INFRASTRUCTURE
RELIABILITY AND RESILIENCE: R&D

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Forum on Infrastructure
Stillwater, OK
USACE CIVIL WORKS INFRASTRUCTURE

- $250B infrastructure replacement value
- 12,000+ miles of navigable inland waterways
- 926 commercial harbors
- 191 locks
- 353 hydroelectric power generation units
- 694 dams
- 14,700 miles of levees
- Over 800 bridges
- Buildings, roads, recreation sites, environmental projects, etc…
WHAT DO WE EXPECT FROM OUR NATION’S WATER INFRASTRUCTURE?

Safety

Recreation

Sustainability

Navigation

Figures: Lake Lanier (USACE-SAM), Mississippi River (Vidalia, LA), Proctor Creek (GA), Beaver Lake (USACE-SWL), Chatfield Reservoir (USACE-NOW), Cape Fear L&D (USACE-SAW)
## STATUS OF US INFRASTRUCTURE: NOT JUST A USACE CHALLENGE

<table>
<thead>
<tr>
<th>Infrastructure Type</th>
<th>USACE Portfolio</th>
<th>National Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Dams</td>
<td>692</td>
<td>90,580</td>
</tr>
<tr>
<td>Levee Miles</td>
<td>14,000</td>
<td>100,000 (est)</td>
</tr>
<tr>
<td>Water Main Breaks</td>
<td>0</td>
<td>240,000</td>
</tr>
<tr>
<td>Structurally deficient bridges</td>
<td>0</td>
<td>56,007</td>
</tr>
</tbody>
</table>

**Figures:** Czech (2010), ASCE (2017), USACE LRL, Civil Works Fact Sheet
ASSET MANAGEMENT: A PROBLEM THAT GETS HARDER EVERY YEAR

Figures: Juracek (2013), Ontario Ministry of Transportation
HOW CAN WE ENSURE THE RELIABILITY AND RESILIENCY OF OUR INFRASTRUCTURE?

A portfolio of assets that:
1. Is reliable in condition and performance from a system perspective.
2. Is flexible and resilient to variability, change, hazards, and evolving national need.
3. Works with (not against) local ecosystems.
1. ASSET RELIABILITY
MEASURING CONDITION AND PERFORMANCE

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Inspection
Sensors/Monitoring
Testing
Structural Health Monitoring

ALTERNATIVE 1
ALTERNATIVE 2
ALTERNATIVE N

Lifecycle Model

- Uncertainty
- Now
- Time to Fail
- Fail
- Acceptable
- Unacceptable

DECISION
Risk Metrics (Value Model)

DEMANDS

ERDC
US Army Corps of Engineers
CURRENT SHM EFFORTS

PERIODIC INSPECTIONS
- Visual
- NDT
- FEM

- Tension in Trunnion Rods
- Corrosion/Coating Measurement Robots
- Microbots for Penstocks
- UAVs for Rapid Assessments

MONITORING SYSTEMS
- Trunnion Friction / Uneven Hoisting
- SMART Gate Data Infrastructure
- Underwater Wireless Communication
- Miter Gate Diagonal Tension
- Electrical/Mechanical Monitoring
- Scour Monitoring
- Sensing Skins
- Impedance Sensors
- Corrosion Protection System Monitoring

ENGINEERING/STATISTICS MODEL
- Model Framework
- Failure Modes
- Usage/Demands

- Fatigue Analysis of HSS
- Bridge Inspection-Reliability Model
- Bayesian Model Updating
- Fusion of Multiple Datastreams
- Optimal Sensor System Design
- Operational/Usage Evaluation
- Concrete Degradation Models

DECISION

Investment Alternative
- Dewatering Schedules
ADVANCED MATERIALS FOR INFRASTRUCTURE

Dual use technologies:

Example ERDC Novel Material Technologies

Ultra-High Performance Concrete

ERDC’s modular protective system

Field Demonstrations:

Composites and rapid repair materials for bridge and lock structures

Rapidly restore operations with 50% less cost and increased durability

Repairs informed by simulations:

Materials for Rapid Repair of Infrastructure
1. ASSET RELIABILITY
SEEPAGE/GEOTECHNICAL TOPICS

Field tests to measure flow from sand boils

Tubular internal erosion flume test

Finite element model using results from tube test
1. ASSET RELIABILITY
CHALLENGES AND FUTURE NEEDS

• Challenges:
  • Connecting knowledge from data or models with the metrics/criteria by which investment decisions are made
  • Identifying where more rigor is needed and where it isn’t

• Future Needs:
  • More consistent condition, performance, demand, and failure data
  • Systems approaches to distinguishing component vs project reliability and performance
  • Time-dependent failure mode/degradation models

Figures: ASCE
2. ASSET RESILIENCE
ONGOING R&D AND FUTURE NEEDS

- South Shore of Staten Island Feasibility Study – NY District

![Diagram showing asset resilience with categories: Prepare, Anticipate, Adapt, Evolve, Resist, Withstand, Recover, Bounce Back]

**South Shore of Staten Island Feasibility Study**

Study Area: Phase 1 + Phase 2

**Phase 1** = Fort Wadsworth to Oakwood Beach

**Phase 2** = Great Kills to Tottenville (separate action)

![Map showing study area with labels and boundaries]

**Future Adaptability of Recommended Plan for SLC Considerations**

Figures: ASCE
3. ECOLOGICAL INFRASTRUCTURE
WORKING WITH ECOSYSTEMS

1. Ecosystem restoration opportunities via aging infrastructure
2. Ecosystems as infrastructure
3. Adaptive management of built, natural, & coupled systems
4. Enhancing value of traditional infrastructure
5. Environmental compliance of traditional infrastructure
6. Managing ecological interactions with traditional infrastructure

Challenges include: forecasting outcomes, shifting design paradigms, and practically informing operational decisions

Figures: ASCE
3. ECOLOGICAL INFRASTRUCTURE
ONGOING R&D AND FUTURE NEEDS

Engineering with Nature for Coastal Storm Damage Reduction (e.g., Sandy Recovery)
• Ecosystem often provide infrastructure functions such as wave attenuation
• When do ecological benefits justify the cost?
• What are design standards for ecosystems?
• How do NNBFs perform over time?

Areas for growth:
• Ecological benefits of infrastructure disposition
• Predicting socio-economic outcomes of ecosystems
• Design standards
• Ecological interactions influencing infrastructure purposes

Figures: Bridges et al. (2015)
A GROWING CADRE OF PARTNERS
BIG PROBLEMS REQUIRE COLLABORATION

Who you expected to be at the party

Who also came to help out
The nation behaves well if it treats the natural resources [and infrastructure] as assets which it must turn over to the next generation increased and not impaired in value. 

Theodore Roosevelt, The New Nationalism