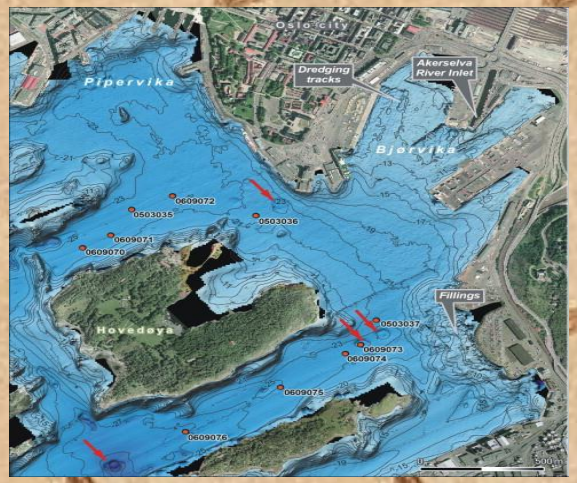
Battelle
The Business of Innovation

Integrated Approaches to Sustainable Sediment Management
The Paradox of Having it All

Eric A. Stern[1] and Eugene Peck[2]

Battelle Memorial Institute - Montclair, New Jersey USA[1]
Viridian Alliance - New Haven, Connecticut USA[2]

NORDROCS 2012
4th Joint Nordic Meeting on Remediation of Contaminated Sites
18-21 September 2012 – Oslo, Norway



Global Sediment Management Challenges

- Changes in Ocean Placement Criteria
- CDFs/CADs are nearing capacity
  - Difficulty siting / re-siting (including public opposition)
  - Loss of benthic habitat / mitigation - **Natural Resource Damage Assessment**
  - Long-term liability
  - Costs not including climate change adaptation / long-term monitoring
- Dredge – Dewater – Haul (> distances) – Landfill
  - Cost prohibitive
  - Paradox to Green Remediation / Sustainability
  - Long-term liability
- Integrating hybrid solutions

❑ ***Moving demonstrations to commercial applications***

- **Competing regulatory programs**

Loading unit train for transport to Idaho landfill from NY – GE Hudson River PCBs

- Protective of human and ecological health
- Use in multi-environments (ocean, estuarine, lakes, fjords, urban)
- Socially and politically acceptable
  - Stakeholder buy-in
- Education and public outreach
- **No re-contamination (source control)**
- Compliance and reduced liability
- Sustainability and restoration is a part of the outcome

What is the desired outcome in a perfect sediment world?

➢ Long-term monitoring consideration of the remedy?

➢ **Complete project before I'm 90**

➢ Component of a Regional Sediment Management Program

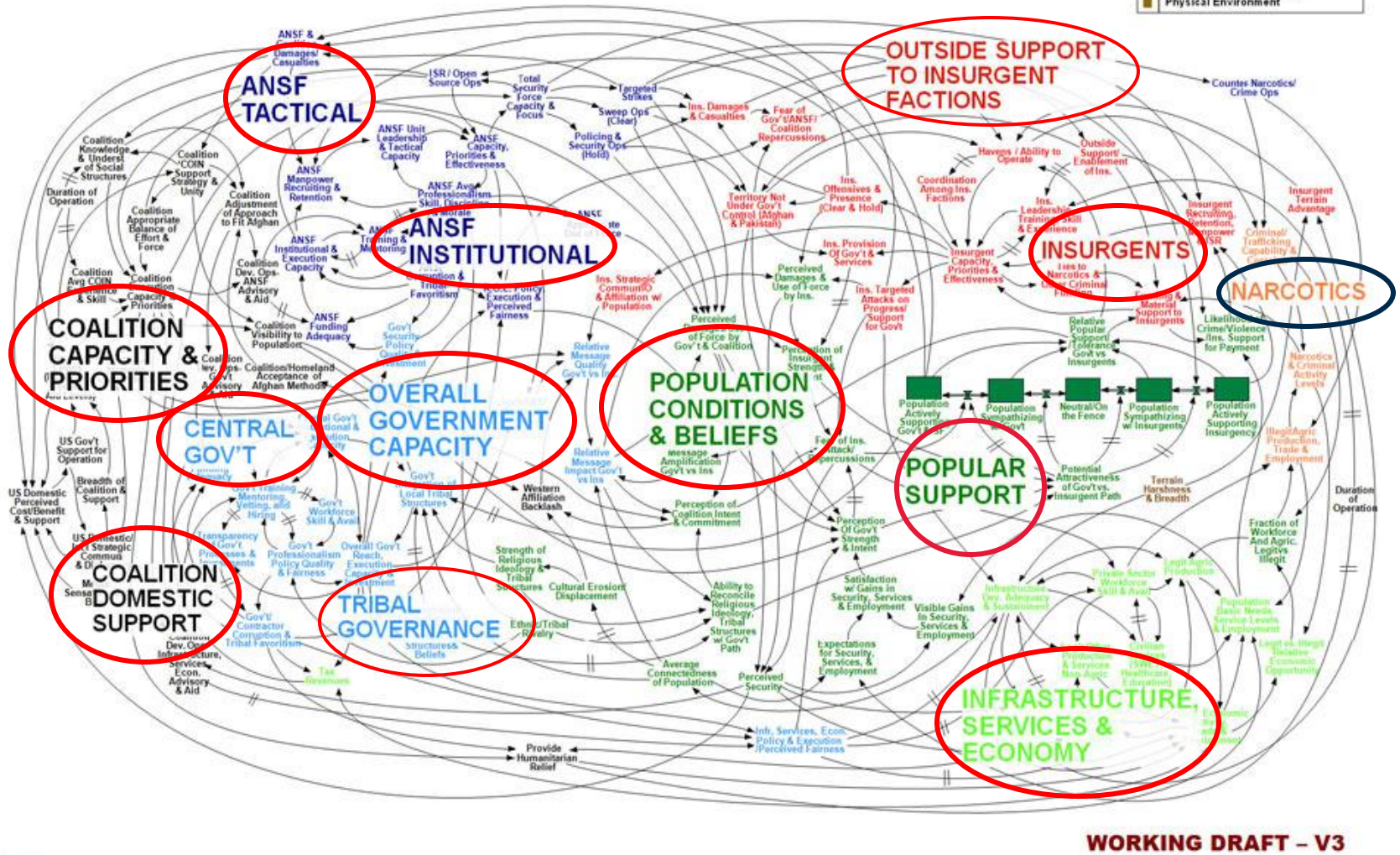
  ➢ *Transferable to other Norwegian harbors and Ports*

❑ **Least cost / economically efficient (public, gov't, businesses)**

❑ **Who Pays?**

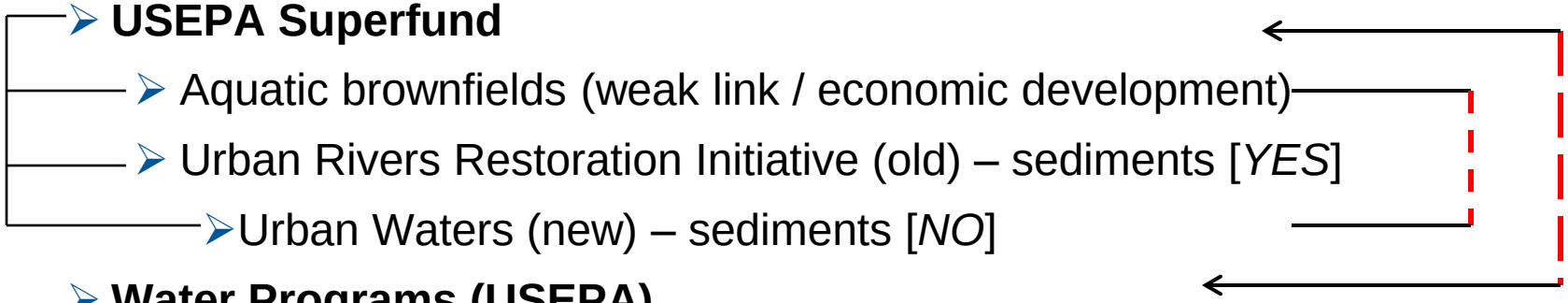
Afghanistan Stability / COIN Dynamics

Application to Sediment Management (over the years)



Programs in United States that Addresses Sediments:

- US Commission on Ocean Policy
- (USACE/USEPA) - Regional Sediment Management - *Policy*
- **USACE Dredged Material** - *Navigation*
  - HTRW / Sec. 312b environmental dredging (USACE)
- **USEPA Superfund**
  - Aquatic brownfields (weak link / economic development)
  - Urban Rivers Restoration Initiative (old) – sediments [*YES*]
    - Urban Waters (new) – sediments [*NO*]
- **Water Programs (USEPA)**
  - Stormwater, CSOs, TMDLs – source control
  - National Estuary Program
  - Dredged Material
- RCRA / Solid Waste
- Enforcement Programs
- US Geological Survey
- US Department of Agriculture



Having the Heretical Debate Sediment Management

- ***Rethinking Risk Assessment / Policy***
- **Sustainable Approaches**
  - Design (early decision making)
    - Socio-economic-political-structural (defining risk)
  - Beneficial use
- ***Life Cycle - MCDA Analysis***
- **Technology (driver)**
  - **Innovation**
- ***Cost-Share Models***

Policy-makers will have to face up to making some hard choices and perhaps accepting slightly lower levels of perceived protection to the public – J.Waters

Contaminated Land Bulletin – July 2010

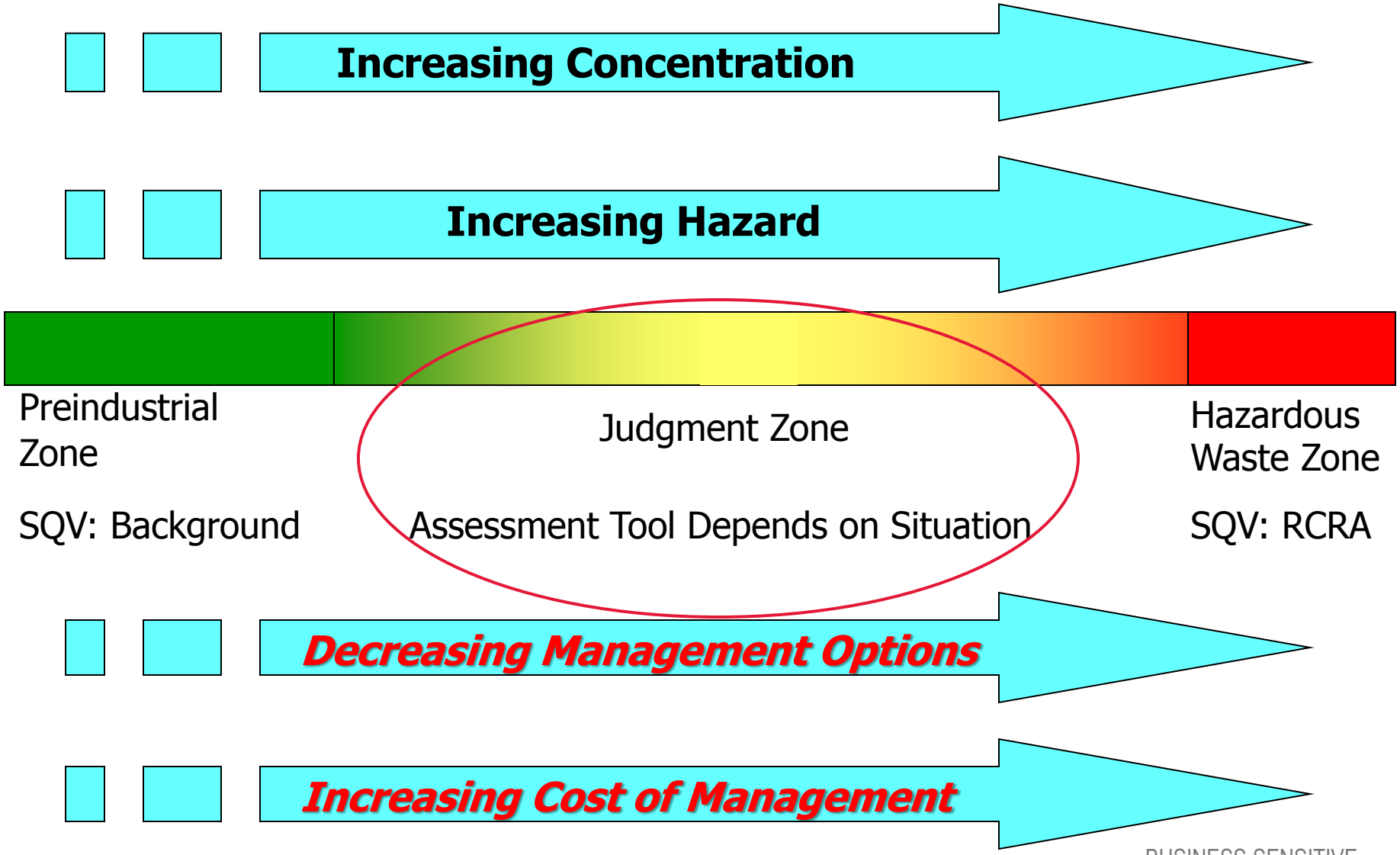
Why do we care?

- Complicated media and environmental management of the system [watershed] + Source Control
  - Innovation / Integration – hybrid approaches

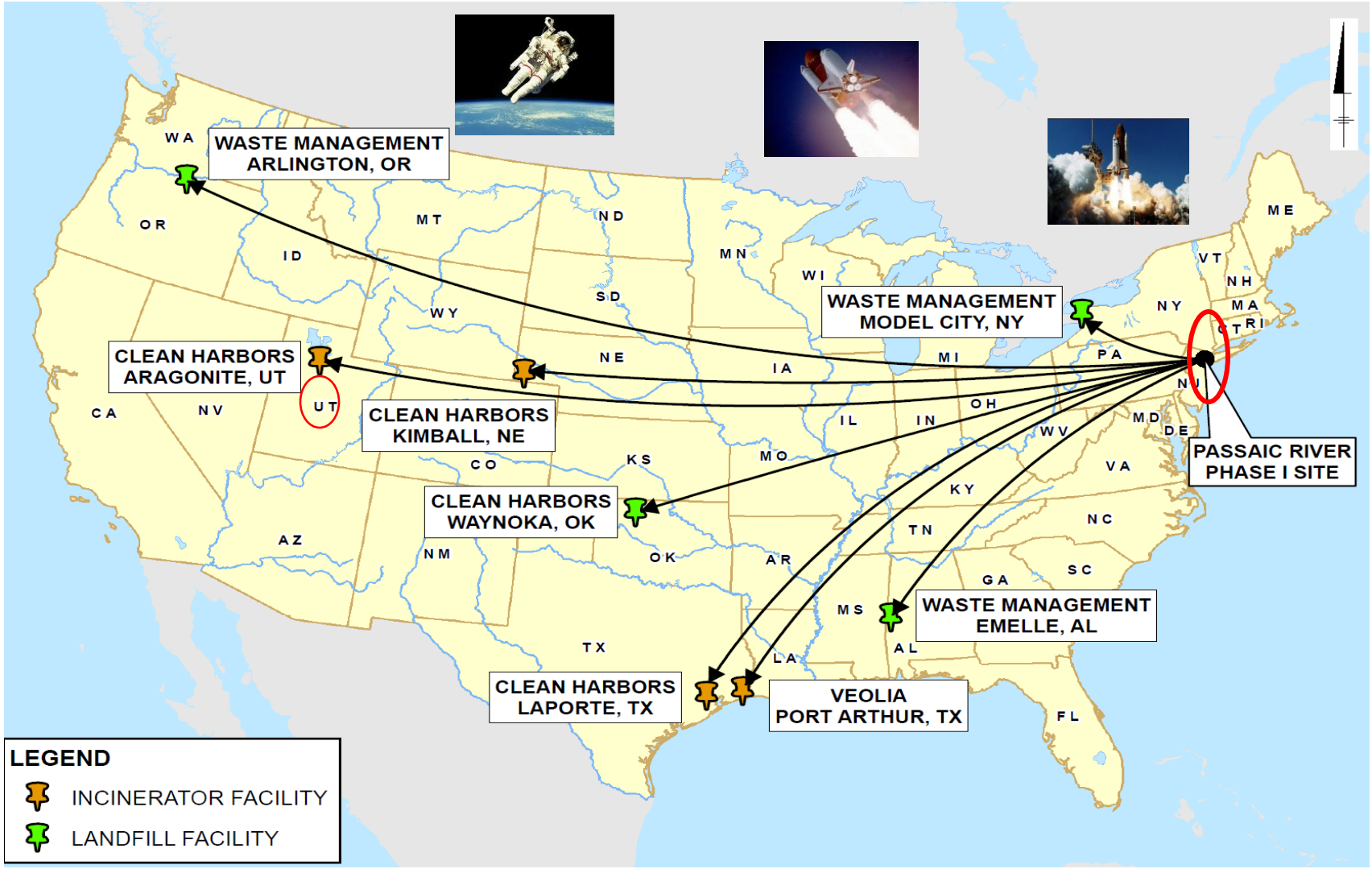
- What is different?
  - ❑ Costs for remediation can be prohibitive
  - ❑ ***Timelines to remediation can be years/decades***
  - ❑ **Green Remediation/Sustainability**
  - ❑ **Sustainable Sediment Management**
    - ❑ **Climate Change Adaptation**
  - ❑ **Regional Sediment Management**
  - ✓ **Who Pays? / long-term liability**

- **Need to balance remedial project cost with:**
  - **risk/environmental protection**
  - **liability**
  - **sustainability (green remediation?)**
  - **regulatory and public/political challenges**
  - **depth (maturity) of technology development, and**
  - **long-term management of the system**
  - **Innovation**
- Can you have it all?
  - I don't think so….well maybe….. not really sure….
  - There is no one *paradigm* / *process* / *technology*….
  - ❑Integrated approaches to sediment management
  - ❑Regional Systems Approach – transferable ?

Sediment Management Decision Making: Simple

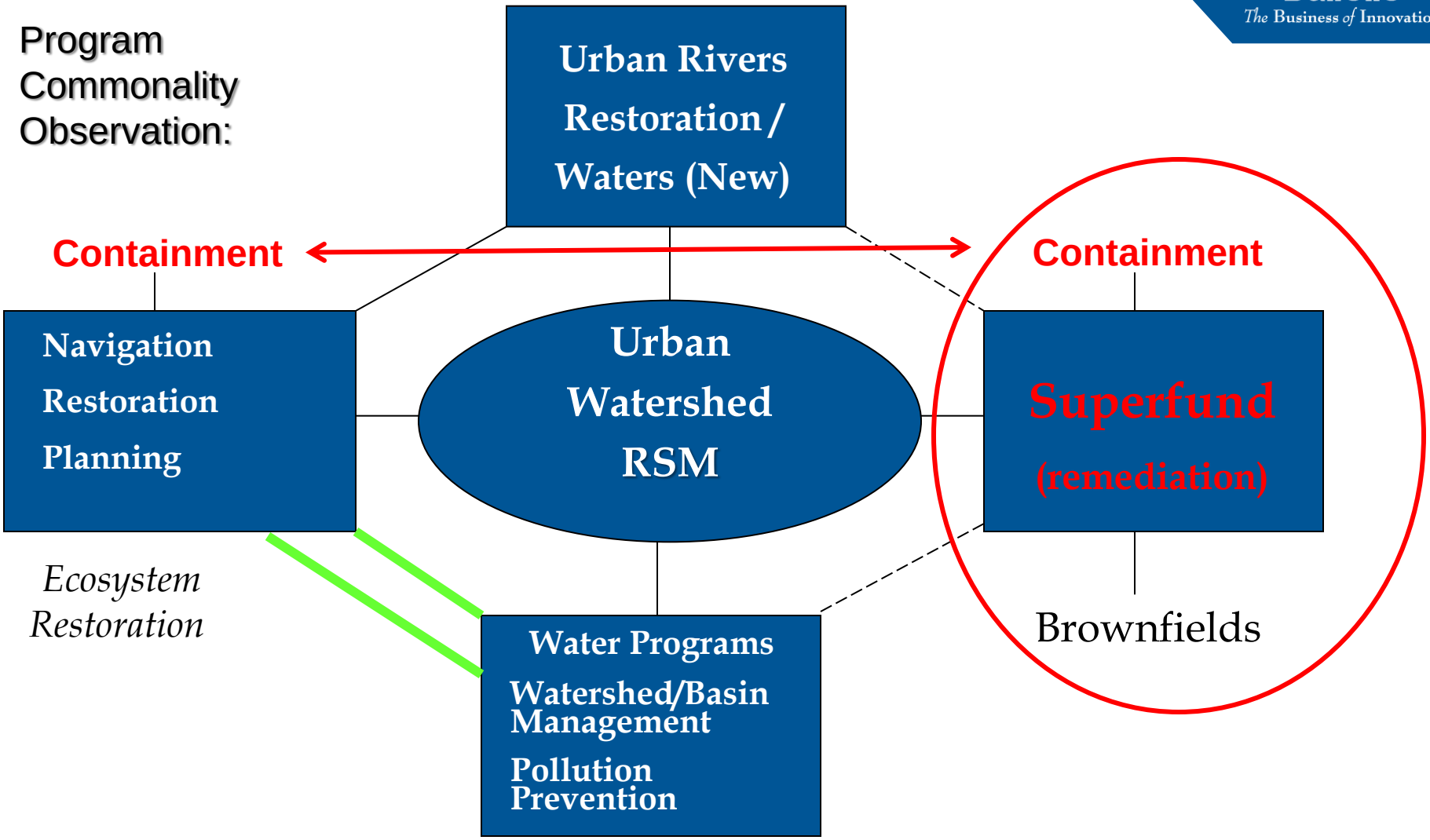


Sediment Containment/Disposal Sites



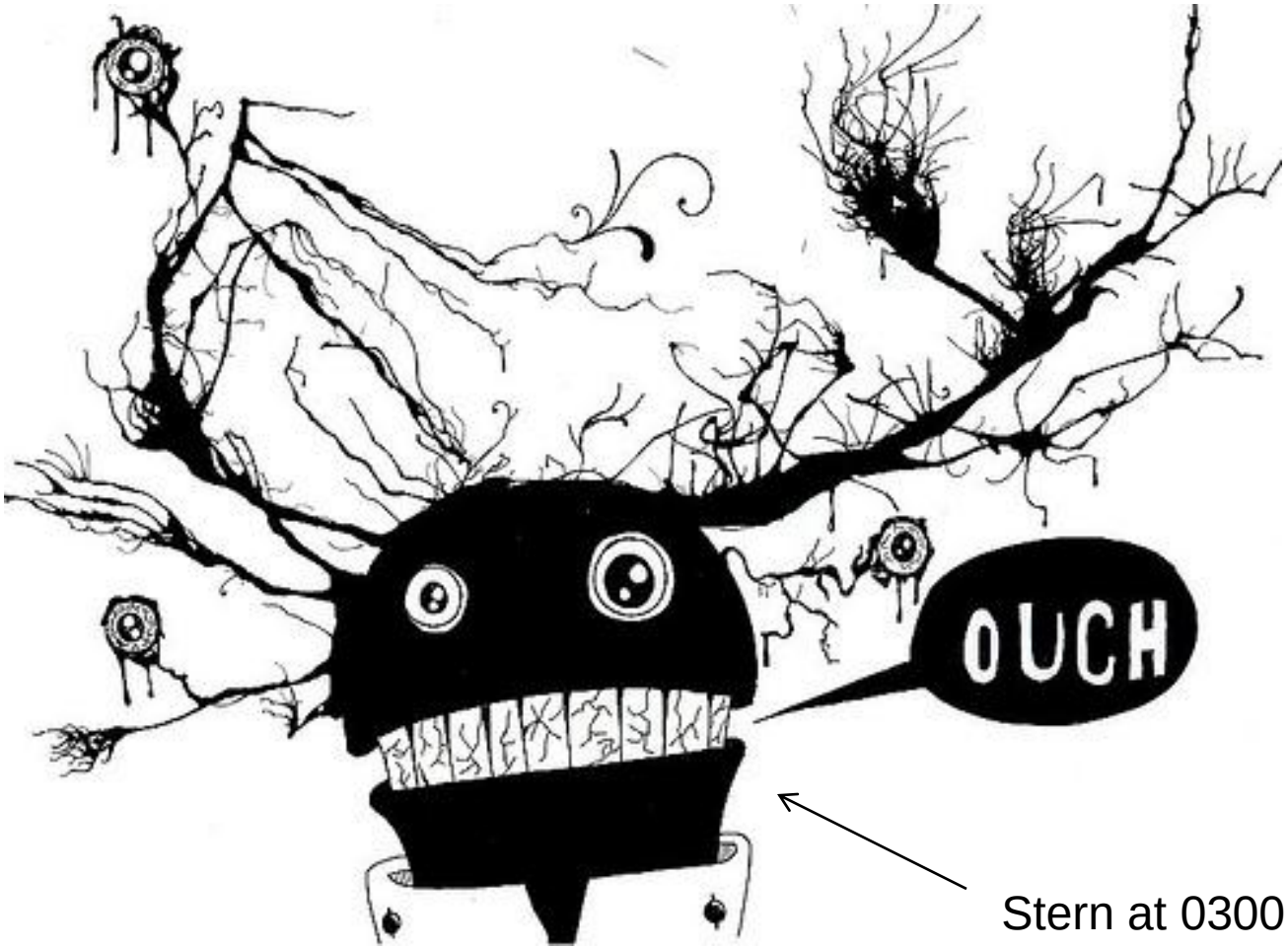
Passaic River, NJ Proposed Cleanup Phase 1 Public Meeting – 2 Dec. 2008

Program Commonality Observation:



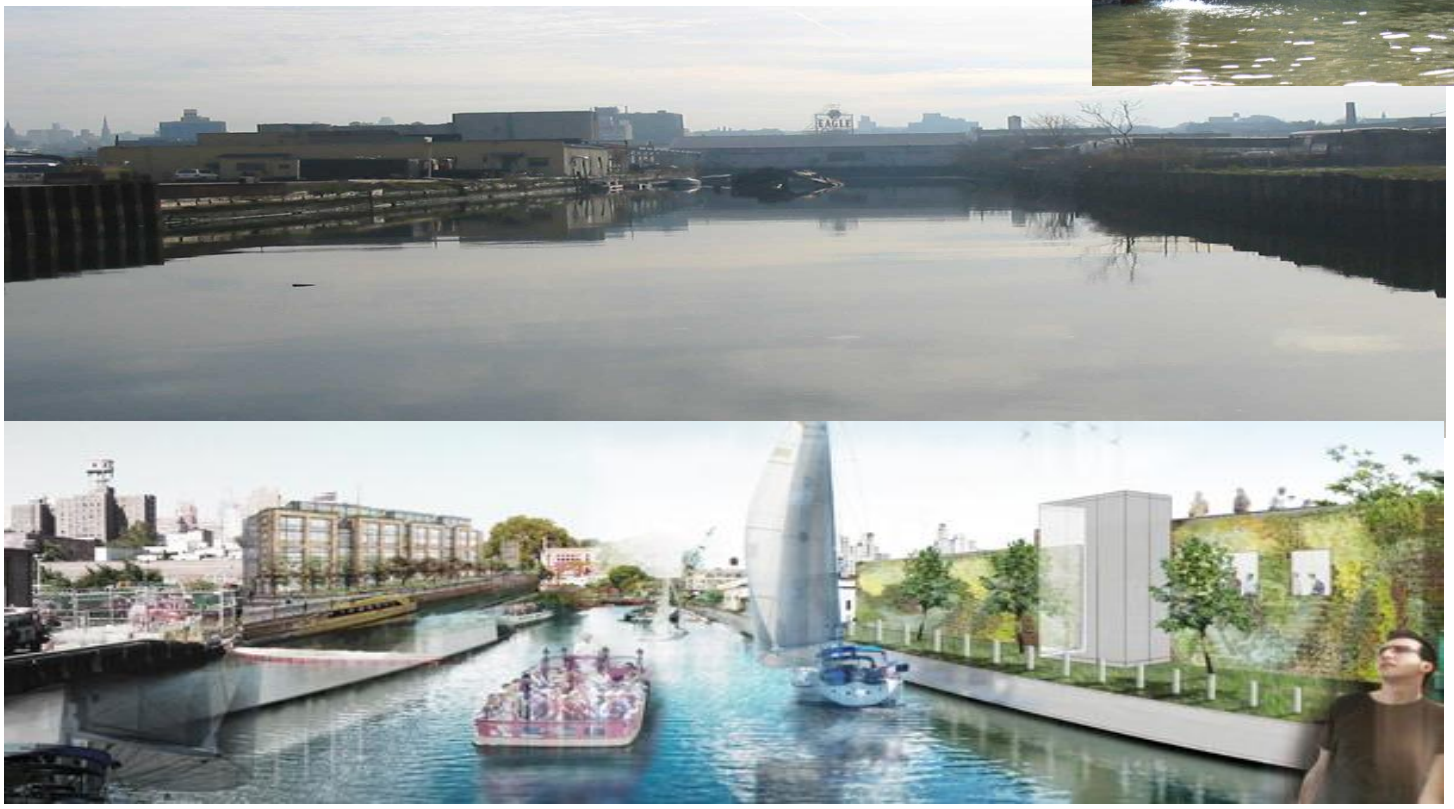
(Stern, 2009)

This stuff keeps me up at night……

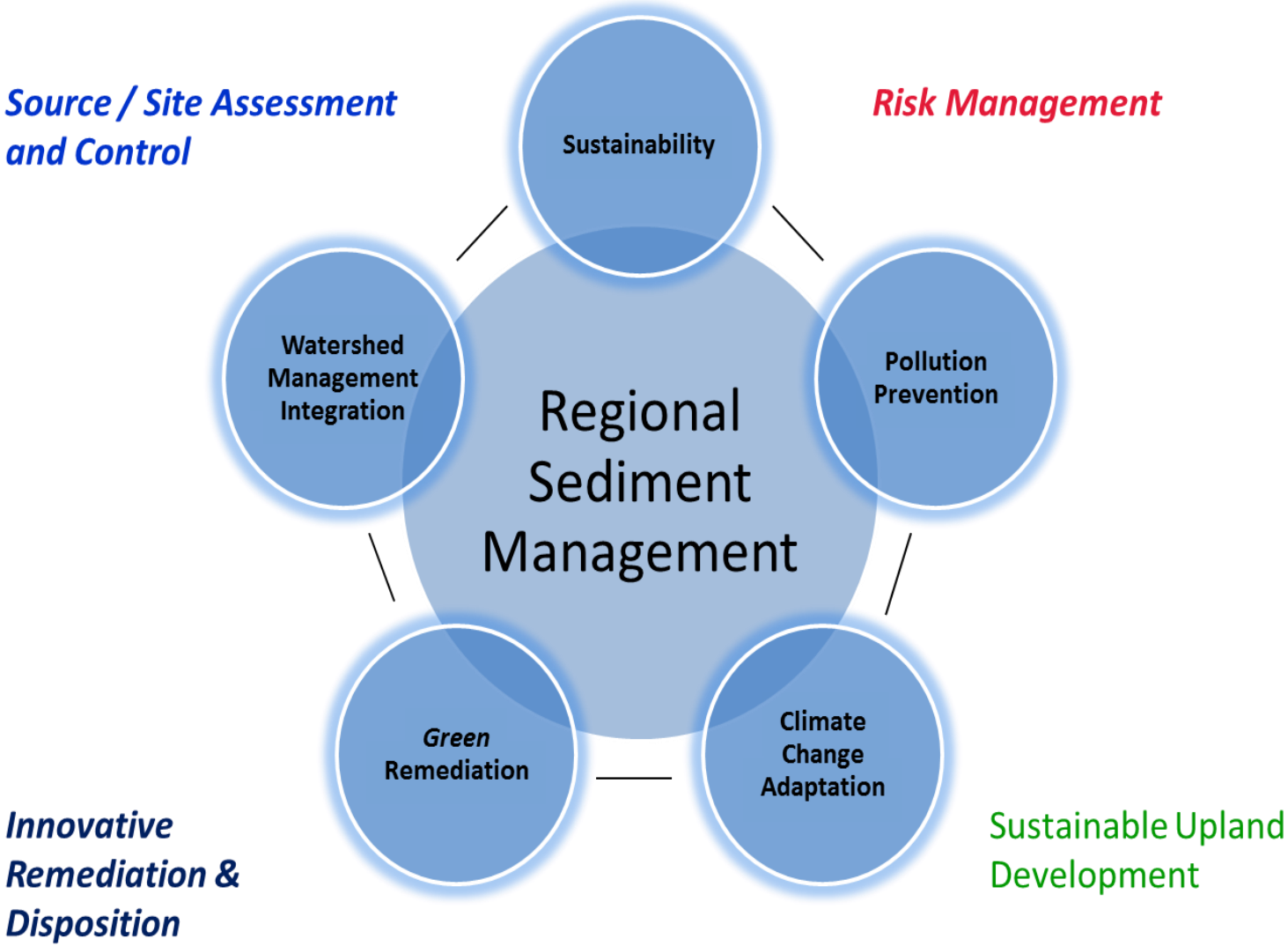


- Applications to Regional Urban Sediment Management

The paradox of having it all



Integrated Approach to Sediment Management



NY/NJ Watershed: The R [urban] SM Perfect Storm

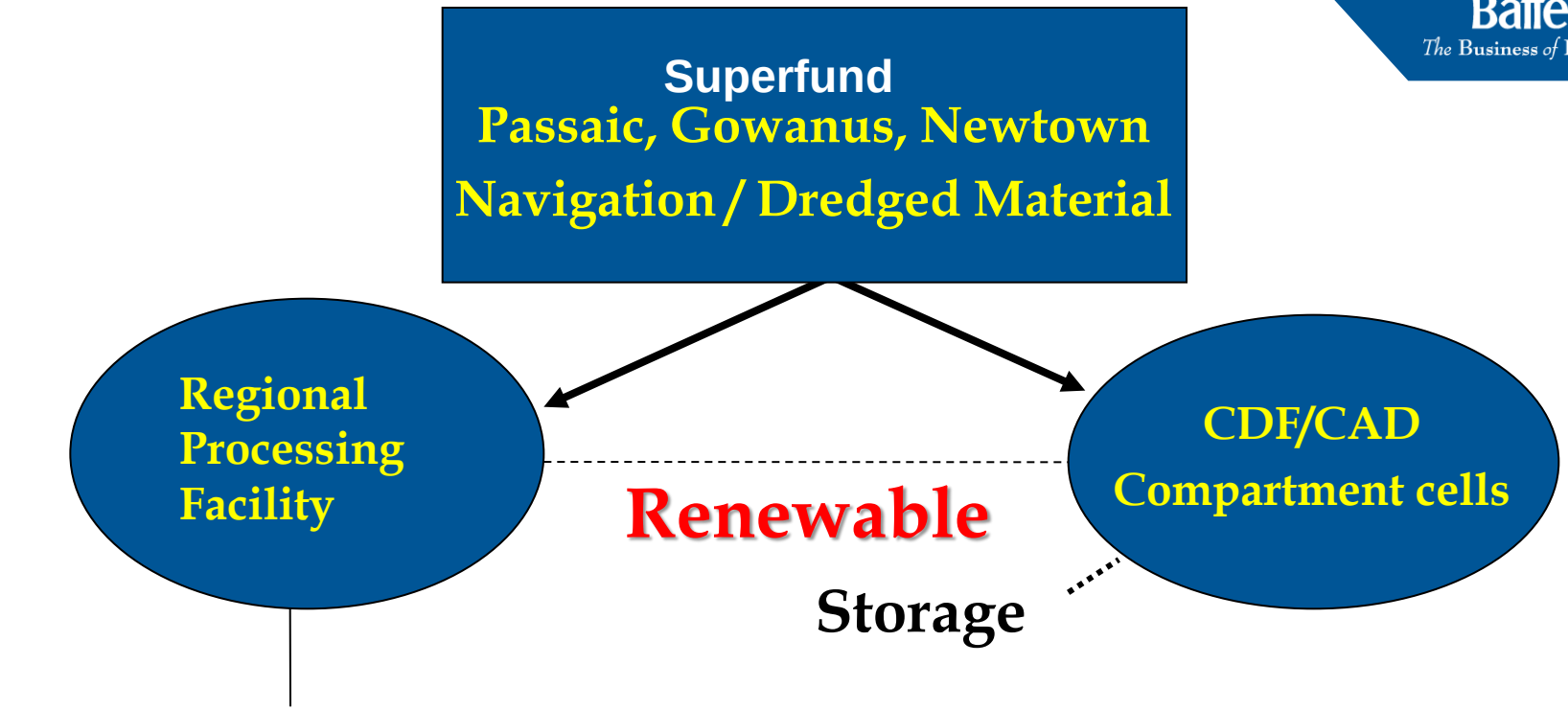
Regional (Urban) Sediment Management

The Perfect Storm:

2012 - 2022

Remediation / Restoration +

USACE Navigation dredging with placement (non- ocean placement material)



Regional Sediment Management Integrated Approach

Application to Sustainable Sediment Management

Comprehensive (*Integrated*) approach for addressing the ***long-term*** management / conservation of sediments within a ***watershed*** in order to maintain current and future uses while promoting ***beneficial uses*** (as a resource).

To be in synch with addressing regional *E*nvironmental, *E*conomic, Social and *Political* challenges…

David Moore, Shelly Anghera, Jack Word*, Matt Wartian and Kurt Frederick

Weston Solutions, Inc. *Newfields Northwest, LLC. – Presented at SETAC, Milwaukee 2007

(modified by Stern)

Intergenerational Equity [Sustainability] Decision Making - Restoration

- Do not make decisions that have irreversible consequences
  - ***Don't get over your head……***
- Do not make decisions that could seriously threaten the resource base over the long-term
  - ***Don't mess up……***

✓***<u>Do not make decisions that could foreclose options for future generations to utilize resources</u>***

- ***Don't really, really mess up!! [sustainability]***
  - ***Implications of long-term monitoring and site use***
    - ***Effects of climate change adaptation (design)***

Apply Integrated Management

- Environmentally efficient
- Economically affordable
- Socially acceptable
- Ensure human health and safety
- Must reduce as much as possible the environmental impacts of waste mgmt (long-term)
  - Energy consumption
  - Pollution of air, land and water and loss of amenity
  - *Take it out of the system – (treatment)*

  ❑ *Reduce/extinguish liability*
- Operate at a cost acceptable to private citizens, businesses, and government

Remediation of Sediments
Integrated System Approaches

Integrate BMPs to drive sustainable solutions to reduce long-term impacts and *liability*

Multi-complex contaminants – Urban Environments
(TCDD, PAHs, Pb, Hg, Cr, TBT…..)

- **Environmental Precision Dredging**
  - Geophysical surveys – debris fields
  - Mechanical, Hydraulic
- **Materials Handling** (most critical step - *economics*)
  - Pumping slurries
  - Dewatering (passive – geotubes): mechanical (filter presses)
  - Transport / Carbon footprint consideration for LCA

- **Sediment Remediation Applications:**

✓ Capping
  - Active/Reactive Core Mats – specialized caps (Organoclay, Activated Carbon, Thin Layer Cap), *Polymeric Marine Mattress*
    - AquaBlok^{tm}, BioBlok^{tm} SediMite^{tm} (delivery systems)

✓ Stabilization/Solidification + (ISCO) (portland cement) + (oxidation)
  - H_20_2, $KMnO_4$, NaS_2O_8

- ✓ Confined Disposal Facility (upland & nearshore)
- ✓ Confined Aquatic Disposal (aquatic)
  - Siting is becoming a challenge / aquatic real estate
- ✓ Containment Islands (near capacity / expand? $$$$)
- ✓ Landfills (significant transport – Carbon footprint) / liability?
- ✓ Mine Reclamation

- ❑ Ex-situ / In-Situ Innovative Sediment Technologies
  - Thermal
  - Non-thermals
  - In-Situ Stabilization (cement injection) / caps

- ❑ In / Ex-Situ Bioremediation
  - – Mudflats – ecosystem restoration
    - Space limitation

- Monitored Natural Attenuation/enhanced (eMNR)

INTEGRATE PHYSICAL INFRASTRUCTURE IN ALL ALTERNATIVES:

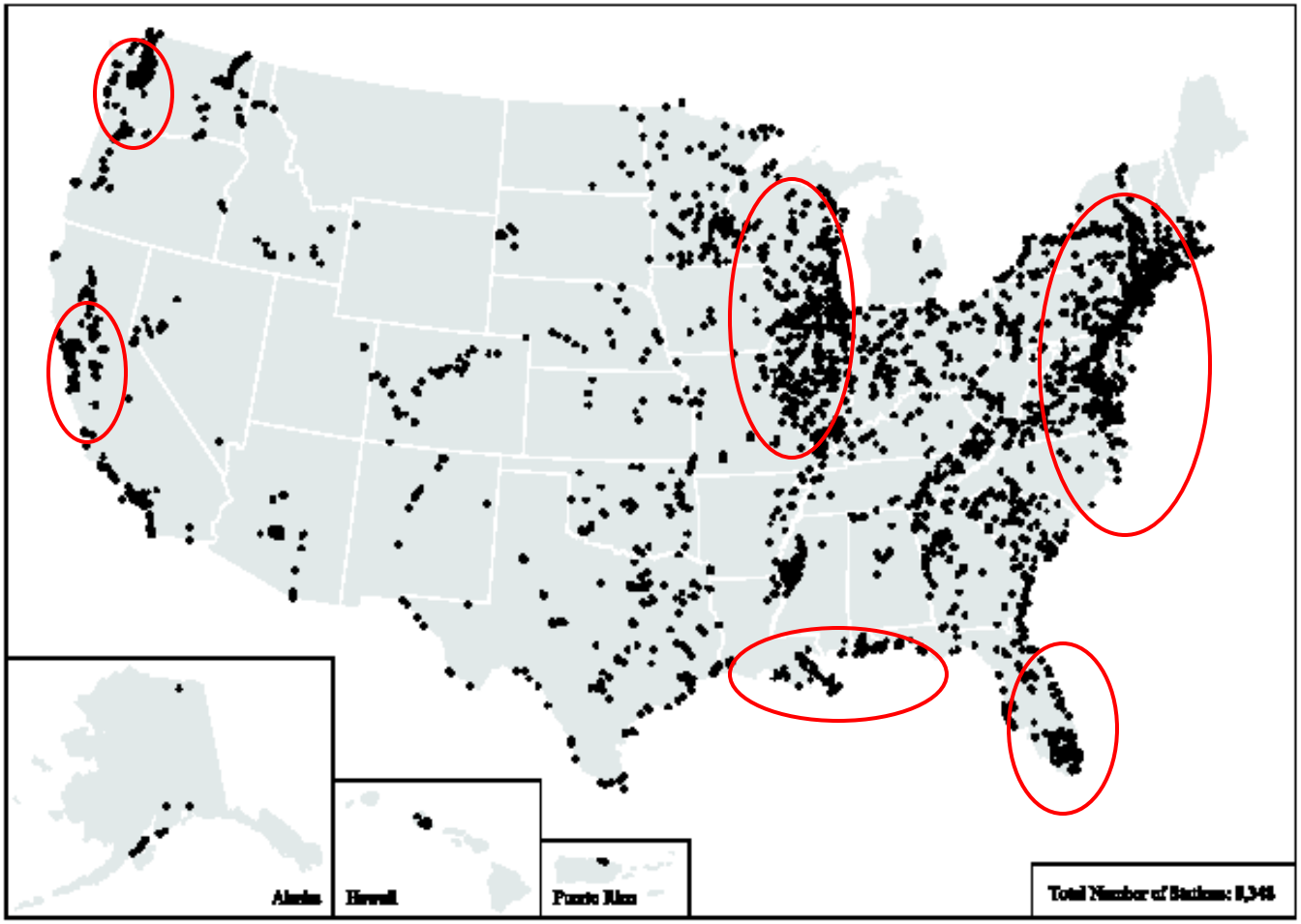
- ❑ **Climate Change**
- ❑ **Hurricanes**
- ❑ **Earthquakes**

US Nationwide Tier 1 Sites – Probable Adverse Aquatic/Human Health Effects

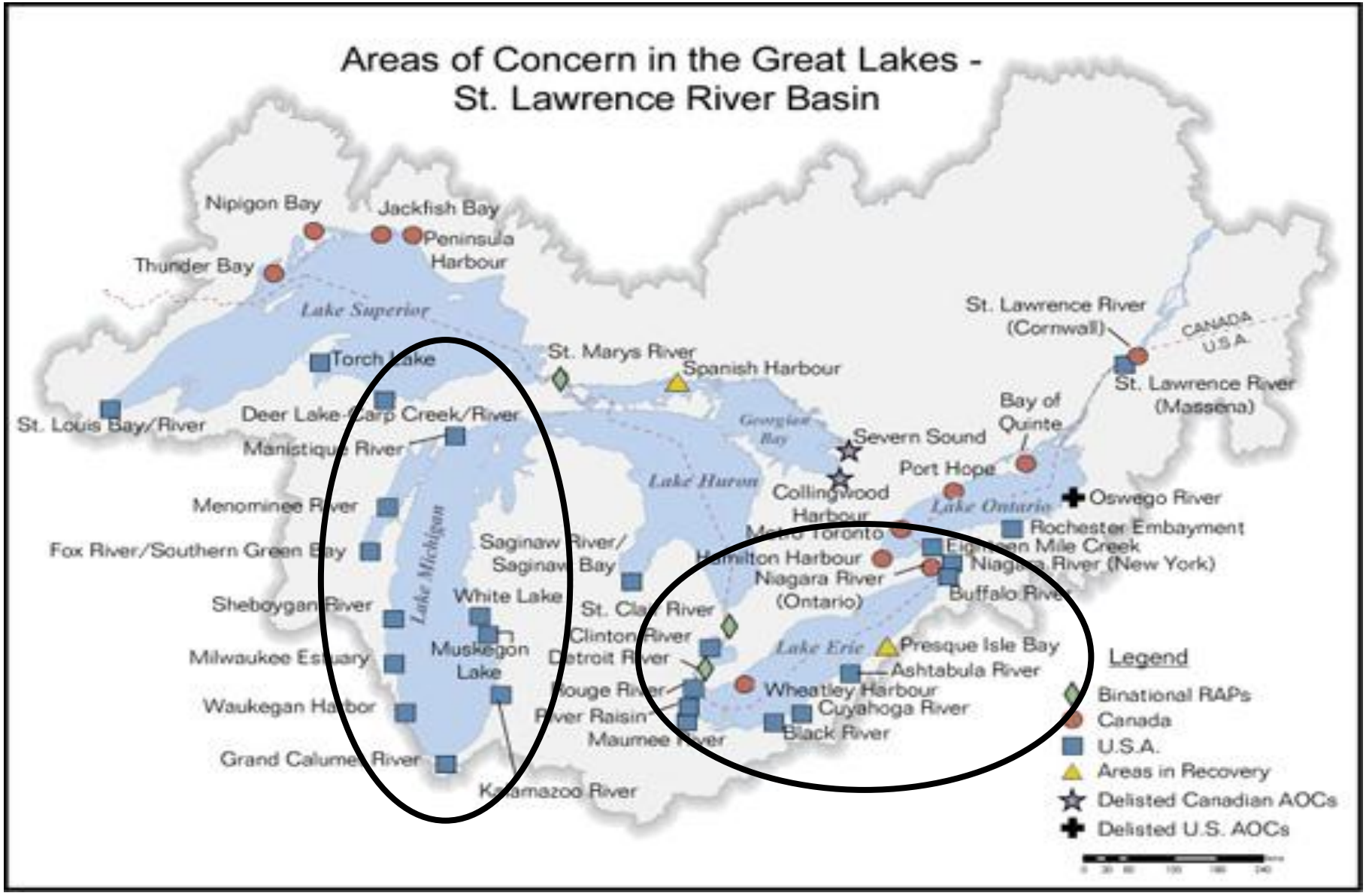
8,348 sites

43% of sites surveyed

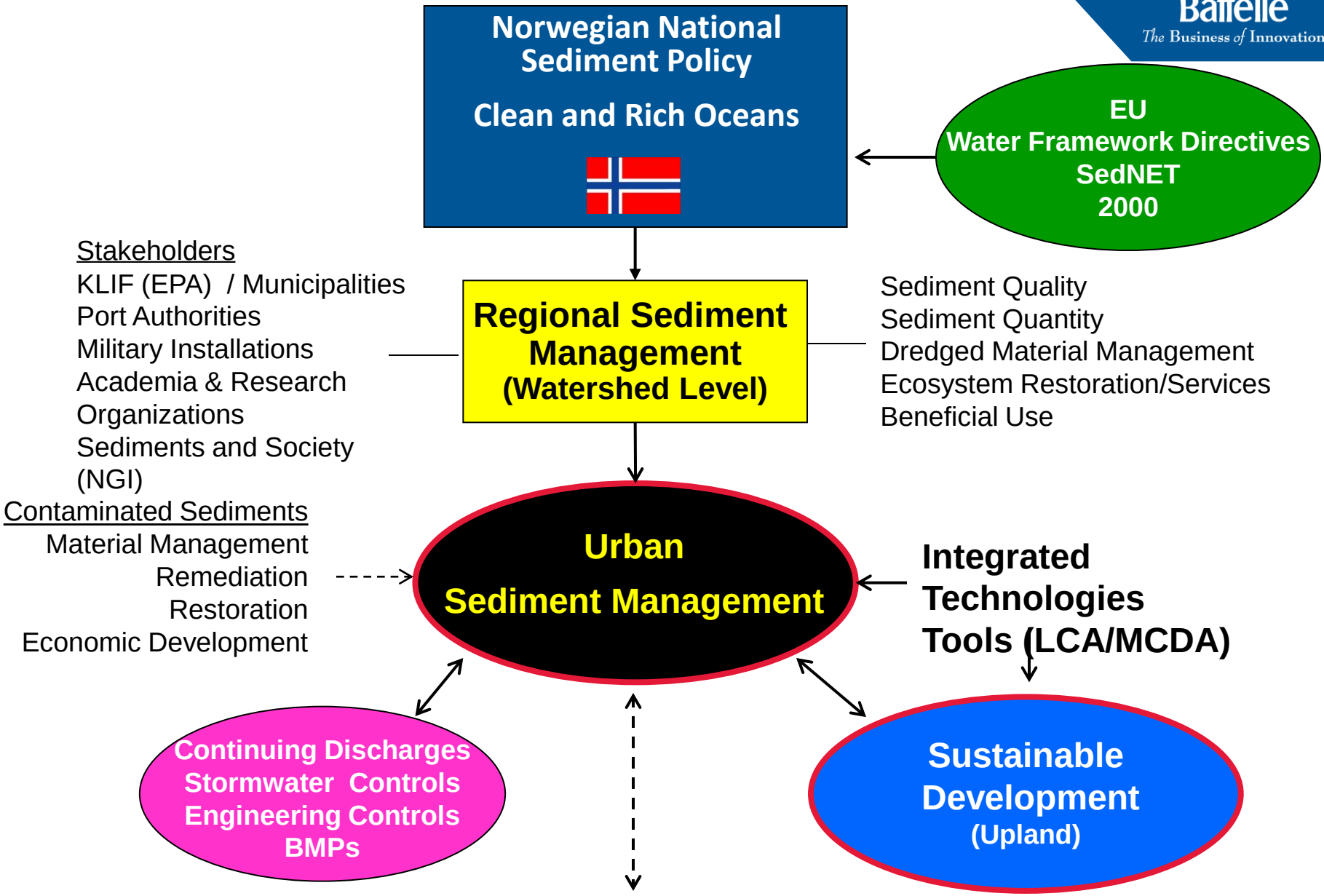
8.8 % of river reaches



Source: National Sediment Quality Survey (EPA, 2004)


Areas of Concern in the Great Lakes -
St. Lawrence River Basin
Nipigon Bay
Jackfish Bay
Peninsula Harbour
Thunder Bay
Lake Superior
St. Louis Bay/River
Deer Lake
Carp Creek/River
Manistique River
Menominee River
Fox River/Southern Green Bay
Sheboygan River
Milwaukee Estuary
Waukegan Harbor
Grand Calumet River
Lake Michigan
White Lake
Muskegon Lake
Kalamazoo River
Torch Lake
St. Marys River
Spanish Harbour
Saginaw River/
Saginaw Bay
St. Clair River
Clinton River
Detroit River
Rouge River
River Raisin
Maumee River
Lake Huron
Georgian Bay
Severn Sound
Collingwood Harbour
Lake Erie
Presque Isle Bay
Ashtabula River
Wheatley Harbour
Cuyahoga River
Black River
Niagara River
(Ontario)
Hamilton Harbour
Buffalo River
Lake Ontario
Port Hope
Bay of Quinte
St. Lawrence River
(Cornwall)
CANADA
U.S.A.
St. Lawrence River
(Massena)
Oswego River
Rochester Embayment
Eighteen Mile Creek
Niagara River (New York)
Legend
Binational RAPs
Canada
U.S.A.
Areas in Recovery
Delisted Canadian AOCs
Delisted U.S. AOCs


National action plan 2005
Investigated in phase I
Honningsvåg
Båtsfjord
Hammerfest
Tromsø
Harstad
Ranfjorden
Vefsnfjorden
Trondheim
Sunndalsfjorden
Ålesund
Årdalfjorden
Sørfjorden
Bergen
Saudafjorden
Karmsundet
Stavanger
Sandnes
Fedafjorden
Flekkefjord
Farsund
Kristiansand
Grimstad
Arendal
Tvedestrandsfjorden
Grenlandsfjordene
Sandefjordsfjorden
Tønsbergfjorden
Drammensfjorden
Oslo havn


Norwegian National Sediment Policy
Clean and Rich Oceans
EU
Water Framework Directives
SedNET
2000
Stakeholders
KLIF (EPA) / Municipalities
Port Authorities
Military Installations
Academia & Research Organizations
Sediments and Society (NGI)
Regional Sediment Management
(Watershed Level)
Sediment Quality
Sediment Quantity
Dredged Material Management
Ecosystem Restoration/Services
Beneficial Use
Contaminated Sediments
Material Management
Remediation
Restoration
Economic Development
Urban
Sediment Management
Integrated Technologies Tools (LCA/MCDA)
Continuing Discharges
Stormwater Controls
Engineering Controls
BMPs
Sustainable Development
(Upland)
Long – Term Implementation / Monitoring
Adaptive Management

[Urban] / Port Sediment Management

- Sustainability (long-term)

- ***Eco-psychology*** (Urban Sed. Mgmt.)
  - Behavioral understanding of moving forward
    - **Open to Change**
    - Urban – City / Port Environment
    - Leadership
    - Education (K-12) / Stakeholder Outreach
    - ***Different brain wiring (political) – short vs. long-term***

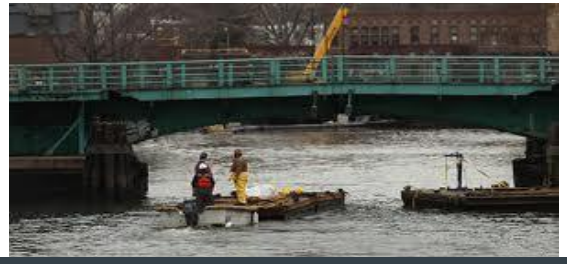
complicated media

can't see it

- *Integrated Sediment Management*
  - Hybrids – Holistic – Treatment Train Approaches
    - Multi Contaminants / Multi Media / Cultural Resources
  - Regional Sediment Management (watersheds/basins) – **SOURCE CONTROL**

- Beneficial Use
  - Un-renewable resources (economic re-development)

Competing / Integrated Uses of the Gowanus Canal, New York: Case Study



To Place on Superfund National Priority List or Not – ***debate:***

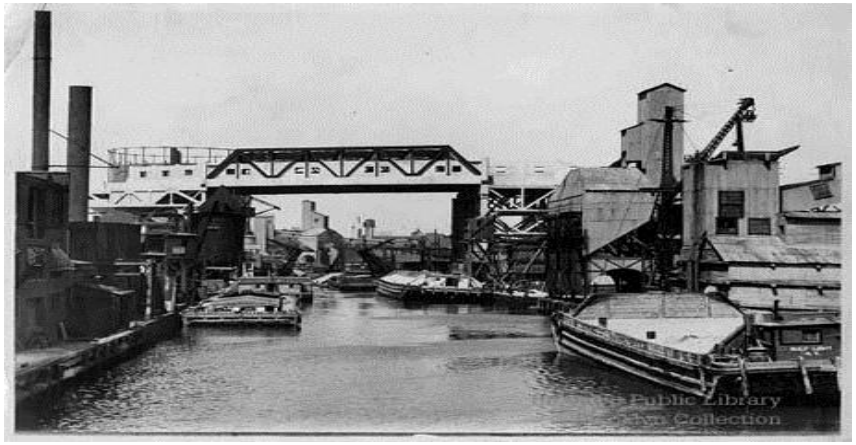
- Superfund (State to Federal lead)
  - 10-11 years / $500M+

- Water Resource Development Act + Superfund (NYC / Mayor Bloomburg)
  - 6 years (cost-share) …..(Great Lakes Legacy Act Model)
    - Federal/State/City – PRPs
  - Economic Development and Revitalization
  - Source Control – Combined Sewer Overflow abatement

- (Opinion): Debate was more political – socio – economic
  - To develop or not develop….

RSM Sediment Sustainability:

Historical –
Economic Engine



Present

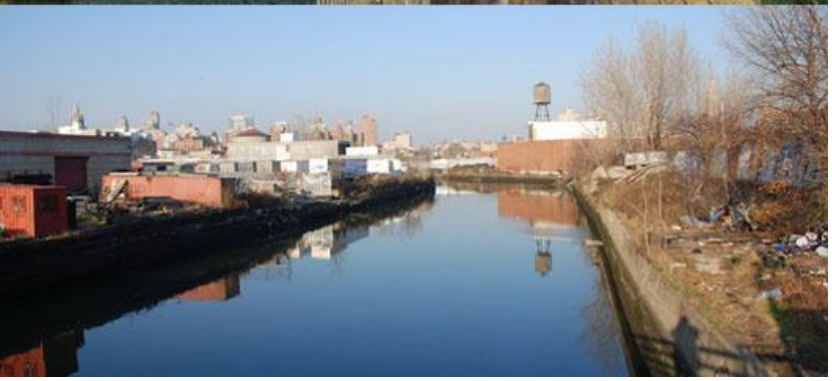
Gowanus Canal – Brooklyn, New York

Linkage between sediment remediation / restoration and upland economic development

DISCONNECT

TMDLs
CSOs

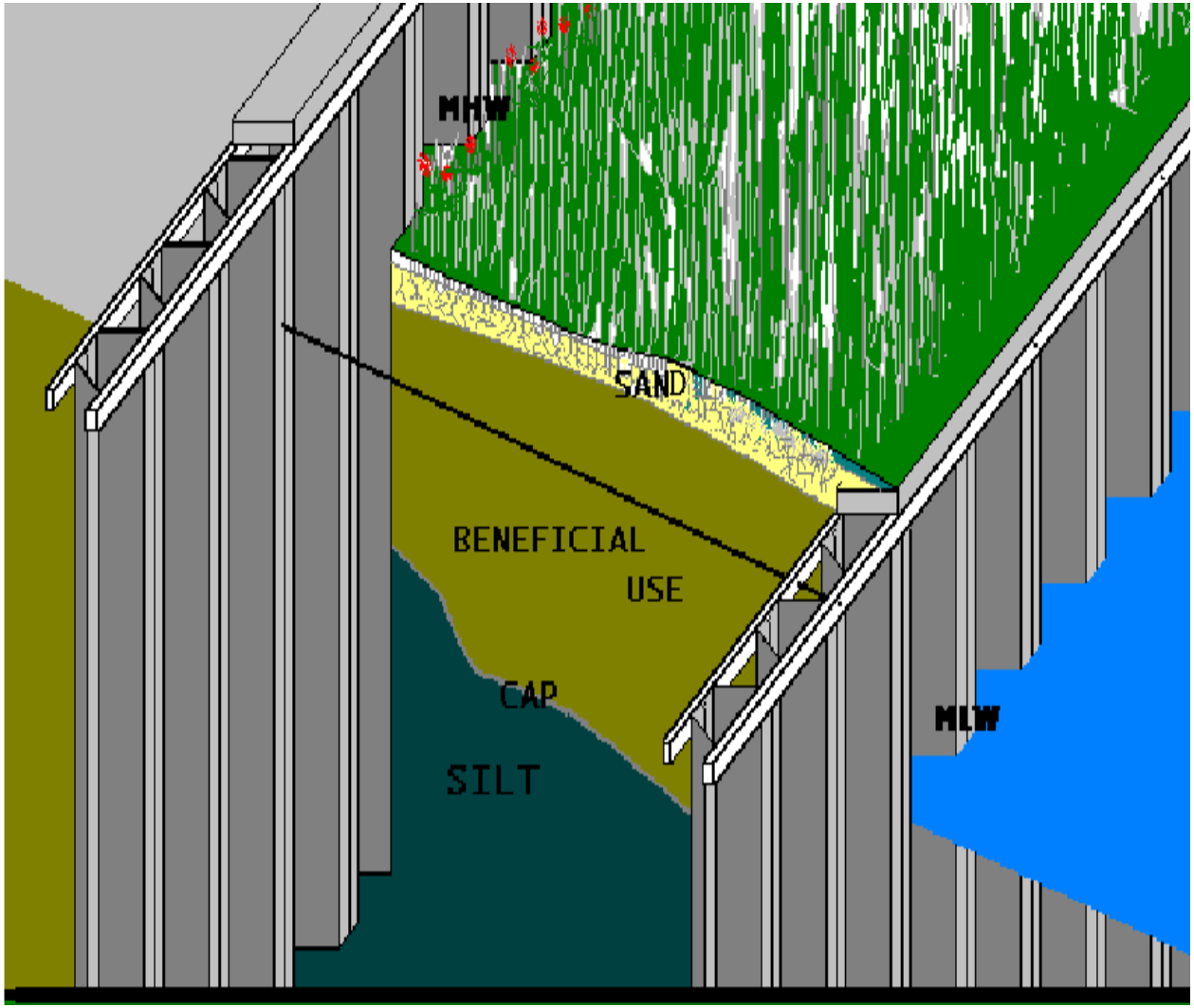
Sponge Park – Gowanus Canal



Public open space that slows, absorbs and filters surface water runoff to remediate contaminated water, activate the private canal waterfront and revitalize the neighborhood.

Develop strategies to direct, collect and absorb excess SW runoff – phytoremediation and wetland habitat creation

Bionautics^{tm} Bulk and Tiering System



Sediment Management Decision Making Tools

- Life-Cycle Assessment
  - Evaluating total effects a product has on the environment over its entire existence (production through disposal)
    - Energy (consumption) + resource use (un-renewable resources/beneficial use)
    - Transportation (carbon footprint)
    - Final disposition (landfill, CAD, CDF, capped site)
    - Applications of beneficial use
    - Climate change adaptation
    - Habitat and ecosystem recovery/restoration
      - treatment technologies + beneficial use, CDFs/CADs, capping, landfills etc.
        - » Short vs. long-term options (in it for the long-term)

Sediment Management Decision Making Tools

- SiteWise ™ Baseline LCA Assessment Tool (Battelle, Navy, USACE)/Microsoft Excel **(not applied to sediments)**
  - metrics: GHGs, energy usage, air pollutants (SO_x, NO_x), particulate matter, H_20 usage and accident risk
    - Remedial Investigation, Remedial action construction/operations and long-term monitoring
      - Transportation/material production/equipment use/residual management
- Multi-Criteria Decision Analysis
  - (USACE ERDC: Linkov, Bates / NGI: Sparrevik, Oen
  - Supports selection of suitable sediment remediation alternatives
    - Environmental, technical, social and economics relative to the remedy
      - Probability and sensitivity analysis (stakeholders/risk perception)
        - » Critical in making decisions with imperfect information (time and $$)

Battelle
The Business of Innovation

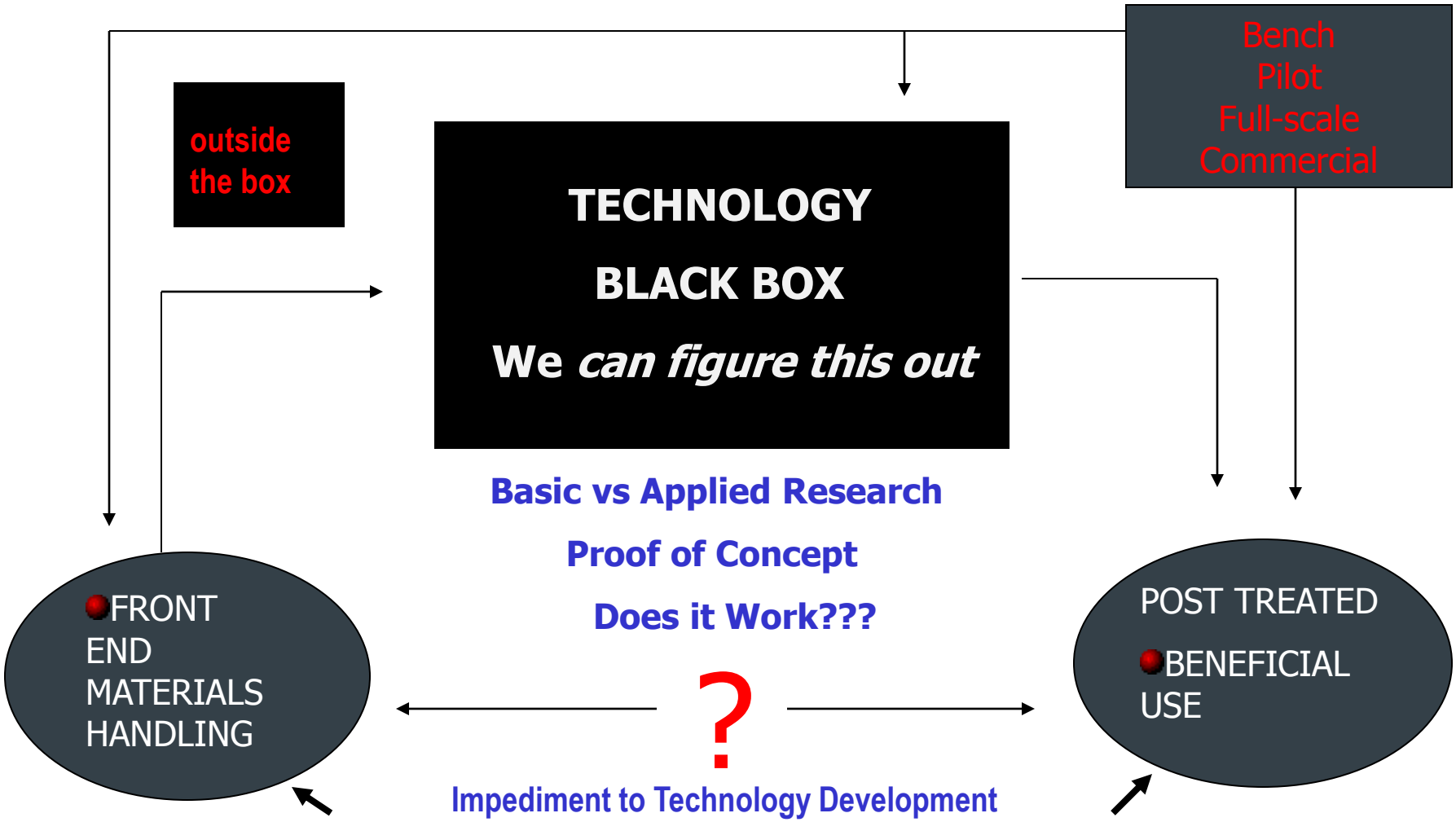
Use of Innovative Sediment Management Programs and Technologies Positioning for the Future

Regional Processing

Beneficial Use

Sustainability

Sediment Treatability Treatment Train Development: (Ex/In-situ)



Ex-SituTreatment Technologies Tested USEPA/NJDOT Decontamination Programs (1995-2010)

- ✓Sediment Washing *
- ✓Thermo-Chemical Rotary Kiln *
- ✓Plasma-Arc Vitrification
- ✓Base-Catalyzed Decomposition
- ✓Rotary Kiln -Thermal Desorption
- ✓Solvent Extraction
- ✓Solidification/Stabilization with Oxidation *
- ✓Fluidized Bed Reactor

* Full – Commercial Scale

Ex-situ Technologies with Beneficial Use

- *Cement-Lock ™ Technology** ++ F
  - ***Commercialized by Volcano Partners LLC***
  - Thermo-chemical rotary kiln **(cement and WTE)**
- *BioGenesis ™ Enterprises** ++ F
  - Sediment washing **(soils, bricks, polymer coating)**
- Upcycle / BayCycle Aggregates * ++
  - *Existing* Rotary Kiln **(light-weight aggregate)**
- Harbor Resource Environmental Group, Inc *
  - Oxidation/dewaterimg/Stabilization **(structural fill)**
- Westinghouse/The Solena Group + *
  - Plasma-arc vitrification **(glass tiles / gasification – biofuels / BA)**

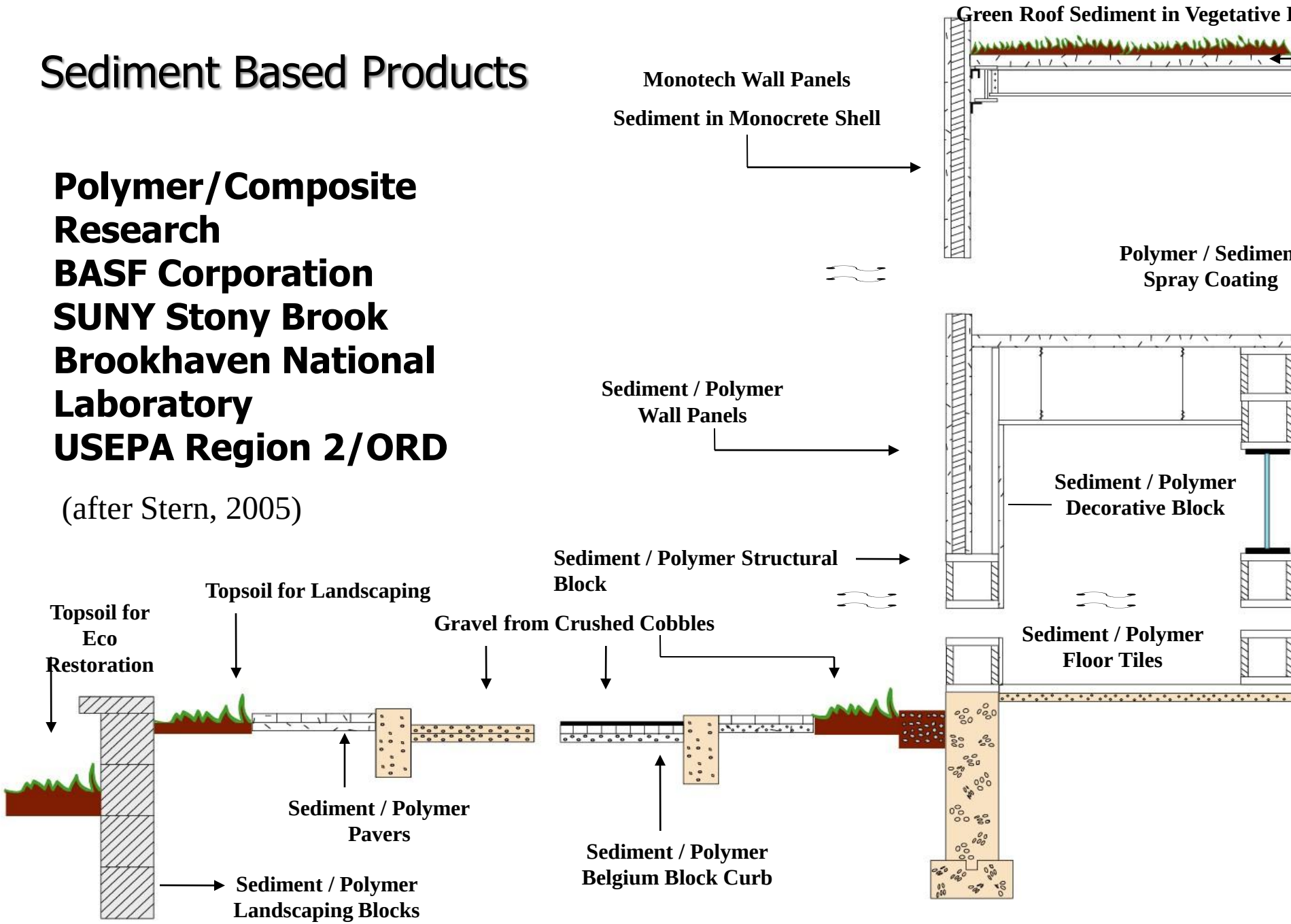
•Full Scale F Pilot Scale *

•ERDC Review ++

Sediment Based Products

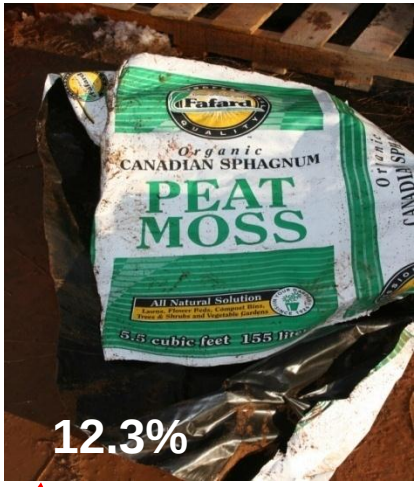
Polymer/Composite Research
BASF Corporation
SUNY Stony Brook
Brookhaven National Laboratory
USEPA Region 2/ORD

(after Stern, 2005)



Doug Reid Green - BASF

Montclair State University, NJ Manufactured Soil and EcoMelt™ Sustainable Landscape Demonstration (2010)



Manufactured soil compared against residential/non-residential soil criteria

Treated Manufactured Soil / Construction-grade Cement: MSU/Fall 2011

Meets NJ Residential Soil Criteria

30-40% replacement for Portland cement

To Place on Superfund National Priority List or Not – ***debate:***

- Superfund (State to Federal lead)
  - 10-11 years / $500M+

- Water Resource Development Act + Superfund (NYC / Mayor Bloomburg)
  - 6 years (cost-share) …..(Great Lakes Legacy Act Model)
    - Federal/State/City – PRPs
  - Economic Development and Revitalization
  - Source Control – Combined Sewer Overflow abatement

- (Opinion): Debate was more political – socio – economic
  - To develop or not develop….

Accelerating Progress at Contaminated Sediment Sites: Moving from Guidance to Practice

Bridges, T.S., Nadeau, S.C and M. McCulloch (2011). SETAC on-line.
Integrated Environmental Assessment and Management

- **Development of detailed and explicit project vision & accompanying objectives**
  - Achievable short-long term goals
  - Metrics of remedy success at beginning of project
  - Dynamic – adjust

- **Strategic engagement of stakeholders**

- **Optimization of risk reduction / risk management & remedy selection**
  - **Deliberate use of early action remedies (IRMs) to accelerate risk reduction (Bergen Capping Studies)**
  - 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

USEPA Great Lakes Legacy Act Cost Share Model

- Goal: Accelerate the pace of sediment remediation at Areas of Concern (AOCs)
  - Federal Government Authorization (Act of Congress)
- Mechanism: Use partnerships as an innovative approach to conducting sediment remediation

✓ **Cost Sharing:** Requires a minimum 35% non-federal cost share

❖ Not been implemented anywhere outside the Great Lakes

Great Lakes Legacy Act Project Types

- Must be in U.S. Areas of Concern (AOCs) and:
  - 1) Implement a plan to remediate contaminated sediment (highest priority)
  - 2) Monitor or evaluate contaminated sediment
  - 3) Prevent further or renewed sediment contamination
  - 4) **Habitat Restoration** in conjunction with sediment remediation

USEPA Legacy Act Industry Project Cost Share (2011)

- DuPont Co.
- GenCorp Inc.
- Honeywell International Inc.
- Illinois Tool Works, Inc.
- United Technologies BP-Husky Refining
- Cleveland Illuminating Co.
- Mallinckrodt Inc
- Millenium Inorganic Chemicals
- Ohio Power
- Olin Corp
- Occidental Chemical
- RMI Titanium Co
- Sherwin Williams
- Union Carbide
- CBS Operations (Viacom Intl)
- Elkem Metals
- Perstorp Polyols, Inc.
- Chevron USA
- Sunoco, Inc
- Pilkington North America, Inc
- Allied Waste Industries, Inc.
- Phelps Dodge (Now Freeport-McMoRan)
- Cabot Corp
- Detrex Corp
- XIK Corp
- Consumers Energy
- Varta Microbattery, Inc.
- The Mosaic Co.

Legacy Act Regional Sediment Treatment Program (example)

- **Partner with GLNPO (Legacy Act) to provide non-federal cost share (65-35%)**
- **Dredge, decontaminate, recycle to useful products instead of placement in CDF or landfill**
- ***PROCESS AT CENTRAL LOCATION***
  - Standardized materials handling approach
  - **Combine several projects for sediment volume throughput:** Regional facilities (Lake Michigan/Erie)
  - Improved efficiencies

→ Sustainable reclamation of a non-renewable resource

↓

Long Term Disposal and Placement Options

CDFs nearing capacity

Landfills?

Long-term monitoring

LEGACY?

Summary:

- [environmentalists] have become more equity conscious, and through their adoption of the sustainable growth logic of the appropriate technology movement, they have largely cast off changes of obstructionism
  - Cicin-Sain and Knecht (1998)
    - Integrated Coastal and Ocean Management

- ….Need to be open to new ideas – behavioral (shift)
  - Innovation grinds to a halt (no intellectual motivation) if the most desired outcomes are long-term dumps or that clean-ups continue to take decades

- ***Don't believe when someone tells you "If it ain't broken – don't fix it" – translates globally***
  - It probably is broken and you just don't quite yet know how to fix it.. - ***stuck in the mud…***
  - ***Impedes innovative technology development***

❑***Move demonstrations to full-scale/commercial applications***

- ***Application of Regional Sediment Management***
  - ***Integrated solutions (play nice with each other)***
  - ***Understand / apply sustainability component***
    - Integrate Life Cycle Assessment - MCDA / Sustainability / Environmental Cost Benefit of paying more in the short-term as it relates to long-term sustainable approaches
- ***Don't discount sediment treatment as too expensive*** Technologies over a decade that have stayed in the game have advanced through bench/pilot/full-scale programs with better environmental economic data
  - This has caught up (w/in magnitude) with other alternatives (LCA)