Use of Natural and Nature-Based Features to Enhance the Resilience of Coastal Systems

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Coastal Risk Reduction and Resilience

The USACE planning approach supports an **integrated approach** to reducing coastal risks and increasing human and ecosystem community resilience through a combination of **natural, nature-based, non-structural and structural measures**. This approach considers the engineering attributes of the component features and the dependencies and interactions among these features over both the short- and long-term. It also considers the **full range of environmental and social benefits** produced by the component features.
Natural and Nature-Based Features

Natural features are created and evolve over time through the actions of physical, biological, geologic, and chemical processes operating in nature. Nature-based features are those that may mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as coastal risk reduction.

The built components of the system include nature-based and other structures that support a range of objectives, including erosion control and storm risk reduction (e.g., seawalls, levees), as well as infrastructure providing economic and social functions (e.g., navigation channels, ports, harbors, residential housing). Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, dunes, beaches, wetlands, and maritime forests. The relationships and interactions among the natural and built features comprising the coastal system are important variables determining coastal vulnerability, reliability, risk, and resilience.
### Natural and Nature-Based Infrastructure at a Glance

#### General Coastal Risk Reduction Performance Factors:
- Storm intensity, track, and forward speed, and surrounding local bathymetry and topography

#### Dunes and Beaches
- **Benefits/Processes**
  - Break offshore waves
  - Attenuate wave energy
  - Slow inland water transfer

- **Performance Factors**
  - Berm height and width
  - Beach slope
  - Sediment grain size and supply
  - Dune height, crest, width
  - Presence of vegetation

#### Vegetated Features:
- **Salt Marshes, Wetlands, Submerged Aquatic Vegetation (SAV)**
- **Benefits/Processes**
  - Break offshore waves
  - Attenuate wave energy
  - Slow inland water transfer

- **Performance Factors**
  - Marsh, wetland, or SAV elevation and continuity
  - Vegetation type and density

#### Oyster and Coral Reefs
- **Benefits/Processes**
  - Break offshore waves
  - Attenuate wave energy
  - Slow inland water transfer

- **Performance Factors**
  - Reef width, elevation and roughness

#### Barrier Islands
- **Benefits/Processes**
  - Wave attenuation and/or dissipation
  - Sediment stabilization

- **Performance Factors**
  - Island elevation, length, and width
  - Land cover
  - Breach susceptibility
  - Proximity to mainland shore

#### Maritime Forests/Shrub Communities
- **Benefits/Processes**
  - Wave attenuation and/or dissipation
  - Shoreline erosion stabilization
  - Soil retention

- **Performance Factors**
  - Vegetation height and density
  - Forest dimension
  - Sediment composition
  - Platform elevation
Natural and Nature-Based Features Evaluation and Implementation Framework

- Define Physical and Geomorphic Setting
- Assess Vulnerability and Resilience
- Identify NNBF Opportunities
  - Formalize NNBF Objectives
  - Identify NNBF Alternatives
  - Define NNBF Performance Metrics
- Evaluate NNBF Alternatives
  - Tier 1
  - Tier 2
  - Tier 3
- Select NNBF Alternatives
- Design Implementation Plan:
  Elaborate Operational and Engineering Practices
- Implement NNBF Alternative
- Monitor for Performance and Assess Ecosystem Goods and Services

Feedback
Authorities

Coastal Zone Management Act

Fish and Wildlife Conservation Act

Clean Water Act

Water Resources Development Acts

National Historic Preservation Acts

Marine Protection, Research and Sanctuaries Act

Sustainable Fisheries Act

Endangered Species Act

National Environmental Policy Act

Etc., Etc., Etc.
Natural and Nature-Based Features Evaluation and Implementation Framework

1. Identify and Organize Stakeholders, Partners and Authorities
2. Define Physical and Geomorphic Setting
3. Assess Vulnerability and Resilience
4. Identify NNBF Opportunities
   - Formalize NNBF Objectives
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5. Evaluate NNBF Alternatives
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6. Select NNBF Alternatives
7. Design Implementation Plan: Elaborate Operational and Engineering Practices
8. Implement NNBF Alternative
9. Monitor for Performance and Assess Ecosystem Goods and Services

Iterate as Needed

Advance through Tiers as Appropriate

Feedback
Define Physical and Geomorphic Setting

Applying a Classification System for Coastal NNBFs

Approach:
Combine the Coastal Geomorphological Classification (Shepard 1948, 1963, 1973) with the National Vegetation Classification System (Anderson et al. 1998)
1 A 1-1. Drowned River Valley

Examples: Chesapeake and Delaware Bays

“Living Shorelines”

Substrate: Silt, some sand, peat
Combined Profiles

1 B 2-a. Glacial Depositional Coast
Examples: New York, Connecticut, and Massachusetts

- Cool Temperate Forest
- Pond
- Temperate Grassland Meadow Shrubland
- Sandy Bluff
- Sandy Beach
- Substrate: Sand, gravel

T8 T17 T4 T5 T6 T9 P1

NOT TO SCALE
Combined Profiles

II B 1. Marine Depositional Barrier Coast

Examples: Virginia coast

NOT TO SCALE
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- Feedback

Iterate as Needed
Vulnerability: Degree to which a system is susceptible to, and unable to cope with, adverse effects from a hazard; vulnerability is a function of the character and magnitude of a hazard to which a system is exposed, its sensitivity, and its adaptive capacity.

Wamsley et al. 2013 (in review)
Assess Vulnerability

Metrics must consider EXPOSURE, SENSITIVITY, and ADAPTIVE CAPACITY of a system.

Vulnerability factors:

- **Internal** – properties of the vulnerable system or community itself
- **External** – factors outside the vulnerable system
- **Socioeconomic** – relate to economic resources, distribution of power, social institutions, cultural practices, etc.
- **Biophysical** – properties investigated by the physical sciences
<table>
<thead>
<tr>
<th>Valued System Functions</th>
<th>Vulnerability Factors</th>
<th>Adaptive Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coastal Storm Damage Reduction</strong></td>
<td><strong>Exposure</strong>&lt;br&gt;• Water level (Surge)&lt;br&gt;• Tide range&lt;br&gt;• Wave height (Waves)&lt;br&gt;• Wave period (Waves)&lt;br&gt;• Wave runup (Waves)&lt;br&gt;• Beach and nearshore slope&lt;br&gt;• Storm duration&lt;br&gt;• Storminess</td>
<td><strong>Sensitivity</strong>&lt;br&gt;• Median sediment grain size (Sediment type)&lt;br&gt;• Berm width (Beach berm)&lt;br&gt;• Dune height (Dune)&lt;br&gt;• Dune or dune field width (Dune)&lt;br&gt;• Dune or dune field volume (Dune)&lt;br&gt;• Presence of vegetation (Vegetation type)&lt;br&gt;• Dune sediment compaction</td>
</tr>
<tr>
<td><strong>Beach recreation</strong></td>
<td><strong>Exposure</strong>&lt;br&gt;• Water level (Surge)&lt;br&gt;• Wave height (Waves)&lt;br&gt;• Wave period (Waves)&lt;br&gt;• Tide range&lt;br&gt;• Beach slope&lt;br&gt;• Storm duration&lt;br&gt;• Storminess</td>
<td><strong>Sensitivity</strong>&lt;br&gt;• Median sediment grain size (Sediment type)&lt;br&gt;• Berm width (Beach berm)&lt;br&gt;• Dune or dune field volume (Dune)</td>
</tr>
</tbody>
</table>
Resilience

The ability of a system to resist, recover and/or adapt to the stresses of adverse events

- **Engineering**: resist damage, or return to a prior relatively stable state following a disturbance.

- **Ecological**: resist damage, or self-organize into a new configuration after disturbance.

- **Community/Social**: learn and adapt to avoid loss in functionality; develop new functions in response to disturbance.

_Schultz et al. (2012)_
Resilience

Framework to quantify resilience for Integrated Coastal Systems (ICS)

- Focus on functional performance of engineered projects.
- Incorporates multiple projects in the ICS.
- Develops a quantified measure of resilience based on speed and magnitude of restoring functionality or service following a disturbance.
- Functionality/service can be restored via natural processes and/or human maintenance.
- Not limited by mission area.
Natural and Nature-Based Features Evaluation and Implementation Framework

- Evaluate NNBF Alternatives
  - Tier 1
  - Tier 2
  - Tier 3

- Identify NNBF Opportunities
  - Formalize NNBF Objectives
  - Identify NNBF Alternatives
  - Define NNBF Performance Metrics

- Select NNBF Alternatives

- Design Implementation Plan: Elaborate Operational and Engineering Practices

- Implement NNBF Alternative

- Monitor for Performance and Assess Ecosystem Goods and Services

- Feedback

- Iterate as Needed

- Advance through Tiers as Appropriate

- Organizational Alignment

- Define Physical and Geomorphic Setting

- Assess Vulnerability and Resilience

- Identify and Organize Stakeholders, Partners and Authorities

EVALUATION

IMPLEMENTATION

ORGANIZATIONAL ALIGNMENT
Key Definitions

**Ecosystem Goods and Services** are tangible items or intangible commodities generated by self-regulating or managed ecosystems whose composition, structure, and function are comprised of natural, nature-based and/or structural features that produce socially valued benefits that can be utilized either directly or indirectly to promote human well-being.

Key Take-home points:
1. EGS can be derived from either built or natural capital (or a combination of the two).
2. Their value is simply a way to depict their importance or desirability to the consumers.
3. The ability of ecosystems to provide goods and services is dependent on critical ecosystem processes tied to structure and function either alone or in concert.
21 Ecosystem Goods and Services Associated with NNBF

1. Aesthetics - appreciation of natural scenery (other than through deliberate recreational activities), Inspiration for culture, art and design
2. Biological diversity (biodiversity)
3. Carbon sequestration
4. Clean water provisioning (sediment, nutrients, pathogens, salinity, other pollutants)
5. Commercial harvestable fish and wildlife production
6. Cultural heritage and identity - sense of place and belonging, spiritual and religious inspiration
7. Education and scientific opportunities (for training and education)
8. Erosion protection and control (water and wind, any source)
9. Habitat for fish and wildlife provisioning (nursery, refugium, food sources, etc.)
10. Increase or maintain land elevation, land-building, sediment source reduction
11. Keeping unwanted sediments out of storm waters
12. Nutrient sequestration or conversion
13. Property value protection
14. Provision and storage of groundwater supply
15. Raw materials production (timber, fiber and fuel, etc.)
16. Recreation - opportunities for tourism and recreational activities
17. Reduce hazardous or toxic materials in water or landscape
18. Reduce storm surge and related flooding
19. Reduce the peak flood height and lengthen the time to peak flood
20. Reduce wave attack
21. Threatened and Endangered species protection
## Metrics – Services to NBI Matrix

<table>
<thead>
<tr>
<th></th>
<th>SB1</th>
<th>NBF 1</th>
<th>NBF 2</th>
<th>NBF 3</th>
<th>ALL</th>
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<tr>
<td>S1</td>
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<td>✓</td>
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<tr>
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<td></td>
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<td>✓</td>
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<tr>
<td>S4</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
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<tr>
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<td>✓</td>
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<td>✓</td>
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<td>✓</td>
</tr>
</tbody>
</table>

- **Bulkhead (B1)**
- **Submerged Breakwater (Nearshore Berm/Oyster Reef/Sill) (NBF 2)**
- **Submerged Aquatic Vegetation (NBF 3)**
- **Emergent Herbaceous Marsh (NBF 1)**
Key Definitions

Performance Metrics are specific measures of production or indicators of system response that can be used to estimate and report the anticipated consequences of an alternative plan with respect to particular planning and engineering objectives.

They articulate the exact information that will be collected, modeled, elicited from experts, or otherwise developed and presented to decision makers to characterize plan performance and engineering designs.

They must provide the ability to distinguish the relative degree of ecosystem response (conveyed in terms of impacts or benefits) across alternatives and designs, either qualitatively or quantitatively, in ways that make sense and will help decision makers consistently and transparently compare alternatives and designs.

Good performance metrics are:

- Complete and concise
- Transparent and unambiguous
- Accurate
- Direct
- Understandable
- Operational
3 Levels of Performance Metrics

- **Level 1** – Qualitative characterization of performance
- **Level 2** – Semi-quantitative characterization of performance
- **Level 3** – Quantitative characterization of performance

72 individual performance metrics identified for NNBF
Natural and Nature-Based Features Evaluation and Implementation Framework

Identify and Organize Stakeholders, Partners and Authorities

Define Physical and Geomorphic Setting

Assess Vulnerability and Resilience

Identify NNBF Opportunities
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Design Implementation Plan: Elaborate Operational and Engineering Practices

Implement NNBF Alternative

Monitor for Performance and Assess Ecosystem Goods and Services

Feedback

Iterate as Needed

Advance through Tiers as Appropriate
Tiered Evaluation Framework

Tier 1
Qualitative – Semi-Quantitative

Tier 2
Semi-Quantitative - Quantitative

Tier 3
Quantitative

More Uncertainty
Less Uncertainty

More Comprehensive
More Specific
Framework Implementation

• Objectives and associated metrics serve as the primary evaluation criteria

• Decision options (i.e., categories of NNBF, specific NNBF projects, or alternatives consisting of groups of NNBF projects and non-structural and structural measures) are evaluated against metrics

• Criteria that measure performance relative to the objectives will depend on the Tier

• Weights can be applied to the objectives

• Opportunities for swing-weighting, value of information assessments, and other decision support may be exercised
### Basic Construct

#### Performance & Vulnerability Metrics

<table>
<thead>
<tr>
<th>Objective</th>
<th>Performance Metric</th>
<th>Measure</th>
<th>Alternative Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impacts</td>
<td>Average annual damages avoided</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recovery time</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Employment impacts</td>
<td>% of workforce unemployed</td>
<td></td>
</tr>
<tr>
<td>Sustain Ecosystem Services Generated by Coastal Systems</td>
<td>Fish &amp; wildlife habitat provision</td>
<td>Habitat Quality Index</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintain water quality</td>
<td>WQ Index</td>
<td></td>
</tr>
<tr>
<td>Promote Resilient Coastal Communities</td>
<td>Population</td>
<td>No. residents</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vulnerability to coastal storms</td>
<td>Exposure + Sensitivity</td>
<td></td>
</tr>
</tbody>
</table>

- Developed by Stakeholders
- Developed from Performance & Vulnerability Metrics (Section 2)
- Selected for Tier (Section 3) & Informed by NNBF Performance (Sections 1&2)
- Formulated Using NNBF Descriptions (Section 1)
- Determined Using Best Available Data/Tools
Tier 3 Assessment

- More quantitative measures, generally involving numerical analysis
- Greater resolution in the “alternative” under consideration

<table>
<thead>
<tr>
<th>Objective Information</th>
<th>Performance Metric</th>
<th>Measure</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective Category</td>
<td>Vulnerability</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Contribution of NNBF to reducing coastal vulnerability</td>
<td>Storm protection</td>
<td>Peak water level (m), maximum wave height (m), (Average Annual Damages Avoided $M)</td>
<td>No Action Alternative</td>
</tr>
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</tbody>
</table>
Natural and Nature-Based Features Evaluation and Implementation Framework

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9. Feedback

Organizational Alignment
EVALUATION
IMPLEMENTATION
Managing Sediment Resources for NNBF: Beneficial Use of Dredged Materials

Linking need, opportunity, and operational practice
Decision Model Application to Long Island Sound

- A MCDA decision framework was collectively developed by stakeholder representatives involved in the Long Island Sound Dredged Materials Management Plan Working Group
- Through group discussion and individual interviews, this approach incorporates stakeholder objectives and concerns into the decision process
D2M2 Vignette – Long Island Sound

Map of the LIS region identifying regional dredging centers and projected dredging needs for a 30 year time horizon.

MCDA Value Tree of costs and impact criteria.
Natural and Nature-Based Features Evaluation and Implementation Framework

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**IMPLEMENTATION**
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**ORGANIZATIONAL ALIGNMENT**
- Identify and Organize Stakeholders, Partners and Authorities

Advance through Tiers as Appropriate

Iterate as Needed

Feedback
Performance Evaluation Case Studies

1. **Proof of concept analysis**
   - Quantify benefits of environmental restoration projects using an ecosystem goods and services (EGS) analysis framework

2. **Hurricane Sandy case study**
   - Use extreme event to improve understanding of restoration effectiveness & benefits

3. **Focused on two general types of services:**
   - Flood damage Reduction
   - Wildlife Habitat (emphasis on T&E species)

4. **3 Study Sites**
   - Jamaica Bay
   - Cape May Meadows
   - Cape Charles South
Moving Forward . . .

• Organize and expand science and engineering understanding regarding NNBF
  – Reduce uncertainties regarding design and performance
  – Differences among types of NNBF
  – Dynamic performance of NNBF

• Integrating expertise both within and across organizations
  – Planning, designing, constructing, monitoring, and maintaining NNBF