When it comes to the resiliency of our coasts, there is not a one-size-fits-all solution. This Roundtable Discussion focuses on the collaborative nature of successful coastal projects from a living shoreline to sustainable sediment management, and highlights how the key to resiliency is collaboration. We have gathered together a number of experts in the fields of coastal geology and engineering who have all successfully executed coastal restoration and sediment management projects. All of the projects share a collaborative nature and various levels of buy-in required to create success. Each panelist will focus on best practices, lessons learned, and forthcoming (or ongoing) projects.
Today’s Agenda

• Each guest will spend 5 to 7 minutes introducing themselves.
• Roundtable discussion with questions from the moderator and the audience.
• The 3 main items that this panel of invited guests will be discussing and sharing with you today:
  1. They will discuss coastal restoration and resilience in terms of a systems approach.
  2. They will prove that collaboration is the key to coastal resiliency.
  3. They will end with a conversation about what best practices each of the panelists has developed through their experience.
Roundtable Introduction

- Paul T. Eickenberg, MSCE, MSLE, PE (MN), Geo-Structural and Flood/Coastal Protection Engineer, Director of Engineering, HESCO Bastion, Inc.
- Have about 19 years of experience focusing on general structural engineering, geotechnical testing and monitoring, slope stabilization, dam inspections and repair, retaining and flood wall design and installation, and stream/coastline restoration.
- Spent 9 years as a Civil Engineering instructor at the University of Minnesota.
- Have been presented with engineering awards including the Society of American Military Engineers (SAME) Tudor Medal, a MN CEC Grand Award, a MN Seven Wonders of Engineering Award, and the University of Illinois Civil and Environmental Engineering Young Alumnus Achievement Award.
What is a Systems Approach?

• Ackoff (1994) generally defines a system as a whole that cannot be broken into parts.

• Scharmer (2009, p. 66) states that “the whole of an organization or field is dependent on and emerges from the relationship of all its parts.”

☆ Thus, if we want to create a true solution, we must collaborate with people and with varying solutions.

• Think of the parts of a coastal system:
  • Water levels
  • Barrier islands
  • Coastal forests, marshlands, etc.
  • Interior wetlands
  • Beaches
  • Dunes, levees, walls, etc.
  • Rivers and navigation channels
  • People and development
  • Pollution

These are all part of the coastal system. Collaboration among all of these parts must be considered when creating a resilient system.

Today’s guests represent the type of experience and diversity that must be involved in a Collaborative Resiliency Program.


Basis for inviting our Guests

Heifetz, Grashow, and Linsky (2009) state that “authorities cannot solve an adaptive challenge by issuing a directive or bringing together a group of experts, because the solutions to adaptive problems lie in the new attitudes, competencies, and coordination of the people with the problem itself” (pp. 73-74). They continue by stating that “the work of addressing an adaptive challenge must be done by the people connected to the problem” (p. 74).

• The guests here today have gained their knowledge in the laboratories and the field.
• The guests today are not only a group of experts. They are also fully connected to the problem and are therefore fully qualified to assist in finding, implementing, and furthering restoration and resiliency solutions.
• The guests today have been affected by coastal damage and are passionate about the topic of restoration and resiliency.
• Today’s guests represent the type of experience and diversity that must be involved in a Collaborative Resiliency Program.

Introduction to our Guests

- **James H "Rip" Kirby III**, Lt Col, USAF (ret), CEO, The November 9th Group. A coastal geologist whose practical and research experience includes sediment management, energy attenuation, and upland infrastructure protection. One of his primary focuses is on new methods for sediment distribution on sediment starved coasts and combining semi-sacrificial sediment structures that provide conservation of sediment and wave energy attenuation closer to the swash zone in heavily developed coastal environments.

- **Gene Peck**, PG, LEED-AP, Sustainable Sediment Management Specialist, Vice President and Program Director, Viridian Alliance Inc. An environmental scientist with experience directing large-scale interdisciplinary ecosystem restoration projects in rivers, estuaries and coastal areas.

- **Craig Taylor**, LimnoTech. An engineer with a practical and research focus related to hydraulics and wave loading against natural and structural systems.

- **Mike Mayer**, MS, JD, Director of Resource Management Planning, The Louis Berger Group. A natural resource professional with experience in environmental planning and legal services for federal and private clients.

- **Eric Stern**, Principal, Integrated Sediment Management, Environmental Adaptive Strategies, LLC. A research and practical leader whose experience and knowledge base applies integrated cross-management program approaches to solving complex sediment and multi-media challenges.
Rip Kirby  
*The November 9th Group*

Coastal Dune Field Creation to Manage Barrier Island Sediment Loss and Provide Infrastructure Damage Protection from Flooding and Overwash Processes

Barrier Island Sediment Management Using Anthropogenic Sand Dunes  
EAFB Project: RCS 08-733  
Rip Kirby - University of South Florida, Department of Geology, Coastal Research Lab
Study Area: USF - Site 3
Hurricane Gustav Flooding

Notice the long fetch of impounded floodwater. As the wind increased velocity, this allowed small waves to form that washed over the road. Image date is 9/1/08.
While the wave run up is not high, there is enough fetch in this stretch of impounded water where a sustained high wind (20kts+) will force water to sheet over the road surface. Water runs downhill, parallel to the northern edge of the road surface, and erodes the sand from its matrix of shoulder gravel. Eventually the shoulder elevation is lowered enough for the sheeting water to start eroding in a classic knickpoint pattern. Image date is 9/13/08.
Looking southeasterly from the road, the Gulf of Mexico is visible. This section of road is less than 6’ above mean sea-level. The elevation slowly increases to the south until the back-beach berm is reached. Image date is Aug 12, 2008.
Dune System Design Concept

Sheet Flow (surge flooding and wave run-up)

Meandering path dissipates energy, slows water transport of entrained sediment
Assumptions for calculation scenarios:
1) All basket sediment remains sequestered in baskets, nothing lost to erosion.
2) Overburden sediment is vegetated with native flora shortly after emplacement.
3) Highest elevation sediment moves down slope to replenish lower elevation sediment lost to erosion.
4) Sediment managers replace higher elevation sediment loss on a regular basis (maintenance).
5) Unvegetated sediment surfaces will erode faster than vegetated sediment surfaces.
6) Vegetated sediment surfaces likely will accrete sediment from eolian processes.
7) Hesco Concertainer baskets in this example are 3' by 3' by 3' (one cubic yard).

Calculations (figures returned as cubic feet per linear foot):
Basket Sediment = 54 cubic feet
Total volume per linear foot = 171 cubic feet

Overburden sediment (burial sand) = 117 cubic feet
Designed slope angle = 34.7 degrees
Anchored Sand Dunes

- Use Hesco Concertainer® product to create a stable core of an anchored sand dune
  - Stable core prevents total loss of dune sediment
  - Allows water to move through the dune field slowly
  - Eliminates wave action on large fetches of impounded floodwater
- Installation pattern will mimic natural incipient dune growth pattern
Building and Filling

All structures were based on a design of four sections on the bottom and two sections on the top. The only single level section was the anti-scour pier on the “L” shaped structures.
Anti-scour Design
Survey was done by Choctaw Engineering using certified RTK GPS survey equipment. Elevations are + 2cm due to soft surface sediments.
Using the baseline image of 16 Dec 08, the index dune shows the extent of erosion during the 2009 winter season. Vegetation was planted in May 2009. This slowed down and eventually reversed the erosion rate.
After vegetation was planted in May 2009, sediment erosion within the dune field stabilized and accretion of sand began to occur during the winter season. As the lines indicate, this trend continues into the 2014-15 winter season.
Vegetation planted on the central, northern “L” shaped dune. Slopes with vegetation experienced very little erosion from eolian processes compared to sediment surfaces without vegetation.

Tropical Storm Ida hit the area on November 10, 2009. The storm flooded the runoff channel. The newly reconstructed road was not damaged from wave action in the impoundment area.

Flood water flowed through the designed tortuous path, expending energy and dropping sediment out of transport. Cutbank erosion is shown on the outer bank of the flow path.

After drainage, the flood paths showed deposition in the predicted areas within the site design.
Gene Peck
Viridian Alliance

Dredged Material Management Plan

New York-New Jersey Regional Sediment Management Plan
- Sediment Quantity
- Sediment Quality
- Dredged Material Management

Dredged Material Strategic Plan

Integrated Coastal Zone Management Plan (USAF)

Corporate Contaminated Sediment Strategy
Connected Interests that Involve Sediment

Stern and Peck, 2014
(Sediment Policy Reform – White Paper)
US Federal Watershed (Regulatory) Programs that Involve Sediment

**Abbreviations:**
- RGGI = Regional Greenhouse Gas Initiative;
- SDWA = Safe Drinking Water Act;
- CWA = Clean Water Act;
- MS4 = Municipal Separate Storm Sewer Systems;
- NPDES = National Pollutant Discharge Elimination System;
- NPS = Non-point Source;
- NRD = Natural Resource Damages;
- CAA = Clean Air Act;
- CERCLA = Comprehensive Environmental Response, Compensation and Liability Act (Superfund);
- USEPA/USACE = Dredged Material Management

What’s Missing?

Valued Services

- Provisioning
  - Food
  - Energy
  - Transportation
- Biodiversity
- Regulating
  - H₂O, soil, T°, nutrient cycling, floods, waste assimilation
- Cultural Services
  - Aesthetic, spiritual, recreational

Peck and Stern, 2014

Resistance

- Lack a methodology for accounting for values of aquatic ecosystems services
- Remediation protocols only quantify valuation of human and eco risk associated with the presence of contaminants
- Cost sharing
- Covenant not to sue
- All-in Costs – long term liabilities, depressed economies

Peck and Stern, 2014
## Comparison of Social and Superfund Remediation Timescales

<table>
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<tr>
<th>Timescales</th>
<th>Typical Duration (Years)</th>
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<tr>
<td></td>
<td>Lower</td>
<td>Higher</td>
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<tr>
<td><strong>Social timescales</strong></td>
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<td></td>
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<tr>
<td>Political representative terms</td>
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<td>6</td>
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<tr>
<td>US Congress bill to law</td>
<td>6</td>
<td>10+</td>
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<tr>
<td>Development</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Developer return on investment</td>
<td>5</td>
<td>8</td>
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<tr>
<td><strong>Superfund process timescales</strong></td>
<td></td>
<td></td>
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<tr>
<td>Listing on National Priority List</td>
<td>2</td>
<td>25+</td>
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<tr>
<td>Remedial Investigation - Studies</td>
<td>2</td>
<td>10+</td>
</tr>
<tr>
<td>Design</td>
<td>1</td>
<td>3+</td>
</tr>
<tr>
<td>Construction</td>
<td>1</td>
<td>7+</td>
</tr>
<tr>
<td>Recovery (human/ecological health)</td>
<td>20</td>
<td>50+</td>
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<tr>
<td>Total Superfund process</td>
<td>25</td>
<td>95+</td>
</tr>
</tbody>
</table>

Stern and Peck, 2014
(Sediment Policy Reform – White Paper)
Climate Impacts to Superfund Sites – Gowanus Canal, NY
Flooding During Superstorm Sandy

http://pardonmeforasking.blogspot.com/2012/10/hurricane-sandy-amazing-gowanus.html

http://project.wnyc.org/flooding-sandy-new/index.html#
Accelerating Progress at Contaminated Sediment Sites

Moving from Guidance to Practice: Bridges, T.S., Nadeau, S.C and M. McCulloch (2011) SETAC on-line.

• Development of detailed and explicit project vision & accompanying objectives
  • Achievable short-long term goals
  • Metrics of remedy success at beginning of project
  • Dynamic / adjust
    • Adaptive Management
  • Strategic engagement of stakeholders (early)

• Optimization of risk reduction/risk management & remedy selection
  • Deliberate use of early action remedies to accelerate risk reduction
  • Systematic/sequential development of suite of actions applicable to ultimate remedy:
    • Starting with Monitored Natural Recovery and adding engineering actions to meet objectives

• Incentive process that encourages and rewards risk reductions to industry
  • Don’t sue…

✓ Pursuit of sediment remediation projects as public-private collaborative enterprises (cost share)
  • USEPA Legacy Act
• Could benefit by Regional Sediment Management structure buy-in at a high policy level (reform)
• Hybrid / integrated remedial / restoration designs
• Sustainability concept may be configured by
  • Tools (LCA/MCDA) in Remedy/Alternative Analysis
  • Beneficial Use (technology driven)
  • Upland source control
  • Landscape design functions / green infrastructure
• Climate change adaptation and effect on long-term coastal infrastructure
  • Effects of Contaminated Sediments
  • In Navigational Channels

✓ It is necessary to manage expectations that cleanup will be a “one-shot deal,” given that cleanups often require iterations and long-term management
  
  Doug Tomchuk – USEPA Region 2 Remedial Program Manager
• Siloed/localized vs. Holistic/integrated: adaptive
  • Economic recovery/revitalization of blighted urban environments are dependent on functional healthy systems
  • Siloed approaches bring only partial solutions
  • Integrated investing costly in the short-term will get to the long-term remediation and restoration goal/visions with multiple net benefits
  • Use existing (cross) programs with more efficient integration that cuts across multiple visions/goals and objectives
  • Understand better the relationship between academia, NGO’s, consulting community and what is important to policy and political decision makers – do they really care about sediments if it’s only sediments (sediment only solutions…)
• Requires a National Public - Private Policy with a broader and more inclusive approach to environmental management / innovations
Delta Modeling

38hr:33min

Delta Topography at 38hr 33min
Ocean Elevation = 85.9mm

Delta Topography at 38hr 33min
Ocean Elevation = 85.9mm
Wave Modeling

• 1:5 Scale Model
• Froude Number Scaling
  • Maintains similitude between model free-surface and prototype (field) free-surface
  • Valid for fully turbulent flows

\[ Fr = \frac{C(h_e - R_c)}{\nu} \]
Wave Visualizations
Square Breakwater
## Wave Reduction Efficiency

<table>
<thead>
<tr>
<th>Shape</th>
<th>Material Volume (equivalent Units)</th>
<th>Average $K_t$</th>
<th>Reduction Efficiency</th>
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<tbody>
<tr>
<td>Square (3 Units)</td>
<td>3</td>
<td>0.47</td>
<td>0.18</td>
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<tr>
<td>1 Unit</td>
<td>1</td>
<td>0.49</td>
<td>0.51</td>
</tr>
<tr>
<td>Spaced</td>
<td>2</td>
<td>0.46</td>
<td>0.27</td>
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<tr>
<td>3:1 Mound</td>
<td>3</td>
<td>0.57</td>
<td>0.14</td>
</tr>
<tr>
<td>3:1 Mound + 1 Unit</td>
<td>4</td>
<td>0.47</td>
<td>0.13</td>
</tr>
<tr>
<td>3:1 Mound + 2 Units</td>
<td>5</td>
<td>0.39</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Native Mussels & Sediment Transport
“To keep every cog and wheel is the first precaution of intelligent tinkering”

– Aldo Leopold
What is it to be Resilient?

Resiliency defined:

- the ability of a substance or object to spring back into shape; elasticity.
- the capacity to recover quickly from difficulties; toughness.

But what are we recovering to? Are we looking at mitigating disasters—disaster risk reduction?

Or are we talking about adapting to a shifting environmental baseline?
Resiliency

The Federal Government must build on recent progress and pursue new strategies to improve the Nation's preparedness and resilience. In doing so, agencies should promote: (1) engaged and strong partnerships and information sharing at all levels of government; (2) risk-informed decision-making and the tools to facilitate it; (3) adaptive learning, in which experiences serve as opportunities to inform and adjust future actions; and (4) preparedness planning. (Executive Order -- Preparing the United States for the Impacts of Climate Change, November 1, 2013)
Adaptation - CEQ

- Climate change adaptation means adjusting to a changing climate to reduce the negative impacts already occurring and taking advantage of new opportunities. In general, planning in advance for climate change impacts will help avoid disruptions to Federal agency operations and allow the Government to design and implement programs that are capable of achieving their missions across a range of future climate conditions.

- An example would be designing projects that are resilient across a range of future climate scenarios. In their recent draft guidance, the CEQ relies on 40 C.F.R. § 1502.24 when it states that “[w]ith regard to the effects of climate change on the design of a proposed action and alternatives, Federal agencies must ensure the scientific and professional integrity of their assessment of the ways in which climate change is affecting or could affect environmental effects of the proposed action” (CEQ 2010).
Resiliency

It is forever. A new model of management. Increased sensitivities in model predictions may allow for better allocation of resources in the future.
Risk-Informed and Adaptive Decision-Making

What tools/processes are available for informed decision-making?

• NEPA- required for all federal actions; efforts to include climate change in analyses
• PrOACT- similar to NEPA in approach
• USACE SMART Planning – balances uncertainty and risk with level of detail
• Adaptive Management – incorporates learning and adjustment in the planning and implementation
Sustainable Decision Making Models

- Proposed Action
- Economic Considerations
- Environmental Considerations
- Social Considerations
How Climate Fits In
Adaptive Management Process

- Assess Problem
- Design
- Implement
- Monitor
- Evaluate
- Adjust
Double Loop Learning

- Assess Problem
- Design
- Implement
- Evaluate
- Monitor
- Adjust

DOI Tech Guide
Multi-Decision-Maker Coordination

• Local, state, tribal, federal and private.

• Develop strong partnerships to secure funding and adapt to changes—adaptation is key to a resilient system

• Consider paradigm shift in coastal development
Multiple-Scales of Planning: System vs. Site-Specific

Why Plan at the System Level?

• Ecosystems have properties that can’t be seen by looking only at its components.

• Some effects are too small to see at the site-specific levels.

• Effects from policy may already be present at the system level
Important Considerations

• Allow natural processes to reduce overall need for built solutions.

• Develop a **common understanding** and **valuation** of ecosystem services.

• Incorporate those services into planning.
From Cape Cod to the Gulf Coast
Questions for the Panel
• For purposes of today’s discussion, what is Coastal Restoration? Resiliency?
• How long is resiliency? 5 years? 10 years? 100 years?
• How are “resiliency,” “adaptability,” and “sustainability” different or related?
• In general, discuss the role of wetlands versus barrier islands.
  • Are there similarities or differences in terms of restoration and resiliency?
• What does “let nature take its course” mean?
  • How does energy attenuation come into play when considering a long-term plan?
  • What are your thoughts regarding the resiliency of a reinforced versus a non-reinforced solution?
  • How does sediment management fit into resiliency?
• Why do restoration projects have trouble with funding for advancing coastal restoration projects?
• How do you combine long-range planning and resiliency?
• Collaboration is the key to resiliency – discuss.
  
  • Entities (government, citizen groups, engineers/scientists, etc.).
  
  • Products (natural or manmade) required to create success.
Final Question

How would you change today’s best practices based on your experience and specific lessons learned?
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Collaborative Approaches to Coastal Restoration and Resiliency: Best Practices, Lessons Learned, and Moving Forward

Concurrent 6. Tuesday, November 4, 2:00 pm – 3:30 pm (National Harbor 12)
Moderator: Paul T. Eickenberg, MSCE, MSLE, PE (MN), Geo-Structural and Flood/Coastal Protection Engineer Director of Engineering, HESCO Bastion, Inc.

Thank you for this opportunity and your time
Gene Peck - Additional Information
Case History – Long Slip Canal

Long Slip Canal Project Area
Long Slip Canal and Environs
Long Slip Canal Yard A
View Looking East
Hoboken Terminal and Habitat Creation Area

Long Slip Canal

Canal Entrance Basin
Habitat Creation Area
Regional Dissolved Oxygen

Minimum Dissolved Oxygen Level
Hudson River-New Jersey Waterfront

Dissolved Oxygen (mg/l)

MILL CREEK
LONG SLIP CANAL

NJDEP Minimum Standard

Bayonne, NJ
Piermont, NY

River Mile
Density Stratification

May 1, 1996: 0400

Surface layer - Existing condition

- Arrows indicate direction and magnitude of flows
- Color indicates relative salinity:
  - fresh is blue
  - red for most saline
Density Stratification

May 1, 1996: 0400
Bottom layer - Existing condition

• Arrows indicate direction and magnitude of flows
• Color indicates relative salinity:
  • fresh is blue
  • red for most saline
Benthic Faunal Densities

Numbers atop bars are no. of animal taxa
Water Quality Stressors

Stormwater Runoff

- Hoboken Observer Highway CSO
- Hoboken Park Avenue CSO
- Jersey City CSO
- PATH Caisson #2 Sump
- Inactive

SHOAL

69
Measures to Create Habitat

- Extension of existing CSO improved by removal of sediment and floatables
- Existing discharges to be eliminated
- Rubble bermface (shelter and hard attachment substrate)
- Isolation of oxygen demanding sediment
- Reconfiguration of shoreline and bottom to optimize circulation
- Area of managed stormwater
Hoboken Terminal and Habitat Creation Area
Existing Bottom Topography

Canal Entrance Basin

Meters Below NGVD

North
East - West Excavation Through Entrance Basin
Mean Daily Dissolved Oxygen

![Bar chart showing mean daily dissolved oxygen levels for different basin configuration options: Existing, Option 1, Option 2, and Option 3. The x-axis represents basin configuration options, and the y-axis represents percent of basin area. The chart indicates the area above 4 mg/l, 5 mg/l, and 6 mg/l for each option.](image-url)
## Impact and Mitigation Acreages

<table>
<thead>
<tr>
<th>Activity</th>
<th>Acreage</th>
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<tr>
<td><strong>Alteration</strong></td>
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<tr>
<td>Canal Fill</td>
<td>4.6</td>
</tr>
<tr>
<td>Entrance Basin excavation</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>Total Alteration</strong></td>
<td>8.7</td>
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<tr>
<td><strong>Mitigation Measures</strong></td>
<td></td>
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<tr>
<td>Created fish habitat (Improved circulation)</td>
<td>26</td>
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<tr>
<td>Improved circulation and DO levels</td>
<td>11</td>
</tr>
<tr>
<td>CSO improvements</td>
<td>381</td>
</tr>
<tr>
<td>Controlled non-point source discharge</td>
<td>19</td>
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<tr>
<td>Compensatory wetlands</td>
<td>5</td>
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<tr>
<td><strong>Total Mitigation</strong></td>
<td>478</td>
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<tr>
<td><strong>Net Improvement</strong></td>
<td>473</td>
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Craig Taylor - Additional Information
Grassy Point Location
Guidance on handling contaminated materials

Grassy Point Sediment Samples - SQT Exceedances

Minimum Depth (ft) Exceeding SQT2

- 0
- 1
- 3

>= SQT1, < SQT2

- Intermediate Contour (1')
- Index Contour (5')

- Intermediate Contour (1') - Depression
- Index Contour (5') - Depression

- Assumed Wood Waste
- Pure Chips
- Wood Chunks
- Wood/Sediment Mix
- Shoreline
- Project Boundary

Note: Water depths referenced to Lake Superior IGLD 1985 - Low water datum 601.1'
Don River Watershed: Changing Land Use with Time

1990 – 70% Impervious  
2005 – 84% Impervious

From Amirsalari, 2007, Masters Thesis University of Waterloo, Dept. of Geography
Yearly Range of Water Surface Elevations Measured at Toronto Harbor

Lake Ontario Historic Water Levels (1906 - 2006)

Lake Ontario/St. Lawrence Regulation
River and Wetland Plan

Within a changing climate, the sustainability of the river channel is the core driver for its design and development

Sediment Management
- Economize dredging in harbour and channels
- Reduce management of river channel
- Utilize sediments as habitat resource

Baseflow and River Fluctuations
- Inundation of soil and improved water quality
- Sustaining wetland vegetation
- Adaptability of conveyance
Final Condition
Regulatory Event (SC034)

Velocity

Unsteady Flow

Estimated Velocity (cm/s)

- 0.5 - 100
- 100.1 - 200
- 200.1 - 300
- 300.1 - 400
- 400.1 - 500
- 500.1 - 600
- 600.1 - 700
- 700.1 - 800
- 800.1 - 900

Grading contour line from MVIA

LimnoTech

DRAFT
Conclusions

• Challenge was to provide viable restoration in the context of
  • Urbanized watershed
  • Managed lake levels
  • Competing uses in lower Don Lands
  • Climate change impacts

• An urbanized system in a changing climate demands adaptation strategy
  • Understanding of the historical and urbanized watershed
  • Design for low baseflow and diminished water quality
  • Design for flashy hydrology, floodwater conveyance
  • Design for potential range of changes in GL levels
Marmot: The Remains of the Day

Gordon Grant
PNW Research Station
USDA Forest Service
Corvallis, Oregon

Jim O'Connor
Jon Major
Chuck Podolack
Sarah Lewis
Peter Wilcock

Marmot Dam, Sandy River, Oregon USA (1913 – 2007)
Marmot Dam Removal Scientific Context:

Sediment Releases

Reervoir sediment (m$^3$)

10$^8$  10$^7$  10$^6$  10$^5$  10$^4$  10$^3$  10$^2$


Large dam removals

Elwha Dams

Milltown

Condit

Savage Rapids

Matilija

Klamath Dams

Previous small dam removals

Big Rapids

Edwards

Embrey

Marmot
~ 750,000 m³ of sediment

PGE Timeline for Marmot Dam Removal

1999: Announce intent to remove
2002: Application to surrender FERC license
July 2007: Begin in-water removal process
Oct. 19, 2007: Coffer dam breach
Summer 2008: Little Sandy dam removed
Physical Model

St. Anthony Falls Laboratory, National Center for Earth-surface Dynamics (NCED)
Reservoir sediment erosion for experimental runs:

**Notch Position:** average of 3 runs at 70.8 m$^3$/s discharge

- river right notch: 32.0% eroded
- river left notch: 36.6% eroded

**Discharge:** single run, right notch position

- 70.8 m$^3$/s: 34.4% eroded
- 155.7 m$^3$/s: 40.2% eroded
Marmot Dam explodes into souvenir bits

More than 200 people watch a blast that signals the end of a longtime hurdle to salmon

- Construct cofferdam
- Remove concrete dam
- Let the river erode the sediment
Knickpoint Migration:
Observations from October 2007 - September 2008

Reservoir Sediment Erosion
Cross sections measured 2007-2009
Forthcoming:
Major et.al, in review.
Geomorphic response of the Sandy River, Oregon, to removal of Marmot Dam.
USGS Professional Paper