Current and Future State of Bioengineering

Brian Majka
Restoration Ecologist
GEI Consultants

March 9. 2023

What is Bioengineering?

- "Bioengineering is the combination of biological, mechanical, and ecological concepts to control erosion and stabilize soil through the sole use of vegetation or in combination with construction materials. Both living and nonliving plants can be used. Nonliving plants are used as construction materials, similar to engineered materials." -US Army Corps of Engineers
- Techniques originated by Forest Service to stabilize eroded areas using natural, on-site materials
- Focuses on balancing functionality with the surrounding ecosystem
- Incorporates natural and man-made materials to prevent or minimize erosion

2017 Shoreline and Shallows Conference

- "Current Trends in Natural Shoreline Engineering"
- Focused on techniques and products
- General growing trend and acceptance of bioengineered practices at the national level

Where have we been?

Where have we been?

Where have we been?

Where have we been?

1935

HOW DYNAMITE *streamlines streams*

Straightening of Pequest River in New Jersey by CCC workers stopped its yearly floods. Location of new channel is seen at right. Note temporary dam at left to provide volume of water for scouring blasted channel.

Explosion of dynamite charge by propagation excavates new channel.

Immediately after explosion, water is entering new channel, whose banks will be smoothed and "stream-lined" by the speedier flow of water.

CROOKED STREAMS are a menace to life and crops in the areas bordering on their banks. The twisting and turning of the channel retards the flow and reduces the capacity of the stream to handle large volumes of water. Floods result. Crops are ruined. Lives are lost. Banks are undermined, causing cave-ins that steal valuable acreage.

In many instances straightening out a stream has doubled its capacity for disposing of run-off water.

DYNAMITE may be used most efficiently and economically in taking the kinks out of a crooked stream. The dynamite is loaded along the length of "cut-off" channel. When fired, the dirt and other debris is heaved high in the air and is scattered over the adjoining territory—leaving practically no spoil-banks. In addition to the material actually thrown out, much dirt is loosened and is later scoured out by the water which rushes swiftly through the straightened channel.

Du Pont Dynamite has straightened many thousands of miles of crooked streams. Du Pont engineers have worked for years to develop the best blasting methods for the cleaning out and straightening of streams. All their data is in a 48-page book, "Ditching with Dynamite." It is for your use. Write for it.

Dynamite can help you do other jobs, too. It can help you build highways, dams; fight soil erosion; work quarries. Du Pont has an explosive for every purpose.

DU PONT

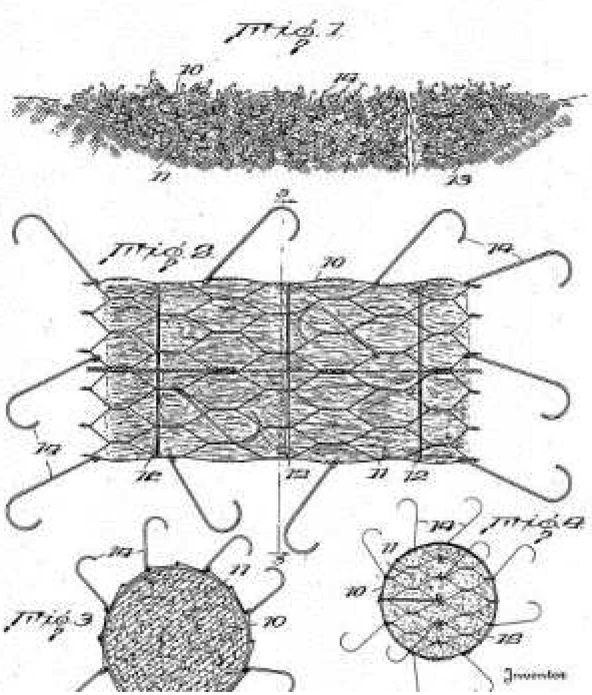
E. I. du Pont de Nemours & Co., Inc.
Explosives Department
6107 du Pont Building
Wilmington, Del.

1937

Feb. 23, 1937. M. S. WILLING 2,071,779

MEANS FOR PREVENTING SOIL EROSION

Original Filed July 10, 1935



Inventor

UNITED STATES PATENT OFFICE

2,071,779

MEANS FOR PREVENTING SOIL EROSION

Mark S. Willing, Mount Holly, Va.

Application July 10, 1935, Serial No. 38,722
Renewed November 6, 1936

3 Claims. (Cl. 61—3)

This invention relates to improvements in means for the prevention of soil erosion by flowing water.

One object of the invention is to provide a device of simple and inexpensive construction but which will be highly efficient in preventing soil erosion by flowing water.

A further object is to provide a device of this nature which lends itself readily to being assembled in any desired numbers, the several individual devices being interlocked, one with the other, to form an entangled mass of desired size to stem the flow of water over any given area, thus preventing or curtailing the scouring or eroding action of the water.

A still further object is to provide a frameless container of flexible material which will readily adapt itself to the contour of the surface on which it is placed.

More specifically, the invention contemplates means for preventing soil erosion by flowing water, said means consisting of a flexible container of wire mesh material, preferably filled with means for augmenting the accumulation of earthy matter therein and a plurality of hooks secured to said container and more or less promiscuously positioned around the same, whereby two or more of said containers placed in contact with one another will become entangled and form a substantially unitary mass.

With these and other objects in view, the invention consists in certain details of construction and combinations and arrangements of parts, all as will hereinafter be more fully described, and the novel features thereof particularly pointed out in the appended claims.

In the accompanying drawing—

Figure 1 illustrates a mass of the present containers located in a depression in the earth's surface, under which circumstances further erosion by water flowing along the depression will be prevented;

Fig. 2 is a side elevation of one of the individual containers;

Fig. 3 is a transverse sectional view on the line 3—3 of Fig. 2; and

Fig. 4 is an end elevation of the container.

In order that there can be some seepage or flow of water through an obstruction formed by a multiplicity of the containers of the present invention, said containers are made of a mesh-like material, a wire mesh material 10 being illustrated in the present instance. Enclosed within each container is a material which will facilitate stitutes so as to form a substantially closed obstruction to the flow of water in the channel in which the mass of containers is assembled. One material that can be used, as illustrated in the present instance, is brush or heavy weeds 11, or the like, preferably secured more or less in bundle form by bands 12.

As illustrated in Fig. 1, a large number of the containers 10 are massed in a depression or channel in the earth's surface 13. In other words, this depression may be assumed to have been formed by an excessive flow of water over this area, and by damming up the depression with the containers, further erosion or scouring of the earth's surface at this point will be prevented.

If desired, additional weight may be given the individual containers by some suitable means such as enclosing rather large stones or rocks (not shown) within the brush material, but such anchoring means are not essential as the present container is provided with a number of hooks 14 distributed promiscuously around the container. Each hook is formed with an eye at one end, loosely encircling one or more of the wire strands constituting the mesh material, so that the hooks may be said to be pivotally secured to the container. In depositing or throwing the containers in, or on, the area to be protected, a number of them may be secured together by hooking one into the other, prior to placing them on the earth, or they can be thrown in individually and, due to the irregular disposition of the hooks and the swiveling action of which they are capable, the bundles, as they are successively placed in contact with one another, will immediately become entangled and thus build up a mass such as illustrated in Fig. 1. Furthermore, the hooks, in addition to facilitating entangling the containers one with the other, also serve as anchoring means, because they will readily attach themselves to irregularities on the surface on which the containers are placed.

It will also be observed that no frame is used in the present container. Therefore, due to the flexibility of the mesh material of which the container is formed, the containers will readily adapt themselves to major irregularities in the surface of the earth on which they are placed. The construction of the individual containers is such that they may be produced at very little expense and, by the provision of the several hooks on each container, they may be readily and easily secured together to build up a mass of the desired

General Trends in the Past

- Practitioner driven
- Field based research
- Lots of "trial and error"
- Lots of statements like this:

"A great deal of design guidance is available for stream bank soil bioengineering practices. Some of this guidance is applicable to soil bioengineering on lake shores. However, most of the limiting criteria are expressed in velocity or shear exerted by flowing fluvial systems. Little guidance is available for a designer to calculate the required treatment for wave energy. Designers who adapt streambank soil bioengineering techniques to lake shore conditions will have to rely on judgment and local examples of successful approaches. " –NRCS *A Guide for Design and Layout of Vegetated Protection for Earthen Embankments and Shorelines, 2014*

General Trends in the Past

- Practitioner driven
- Field based research
- Lots of "trial and error"
- Lots of statements like this:

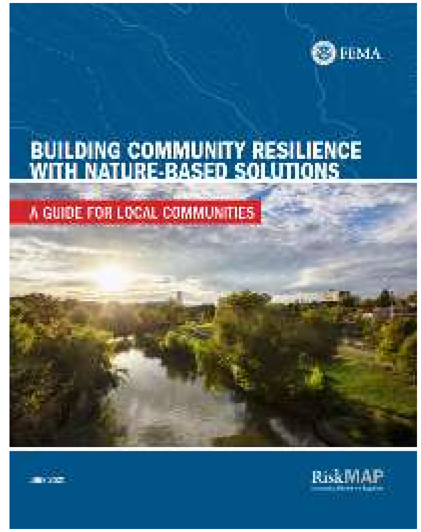
"A great deal of design guidance is available for stream bank soil bioengineering practices. Some of this guidance is applicable to soil bioengineering on lake shores. However, most of the limiting criteria are expressed in velocity or shear exerted by flowing fluvial systems. Little guidance is available for a designer to calculate the required treatment for wave energy. Designers who adapt streambank soil bioengineering techniques to lake shore conditions will have to rely on judgment and local examples of successful approaches. " –NRCS *A Guide for Design and Layout of Vegetated Protection for Earthen Embankments and Shorelines, 2014*

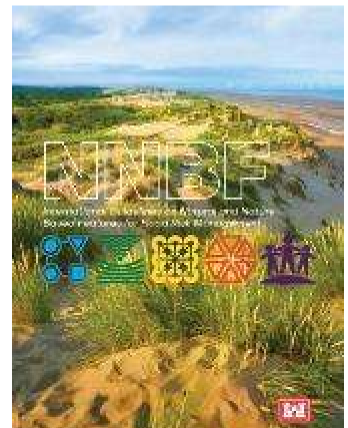
What's Changing and Where are we Going?

- Terminology
- Nationwide Acceptance (and funding)
- Research
- Tools

Terminology

- "Natural and Nature-Based Features (NNBF)" is becoming widely adopted
  - Properly addresses the need for hybridized solutions
  - Helps people understand how nature and society can be compatible
- Living shorelines
- Natural shoreline engineering
- Bioengineering



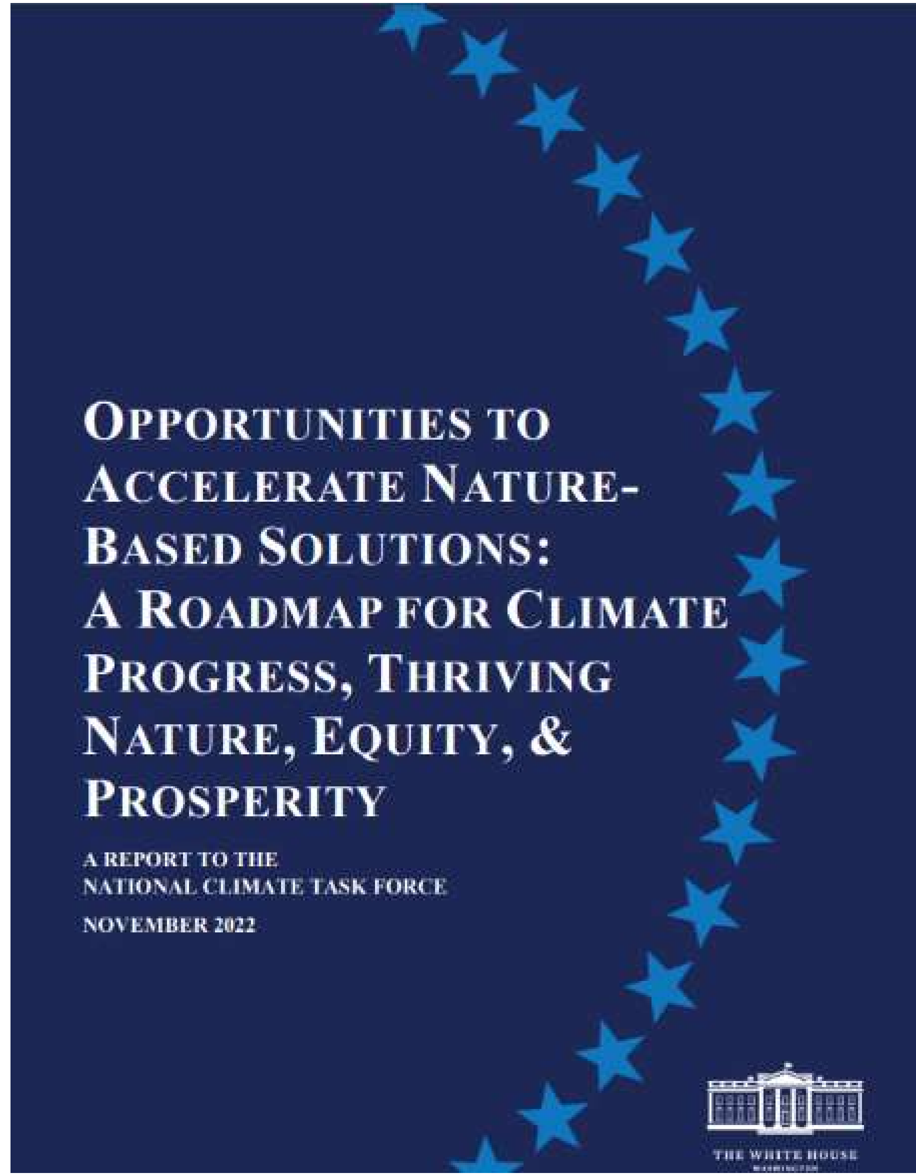



National Park Service

Coastal Engineering—Natural and Nature-based Features

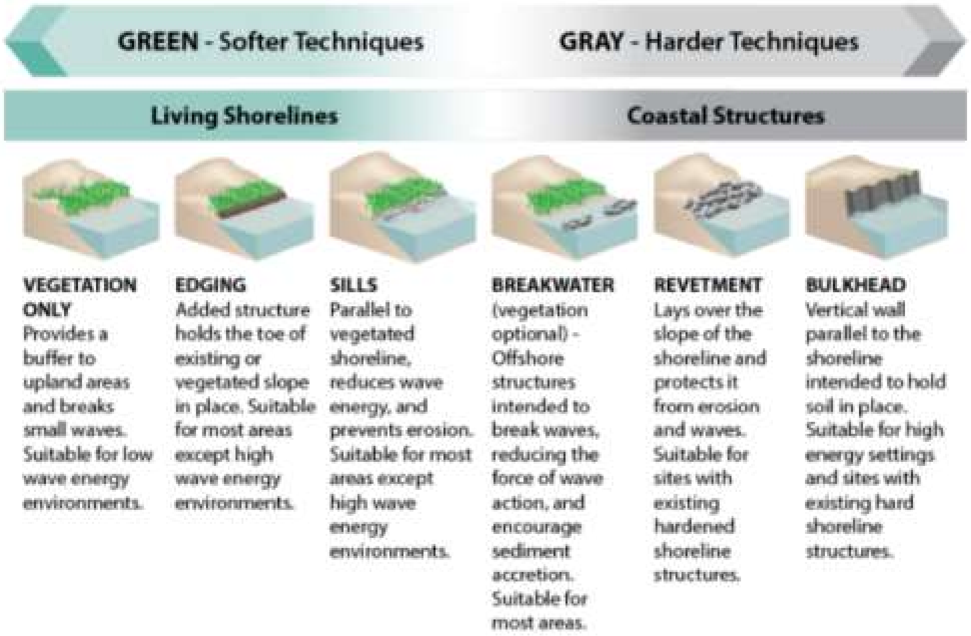
National Attention

- White House issued “Nature Based Solutions Road Map” on November 8, 2022
    1. Update Policies to Accelerate Nature-Based Solutions
    2. Unlock Funding for Nature-Based Solutions
    3. Lead with Federal Facilities and Assets
    4. Train the Nature-Based Solutions Workforce
    5. Prioritize Research, Innovation, Knowledge, and Adaptive Learning



US Army Corps of Engineers “Engineerng with Nature” Program

- https://ewn.erdc.dren.mil/
- “Engineering With Nature® is the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaboration.”
- Focused on flooding and erosion control while creating habitat
- Provides publications, research, seminars, guidance, network, and tool for EWN projects



Great Lakes NNBF Playbook

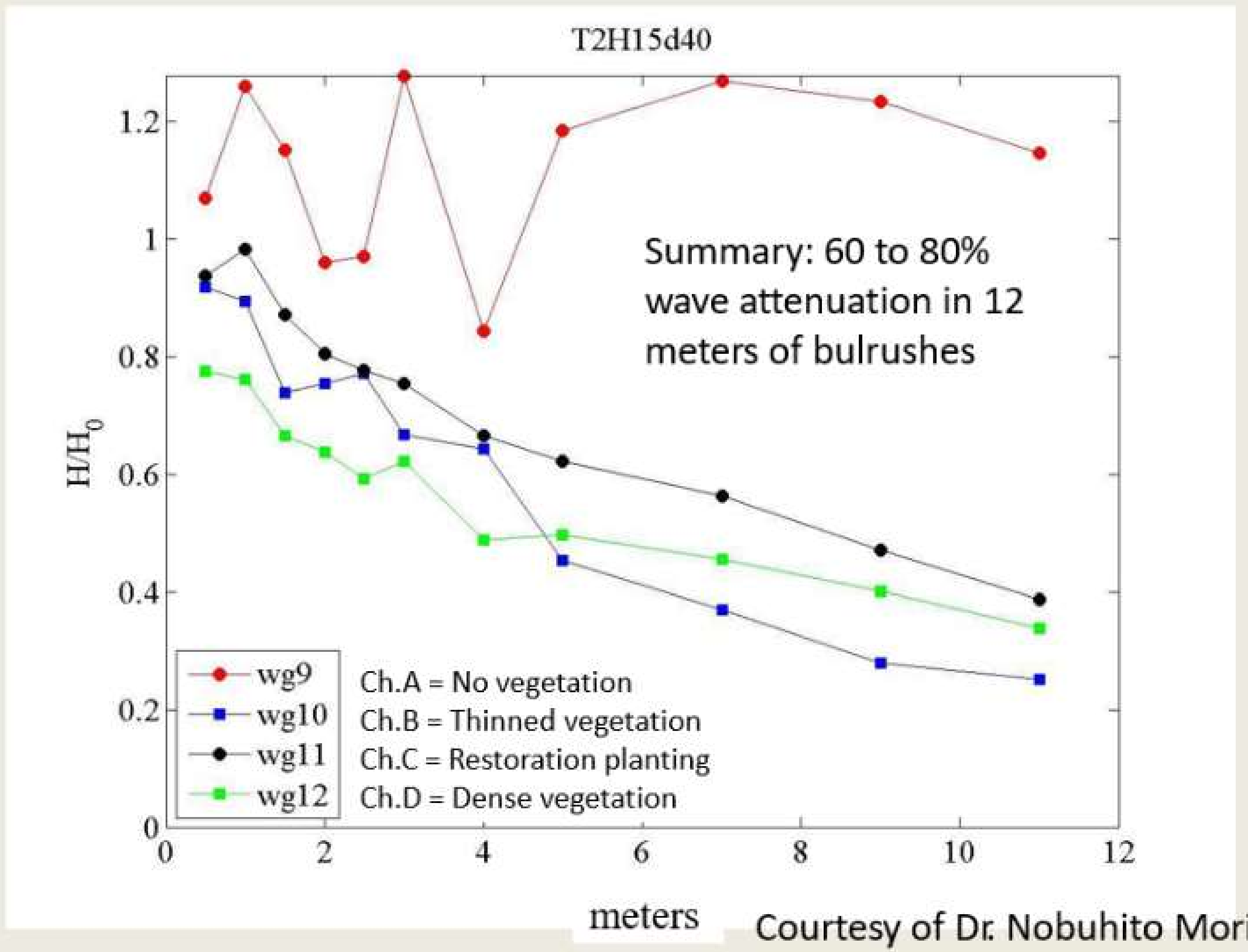
- USACE is developing a Great Lakes-wide NNBF "Playbook"
- Intended to provide detailed guidelines for NNBF projects in the Great Lakes
- Official kickoff in January, 2023 --collaborative workshop in Chicago with representatives from throughout the Great Lakes

Academic Reseach

- Advancing significantly
- Laboratory and field-based research to support NNBF practices
- Starting provide quantified information to support bioengineering design and implementation

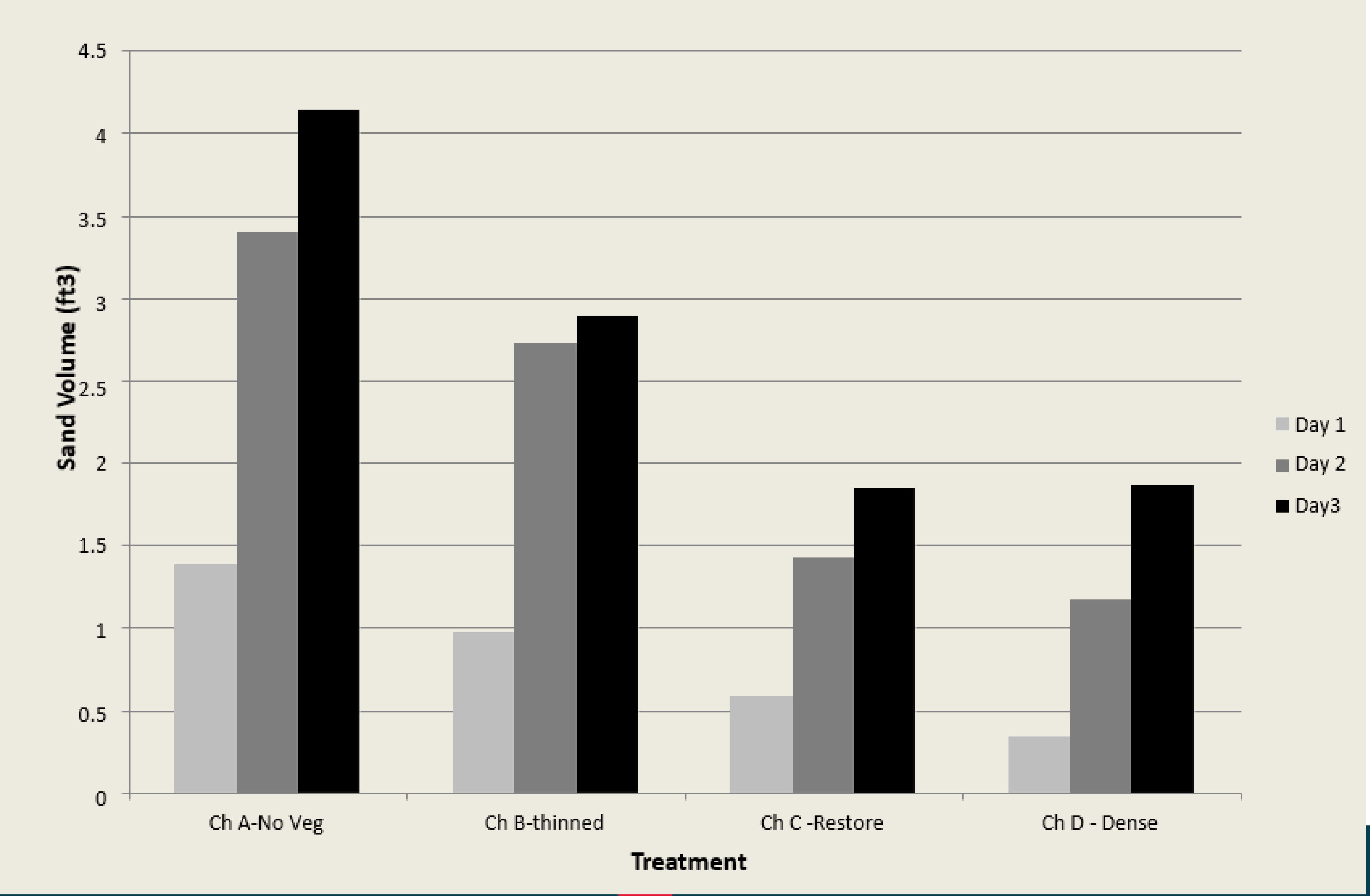
Oregon State University 2010

Oregon State University 2010



Courtesy of Dr. Nobuhito Mori

Oregon State University 2010



University of Ottawa, 2021

Nature-Based Coastal Protection by Large Woody Debris as Compared to Seawalls: A Physical Model Study of Beach Morphology and Wave Reflection

Pauline Falkenrich [1,2], Jessica Wilson [3,4], Ioan Nistor [3], Nils Goseberg [1,5,*], Andrew Cornett [3,6] and Abdolmajid Mohammadian [3]

(a) (b) (c)

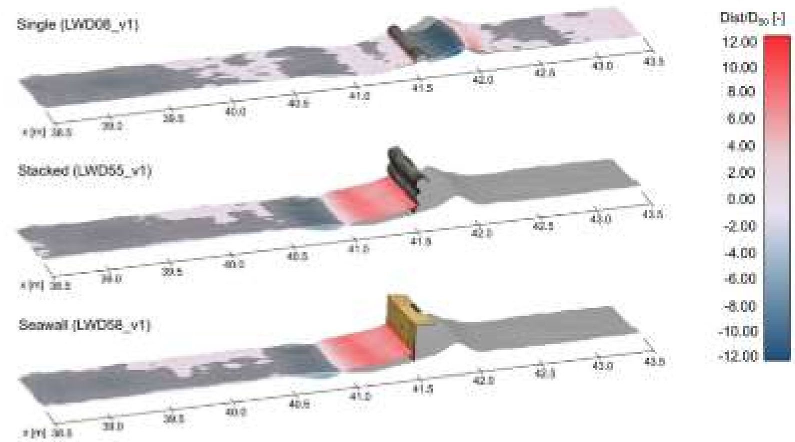


Figure 9. Beach profile changes for each structure configuration in relation to the beach profile with *No Structures* (grey) under small wave conditions (Tp = 1.78 s, Hs = 0.10 m).

University of Padua, 2018

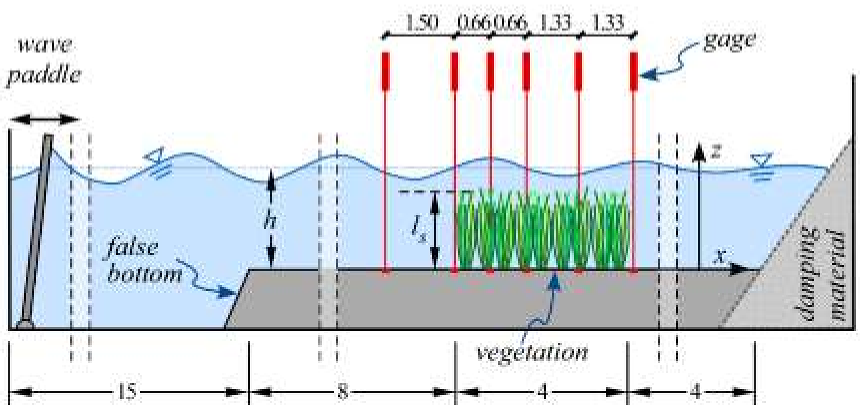
Wave Height Attenuation and Flow Resistance Due to Emergent or Near-Emergent Vegetation

Paolo Peruzzo [1,*], Francesca De Serio [2], Andrea Defina [1] and Michele Mossa [2]

[1] Department of Civil, Architectural and Environmental Engineering, University of Padua, Via Loredan, 20, 35131 Padova PD, Italy; andrea.defina@dicea.unipd.it

[2] Department of Civil, Environmental, Land, Building Engineering and Chemistry, Polytechnic University of Bari, Via Edoardo Orabona, 4, 70126 Bari BA, Italy; francesca.deserio@poliba.it (F.D.S.); michele.mossa@poliba.it (M.M.)

* Correspondence: paolo.peruzzo@dicea.unipd.it; Tel.: +39-049-8275659



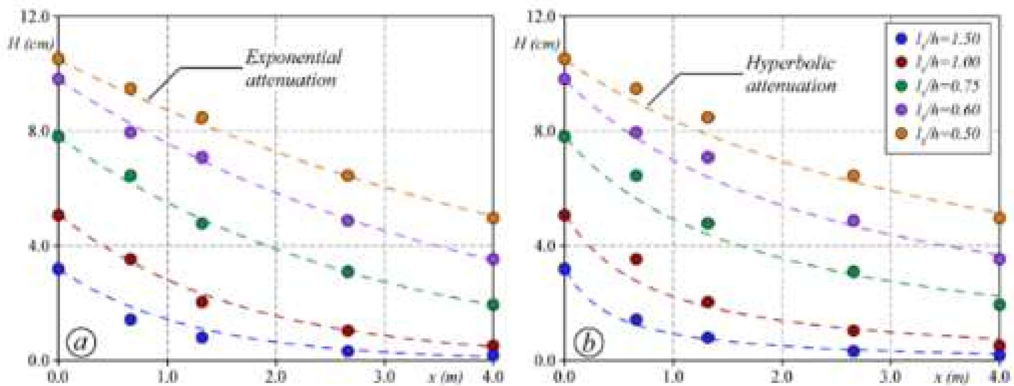


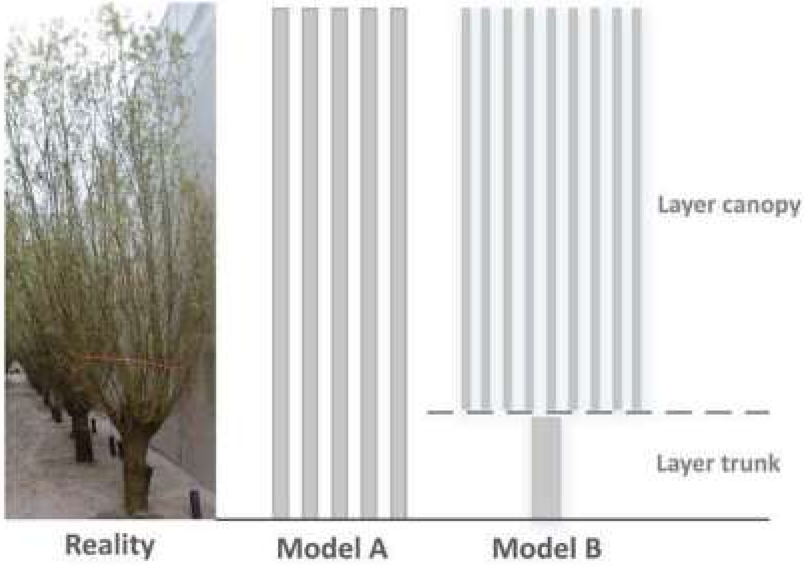
Figure 5. Wave height H along the vegetated reach when density is n_p = 312.5 plant/m^2 and the relative vegetation height is in the range $0.5 \leq l_s/h \leq 1.5$. Wave period and slope are T = 1 s and H_0/L = 0.08. Circles denote the experimental data, dashed line are the modeled wave attenuation either with (**a**) the exponential model given by Equation (6); or (**b**) the hyperbolic model given by Equation (4).

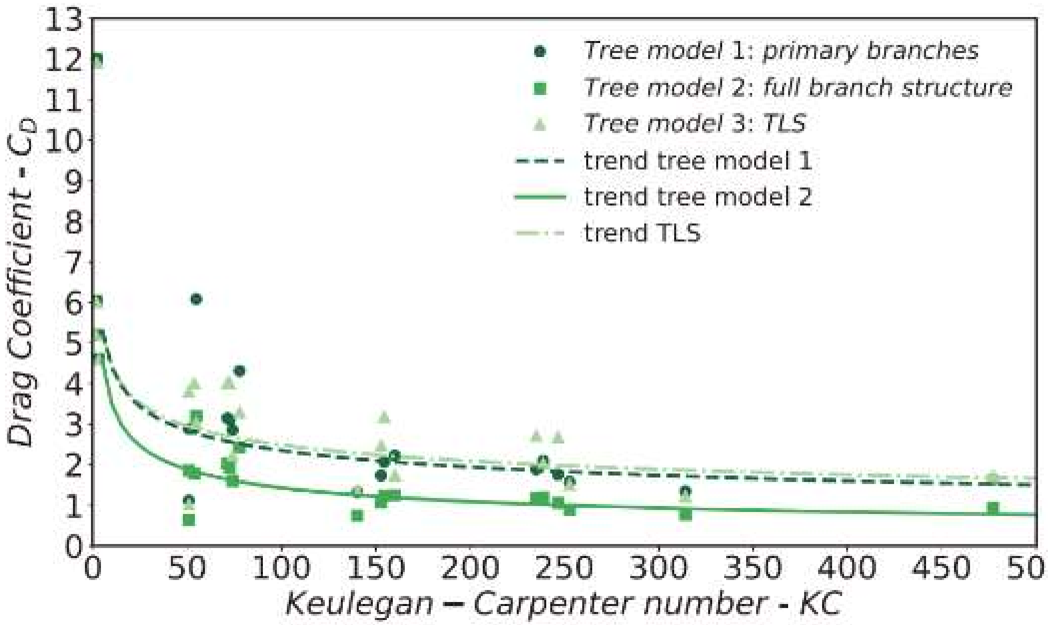
Delft University of Technology, 2022

Quantifying Frontal-Surface Area of Woody Vegetation: A Crucial Parameter for Wave Attenuation

Su A. Kalloe[1*], Bas Hofland[1,2], José A. A. Antolínez[1,2] and Bregje K. van Wesenbeeck[1,2]

[1] Department of Hydraulic Engineering, Delft University of Technology, Delft, Netherlands, [2] Unit for Marine and Coastal Systems, Deltares, Delft, Netherlands

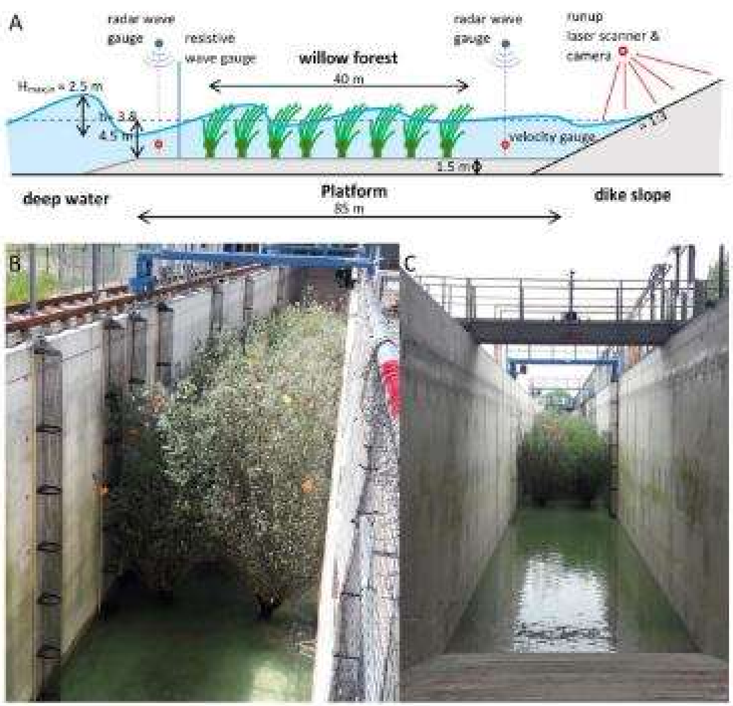


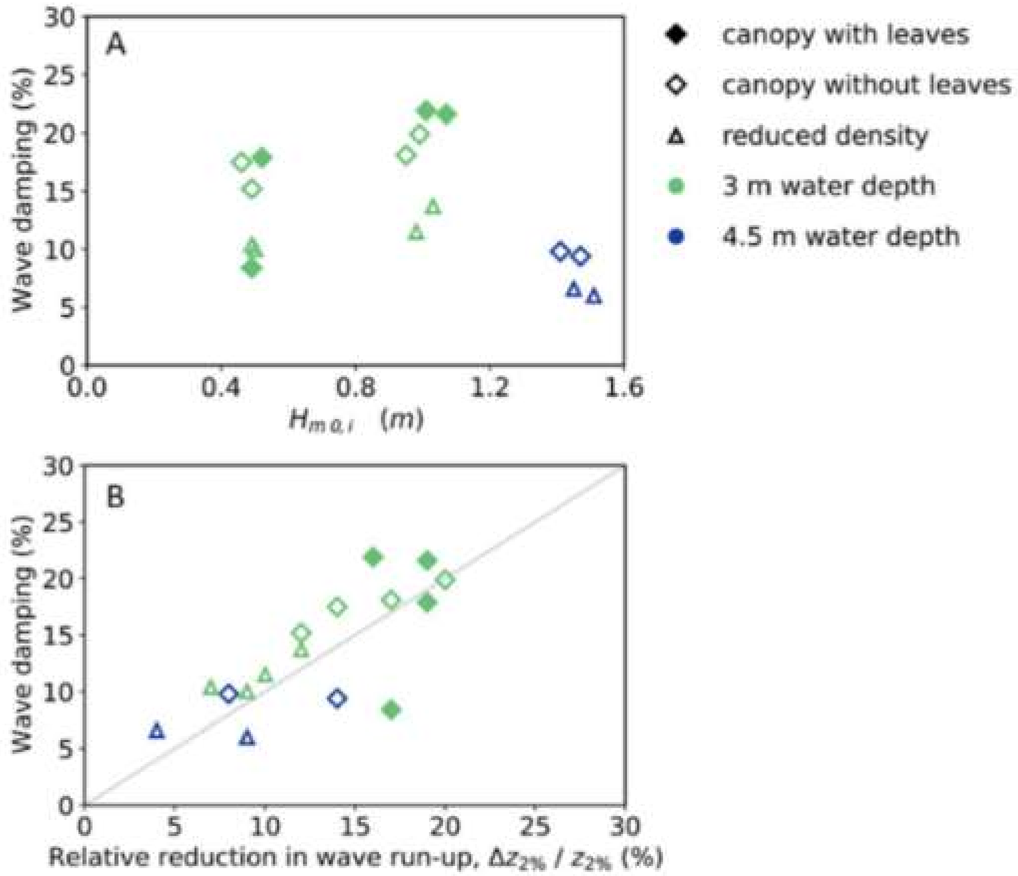


Netherlands, 2022

Wave attenuation through forests under extreme conditions

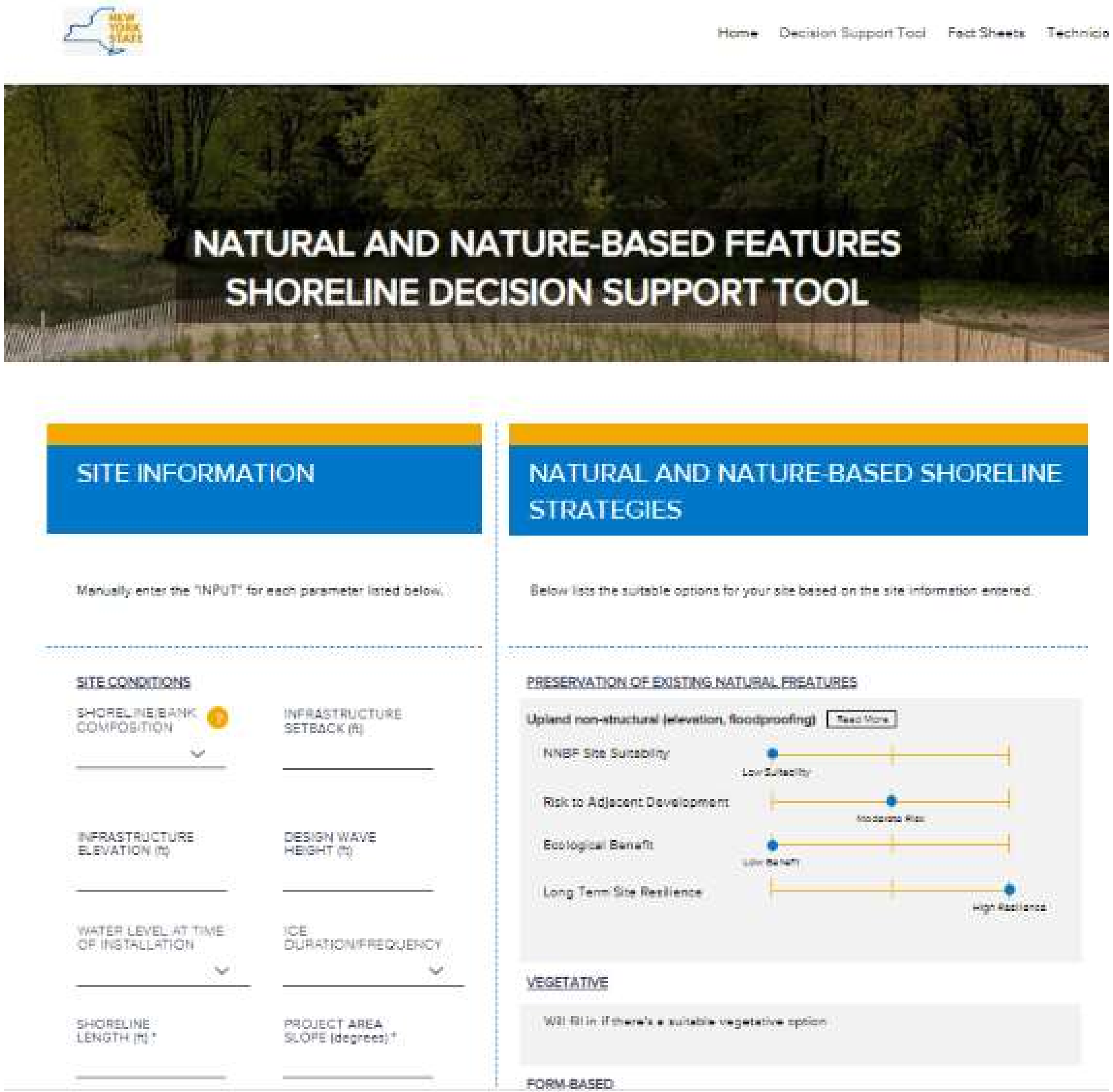
Bregje K. van Wesenbeeck[1,2], Guido Wolters[1], José A. A. Antolínez[1,2], Sudarshini A. Kalloe[2], Bas Hofland[2], Wiebe P. de Boer[1], Ceylan Çete[2] & Tjeerd J. Bouma[3,4]





Natural/Nature-Based Shoreline Decision Tools

- Under development for state of NY and MI
- Algorithms to analyze physical, biological, and regulatory parameters
- Provides site-specific recommendations
- Will be web-based



NY Tool Inputs

Site Inputs — **Directions:** Manually enter the "INPUT" for each parameter (Column C).

Site Parameter Category	Site Parameter	Input
Site Location	Where is the site located?	**Lake Ontario**
Site Conditions	Shoreline/Bank Composition	**Clay/Till**
	Infrastructure Setback (feet)	**None present**
	Infrastructure Elevation (feet)	**5'-10'**
	Design Wave Height (feet)	**4**
	Water Level at the Time of Installation	**Average**
	Ice Duration/Frequency	**Rare**
	Shoreline Length (feet)	**50**
	Project Area Slope (degrees)	**20**
	Shoreline width (feet)	**5**
	Bank height (feet)	**5**
	Coastal Structure Presence	**Shore Parallel**
Ecological Features	Existing Wetlands	**Present**
	Significant Natural Communities	**Not present**
	Rare Plants/ Animals	**Not present**
Regulatory Considerations	OHWM	**Yes**
	Coastal Erosion Hazard Area	**Other waterbody**
	Bed or Bank Disturbance	**Yes**
	Federal Funding	**No**

NY Tool Outputs

Natural and Nature-Based Shoreline Assessment Outputs

Natural and Nature-Based Shoreline Adaptation Strategies	NNBF Site Suitability	Risk of Damage to Adjacent Lands	Relative Ecological Benefit	Long Term Site Resilience
1. Preservation of Existing Natural Features				
a. No action	Moderate Suitability	Moderate Risk	Better	Low Resilience
b. Active conservation (easement)	Moderate Suitability	Moderate Risk	Better	Low Resilience
floodproofing)	Not Recommended	-	-	-
d. Upland non-structural (relocation)	Not Recommended	-	-	-
2. Vegetative				
a. Native Planting (with/ without sediment fill)	Not Recommended	-	-	-
b. Native Planting with coir logs, coir blankets, coir	Not Recommended	-	-	-
c. Native Planting with brush bundles, fascines, ma	Not Recommended	-	-	-
3. Form-Based				
a. Sloped rock toe with sloped dune or bluff	High Suitability	Low Risk	Good	Moderate Resilience
b. Sloped rock toe with shrubs/ vegetation added for joint planting	High Suitability	Low Risk	Better	Moderate Resilience
c. Sloped rock toe with bioengineered lifts for	High Suitability	Low Risk	Better	Moderate Resilience
d. Large woody habitat structures	Moderate Suitability	Low Risk	Better	Moderate Resilience
e. Nearshore sills with wetland vegetation planted landward	Not Recommended	-	-	-
f. Emergent sills	Not Recommended	-	-	-
g. Submerged sills	Not Recommended	-	-	-
h. Crib wall	High Suitability	Low Risk	Better	Moderate Resilience
I. Submerged wave barriers	Not Recommended	-	-	-
4. Process Based				
a. Beach nourishment	Not Recommended	-	-	-
b. Dune/bluff restoration (compatible fill)	Not Recommended	-	-	-
c. Coastal wetland restoration	Not Recommended	-	-	-
b. Grading/sloping of shorelines or bluffs	Not Recommended	-	-	-
c. Sediment Bypassing	Not Recommended	-	-	-

Calculations and Logic

Critical Stone Weight for Wave/Slope Combinations (18" stone is ~500 lbs, 12" stone is ~160 lbs, 6" stone is ~20 lbs)													
	Slope (XH:1V)												
Wave Hei	1	2	3	4	5	6	7	8	9	10	18	19	20
0.5	15	7.7	5.1	3.9	3.1	2.6	2.2	1.9	1.7	1.5	0.9	0.8	0.8
1	124	61.9	41	31	24.7	20.6	17.7	15.5	13.7	12.3	6.9	6.5	6.1
1.5	418	209	139	104	84	70	60	52	46	42	23	22	21
2	989	495	330	247	198	165	141	124	110	99	55	52	50
2.5	1933	966	644	483	386	322	276	242	214	193	107	102	97
3	3340	1670	1113	835	668	556	477	417	371	334	186	176	167
3.5	5305	2652	1768	1326	1060	884	758	663	589	530	295	279	265
4	7918	3959	2639	1979	1583	1319	1131	989	897	791	439	417	396

Vegetative Techniques

Vegetative techniques rely on the root systems of native plant species to stabilize the soil while creating habitat. This can be accomplished through seeding or planting of locally harvested or commercially produced plant materials. Vegetative techniques may be combined with manufactured biodegradable materials or natural wood and brush to provide increased protection to the shoreline.

Influence on Coastal Processes

Vegetative techniques typically have a positive impact on coastal processes because they bind sediment but naturally adapt to dynamic coastal conditions. These techniques typically do not interrupt natural sediment transport and have a limited negative impact on adjacent properties.

Insert drawing of brish bundles

Native Planting with/without soil fill

Installation of coastal native plant species, which in some cases may be combined with clean fill material to create stable shorelines.

Native Plantings with brush bundles, fascines, or mattresses

Native plantings that are established together with woody brush features. Brush features come in varying configurations (i.e. round bundles ~20", mattresses 1' H x 10' L x 10' W) but typically consist of +/- 1-2" woody brush cuttings that are lashed together and tightly packed along the shoreline to provide increased protection. Since the brush features are wood, they will biodegrade overtime. Because these techniques use brush they generally provide a low cost stabilization alternative as the material is readily available in many cases right on site.

Native Planting with coir logs, coir blankets, or coir mattresses

Coastal plantings combined with coir, which is a manufactured biodegradable coconut fiber product that comes in several configurations such as round logs or thin flat blankets. The coir product aids in the establishment of native species by providing an additional measure of stabilization until the plants can firmly take root. As the plants mature, they grow through the coir into the underlying sediment and grow dense root masses. As the plants become established the coir naturally degrades.

Benefits

1. The addition of native plant species to any site will create and/or enhance upland coastal wildlife habitat, providing a high ecological benefit.

2. The physical and biological characteristics of native coastal plant species allow them in many instances to adapt to dynamic coastal conditions.

3. Native plants can provide a lower maintenance and attractive feature to a shoreline landscape.

Used For

1. Sites with relatively low wave energy (less than 1 foot)
2. Shorelines with gentler slopes (less than 45 degrees)
3. Properties where there is relatively low risk to infrastructure
4. Shorelines with sandy or loose sediments in which plants can be easily installed are preferred
5. Sensitive ecological areas where more robust techniques may cause damage to protected or high quality species

Drawbacks

1. Native plants alone may not be sufficient to stabilize soil in high energy environments.

2. The aesthetics of native plants may not always be compatible with adjacent landscapes.

Shorelines and Resiliency—Form vs. Processes

- Form based solutions
  - Traditional engineered solutions
  - Typically designed around static or set conditions
  - Focus on static stability-not dynamic stability
- Process based solutions
  - Understands that shorelines are naturally transient and dynamic systems
  - Allow for movement of sediments and vegetation
  - Create conditions that can naturally adapt with less intervention over time
  - “Living” systems

New York NNBF Monitoring Protocols

MEASURING SUCCESS

MONITORING NATURAL AND NATURE-BASED SHORELINE FEATURES IN NEW YORK STATE

FINAL REPORT

February 2020

Prepared For:

Department of State

NYSERDA

Prepared By:

With:

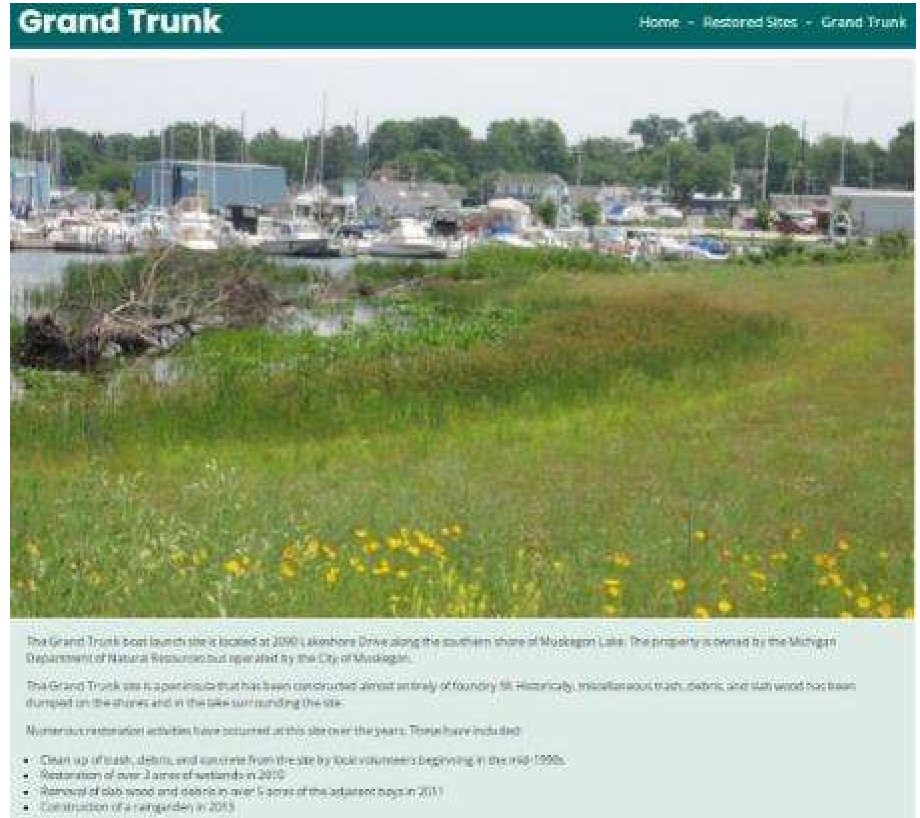
SCAPE

ARCADIS

Contents

Muskegon Lake Monitoring and Maintenance

- Scientific and citizen-based monitoring
- Web-based management plan
- Links to social media groups for long term shoreline stewardship



In Summary—Where Are We Heading?

- A federal focus, including policy, training, and funding support
- Refined, common terminology
- More sophisticated science and engineering
- We're not seeing a lot of new techniques, but our knowledge of when, where, and how to apply them is getting better
- Better focus on maintenance and monitoring

Brian Majka

GEI Consultants, Inc.

bmajka@geiconsultants.com

616-843-3635