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Coastal Green Infrastructure Techniques for the Protection of SR 1 Vulnerability Assessment and Demonstration

Field Seminar No. 1
The Delaware Floodplain: Impacts of Severe Storms on Infrastructure in a Low Lying State

October 30, 2017

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Sovereign Consulting, Inc.

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Delaware Department of Transportation (DelDOT) for the Coastal Green Infrastructure Techniques for the Protection of SR 1.

Today's talk focuses on two elements of the project:

- Phase II - Vulnerability Assessment and Opportunity Identification
- Phase VI - Demonstration Project

Project Sponsor:

- DelDOT Project: DelDOT Agreement 1707, Task 23, December 20, 2016
  - P.O.C. - LaTonya Gilliam, P.E., Group Engineer, Environmental Stewardship
  - P.O.C. - Erika A. Furlong, Environmental Planner, Environmental Studies

Project Funding:

- Delaware Department of Natural Resources and Environmental Control (DNREC) Strategic Opportunity Fund for Adaptation (SOFA); and
- Federal Highway Administration (FHWA) Green Infrastructure Techniques for Coastal Highway Resilience research project grant.

Early Project Coordination – Coastal Corridor Technical Committee

- **DelDOT**
  - LaTonya Gilliam P.E. - Environmental Stewardship
  - Erika Furlong - Environmental Studies
- **DNREC**
  - Mark Biddle –Watershed Assessment & Management Section
  - Jesse Hayden, P.E. - Shoreline and Waterway Management Section
- **CIB**
  - Marianne Walch, Ph.D.
  - Emily Seldomridge, Ph.D. *(now w/ DelDOT)*
- **Sovereign Consulting Inc.** - Douglas Janiec
- **RK&K** – Larry Trout, Jr., P.E.
- **Storm and Stream Solutions, LLC** - Seth Brown, P.E.
- **US EPA - Region III** - Ralph Spagnola

Bayside flooding of SR 1

Strong Winter Storms (Nor'Easters)

(photograph source: DelDOT)

Seaside Dune Access Breach at SR 1 during offshore Hurricane Jose, 2017

Indian River Inlet after Hurricane Sandy

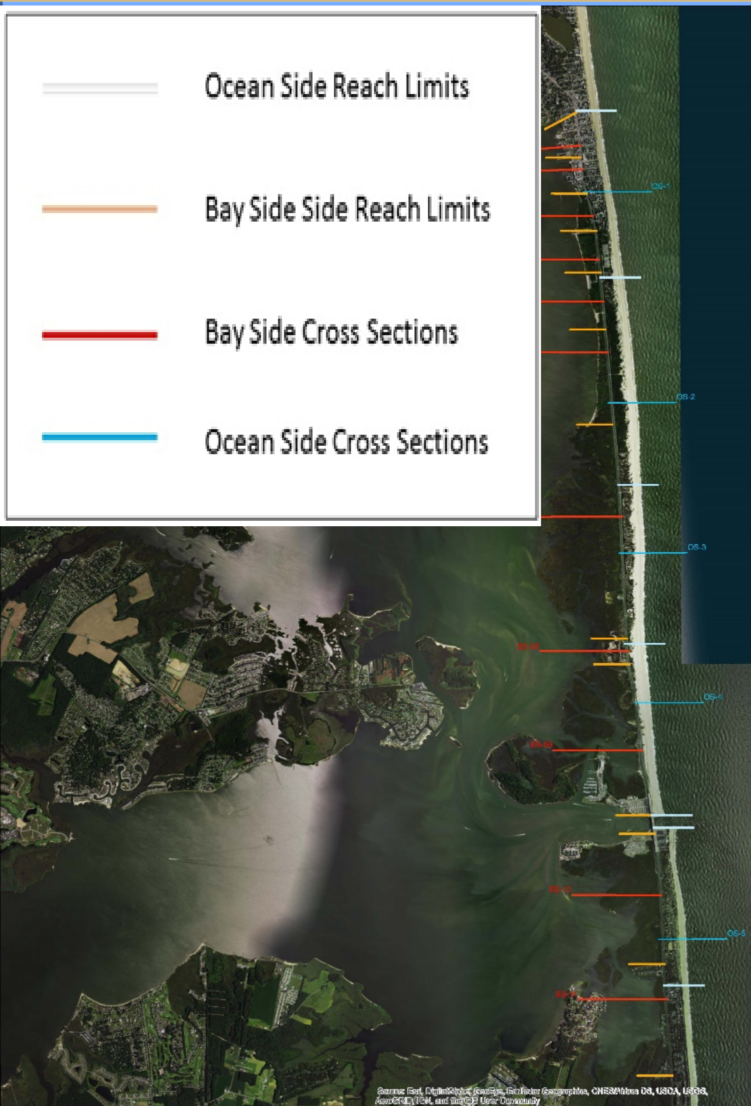
(photograph source: DNREC & DelDOT)

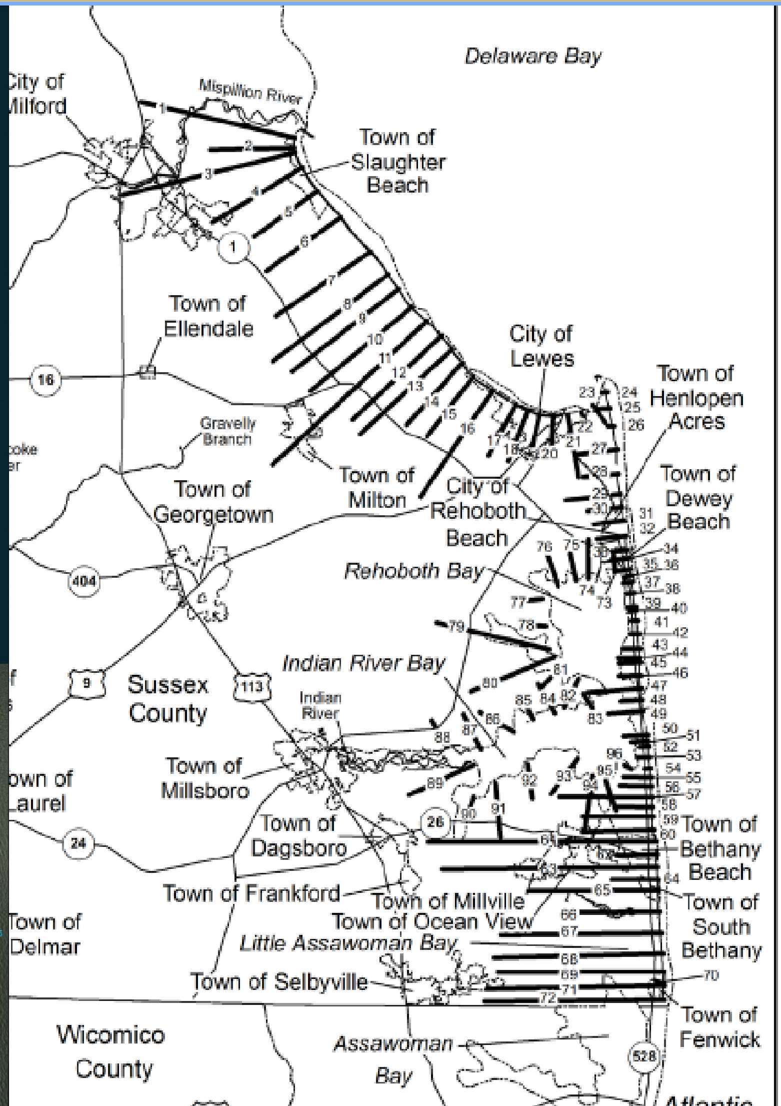
Phase II - Vulnerability Assessment Purpose & Goals

- Identifying vulnerability or resilience to significant and severe flooding conditions;
- Prioritize roadways stretches relative to greatest vulnerability; and
- Provide assessment methods that can be applied to other coastal roadways.

Gather and Review Available Information:

- For General Local Information:
  - o Local Historic Aerial Photography;
  - o LiDAR Data;
  - o Interviews/discussions with DelDOT, DNREC, and municipality representatives;
  - o As-built drawings of roadway; and
  - o Readily available stormwater infrastructure plans;
- For Sea Level Rise Information:
  - o NOAA Sea Level Rise Viewer; and
  - o State of Delaware SLR Tool;
- For Flooding Information:
  - o Delaware Flood Risk Adaptation Map (FRAM) online mapper (1%-annual-chance flood event with the addition of 3 feet of SLR);
  - o NOAA Coastal Flood Exposure Mapper (includes mapping information on a coastal flood hazard composite, shallow coastal flooding, FEMA flood zones, storm surge, and SLR; and
  - o Flood Insurance Study, Sussex County, Delaware (coastal flooding information, cross section data, and modeling data).





Within each reach limit, starting still water elevations from the closest transect from the SC FEMA-FIS was used in the modeling.

15 Bayside (BS)
8 Ocean Side (OS)

WAVE CREST ELEVATION ESTIMATION

PROJECT:	Vulnerability Analysis and Potential Coastal Green Infrastructure Solutions for Delaware Route 1 Coastal Highway		
LOCATION (Reach Segment):	BS-03		
COORDINATES (cross section end points):	Start Lat 754411.9	Start Long 248954.5	End Lat 750347.7 End Long 248955.3
FLOOD SOURCE:	Rehoboth Bay		

			Input / Defualt / Calculated

Parameter	Value		COMMENTS
Vertical Datum=	NAVD88		
n-year=	10.00		Protection Desired by Community/Agency or Due to Site Constraints
Still-water Storm Tide Elevation, S*(ft.)=	3.90		From FEMA FIS Study
Fetch (miles)=	4.47		From Fetch Analysis as Measured by Google Earth or Similar
INITIAL WAVE HEIGHT			
Fetch Factor, F=	0.78		Best Fit Curve from Figure 2 of National Academy of Sciences
Eq. (3) Initial Wave Height (ft.), H1=	2.37		Fetch Limited as in Bays or Estuaries
Initial Wave Height n-year (ft.), H1=	0.00		USACE Shore Protection Manual and Statistical Wind Assessment
Initial Wave Height (ft.), H1=	2.37		Defaults to Lower Computed Wave Height
BREAKWATER OBSTRUCTION			
Average elevation of elongated barrier (ft.), zb=	0.00		If present, based on either LiDAR, designs, as-builts
Average Still-Water Depth (ft.), db=	3.90		
Eq. (2) Breaker Height Upper Limit (ft), Hbb=	3.04		
Eqs. (8,9,10) Transmission Coefficient, Bb=	1.00		
Eq. (4) Transmitted Wave Height (ft.), Hb=	2.37		
Lesser of Eqs (2 and 4) Transmitted Wave Height (ft)=	2.37		
MARSH OBSTRUCTION (fringe)			
Marsh Ground Elevation (ft.),zm=	0.98		Average elevation based upon LiDAR survey
Marsh Grass Height (ft.) =	3.20	h/2 (ft.)= 1.6	h for fringe band of S. alternifolia based on MACWA data; h/2 to account for plant bend
Marsh Grass Mean Effective Dia. (in.), D=	0.25	0.021 ft	Default representing approx. 1/2 TF blade dia.
Marsh Grass Mean Horiz. Spacing (in.), b=	2.00	0.167 ft	Representative density of finge band community
Marsh Average Width (ft.), w=	62.00		Measured marsh width along transect
Mean Depth of Water (ft.), d=	2.92		
Eq. (2) Breaker Height Upper Limit (ft), Hmb=	2.28		
Mean Wetted Height of Marsh Grass (ft.), h=	1.60		
Eq. (11) Transmission Coefficient, Bm=	0.31		
Eq. (4) Transmitted Wave Height (ft.), Hm=	0.74		
Lesser of Eqs (2 and 4) Transmitted Wave Height (ft)=	0.74		
MARSH OBSTRUCTION (interior)			
Marsh Ground Elevation (ft.),zm=	1.31		Average elevation based upon LiDAR survey
Marsh Grass Height (ft.) =	2.00	h/2 (ft.)= 1	h for interior platform band of S. alternifolia based on MACWA data; h/2 to account for plant bend
Marsh Grass Mean Effective Dia. (in.), D=	0.20	0.017 ft	Default representing approx 1/2 SF blade dia
Marsh Grass Mean Horiz. Spacing (in.), b=	2.50	0.208 ft	Representative density of interior community
Marsh Average Width (ft.), w=	669.00		Measured marsh width along transect
Mean Depth of Water (ft.), d=	2.59		
Eq. (2) Breaker Height Upper Limit (ft), Hmb=	2.02		
Mean Wetted Height of Marsh Grass (ft.), h=	1.00		
Eq. (11) Transmission Coefficient, Bm=	0.2486		
Eq. (4) Transmitted Wave Height (ft.), Hm=	0.1845		
Lesser of Eqs (2 and 4) Transmitted Wave Height (ft)=	0.1845		
DUNE/SLOPED OBSTRUCTION			
Dune Top Elevation (ft.), zd=	4.45		Top of SR 1 road elevation (bayside SB lane, ocean NB lane)
Average Still-water Depth (ft.), db=	0.00		
Eq. (2) Breaker Height Upper Limit (ft), Hdb=	0.00		
Eqs. (5,6,7) Transmission Coefficient, Bd=	0.00		
Eq. (4) Transmitted Wave Height (ft.), Hd=	0.00		
Lesser of Eqs (2 and 4) Transmitted Wave Height (ft)=	0.00		
Eq. (1) n-year Flood Elevation (ft.)=	**3.90**		

Inputs:

- Project Name
- Reach Segment Name
- Transect Coordinates (Start/Finish)
- Flood Source Name
- n-Year Event
- Initial Stillwater Elevation for n-year event (from FEMA-FIS)
- Longest Fetch Length
- Fetch Factor
- Average Elevation of Elongated Barrier
- Fringe Marsh Platform Elevation
- Fringe Marsh Width
- Interior Marsh Platform Elevation
- Interior Marsh Width
- Dune Top Elevation

Table II-1 - Modeling Summary Page : N Event = 10 Percent Event

Location	Start Lat	Start Long	End Lat	End Long	FEMA Transect Number	Still-water Storm Tide Elevation, S*(ft.) NAVD88	Fetch (miles)	Fetch Direction	Fetch Factor, F	Initial Wave Height (ft) NAVD88 (H1)	S + H1 (ft) NAVD88	Breakwater Top Elevation (ft.), zb NAVD88	Eq. (4) Transmitted Wave Height (ft.), Hb	Marsh Fringe Elevation (ft), zm NAVD88	Marsh Fringe Average Width, w (ft)	Marsh Fringe Plant Height (ft)	Marsh Fringe Plant Width (in)	Marsh Fringe Plant Spacing (in)	Eq. (4) Transmitted Wave Height (ft.), Hm	Marsh Platform Elevation (ft), zm NAVD88	Marsh Platform Average Width, w (ft)	Marsh Platform Plant Height (ft)	Marsh Platform Plant Width (in)	Marsh Platform Plant Spacing (in)	Eq. (4) Transmitted Wave Height (ft.), Hm	Modeled Minimum Marsh Width To Reduce (n) H2 Wave to 0.2ft	Dune Top Elevation (ft), zd NAVD88	Eq. (4) Transmitted Wave Height (ft.), Hd	Eq. (1) n-year Flood Elevation (ft.)
BS-01	753849.31	252138.97	749799.19	251805.38	36.00	3.90	4.83	NNW	0.79	**2.41**	6.31	2.19	**1.33**	0.00	0.00	3.20	0.40	2.00	**1.33**	0.00	0.00	2.00	0.35	2.50	**1.33**	**N/A**	3.43	**0.37**	**4.16**
BS-02	753935.17	251066.59	749873.35	250938.89	36.00	3.90	4.68	NNW	0.79	**2.40**	6.30	0.00	**2.40**	3.20	154.00	0.00	0.00	0.00	**0.06**	2.95	301.00	2.00	0.35	2.50	**0.03**	**106.70**	4.45	**0.00**	**3.90**
BS-03	754411.86	248954.48	750347.74	248955.27	36.00	3.90	4.47	NW	0.78	**2.37**	6.27	0.00	**2.37**	0.98	62.00	3.20	0.40	2.00	**0.74**	1.31	669.00	2.00	0.35	2.50	**0.18**	**753.00**	4.45	**0.00**	**3.90**
BS-04	754665.66	247010.96	750601.23	247011.72	40.00	4.00	4.25	NW	0.77	**2.41**	6.41	0.00	**2.41**	0.00	0.00	0.00	0.00	0.00	**2.41**	2.79	677.00	2.00	0.35	2.50	**0.05**	**165.50**	3.20	**0.05**	**4.04**
BS-05	754878.38	245109.01	750813.61	245109.75	40.00	4.00	4.15	SW	0.77	**2.40**	6.40	0.00	**2.40**	0.00	0.00	0.00	0.00	0.00	**2.40**	2.46	482.00	2.00	0.35	2.50	**0.11**	**267.00**	1.80	**0.11**	**4.08**
BS-06	755081.79	242825.39	751016.68	242826.08	40.00	4.00	4.40	SW	0.78	**2.43**	6.43	0.00	**2.43**	1.96	50.00	3.20	0.40	2.00	**0.51**	2.79	321.00	2.00	0.35	2.50	**0.09**	**165.50**	1.30	**0.09**	**4.06**
BS-07	755708.10	235423.25	751641.87	235421.76	44.00	3.90	4.95	SW	0.80	**2.42**	6.32	0.00	**2.42**	2.29	160.00	3.20	0.40	2.00	**0.12**	0.98	3300.00	2.00	0.35	2.50	**0.04**	**960.00**	1.40	**0.04**	**3.93**
BS-08	756021.39	229387.91	751954.22	229382.59	44.00	3.90	3.28	SW	0.73	**2.23**	6.13	0.00	**2.23**	0.00	0.00	0.00	0.00	0.00	**2.23**	2.95	1120.00	2.00	0.35	2.50	**0.02**	**106.00**	2.75	**0.02**	**3.91**
BS-09	756619.77	224916.46	752551.89	224928.42	44.00	3.90	0.45	W	0.42	**1.29**	5.19	0.00	**1.29**	0.00	0.00	0.00	0.00	0.00	**1.29**	3.28	175.00	2.00	0.35	2.50	**0.08**	**64.75**	2.25	**0.08**	**3.96**
BS-10	757476.14	218400.24	753407.27	218412.36	51.00	4.70	7.30	W	0.86	**3.14**	7.84	0.00	**3.14**	1.14	50.00	0.00	0.00	0.00	**1.22**	1.15	2500.00	2.00	0.35	2.50	**0.11**	**1450.00**	4.45	**0.11**	**4.78**
BS-11	757741.57	213723.83	753672.16	213729.36	51.00	4.70	0.90	NW	0.53	**1.95**	6.65	0.00	**1.95**	1.14	81.00	0.00	0.00	0.00	**0.75**	1.31	304.00	2.00	0.35	2.50	**0.42**	**1265.00**	4.45	**0.20**	**4.84**
BS-12	758594.60	199396.21	754526.71	199393.98	70.00	2.70	0.35	W	0.38	**0.81**	3.51	0.00	**0.81**	0.00	0.00	0.00	0.00	0.00	**0.81**	2.62	1991.00	2.00	0.35	2.50	**0.00**	**6.97**	4.45	**0.00**	**2.70**
BS-13	759853.16	183537.56	755785.27	183546.25	70.00	2.70	1.38	W	0.60	**1.26**	3.96	0.00	**1.26**	0.00	0.00	0.00	0.00	0.00	**1.26**	2.62	613.00	2.00	0.35	2.50	**0.00**	**7.80**	4.45	**0.00**	**2.70**
BS-14	760481.17	176662.35	756405.72	176652.02	70.00	2.70	1.95	NW	0.65	**1.37**	4.07	0.00	**1.37**	0.98	50.00	0.00	0.00	0.00	**0.35**	0.33	550.00	2.00	0.35	2.50	**0.15**	**590.00**	4.33	**0.00**	**2.70**
BS-15	760648.49	166498.43	756571.96	166535.39	70.00	2.70	0.51	NW	0.44	**0.93**	3.63	2.46	**0.19**	0.00	0.00	0.00	0.00	0.00	**0.19**	0.00	0.00	0.00	0.00	0.00	**0.19**	**N/A**	4.34	**0.00**	**2.70**
OS-01	753916.13	250043.59	756993.69	250055.27	37.00	5.90	20.00	E	1.01	**4.66**	10.56	0.00	**4.60**	0.00	0.00	0.00	0.00	0.00	**4.60**	0.00	0.00	0.00	0.00	0.00	**4.60**	**N/A**	14.66	**0.00**	**5.90**
OS-02	755035.85	240552.35	758114.53	240564.16	42.00	6.00	20.00	E	1.01	**4.74**	10.74	0.00	**4.68**	0.00	0.00	0.00	0.00	0.00	**4.68**	0.00	0.00	0.00	0.00	0.00	**4.68**	**N/A**	27.17	**0.00**	**6.00**
OS-03	755528.13	233787.02	758607.61	233798.88	45.00	6.20	20.00	E	1.01	**4.90**	11.10	0.00	**4.84**	0.00	0.00	0.00	0.00	0.00	**4.84**	0.00	0.00	0.00	0.00	0.00	**4.84**	**N/A**	22.87	**0.00**	**6.20**
OS-04	757303.24	216414.08	760384.76	216426.14	48.00	6.20	20.00	E	1.01	**4.90**	11.10	0.00	**4.84**	0.00	0.00	0.00	0.00	0.00	**4.84**	0.00	0.00	0.00	0.00	0.00	**4.84**	**N/A**	12.89	**0.00**	**6.20**
OS-05	756241.27	227061.33	759321.54	227073.27	52.00	6.00	20.00	E	1.01	**4.74**	10.74	0.00	**4.68**	0.00	0.00	0.00	0.00	0.00	**4.68**	0.00	0.00	0.00	0.00	0.00	**4.68**	**N/A**	15.88	**0.00**	**6.00**
OS-06	758018.74	202404.42	761101.91	202416.54	59.00	6.30	20.00	E	1.01	**4.98**	11.28	0.00	**4.91**	0.00	0.00	0.00	0.00	0.00	**4.91**	0.00	0.00	0.00	0.00	0.00	**4.91**	**N/A**	17.68	**0.00**	**6.30**
OS-07	758251.36	196746.83	761335.19	196758.97	61.00	6.50	20.00	E	1.01	**5.14**	11.64	0.00	**5.07**	0.00	0.00	0.00	0.00	0.00	**5.07**	0.00	0.00	0.00	0.00	0.00	**5.07**	**N/A**	17.13	**0.00**	**6.50**
OS-08	759454.52	181201.32	762540.17	181213.60	66.00	6.30	20.00	E	1.01	**4.98**	11.28	0.00	**4.91**	0.00	0.00	0.00	0.00	0.00	**4.91**	0.00	0.00	0.00	0.00	0.00	**4.91**	**N/A**	21.62	**0.00**	**6.30**

Top of Dune Elevation (i.e., low point of SR 1 SB lane within in reach section)

n-Year Flood Elevation

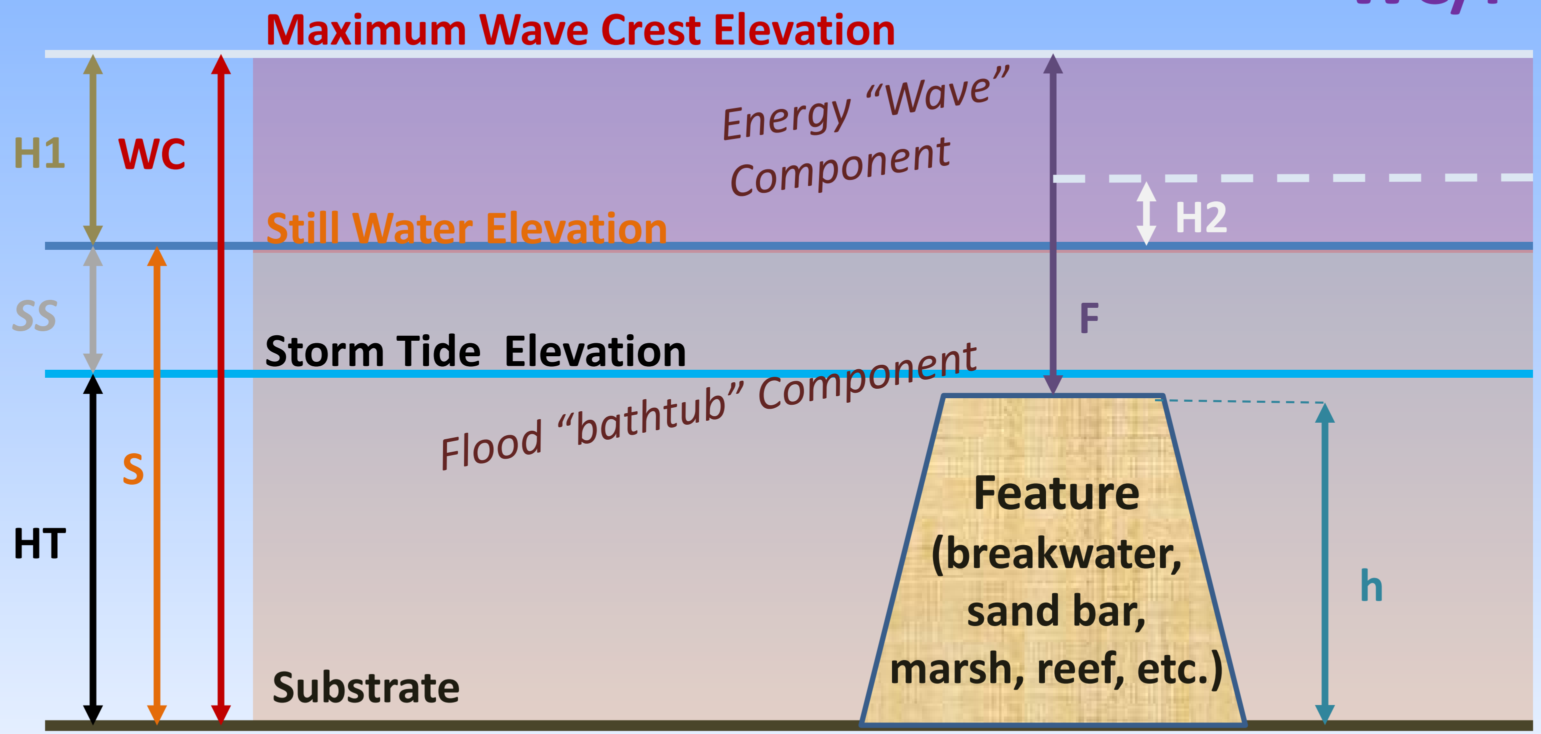
Final Transmitted Wave Height

HT: Storm High Tide
SS: Storm Surge
H1: Initial Wave Height Prior to Contacting a Feature or Limiting Substrate

S: Stillwater Level
WC: Wave Crest Elevation
F: Freeboard (WC-h)

h: Feature Height
H2: Dampened (by Feature) Wave Height

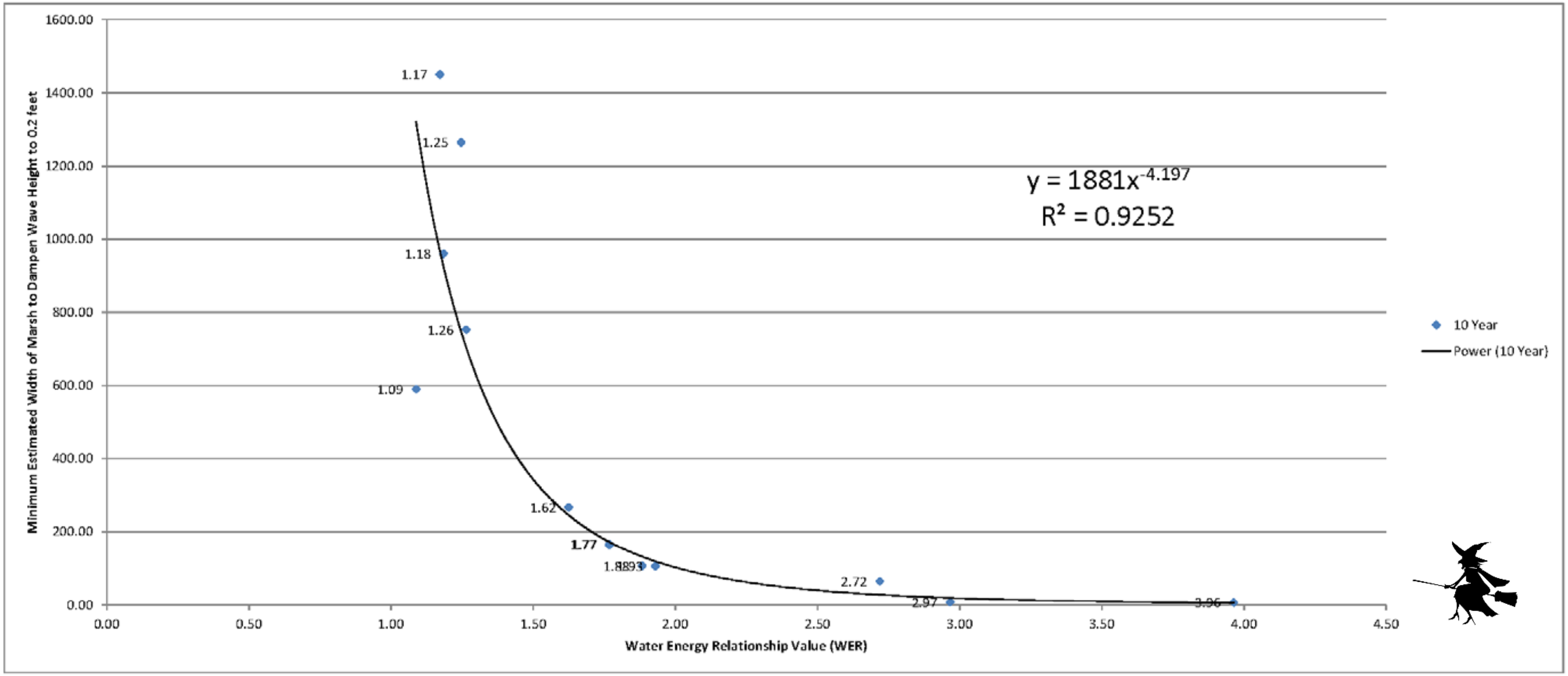
WC/F = ER



With the exception to certain types of dikes and berms, features can affect only the energy component of the water column of a wave, not the bathtub condition.

N-Event = 10-percent Annual Event

Cross Section	BS-02	BS-03	BS-04	BS-05	BS-06	BS-07	BS-08	BS-09	BS-10	BS-11	BS-12	BS-13	BS-14
Still-water Storm Tide Elevation ft. NAVD88 From FEMA FIS Study (S)	3.90	3.90	4.00	4.00	4.00	3.90	3.90	3.90	4.70	4.70	2.70	2.70	2.70
Initial Wave Height ft. NAVD88 NAS Method (H1)	2.40	2.37	2.41	2.40	2.43	2.42	2.23	1.29	3.14	1.95	0.81	1.26	1.37
Initial Wave Crest Elevation (S+H1 = WC)	6.30	6.27	6.41	6.40	6.43	6.32	6.13	5.19	7.84	6.65	3.51	3.96	4.07
Low Marsh Platform Average Height ft. NAVD88 from LIDAR 2016 (d)	2.95	1.31	2.79	2.46	2.79	0.98	2.95	3.28	1.15	1.31	2.62	2.62	0.33
Freedbord (WC/d = Fb)	3.34	4.96	3.62	3.94	3.64	5.34	3.18	1.91	6.69	5.34	0.89	1.33	3.74
Water Energy Relationship Value (WC/Fb = WER)	1.88	1.26	1.77	1.62	1.77	1.18	1.93	2.72	1.17	1.25	3.96	2.97	1.09
Minimum Estimated Width of Marsh to Dampen Wave Height to 0.2 feet	106.75	753.00	165.50	267.00	165.50	960.00	106.00	64.75	1450.00	1265.00	6.97	7.80	590.00



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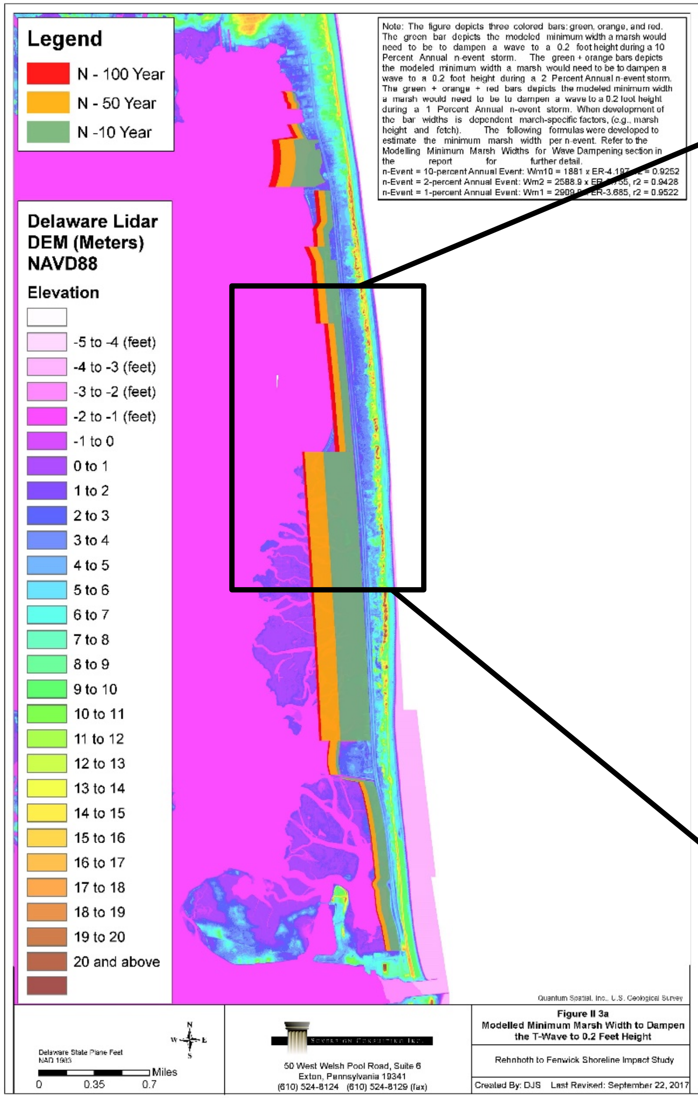
$W_m^{\text{n-Percent Event}}$: Minimum Est. Width to Damp Wave Height to 0.2 ft.

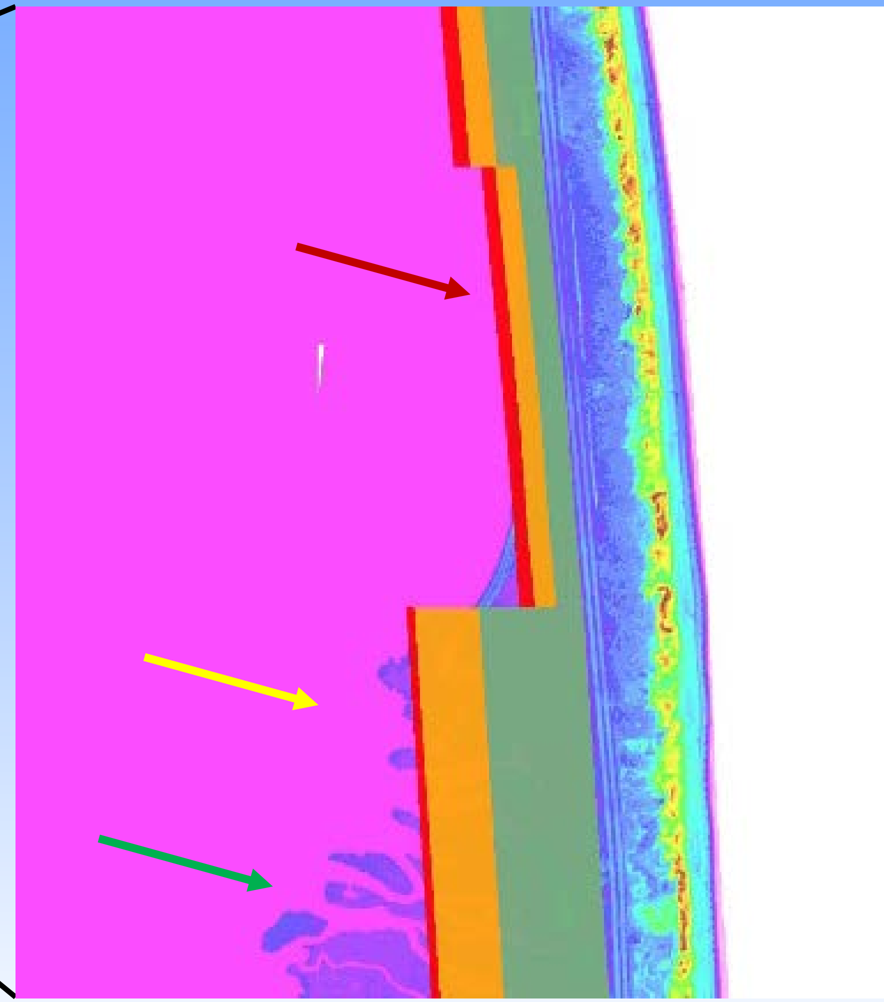
10-percent Annual Event: $W_m^{10} = 1881 \times ER^{-4.197}$, $r^2 = 0.9252$

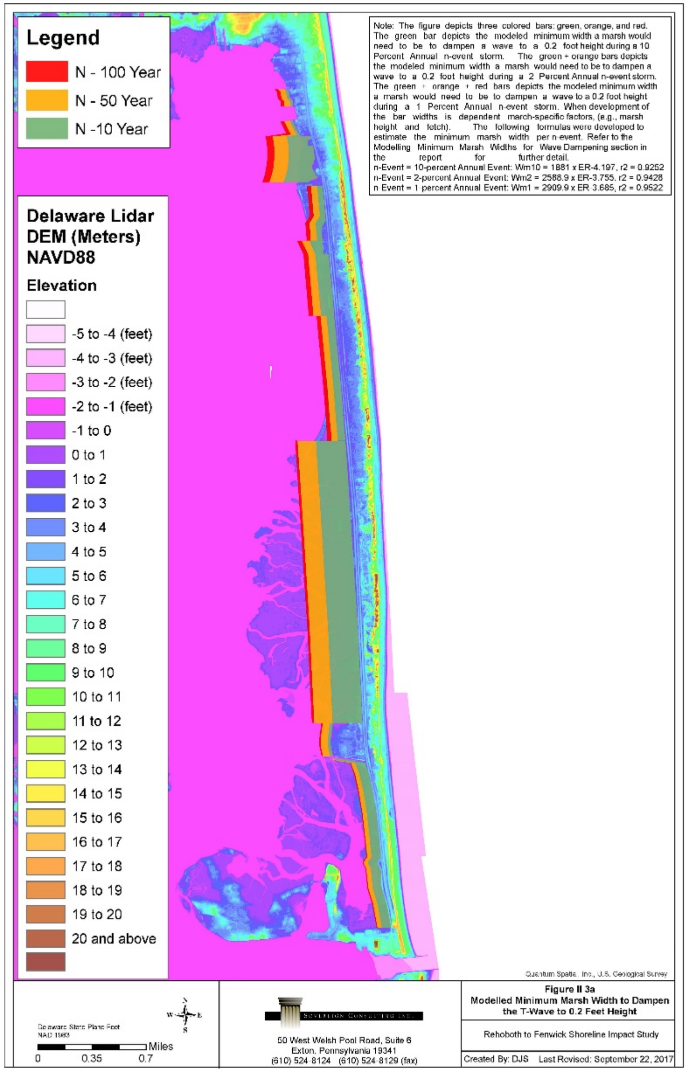
2-percent Annual Event: $W_m^{2} = 2588.9 \times ER^{-3.755}$, $r^2 = 0.9428$

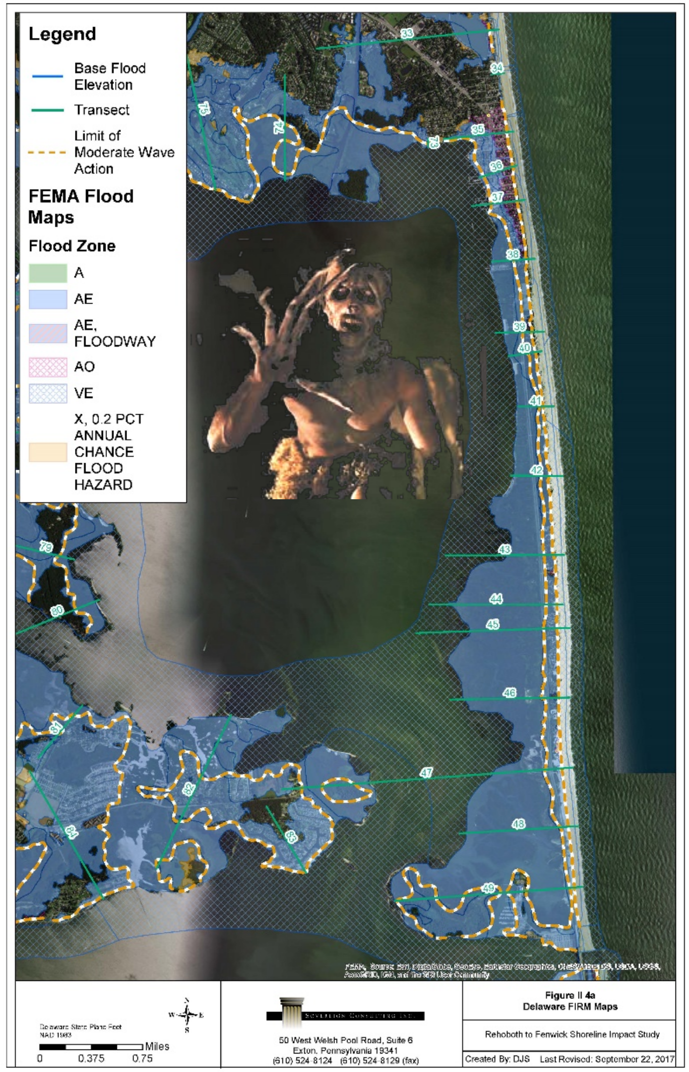
1-percent Annual Event: $W_m^{1} = 2909.9 \times ER^{-3.685}$, $r^2 = 0.9522$

Also developed a method to estimate ideal marsh widths 50 years from now based on marsh loss/gain trends.


Legend
N - 100 Year
N - 50 Year
N -10 Year
Delaware Lidar DEM (Meters) NAVD88
Elevation
-5 to -4 (feet)
-4 to -3 (feet)
-3 to -2 (feet)
-2 to -1 (feet)
-1 to 0
0 to 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 6
6 to 7
7 to 8
8 to 9
9 to 10
10 to 11
11 to 12
12 to 13
13 to 14
14 to 15
15 to 16
16 to 17
17 to 18
18 to 19
19 to 20
20 and above
Note: The figure depicts three colored bars: green, orange, and red. The green bar depicts the modeled minimum width a marsh would need to be to dampen a wave to a 0.2 foot height during a 10 Percent Annual n-event storm. The green + orange bars depicts the modeled minimum width a marsh would need to be to dampen a wave to a 0.2 foot height during a 2 Percent Annual n-event storm. The green + orange + red bars depicts the modeled minimum width a marsh would need to be to dampen a wave to a 0.2 foot height during a 1 Percent Annual n-event storm. When development of the bar widths is dependent march-specific factors, (e.g., marsh height and fetch). The following formulas were developed to estimate the minimum marsh width per n-event. Refer to the Modelling Minimum Marsh Widths for Wave Dampening section in the report for further detail.
n-Event = 10-percent Annual Event: Wm10 = 1881 x ER-4.197, r2 = 0.9252
n-Event = 2-percent Annual Event: Wm2 = 2588.9 x ER-3.755, r2 = 0.9428
n-Event = 1-percent Annual Event: Wm1 = 2909.8 x ER-3.685, r2 = 0.9522
Quantum Spatial, Inc., U.S. Geological Survey
Delaware State Plane Feet
NAD 1983
Miles
0
0.35
0.7
N
W
E
S
Sovereign Consulting Inc.
50 West Welsh Pool Road, Suite 6
Exton, Pennsylvania 19341
(610) 524-8124 (610) 524-8129 (fax)
Figure II 3a
Modelled Minimum Marsh Width to Dampen the T-Wave to 0.2 Feet Height
Rehnhoth to Fenwick Shoreline Impact Study
Created By: DJS Last Revised: September 22, 2017







FEMA's Limit of Moderate Wave Action (LiMWA).

LiMWA: *The landward limit where a wave no less than 1.5 feet high can reach during a 1-percent Annual Event.*


Legend
Shoreline Gain
Shoreline Loss
Note: A significant portion of the ocean shoreline has been altered due to beach nourishment and dune replenishment efforts occurring during the study period. As such, actual rates of shoreline gain and loss could not be accurately quantified during this study.
N
W
E
S
Delaware State Plane Feet
NAD 1983
0
0.325
0.65
Miles
SOVEREIGN CONSULTING INC.
50 West Welsh Pool Road, Suite 6
Exton, Pennsylvania 19341
(610) 524-8124 (610) 524-8129 (fax)
Figure II 2a
Marsh Gain and Loss From 1968 to 2015
Rehoboth to Fenwick Shoreline Impact Study
Created By: DJS Last Revised: September 22, 2017


Legend
Shoreline Gain
Shoreline Loss
Note: A significant portion of the ocean shoreline has been altered due to beach nourishment and dune replenishment efforts occurring during the study period. As such, actual rates of shoreline gain and loss could not be accurately quantified during this study.
N
W
E
S
Delaware State Plane Feet
0
0.275
0.55
Miles
SOVEREIGN CONSULTING INC.
50 West Welsh Pool Road, Suite 6
Exton, Pennsylvania 19341
(610) 524-8124 (610) 524-8129 (fax)
Figure II 2b
Marsh Gain and Loss From 1968 to 2015
Rehoboth to Fenwick Shoreline Impact Study
Created By: DJS Last Revised: September 22, 2017

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Vulnerability Summary - Bayside

Table II-10

n-Event	Reaches														
	BS-01	BS-02	BS-03	BS-04	BS-05	BS-06	BS-07	BS-08	BS-09	BS-10	BS-11	BS-12	BS-13	BS-14	BS-15
10-Percent Annual Event															
Flooding	4	3	3	4	4	4	4	4	4	4	4	2	2	2	2
Wave Energy	2	1	1	1	1	1	1	1	1	1	2	1	1	1	1
Buffer Resilience	4	1	4	1	3	1	1	1	4	1	4	1	1	4	4
Total	10	5	8	6	8	6	6	6	9	6	10	4	4	7	7
2-Percent Annual Event															
Flooding	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3
Wave Energy	3	1	2	1	2	2	1	1	2	1	3	1	1	2	2
Buffer Resilience	4	1	4	1	4	4	1	1	4	2	4	1	1	4	4
Total	11	6	10	6	10	10	6	6	10	7	11	5	5	9	9
1-Percent Annual Event															
Flooding	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wave Energy	3	1	2	1	2	2	1	1	2	1	3	1	1	2	2
Buffer Resilience	4	3	4	2	4	4	1	1	4	2	4	1	3	4	4
Total	11	8	10	7	10	10	6	6	10	7	11	6	8	10	10
Grand Total	32	19	28	19	28	26	18	18	29	20	32	15	17	26	26

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Read Avenue Hybrid Retrofit: Enhancement of Stormwater Drain Outfall and Living Shoreline

Town of Dewey Beach

Monigle Park was constructed in 2008 to protect shoreline from erosion.

Project Background

- Site located at west end of Read Avenue in Monigle Park
- Awarded Delaware Water Infrastructure Advisory Council (DWIC) Community Water Quality Improvement Grant
- Goals of project include:
  - stabilize shoreline
  - reducing flooding
  - improving water quality

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Funding Summary

CWQI Grants = $75,000
Dewey Beach Match = $35,000
DelDOT Match = $60,000
Center for Inland Bays In-kind = $3,209

Total = $173,209

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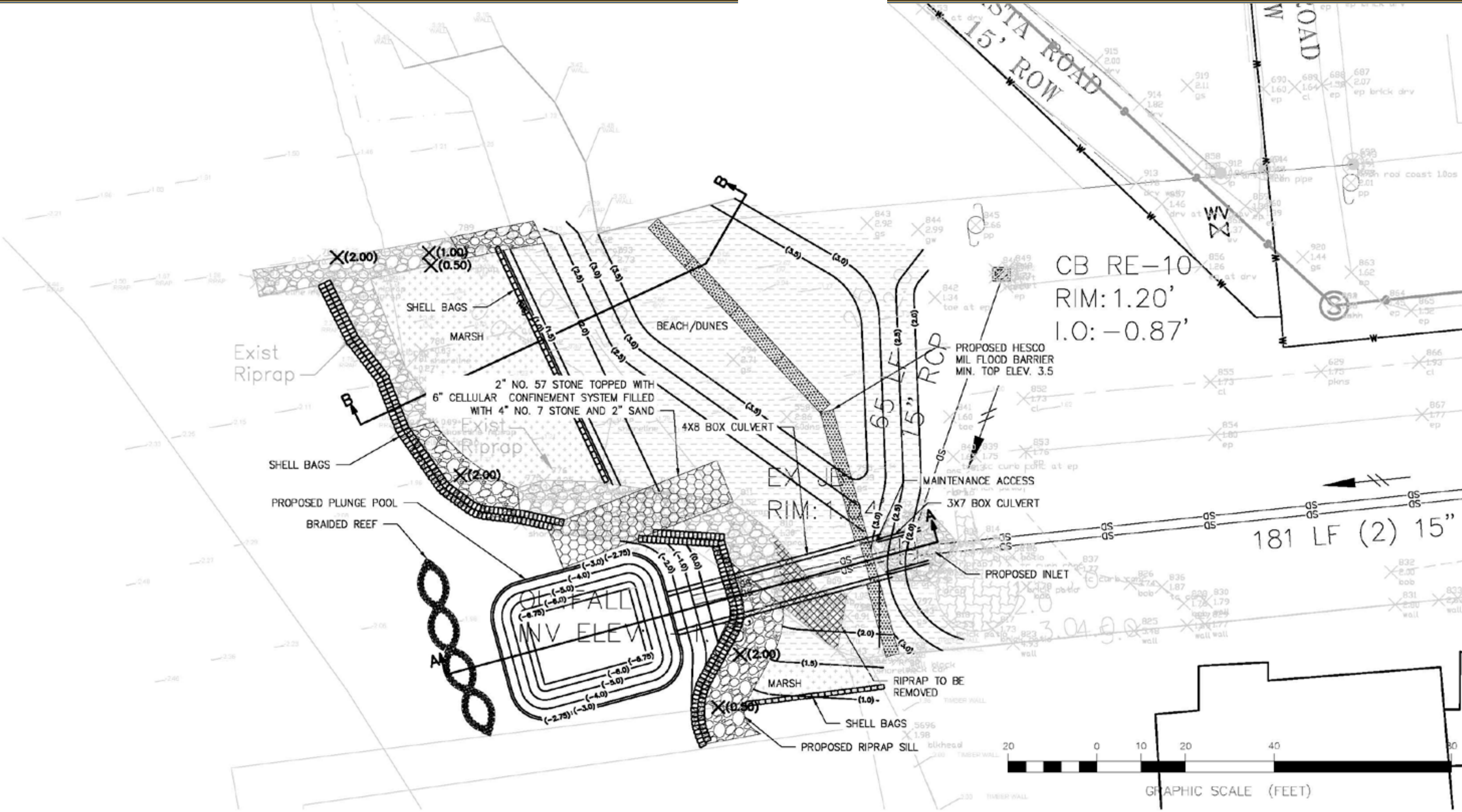

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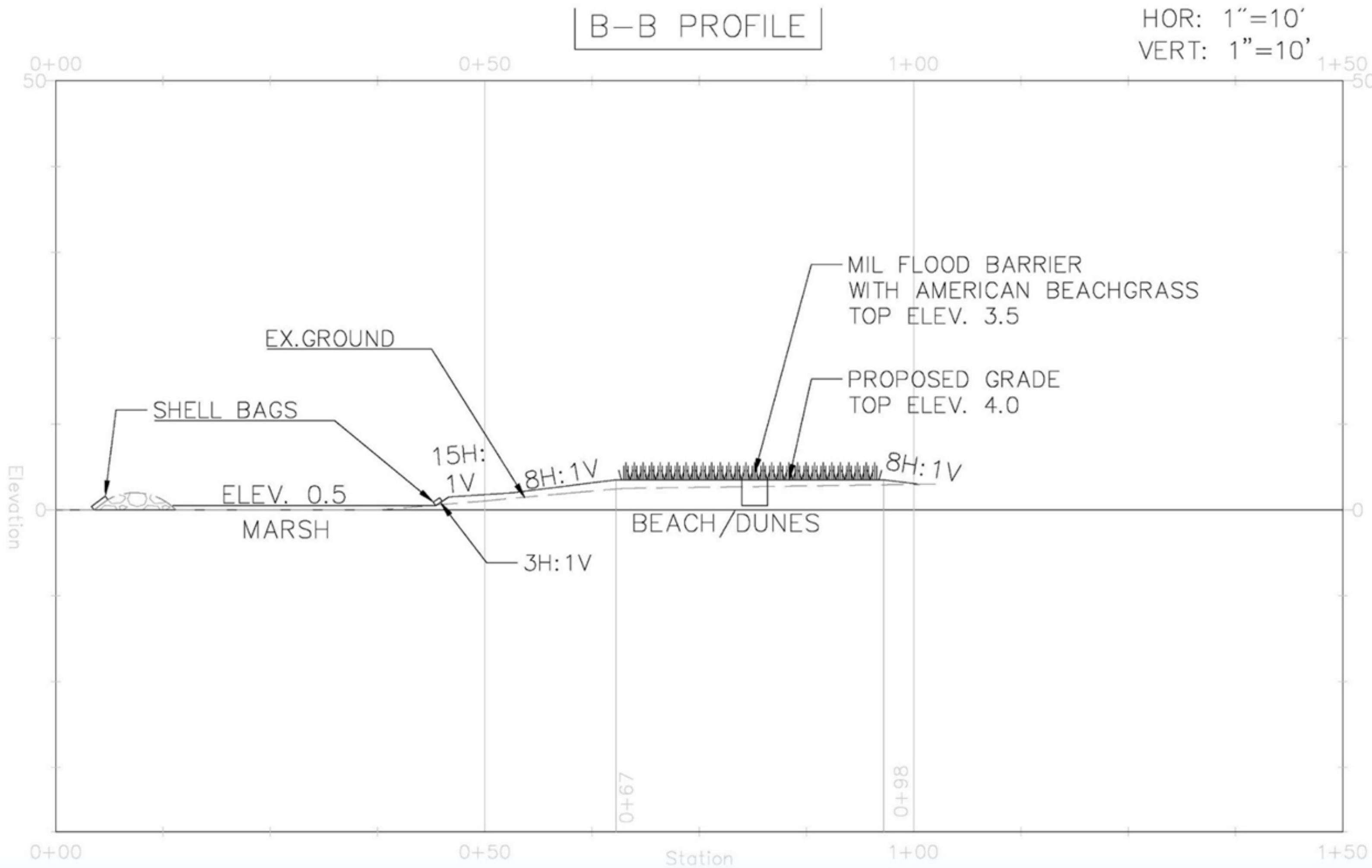
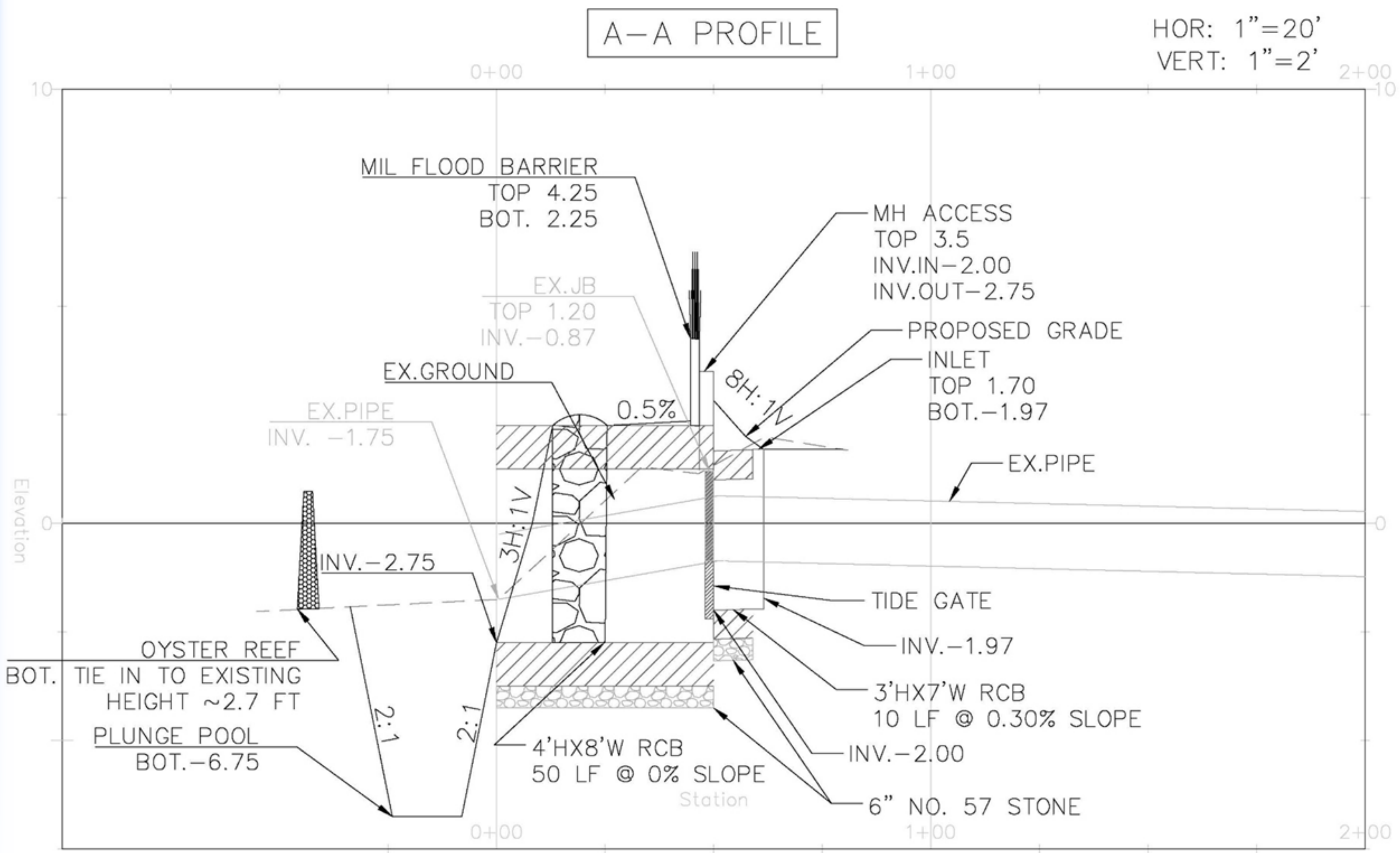
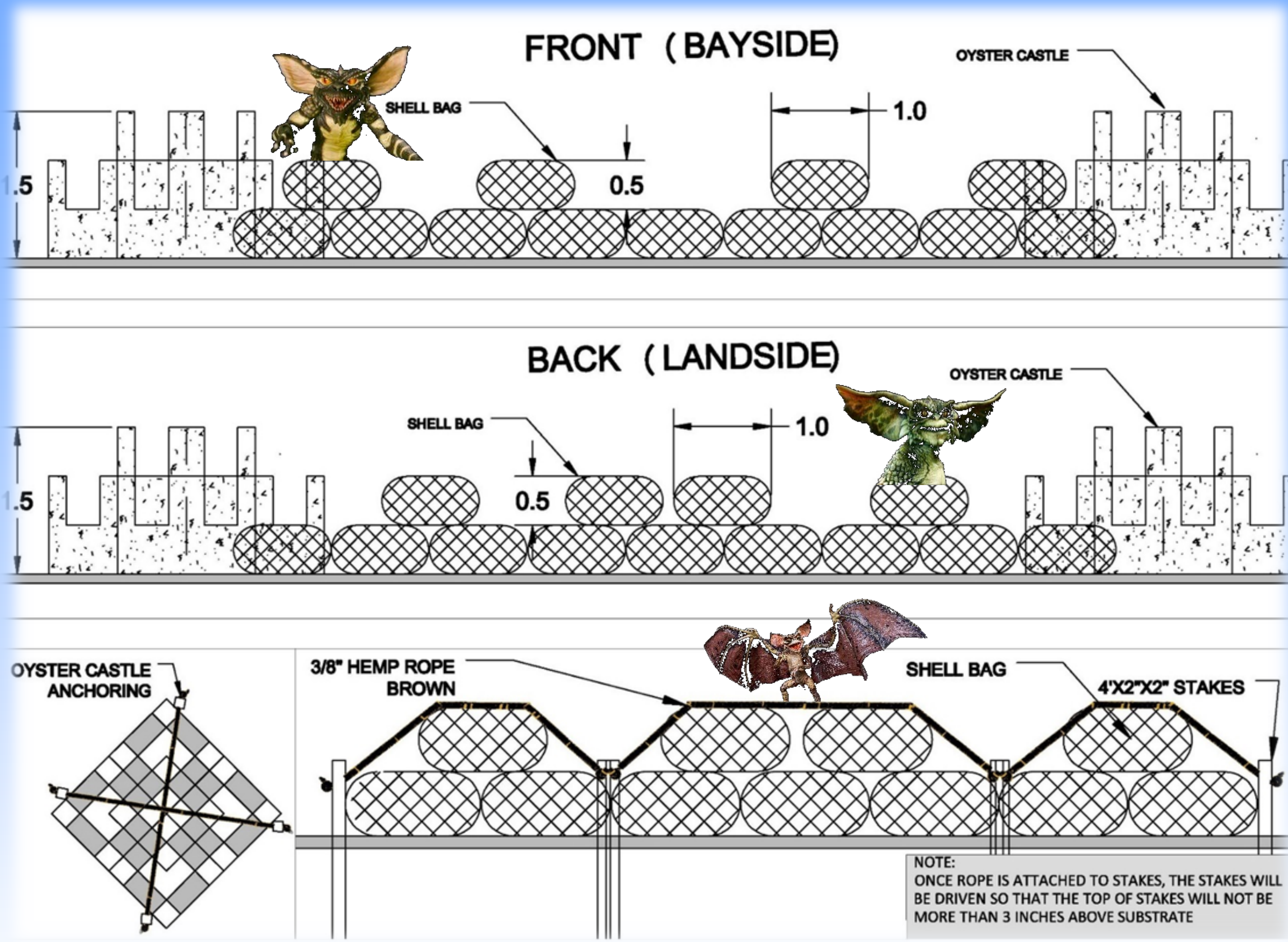



A–A PROFILE
HOR: 1"=20'
VERT: 1"=2'
0+00
1+00
2+00
10
0
Elevation
Station
MIL FLOOD BARRIER
TOP 4.25
BOT. 2.25
EX.JB
TOP 1.20
INV.–0.87
EX.GROUND
0.5%
EX.PIPE
INV. –1.75
MH ACCESS
TOP 3.5
INV.IN–2.00
INV.OUT–2.75
PROPOSED GRADE
INLET
TOP 1.70
BOT.–1.97
8H:1V
3H:1V
EX.PIPE
INV.–2.75
OYSTER REEF
BOT. TIE IN TO EXISTING
HEIGHT ~2.7 FT
PLUNGE POOL
BOT.–6.75
2:1
2:1
4'HX8'W RCB
50 LF @ 0% SLOPE
TIDE GATE
INV.–1.97
3'HX7'W RCB
10 LF @ 0.30% SLOPE
INV.–2.00
6" NO. 57 STONE


FRONT (BAYSIDE)
SHELL BAG
OYSTER CASTLE
1.0
0.5
1.5
BACK (LANDSIDE)
SHELL BAG
OYSTER CASTLE
1.0
0.5
1.5
OYSTER CASTLE ANCHORING
3/8" HEMP ROPE BROWN
SHELL BAG
4'X2"X2" STAKES
NOTE:
ONCE ROPE IS ATTACHED TO STAKES, THE STAKES WILL BE DRIVEN SO THAT THE TOP OF STAKES WILL NOT BE MORE THAN 3 INCHES ABOVE SUBSTRATE

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DelDOT

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Thank You

For More Information Contact

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