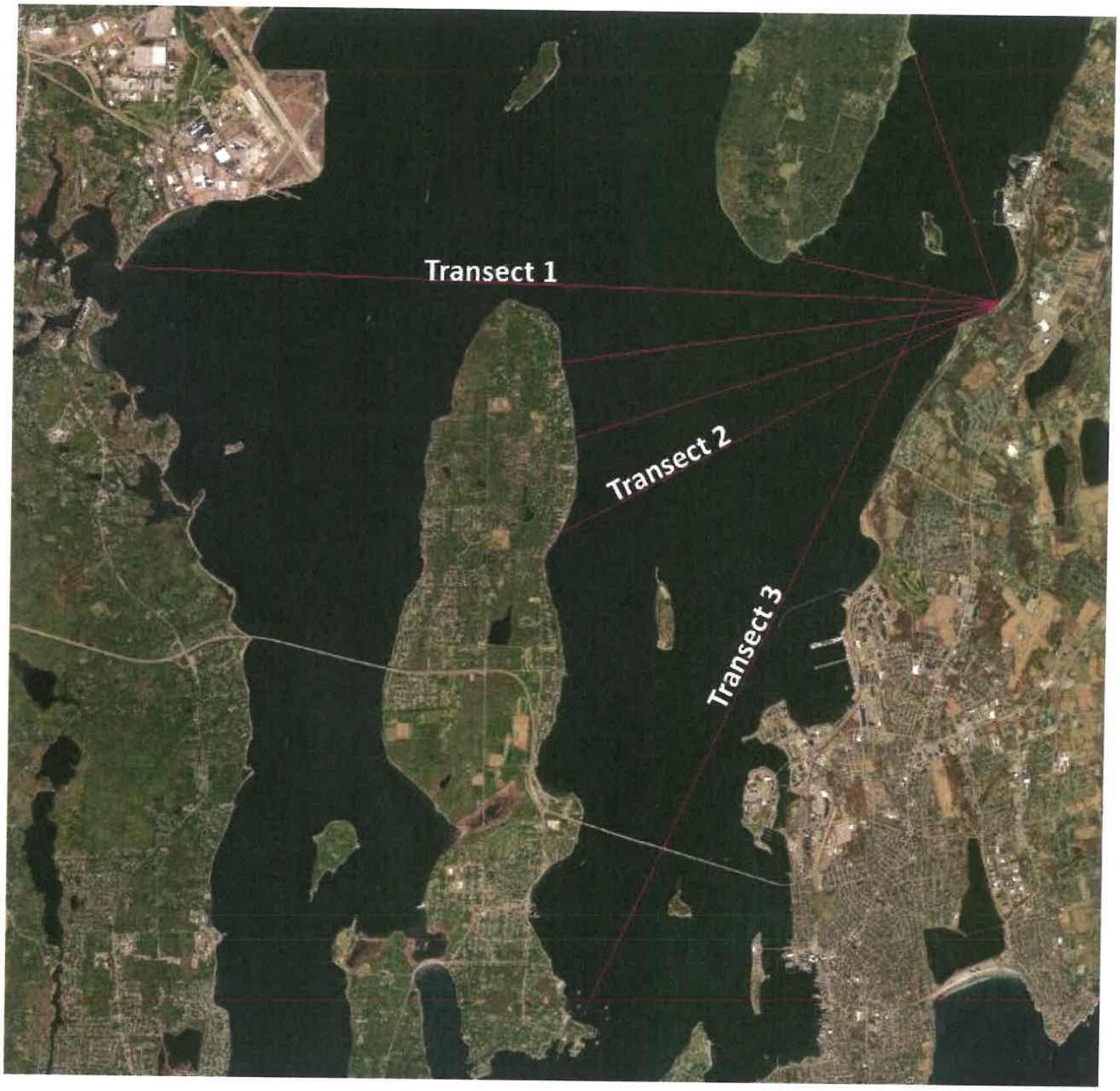
Recurrence Event Probability	Water Level (feet, NAVD88)	GZA 1-minute Wind Speed (SSW, mph)*	Wave Height Transect 3 (feet)	Wave Period Transect 3 (seconds)
Prevailing	1.6 (MHW)	14	0.9	1.8
1-Year	3.6 (NACCS)	(25+25)/2= 25	1.7	2.3
2-Year	4.2 (NACCS)	(33+33)/2= 33	2.3	2.5
5-Year	5.0 (NACCS)	(40+40)/2= 40	2.9	2.7
10-Year	5.8 (FEMA)	(44+45)/2= 45	3.3	2.9
50-Year	9.1 (FEMA)	(55+62)/2= 59	4.6	3.2
100-Year	11.5 (FEMA)	(60+71)/2= 66	5.2	3.3

*GZA's airport wind analysis does not include SSW winds; therefore S and SW winds were averaged to produce SSW values



ARI (yrs)	Stillwater Level (ft, NAVD88)@ NACCS SP 10256 with 95% CI		Significant Wave Height (ft)@ NACCS SP 10256 with 95% CI	
1	3.64	2.40	2.62	4.10
2	4.23	2.49	3.08	4.20
5	5.02	2.43	3.61	4.13
10	5.58	2.49	3.94	4.10
20	6.20	2.69	4.23	4.10
50	7.19	3.12	4.59	4.07
100	8.27	3.25	4.76	4.13
200	9.74	3.25	4.95	4.13
500	11.71	3.25	5.22	4.10
1000	12.96	3.25	5.35	4.10
2000	14.01	3.25	5.51	4.07
5000	15.16	3.25	5.71	4.04
10000	15.88	3.28	5.87	4.00

Attachment 8 Figure 1: USACE NACCS Significant Wave Heights in Project Vicinity



Attachment 8 Figure 2: GZA Wave Calculation Fetches in Project Vicinity

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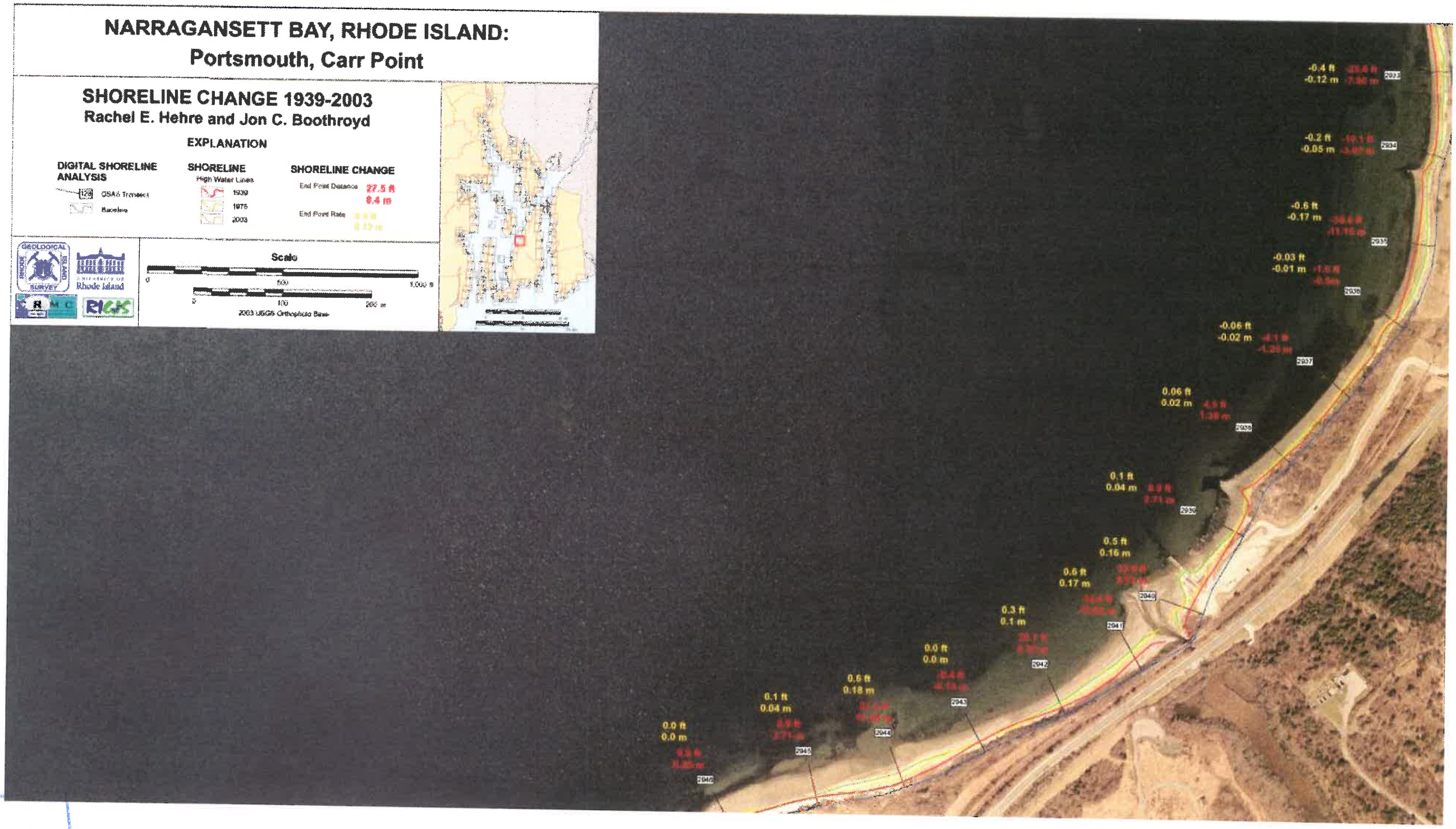
Attachment 9
Shoreline Change

Long term shoreline change is another factor to consider when reviewing coastal structure plans that are intended to last for decades. The Rhode Island Coastal Resources Management Council (CRMC) has developed maps to show shoreline rates of change. These plans were originally created to aid regulatory programs in addressing coastal issues. The maps depict the shoreline location on a given year, based on measurements from vertical aerial photos. The Last High Tide Swash (LHTS) line, where the limit of wave water uprush is observed, was used to denote the shoreline. These shoreline designations can provide long term trends, however large storm events can drastically change beach profiles over short periods (days), so project analysis of the shoreline location should be completed with care.

Since 1939, the shoreline has been accreting sediment both directly North and South of the Site. South of the site appears to be accreting sediment at 0.5 feet/ year, likely due to sediment discharge of upland areas through the tidal marsh outflow to the South of the site. To the North of the site, sediment accretion is slower, around 0.1 feet/ year. Overall, the area appears to have a northward sediment transport cycle with a sediment influx coming from the tidal marsh outflow.



Attachment 9 Figure 1: Shoreline Change 1939 to 2003 in Project Vicinity

Attachment 9 Figure 2: Shoreline Change based on Aerial Photography at Project Area

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2014
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2018
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2019


2020


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