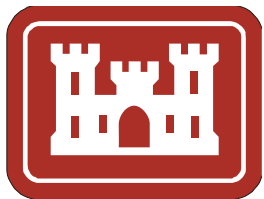


# Informing Decision in View of Diverse Objectives, Risks and Values

Todd Bridges, Igor Linkov, Burton Suedel,  
Martin Schultz, Jongbum Kim

U.S. Army Engineer Research and  
Development Center

Vicksburg, MS

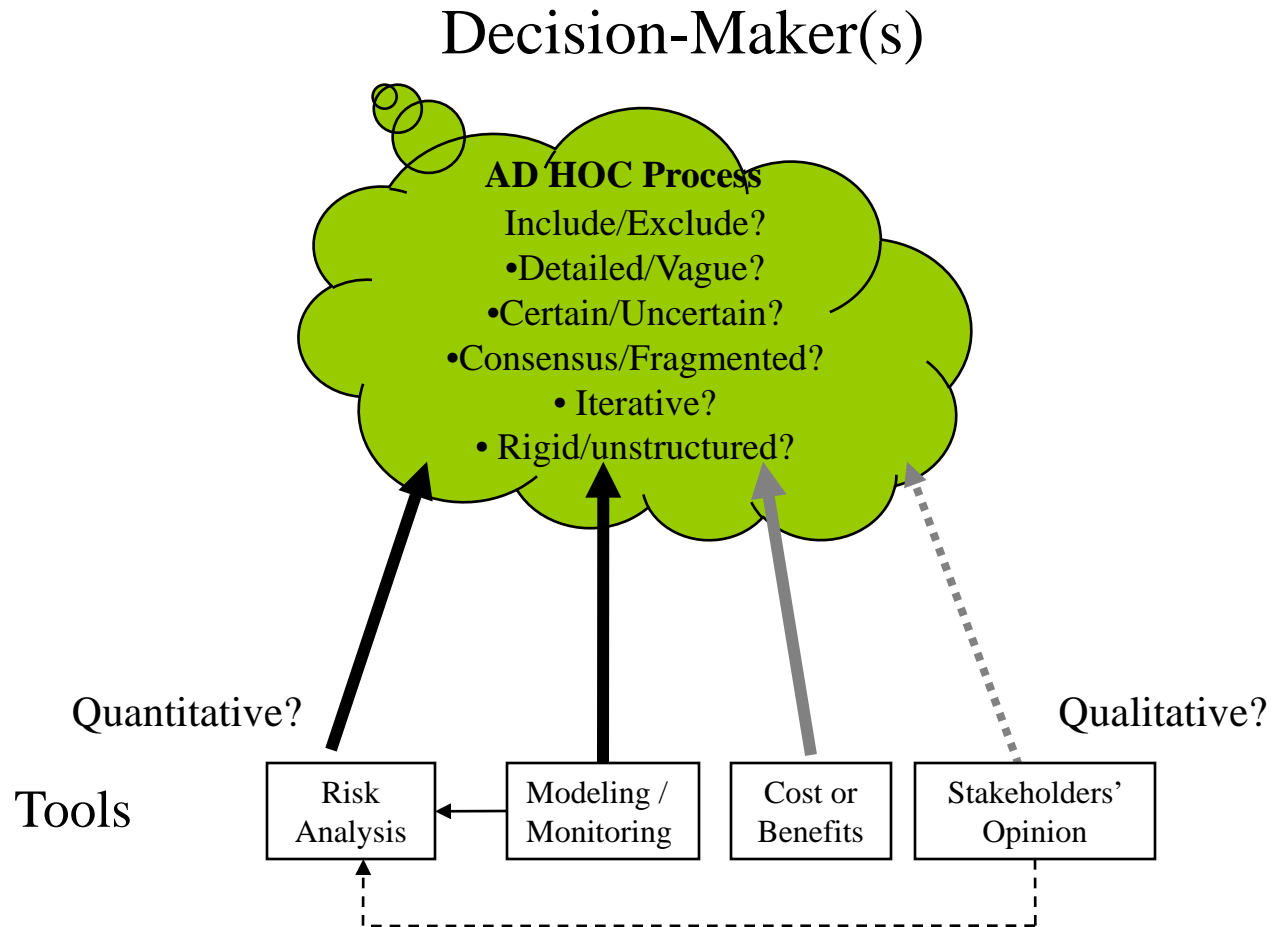


# Our *Systems*

- Navigation system:
  - locks, dams, channels
- Reservoir system:
  - structures and operating procedures
- Flood risk reduction system:
  - Structural, nonstructural, ecosystem features
- Environmental remediation and restoration



# The Decision-Making Process



# Distinguishing Good and Bad Decisions...

- There are good and ~~bad~~ “not so good” decisions
  - Accepting this fact implies that criteria exist for making the distinction
- What makes a decision good?
  - Your boss is happy (or stopped yelling)
  - You spent all the money
  - You took a long time to make the decision
  - You followed “the process”
  - You took an action

# What makes a decision good?

- Satisfies pre-established objectives
- Based on a comparison of decision alternatives
- Explicitly considers trade-offs among objectives
  - E.g., between minimizing cost and maximizing risk reduction
- Includes a plan for tracking performance and managing uncertainty
  - i.e., through adaptive management

# A Few MCDA Examples

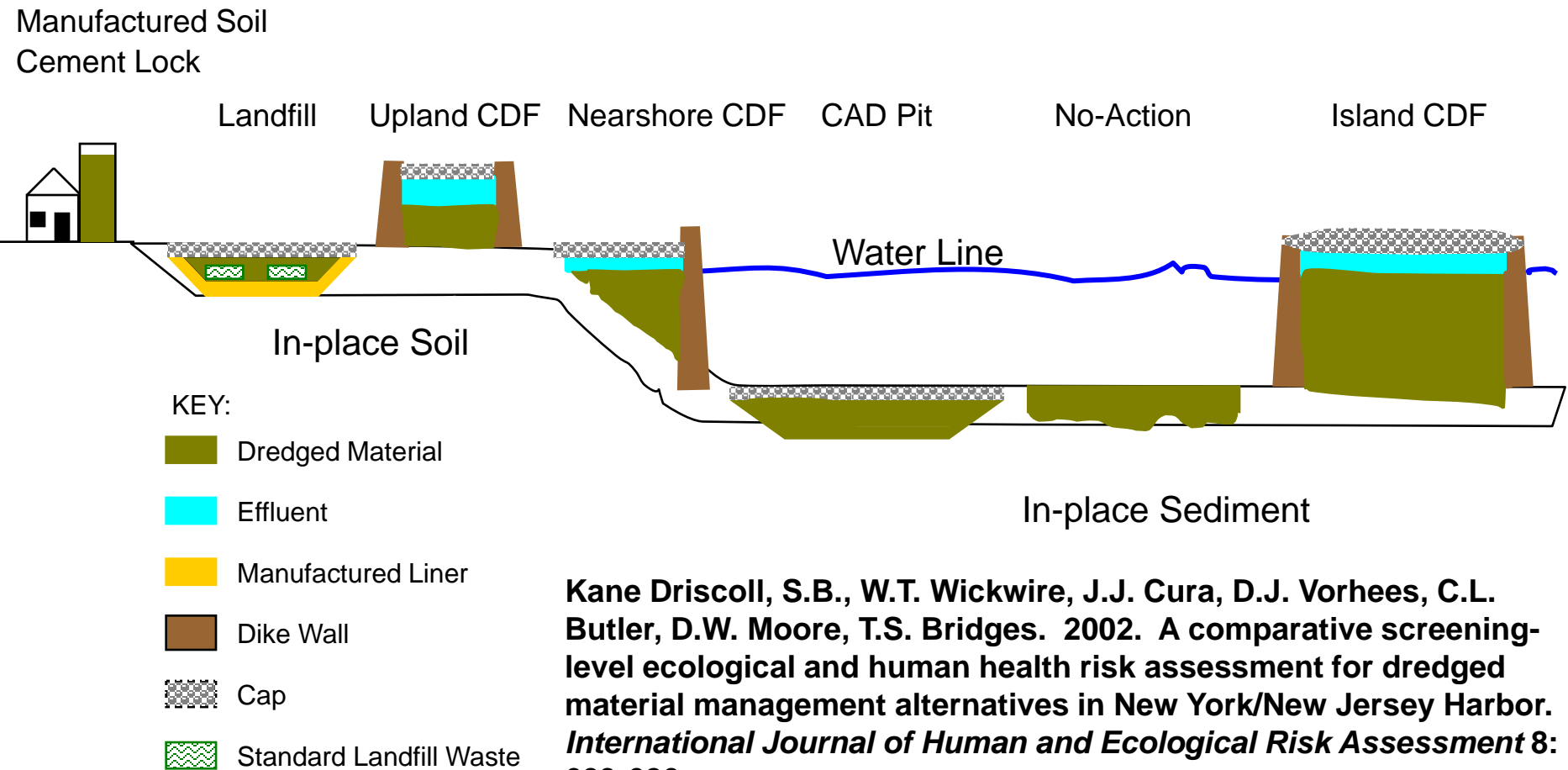
- Managing contaminated sediment
- Oyster restoration in Chesapeake Bay
- Post-Katrina planning for Louisiana
- Then some general observations



# Multi-Criteria Decision Analysis

- MCDA is a tool for structuring and analyzing complex decisions
- Emphasis is given to:
  - Defining the problem
  - Establishing desired objectives
  - Identifying metrics to represent progress toward those objectives
  - Assessing the relative importance of those objectives
  - Determining the level of satisfaction that stakeholders and decision-makers would derive from each alternative

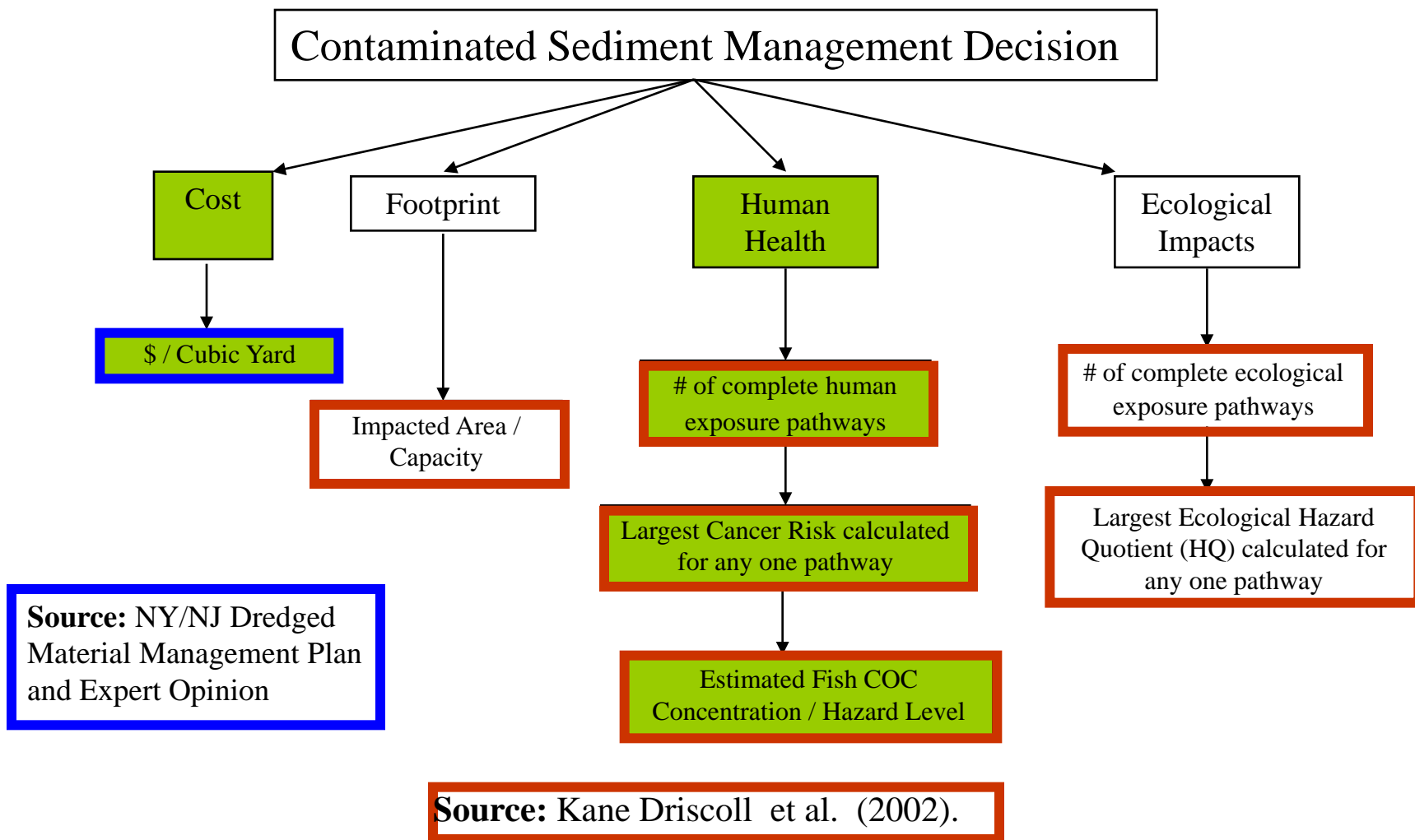
# A Sediment Example



Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. *International Journal of Human and Ecological Risk Assessment* 8: 603-626.

G. A. Kiker, T. S. Bridges, J. B. Kim. 2008. Integrating Comparative Risk Assessment with Multi-Criteria Decision Analysis to Manage Contaminated Sediments: An Example From New York/New Jersey Harbor. *Human and Ecological Risk Assessment* 14:495-511.

# Decision Criteria: NY/NJ Harbor



# Criteria Levels for Each DM Alternative

DM Alternatives	<i>Cost</i>	<i>Footprint</i>	<i>Ecological Risk</i>		<i>Human Health Risk</i>		
	(\$/CY)	Impacted Area/Capacity (acres / MCY)	Ecological Exposure Pathways	Magnitude of Ecological HQ	Human Exposure Pathways	Magnitude of Maximum Cancer Risk	Estimated Fish COC / Risk Level
<b>CAD</b>	5-29	4400	23	680	18	2.8 E -5	28
<b>Island CDF</b>	25-35	980	38	2100	24	9.2 E -5	92
<b>Near-shore CDF</b>	15-25	<b>6500</b>	38	900	24	3.8 E -5	38
<b>Upland CDF</b>	20-25	<b>6500</b>	38	900	24	3.8 E -5	38
<b>Landfill</b>	29-70	0	0	0	21	3.2 E -4	0
<b>No Action</b>	<b>0-5</b>	0	<b>41</b>	<b>5200</b>	<b>12</b>	2.2 E -4	<b>220</b>
<b>Cement-Lock</b>	<b>54-75</b>	0	14	0.00002	<b>25</b>	2.0 E -5	0
<b>Manufactured Soil</b>	54-60	750	18	8.7	22	<b>1.0 E -3</b>	0

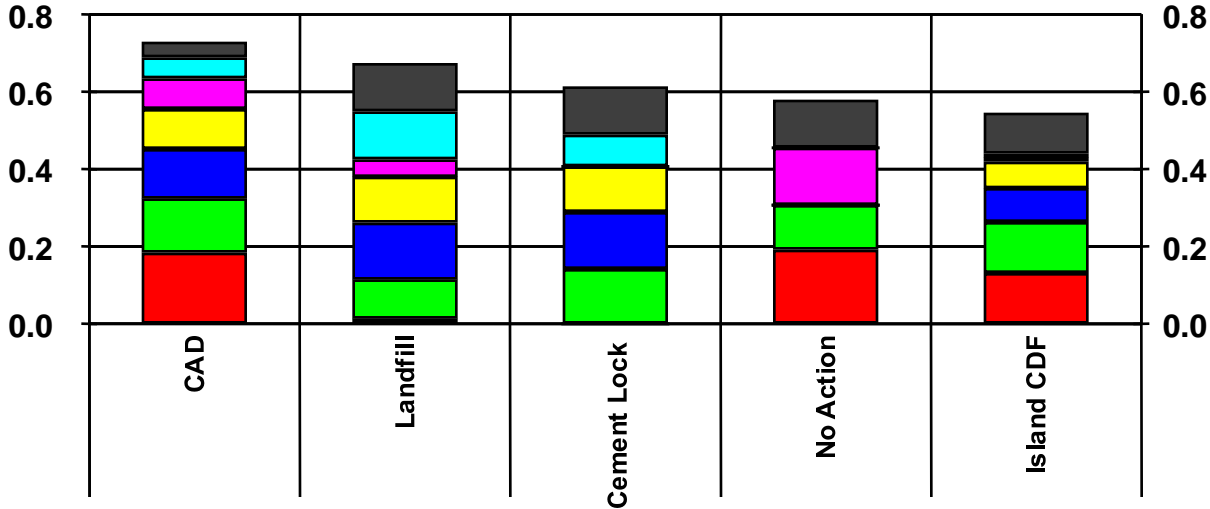
**Blue Text: Most Acceptable Value**

**Red Text: Least Acceptable Value**

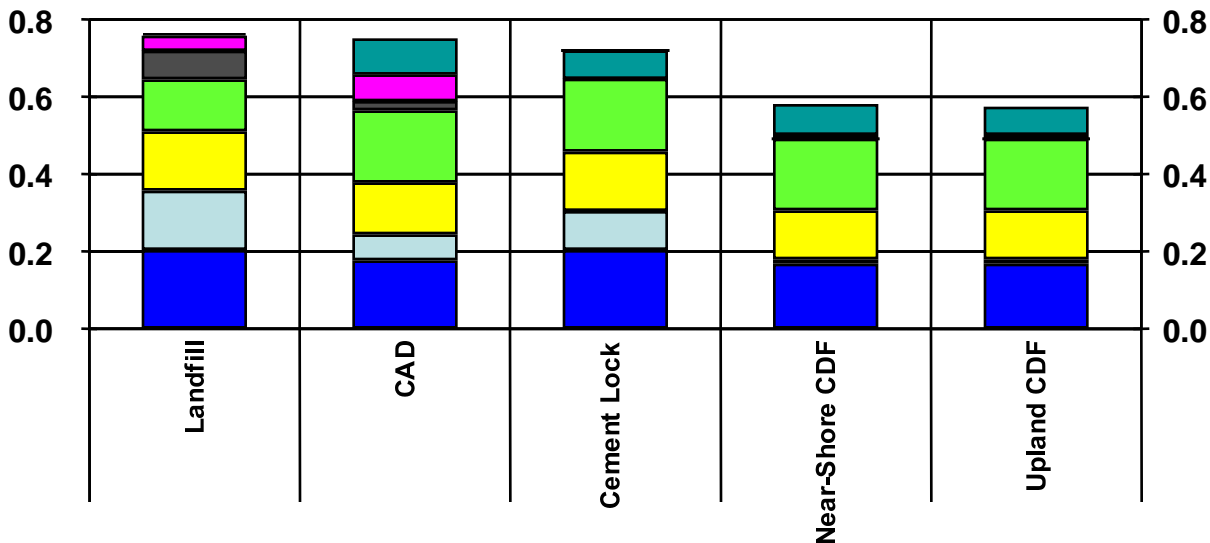
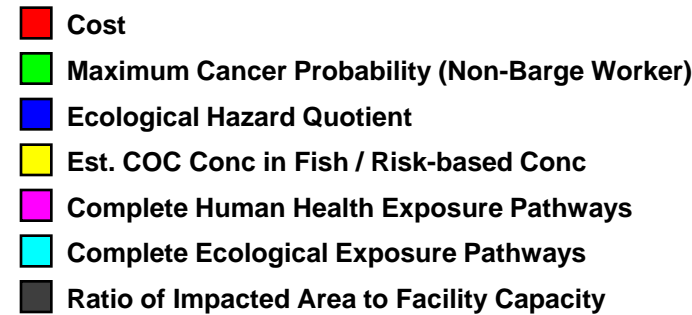
# USACE/EPA Survey Results: Criteria Weights (%)

	EPA	USACE
Footprint	7.4	12.5
Ecological Health	35.6	27.1
Human Health	47.0	40.7
Cost	10.0	19.7

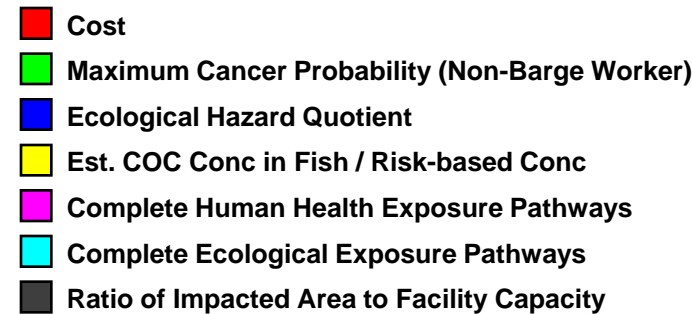
# MCDA Rankings



## USACE weighting



## EPA weighting

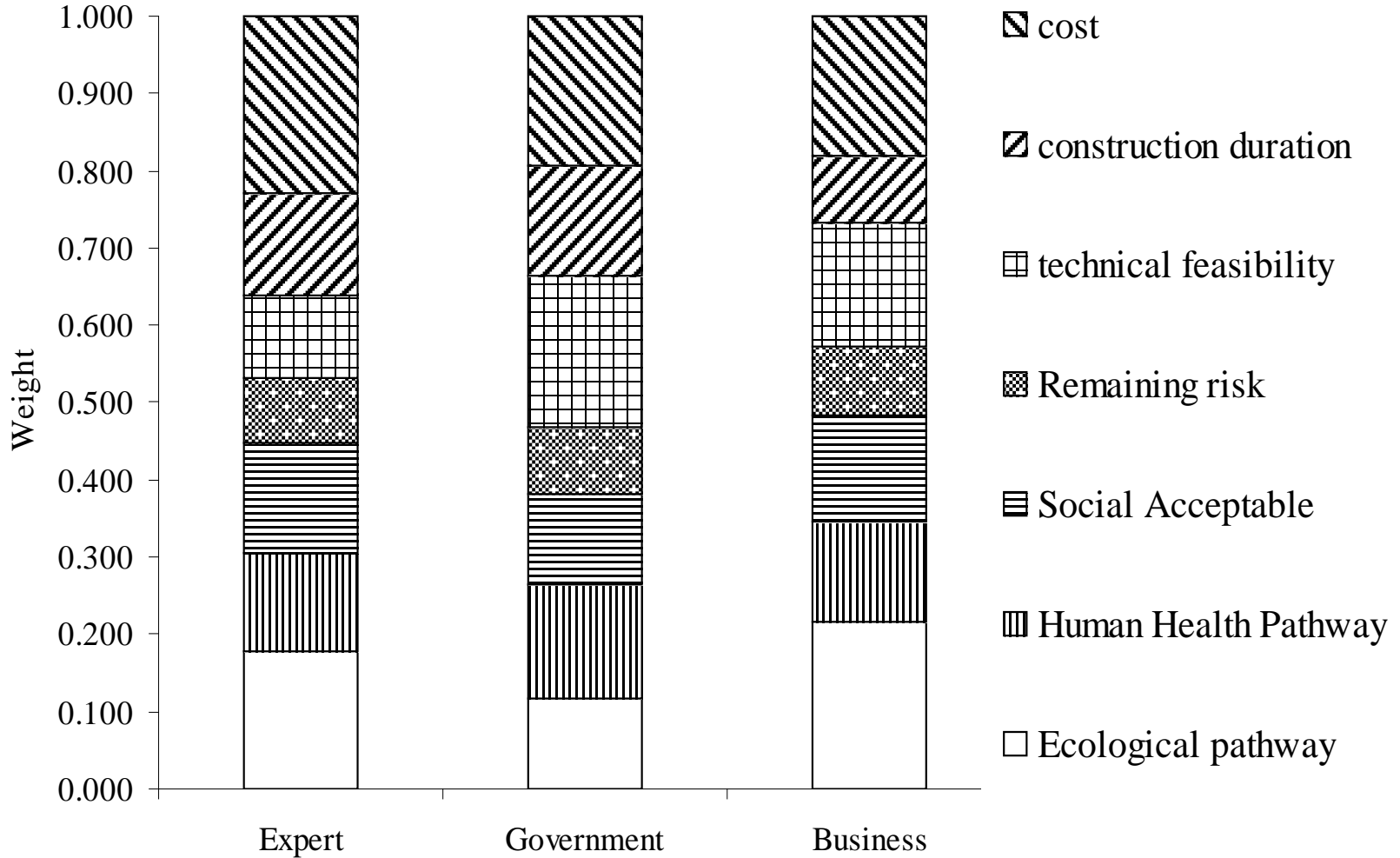


# Southern Busan Harbor, S. Korea



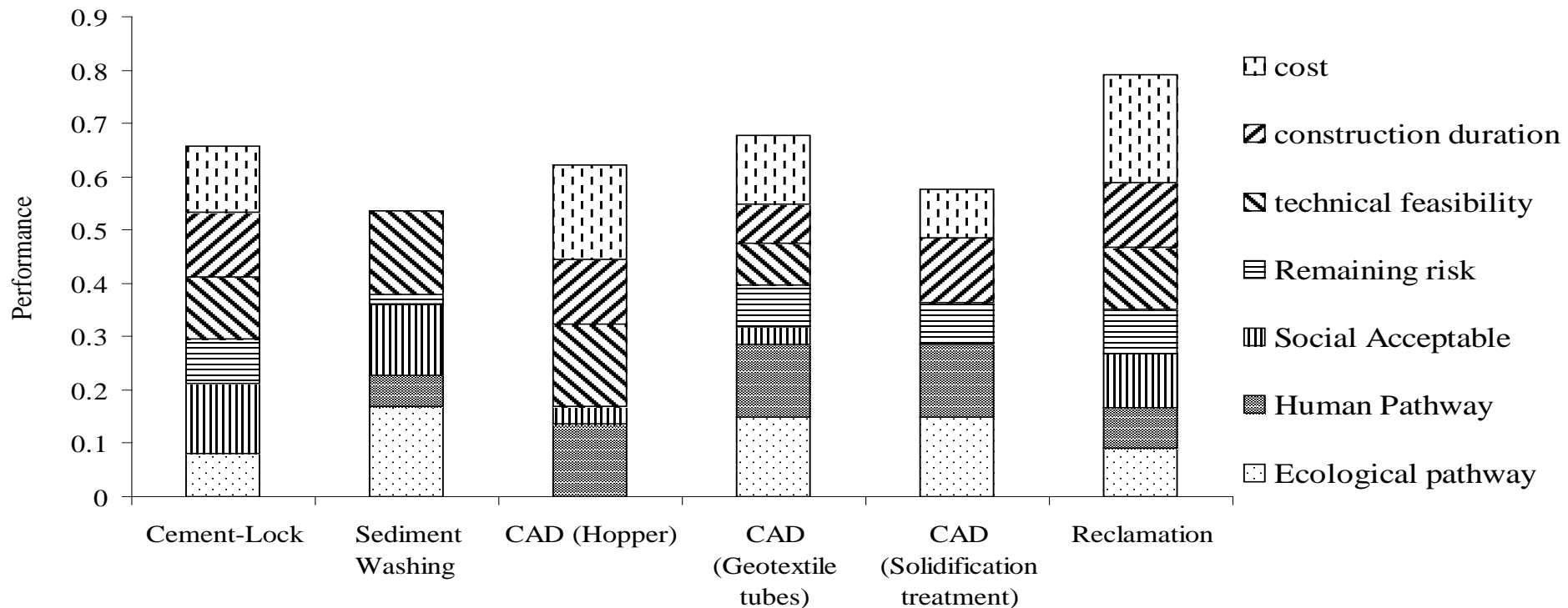
- Busan is densely populated
  - 4,785 individuals / km<sup>2</sup>
- The largest harbor in Korea
- Major fishing port whose fish sales account for 30% of sales nationwide
- Contaminated with organics and metals
- How to manage contaminated dredged material is a serious issue

# Weight Results



# Preferred alternative and performance

Group	Cement - lock	Sediment Washing	CAD (Hopper)	CAD (Geotextile tubes)	CAD (Solid. treatment)	Land (Reclamation)	Total
Expert	0	0	0	3	0	17	20
Gov	0	0	2	3	0	18	23
Business	0	2	0	1	0	7	10



# Oyster Restoration

- USACE lead agency for a PEIS considering 8 alternatives
- Numerous studies conducted, including an ERA, to populate a decision matrix
- Norfolk District using AHP to help organize deliberation on 18 separate decision criteria



# Implemented Within Expert Choice

The screenshot displays the Expert Choice software interface. The title bar shows the file path: C:\Documents and Settings\u4epril3.ERD\Local Settings\Temporary Internet Files\Content.IE5\JD6TWA... The menu bar includes File, Edit, Assessment, Synthesize, Sensitivity-Graphs, View, Go, Tools, and Help. The toolbar contains various icons for file operations and analysis. The main window is divided into two panes. The left pane shows a hierarchical tree of goals and sub-goals, each with a weight (L:). The right pane, titled 'Alternatives: Ideal mode', lists ten proposed actions with their corresponding scores.

**Goal: Minimize Risk**

- Regulatory (L: .180)
  - Attainment of PEIS Goal (L: .250)
  - Environmental Justice (L: .750)
- Social Acceptability (L: .076)
  - Culture (L: .132)
  - Visual & Aesthetic Resources (L: .032)
  - Recreation (L: .071)
  - Historic & Archeological Resources (L: .108)
  - Public Safety & Fishing (L: .462)
  - Resources Outside Chesapeake Bay (L: .196)
- Environmental and Ecological impact (L: .639)
  - Risk to Native Oyster (L: .062)
  - Other Ecosystem Components (L: .233)
  - Water Quality (L: .232)
  - Threat to Endangered Species (L: .045)
  - Essential Fish Habitat (L: .069)
  - Wetlands (L: .105)
  - Sanctuaries & Refuges (L: .074)
  - Air Quality (L: .180)
- Economic (L: .106)
  - Economics (L: .750)
  - Commercial navigation (L: .250)

**Alternatives: Ideal mode**

Proposed Action	.101
No Action	.071
Expand Native Restoration	.132
Harvest Moratorium	.081
Aquaculture (Native)	.126
Aquaculture (NonNative)	.116
Eastern Oyster Only (Alt 2,3 & 4)	.141
Eastern & Triploid Suminoe Oyster (Alt 2,3,4 & 5)	.123
Eastern & Triploid Suminoe Oyster (Proposed)	.108

**Information Document**

# Criteria Weighting

Expert Choice C:\Documents and Settings\lu4epri13.ERD\Local Settings\Temporary Internet Files\Content.IE5\JD...

File Edit Assessment Inconsistency Go Tools Help

Reorder Structural adjust Freeze Judgments

3:1 ABC Y-F(\*)

Risk to Native Oyster

Compare the relative importance with respect to: Environmental and Ecological impact

Other Ecosystem Components

- Extreme
- Very Strong
- Strong
- Moderate
- Equal
- Moderate
- Strong
- Very Strong
- Extreme

	Risk to Nat	Other Ecos	Water Qua	Threat to E	Essential F	Wetlands	Sanctuarie	Air Quality
Risk to Native Oyster		5.0	5.0	1.0	3.0	3.0	1.0	5.0
Other Ecosystem Components			2.0	3.0	3.0	3.0	3.0	3.0
Water Quality				3.0	3.0	3.0	3.0	1.0
Threat to Endangered Species					3.0	3.0	3.0	3.0
Essential Fish Habitat						1.0	2.0	2.0
Wetlands							3.0	3.0

Pairwise Verbal Comparisons

# Alternative Evaluation

Expert Choice C:\Documents and Settings\lu4epril3.ERD\Local Settings\Temporary Internet Files\Content.IE5\JD6TWAQ8\oysters\_3\_1[1].ahp

File Edit Assessment View Go Plot Tools Formula Type Help

Freeze Judgments Redraw

Low	High	Curvature
-9.	9.	Linear

Alternative	INCR Regulatory Attainment of PEIS Goal (L: .250)	INCR Regulatory Environmental Justice (L: .750)	INCR Social Acceptability Culture (L: .132)	INCR Social Acceptability Visual & Aesthetic Resources (L: .032)	INCR Social Acceptability Recreation (L: .071)	INCR Social Acceptability Historic & Archeological Resources (L: .108)
<input checked="" type="checkbox"/> Proposed Action	5	-5	3	0	0	-3
<input checked="" type="checkbox"/> No Action	-7	-5	-7	-3	0	3
<input checked="" type="checkbox"/> Expand Native Restoration	2	2	2	3	0	-1
<input checked="" type="checkbox"/> Harvest Moratorium	-7	-3	-9	-3	0	3
<input checked="" type="checkbox"/> Aquaculture (Native)	1	3	2	-2	-2	0
<input checked="" type="checkbox"/> Aquaculture (NonNative)	3	0	3	-2	-2	0
<input checked="" type="checkbox"/> Eastern Oyster Only (Alt 2,3 & 4)	2	3	2	-2	-2	-1
<input checked="" type="checkbox"/> Eastern & Triploid Suminoe Oyster (Alt	5	-3	5	-2	-2	-1
<input checked="" type="checkbox"/> Eastern & Triploid Suminoe Oyster	7	-5	5	-1	-3	-3

# Implementation Within Expert Choice

The screenshot displays the Expert Choice software interface. The window title is "Expert Choice" and the path is "C:\Documents and Settings\u4epril3.ERD\Local Settings\Temporary Internet Files\Content.IE5\JD6TWA...". The menu bar includes "File", "Edit", "Assessment", "Synthesize", "Sensitivity-Graphs", "View", "Go", "Tools", and "Help". The toolbar contains icons for file operations, assessment, and visualization. The main window is divided into two panes. The left pane shows a hierarchical tree of goals and sub-goals, each with a weight (L:). The right pane shows a list of alternatives with their corresponding scores.

**Goal: Minimize Risk**

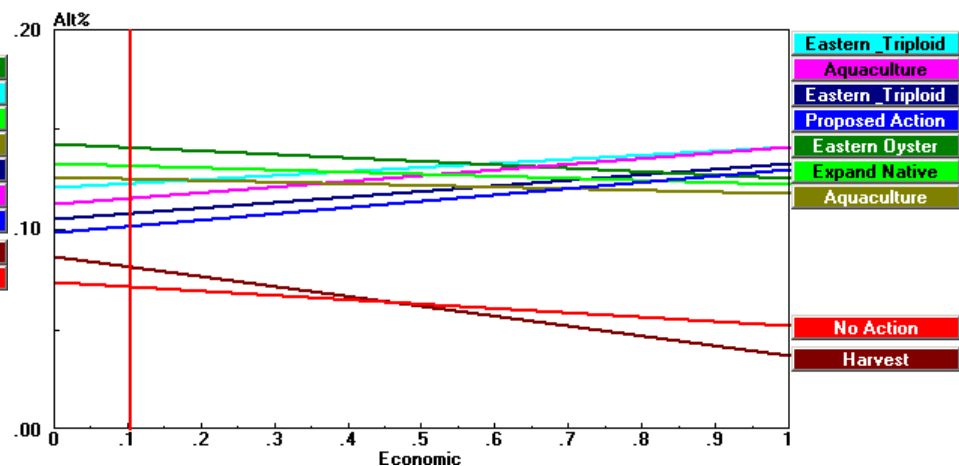
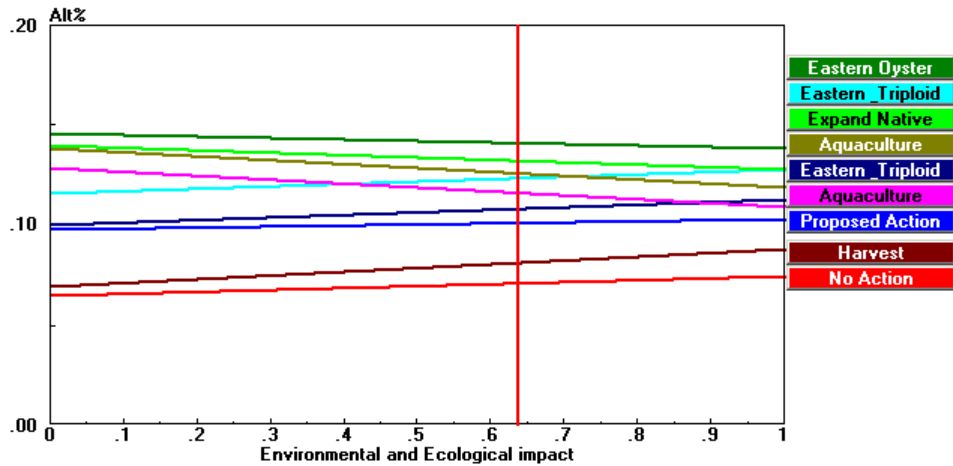
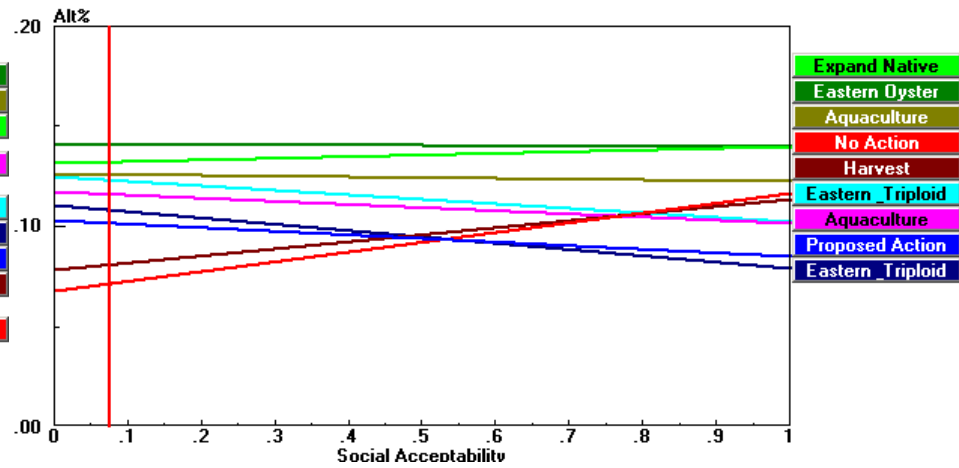
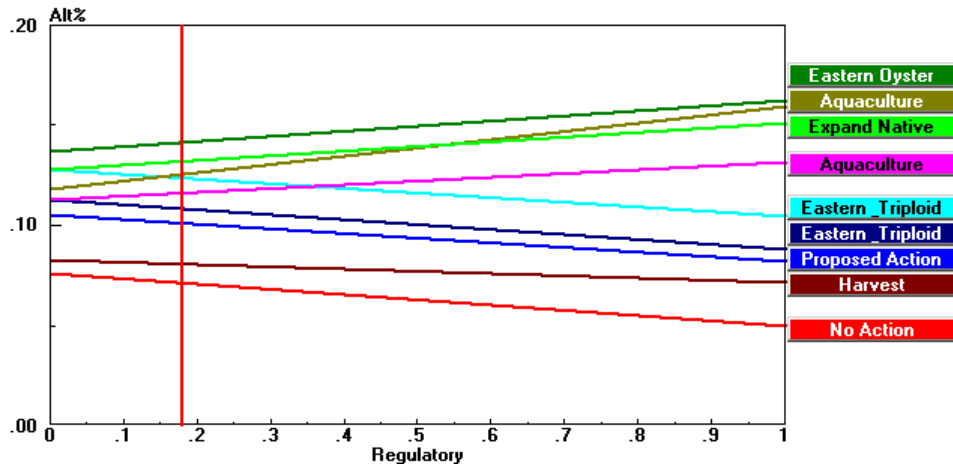
- Regulatory (L: .180)
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**Information Document**

# Sensitivity Analysis



# Katrina: A “Big” Event

- Landfall 0610, 29 August 2005
- Category 3
  - 125 mph sustained winds
  - 24-28 ft. max surge
- >1,800 deaths
- \$100B in damages
- 100 mcy of debris



# Congressional Direction for LaCPR

- Comprehensive hurricane protection analysis and design
- Full range of flood control, coastal restoration, and hurricane protection measures
- Storm surge equivalent to a “Category 5” hurricane
- Exclusive of normal policy considerations
- Preliminary Technical Report (PTR) within 6 months
- Final Technical Report (FTR) within 24 months
- Reports on component areas for authorization as soon as practicable
- Close coordination with the State of Louisiana

# LaCPR Objectives and Metrics

## Planning Objectives

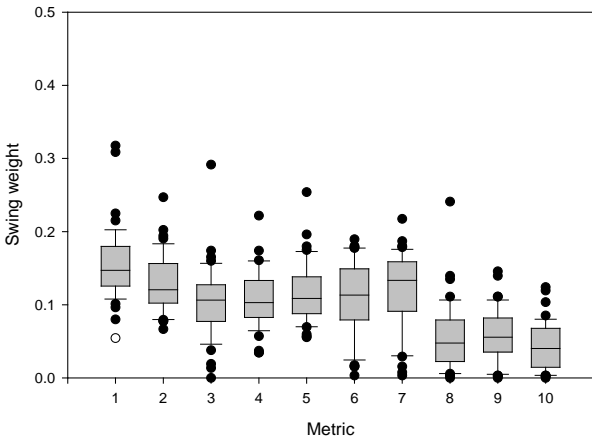
- Reduce risk to public safety from catastrophic storm inundation
- Reduce damages from catastrophic storm inundation
- Promote a sustainable ecosystem
- Restore and sustain diverse fish and wildlife habitats, and
- Sustain the unique heritage of coastal Louisiana by protecting historic sites and supporting traditional cultures

## Risk Metrics

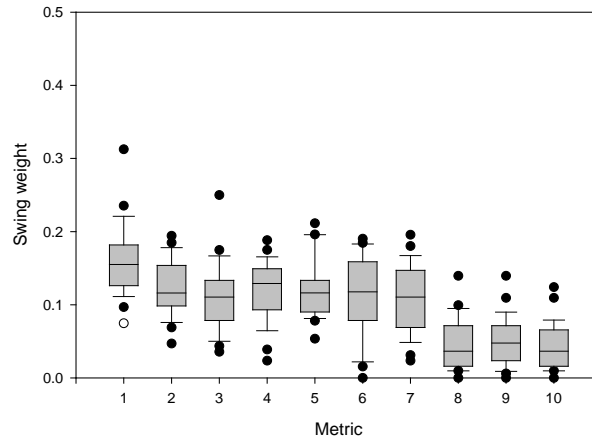
- Population Impacted
- Residual Damages
- Life-Cycle Costs
- Construction Time
- Employment Impacted
- Indirect Environmental Impact
- Direct Wetland Impacts
- Historic Properties Protected
- Historic Districts Protected
- Archeological Sites Protected

# Distribution of Swing Weights Across Planning Units

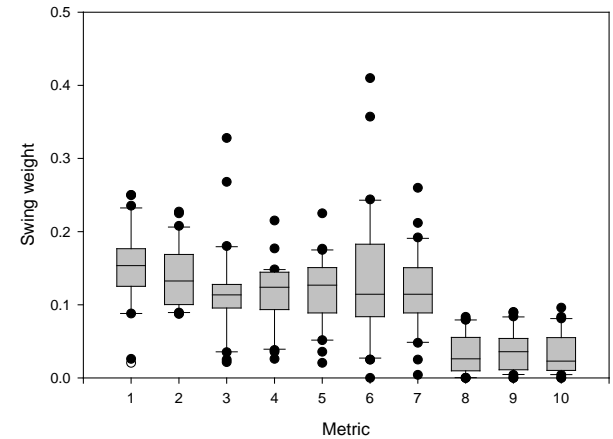
Planning Unit 1  
Swing Weights for all Respondents



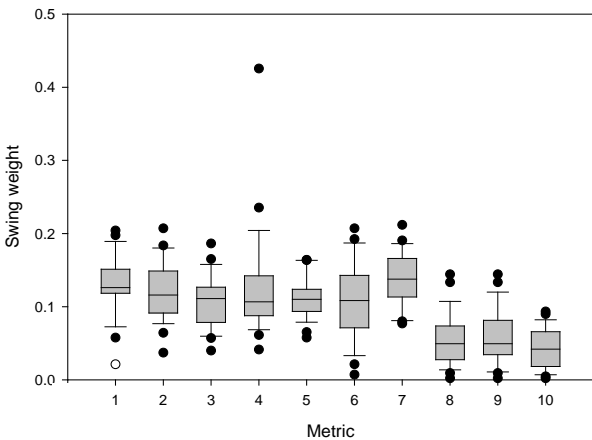
Planning Unit 2  
Swing Weights for all Respondents



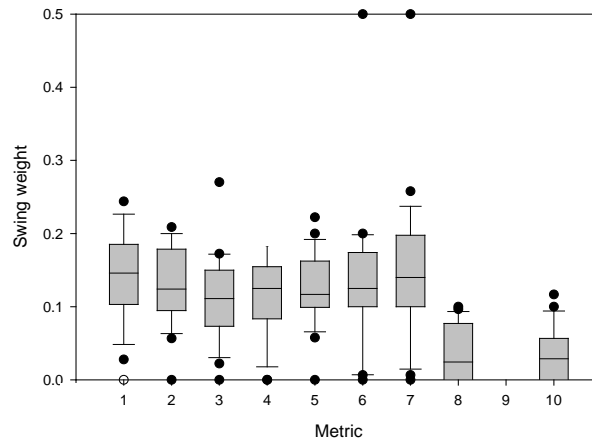
Planning Unit 3a  
Swing Weights for all Respondents



Planning Unit 3b  
Swing Weights for all Respondents



Planning Unit 4  
Swing Weights for all Respondents



#	Metric Name
1	Population Impacted (People/Year)
2	Direct Economic Damages (\$ Millions/Year)
3	Life-cycle Cost (\$ Billions)
4	Construction Time (Years)
5	Employment Impacts (Jobs Disrupted/Year)
6	Indirect Impacts (Unitless Scale; -8 to +8)
7	Direct Wetland Impacts (Acres)
8	Historic Properties Protected (Number of Properties)
9	Historic Districts Protected (Number of Districts)
10	Archeological Sites Protected (Number of Sites)

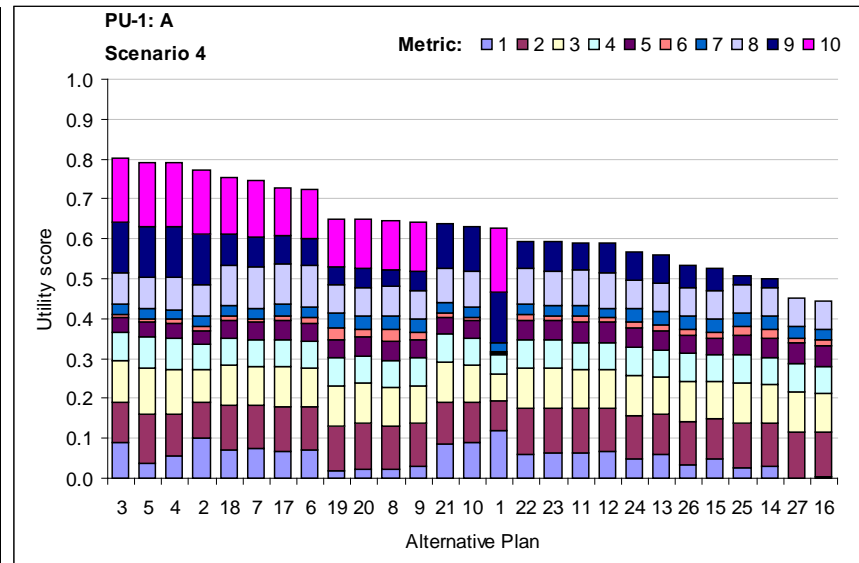
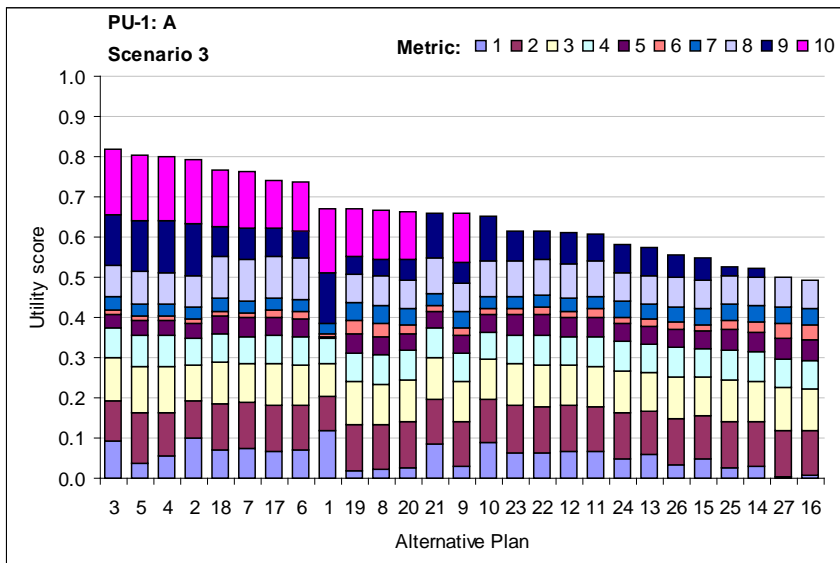
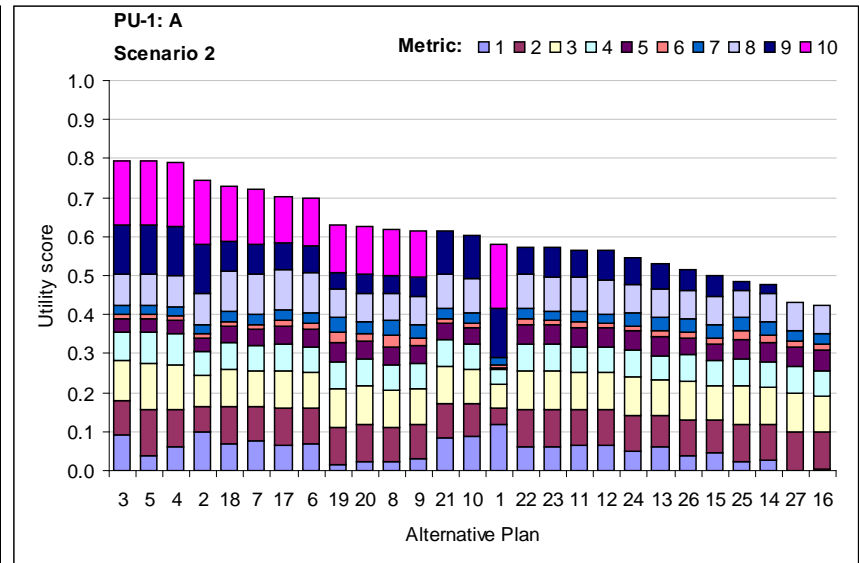
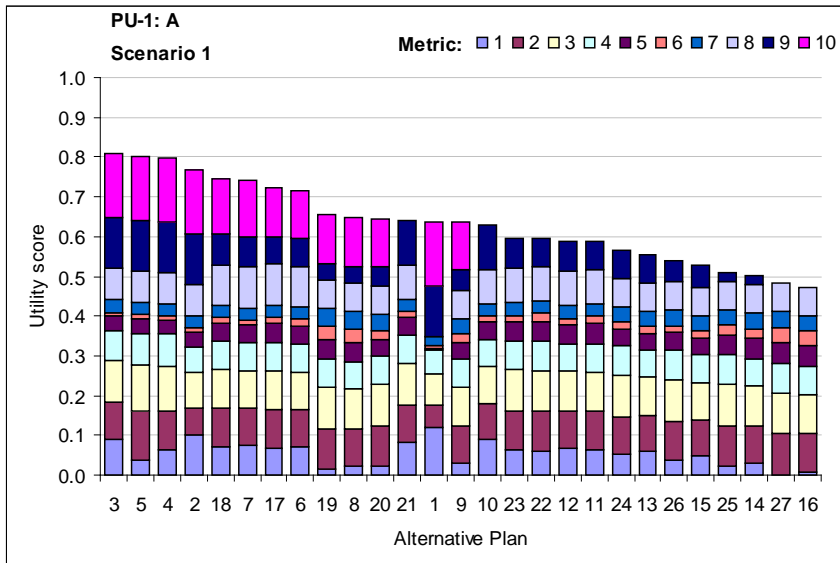
# Plan Rankings

PU-1: A

Scenario 1		
Plan	Plan Code	Utility
3	PU1-NS-100	0.808
5	PU1-NS-1000	0.802
4	PU1-NS-400	0.799
2	PU1-R2	0.767
18	PU1-C-HL-a-100-3	0.747
7	PU1-HL-a-100-3	0.740
17	PU1-C-HL-a-100-2	0.721
6	PU1-HL-a-100-2	0.715
19	PU1-C-HL-b-400-2	0.654
8	PU1-HL-b-400-2	0.646
20	PU1-C-HL-b-400-3	0.646
21	PU1-C-LP-a-100-1	0.641
1	PU1-0	0.638
9	PU1-HL-b-400-3	0.637
10	PU1-LP-a-100-1	0.630
23	PU1-C-LP-a-100-3	0.595
22	PU1-C-LP-a-100-2	0.595
12	PU1-LP-a-100-3	0.588
11	PU1-LP-a-100-2	0.588
24	PU1-C-LP-b-400-1	0.564
13	PU1-LP-b-400-1	0.553
26	PU1-C-LP-b-1000-1	0.541
15	PU1-LP-b-1000-1	0.529
25	PU1-C-LP-b-400-3	0.510
14	PU1-LP-b-400-3	0.501
27	PU1-C-LP-b-1000-2	0.482
16	PU1-LP-b-1000-2	0.474

Table of Top Ranked Plans: PU1, Scenario 1						
PLAN CODE Frequency	Rank Based on Swing Weights					Total
	1	2	3	4	5	
PU1-C-HL-a-100-2	0	0	0	0	5	5
PU1-C-HL-a-100-3	0	0	0	10	28	38
PU1-C-HL-b-400-2	1	0	0	3	0	4
PU1-C-LP-a-100-1	0	0	0	3	1	4
PU1-C-LP-a-100-2	0	0	0	0	1	1
PU1-C-LP-b-1000-2	0	0	1	0	0	1
PU1-HL-a-100-2	0	0	0	0	0	0
PU1-HL-a-100-3	0	0	0	1	2	3
PU1-HL-b-400-2	0	1	0	0	2	3
PU1-LP-b-1000-2	0	0	0	1	0	1
PU1-NS-100	16	13	15	0	0	44
PU1-NS-1000	28	6	7	2	0	43
PU1-NS-400	0	23	21	0	0	44
PU1-R2	0	2	1	25	6	34
<b>Total</b>	<b>45</b>	<b>45</b>	<b>45</b>	<b>45</b>	<b>45</b>	<b>225</b>

# Contributions to Rankings Across Scenarios



# Conclusions

- There are clear benefits to be gained by advancing the use of formal risk and decision analysis methods:
  - Opportunities to explore trade-offs among diverse objectives
  - The ability to distinguish science and engineering inputs to a decision from values associated with objectives
  - Means for exploring the implications of uncertainty and the value of reducing it
  - Providing a quantitative framework to implement adaptive management
- However, efforts to apply these approaches will confront a number of practical issues related to the following:
  - Under-estimating the level of effort required to accomplish effective deliberation through the use of decision analysis
  - Determining who can/should be involved in value/preference elicitation
  - Intolerance for transparency in decision-making
  - The misconception that decision analysis is a substitute for an actual decision