The Comparative Restoration Ratio for the HRE

Restoration Working Group Meeting

9 December 2010

The Plan Formulation Problem

- Use of funds to meet competing needs (Policy and Resource Driven)
- Calculating typical Corps BCR (Policy Driven)
  - The HRE Study effort is the logical ecosystem restoration complement to the HDP navigation project
- Where to stop (Policy and Resource Driven)
- How to choose what's best for the ecosystem of the HRE? (Technical)

How do we solve the Plan Formulation Problem?

- Technical Problem: How to choose between different habitat types?
- Since justifying everything the Corps does is based in economics, there should be an economic theory that will enable us to identify how to best use our scarce resources.
  - With unlimited resources, we can restore everything.
  - However, we have limited funds, so we need to make choices on what to restore first.
  - *If maximizing total utility (benefits) were only consideration, keep restoring until marginal utility = 0.*
  - *Need to maximize total utility, subject to cost constraints*
- That theory is the Equimarginal principle (a tool that can be applied to any decision that involves alternative courses of action), which helps to optimize between needs when there are competing uses for limited resources – the equation is shown below:

$$\frac{MU_x}{P_x} = \frac{MU_y}{P_y} = \frac{MU_z}{P_z}$$

What answers does this provide to solve the Plan Formulation problem for HRE Study?

- Measure success against targets
  - Target Ecosystem Characteristics
  - Developed by a scientific, academic, agency and stakeholder group
- Balance restoration opportunities throughout the ecosystem
  - Process allows to distribute restoration types throughout the HRE
  - Opportunities more difficult to accomplish more heavily weighted

How do we solve the HRE Plan Formulation problem?

- Developed "Comparative Restoration Ratio" method in close collaboration with regional experts and stakeholders
  - Based on Target Ecosystem Characteristics
- CRR serves as an analog to the traditional BCR
- The use of the Equimarginal Principle is comparable to the formulation approach used in the NY-NJ Harbor Study. Both studies use some form of optimization, but in HRE, benefits and costs are not in the same terms.
- There are 11 index measurements in this study being compared.

Relationship among the TECs

Input TECs

Equilibrium TECs

Environmental Support Structures
- Enclosed and Confined Waters
- Habitat Connections for Fish
- Reduction in Sediment Contamination

Habitats
- Oysters & Oyster Reefs
- Eelgrass Beds
- Coastal Wetlands
- Islands for Waterbirds
- Maritime Communities

Habitat Complexes
- Shorelines & Shallows
- Habitat Adjacency for Fish, Crustaceans & Other Benthic Habitats

Other Societal Effects
- Public Access

CRR Process Demonstration for HRE

- Comparative Restoration Ratio (CRR) = Z / V
  - Z is the benefit side
    - based on collaborative effort by environmental stakeholder community & scholars
    - Uses TECs as metrics
  - V is the cost side
- Analysis is conducted on list of identified sites
  - One conceptual plan per site
  - Desktop exercise

Overview – Z score equation

Z= [Raw benefit score] x [Interaction Factors] x [Quantity Factors]

$$Z= [\Sigma_{\text{Tec 1}}^{\text{Tec11}} I \text{ x } S] \quad \text{x} \quad [\,1/d^2 \text{ x } e^t\,] \quad \text{x} \quad [(1 \text{ if } c>10,\ 50 \text{ if } c<10) \text{ x } e^{-p}]$$

Where:

I = Intensity of degradation

S = Extent of degradation

$1/d^2$ = Proximity/Connectivity; d = distance to closest habitat

e^t = TEC diversity; t=number of TECs in project

x1 is c >10; x50 if c <10 = Scarcity factor; c = number of prior sites addressing contaminated sediments TEC

e^{-p} = Diminishing Marginal Utility factor; p = prior completed acreage factor completed per TEC

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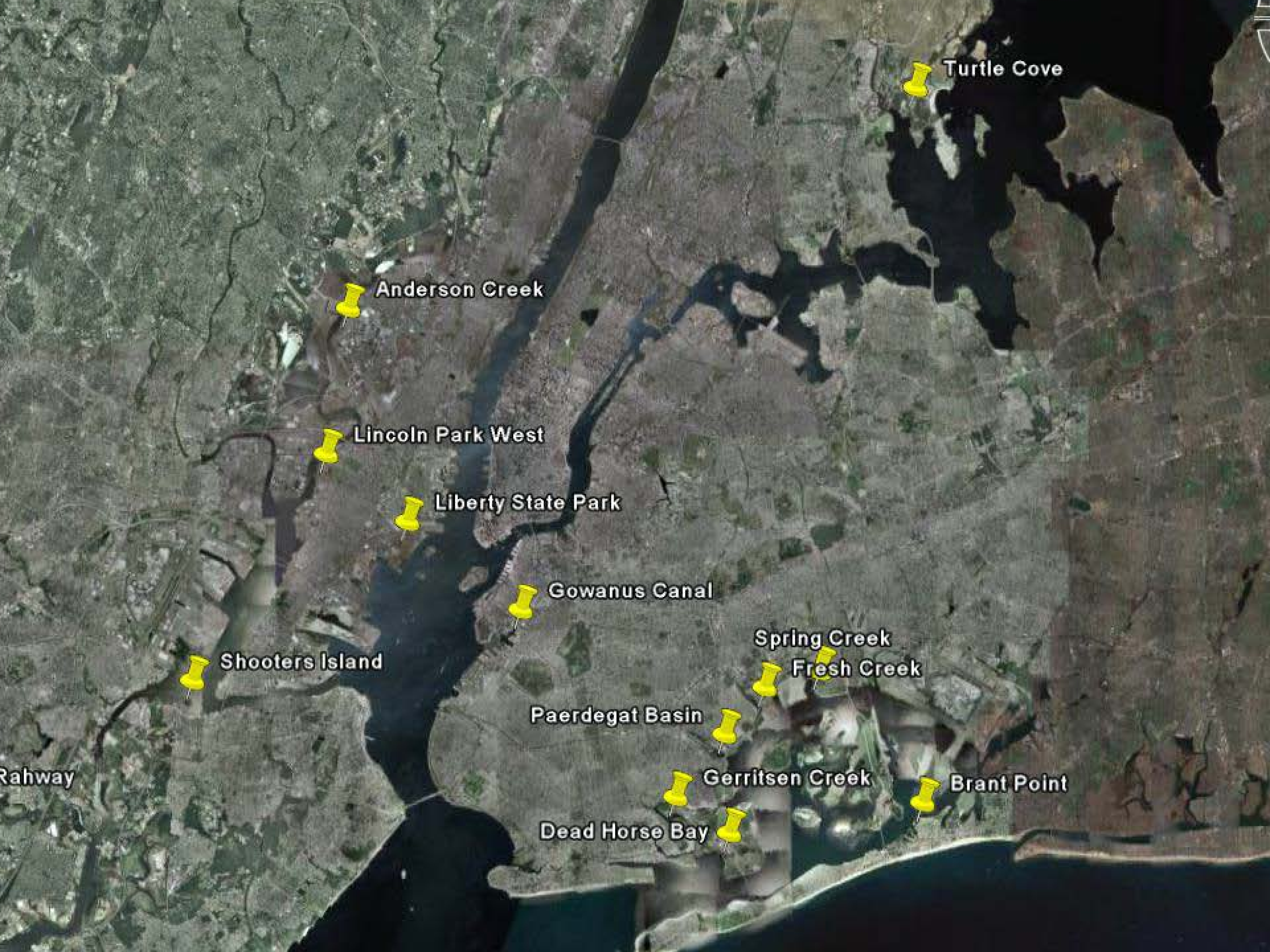
S = Extent of degradation

$1/d^2$ = Proximity/Connectivity; d = distance to closest habitat

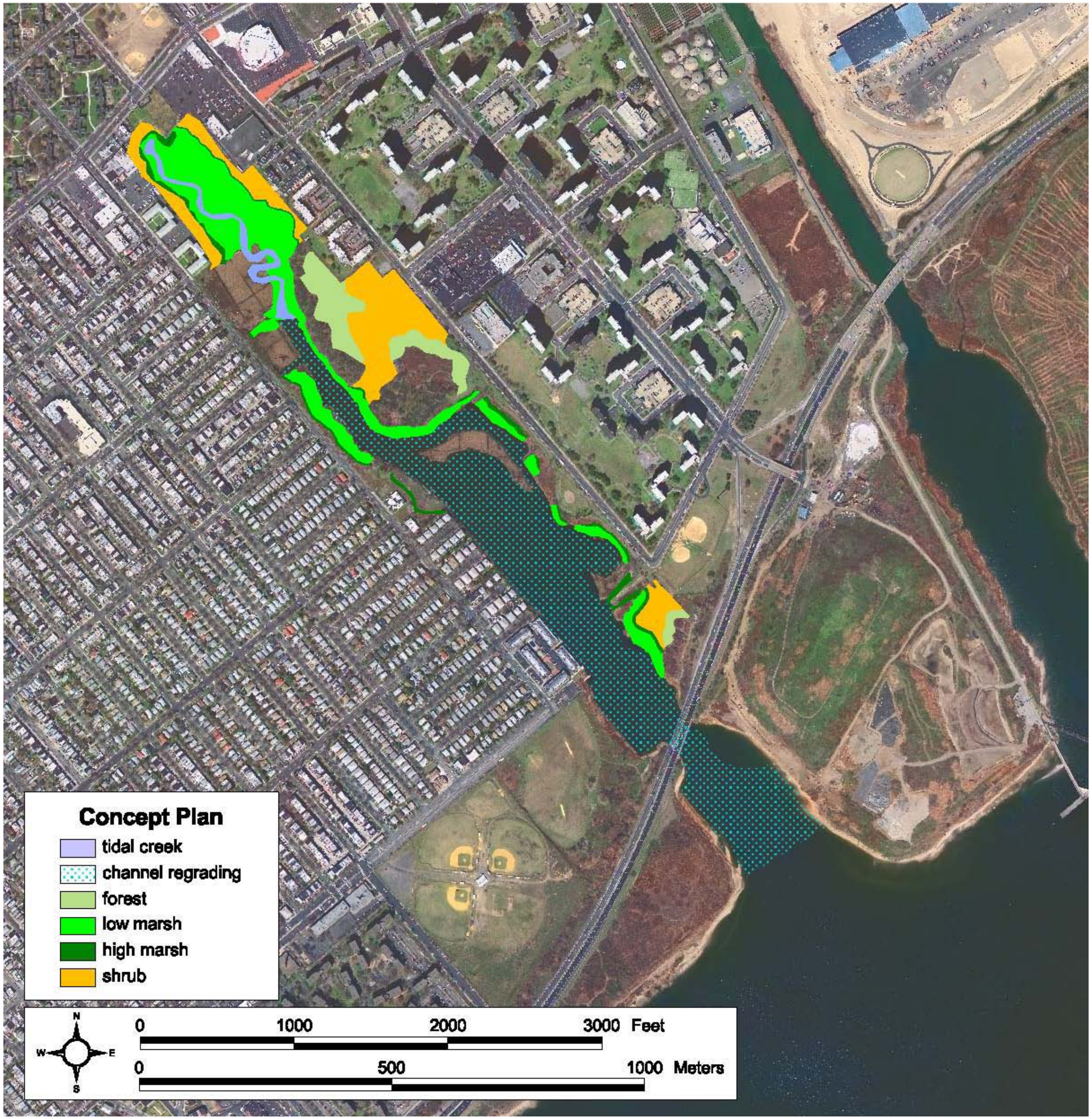
e^t = TEC diversity; t=number of TECs in project

c = number of prior sites built that address contaminated sediments score is 1 is c >10; x50 if c <10 = Scarcity factor;

e^{-p} = Diminishing Marginal Utility factor; p = prior completed acreage factor completed per TEC


Turtle Cove
Anderson Creek
Lincoln Park West
Liberty State Park
Gowanus Canal
Spring Creek
Fresh Creek
Shooters Island
Paerdegat Basin
Rahway
Gerritsen Creek
Brant Point
Dead Horse Bay

Fresh Creek Conceptual Plan (sample)



Sample Raw Benefit Score Calculation Tables

Coastal Wetlands

Description of Score Value	Score	Probability for Success
Restoration on or near degraded historic wetlands near a hydrologic source	10	High
Creation of wetlands on a new site	5	Medium
Enhance existing high quality wetlands	1	Low
No impact/effect	0	None

Oysters and Oyster Reefs

Description of Score Value	Score	Probability for Success
Creation of habitat at historic oyster reef locations	10	High
Creation of habitat at new reef sites	5	Medium
Enhance existing habitat	1	Low
No impact/effect	0	None

Calculation of Z Score - Step 1

The first step is to calculate the intensity (I) of degradation score, which measures the ability of a site to meet the 11 TECs listed below. For each TEC, the intensity is multiplied by the number of affected acres – This example for the Fresh Creek Site.

TEC No.	TEC Description	Index Score	Affected TEC acres	Score	Notes
1	Waterbird	0	0	0	no impact / effect
2	Habitat Adjacency	10	93	930	3 or more potential habitat types near each other
3	Oyster Reefs	0	0	0	no impact / effect
4	Coastal Wetlands	10	17	170	on or near degraded historic wetlands near a hydrologic source
5	Shallows & Shoreline	10	10	100	publicly owned, good buffer, no impact to infrastructure
6	Eelgrass Bed	0	0	0	no impact / effect
7	Enclosed/Confined Basin	5	60	300	meets state H20 between 33 & 66% of the time
8	Habitat Connections	0	0	0	no impact / effect
9	Sediment Quality	0	0	0	no impact / effect
10	Public Access	1	93	93	improve public access
11	Maritime Forest Buffer	10	15	150	nexus of multiple habitats
	Raw Benefit Score:	46		1743	
	$\sum (I) =$			**1743**	

Calculation of Z Score - Step 2

Interaction Factor	Formula	Value	Score
TEC Diversity	e^t	6	**403.43**
Proximity/ Connectivity	$1/d^2$	1	**1**

TEC Diversity	Weight
0	1
1	2.72
2	7.39
3	20.09
4	54.60
5	148.41
6	403.43
7	1096.63
8	2980.96
9	8103.08
10	22026.46
11	59874.13

Proximity/ Connectivity (Distance in Miles)	Weight
1	1.000
2	0.250
3	0.111
4	0.062
5	0.040
6	0.0278
7	0.020
8	0.016
9	0.012
10	0.010
11	0.008

Calculation of Z Score - Step 3

Quantity Factor	Formula	Value If c<10, x50. If c>10, x1	Score	Qualifier
Scarcity	**c**	n/a	**1**	
DMU	$\mathbf{e^{-p}}$	0 = 1	**1**	If 0, choose 1

Calculation of Z Score

"Putting the benefits together"

Z= [Raw benefit score] x [Interaction Factors] x [Quantity Factors]

$$Z = \left[\sum_{Tec\ 1}^{Tec11} I \times S\right] \times \left[1/d^2 \times e^t\right] \times \left[(1 \text{ if } c>10,\ 50 \text{ if } c<10) \times e^{-p}\right]$$

Results for the Fresh Creek Site:

Z = 1743 x [1 x 403.43] x [1 x 1]

(I x S) x (Proximity x TEC Div.) x (Scarcity x DMU)

Z = 703178.49

Z Score Results

Site Name	Restoration Acreage	Z Score (Benefit)
Liberty State Park	234	1835203.0
Paerdegat Basin	161	1274839.0
Fresh Creek	93	703178.5
Dead Horse Bay	130	618885.1
Spring Creek	151	438414.1
Gerritsen Creek	36	123480.2
Echo Bay	7	11296.0
Turtle Cove	7.5	8533.8
Brant Point	7.5	5732.8
Anderson Creek	35	3916.2
Lincoln Park West	47	1117.6
Shooters Island	10.5	622.4
Rahway 1135	4	253.6

V Score – Cost Factors

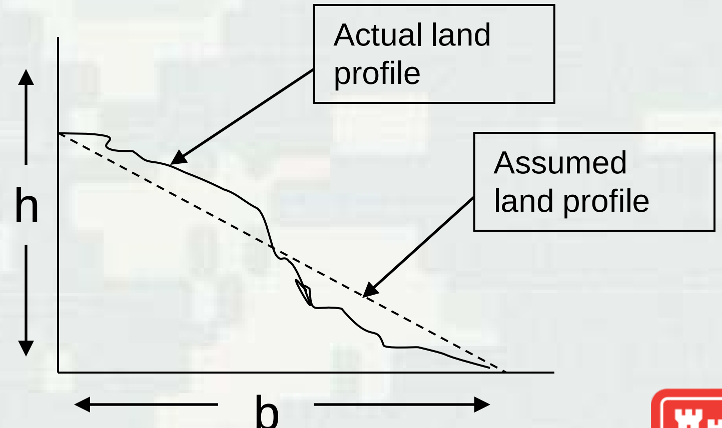
- Development of Average Cost Curves per TEC:
  - ► Based on costs of built or studied (feasibility level) projects
  - ► Average cost curves were developed per TEC because we are trying to identify steps to meet the TEC goals
  - ► Developed for the 8 input TECs
  - ► Cost driver for each TEC may not match unit of measurement for success (cubic yards vs. acres)
  - ► For each conceptual plan, the biggest cost drivers are identified & the relevant TEC cost curve is consulted.

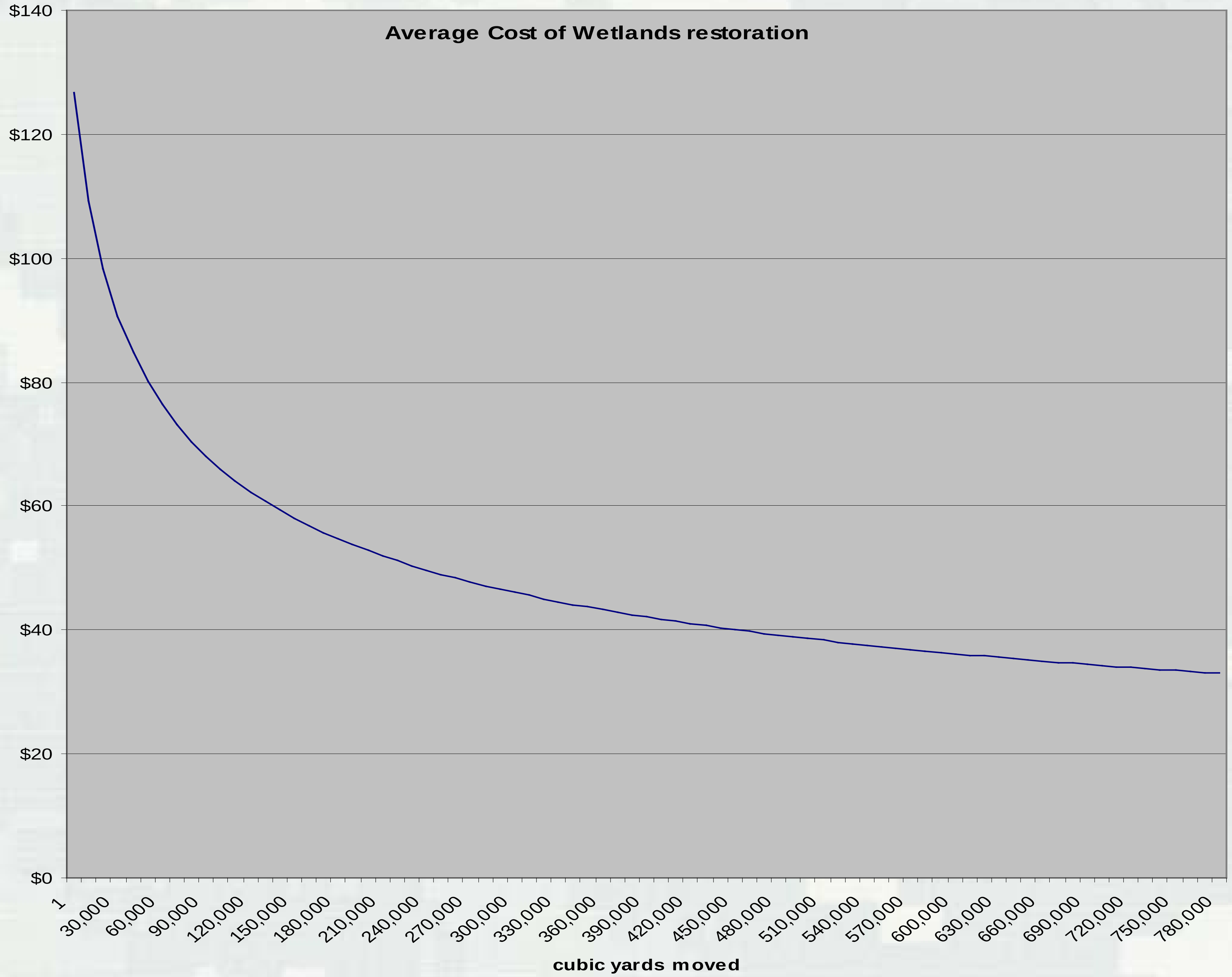
Example Cost Curve Development for TEC: Wetlands

Site	Cost	Volume (CY)	Cost/CY
BUG	$6,422,122	44,450	$144
Elders East	$14,569,579	294,792	$49
Medwick	$4,093,532	33,500	$122
Woodbridge	$5,158,644	66,458	$78
Woodbridge (opt)	$2,409,975	45,098	$53

Volume to be estimated per site from Google earth, which provides elevation:

1/2 b x h x shoreline length = cubic yards




Average Cost of Wetlands restoration
$140
$120
$100
$80
$60
$40
$20
$0
1
30,000
60,000
90,000
120,000
150,000
180,000
210,000
240,000
270,000
300,000
330,000
360,000
390,000
420,000
450,000
480,000
510,000
540,000
570,000
600,000
630,000
660,000
690,000
720,000
750,000
780,000
cubic yards moved

Wetlands TEC Cost Comparison (Volume vs. Acreage)

Site	Cost	Volume (CY)	Cost/CY	Acres	Cost/Acre
BUG	$6,422,122	44,450	$144	9	$714K
Elders East	$14,569,579	**294,792**	**$49**	39	**$374K**
Medwick	$4,093,532	33,500	$122	14	$292K
Woodbridge	$5,158,644	66,458	$78	24	$219K
Woodbridge (opt)	$2,409,975	45,098	$53	9	$277K

Sample V calculations: LSP and Dead Horse Bay

Site	Wetland restoration acres	$$/acre (from curve)	Cost Estimate based on acres	Estimate of cubic yards to be moved	$$/cy (from curve)	Cost Estimate based on cubic yards	Feasibility Level Cost Estimate
Liberty State Park	75	$275,000	$20,625,000	800000	38	$30,400,000	$32,000,000
Dead Horse Bay	42	$300,000	$12,600,000	997500	35	$34,912,500	$52,000,000 *

* Cost is higher due to shore protection measures also needed at Dead Horse Bay.

First Round of Sample Calculations

Site Name	Restoration Acreage	Z score (benefit)	V score (cost in millions)	Comparative Restoration Ratio	Order
Liberty State Park	234	1835203.0	32	57350.1	1
Fresh Creek	93	703178.5	28	25113.5	2
Gerritsen Creek	36	123480.2	5	24696.0	3
Paerdegat Basin	161	1274839.0	55	23178.9	4
Dead Horse Bay	130	618885.1	52	11901.6	5
Spring Creek	151	438414.1	57	7691.5	6
Turtle Cove	7.5	8533.8	5	1706.8	7
Brant Point	7.5	5732.8	5	1146.6	8
Echo Bay	7	11296.0	15	753.1	9
Anderson Creek	35	3916.2	7	559.5	10
Rahway 1135	4	253.6	1.7	149.2	11
Lincoln Park West	47	1117.6	7.5	149.0	12
Shooters Island	10.5	622.4	13	47.9	13

Plan Formulation Problem Revisited: How to choose between sites with different TECs?

- With unlimited resources, we can restore everything.
- However, we have limited funds, so we need to make choices on what to restore first.
- *If maximizing total utility (benefits) were only consideration, keep restoring until marginal utility = 0.*
- *Need to maximize total utility, subject to cost constraints*
- The Equimarginal principle helps to optimize between needs when there are competing uses for limited resources – the equation is shown below:

$$\frac{MU_x}{P_x} = \frac{MU_y}{P_y} = \frac{MU_z}{P_z}$$

How is the Equimarginal Principle Applied to HRE?

1. Calculate the CRRs
2. Once a site is implemented, the score for that site is set aside
3. Recalculate CRRs for remaining sites
4. Repeat this process until list of sites is exhausted

Implementation of any site leads to a new Existing Condition

- **Z scores** may change
  - Diminishing Marginal Utility
  - Distance to other sites
  - Adaptive Management (refinement of Z score calculation)
- **V score** will be refined
  - Site Implementation will add more observations to average cost curves

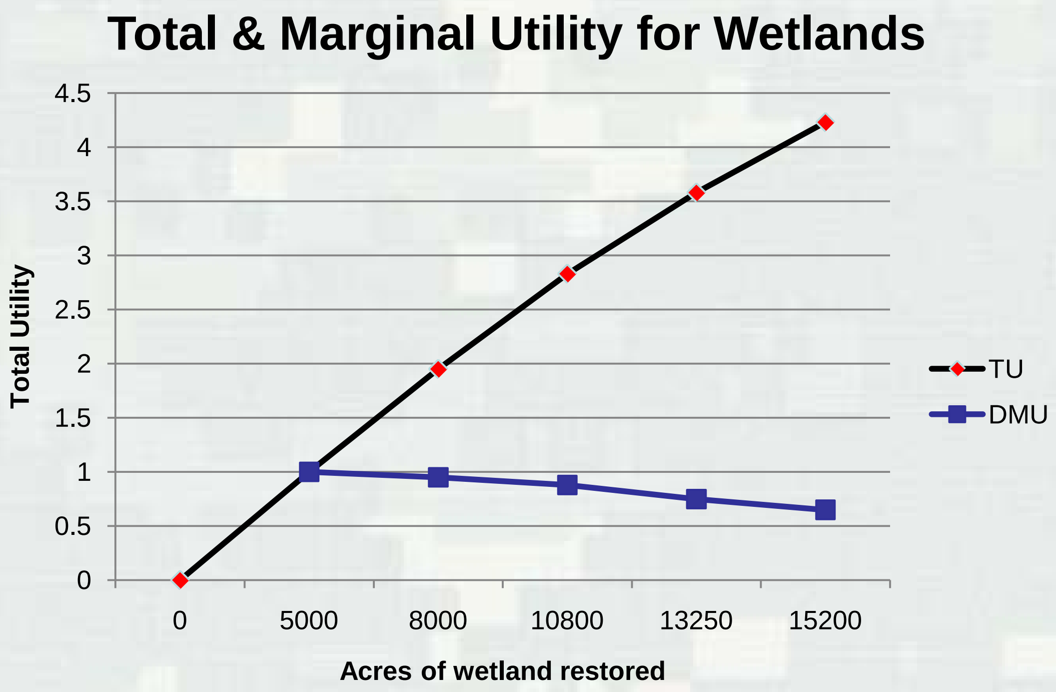
2nd Round of CRR calculations

Scenario: Gerritsen Creek and Liberty State Park are implemented. CRRs are recalculated based on this change. The bottom seven sites have been re-ordered from when there were 13 sites.

Site Name	Restoration Acreage	Z score (benefit)	V score (cost in millions)	Comparative Restoration Ratio	Previous Rank	New Rank
Fresh Creek	93	703178.5	28	25113.5	2	1
Paerdegat Basin	161	1274839.0	57	22365.6	4	2
Dead Horse Bay	130	618885.1	53	11677.1	5	3
Spring Creek	151	438414.1	59	7430.7	6	3
Brant Point	7.5	5732.8	5	1146.6	**8**	**4**
Turtle Cove	7.5	8533.8	8	1066.7	**7**	**5**
Echo Bay	7	11296.0	15	753.1	**9**	**6**
Anderson Creek	35	3916.2	7	559.5	**10**	**7**
Lincoln Park West	47	1117.6	7.5	149.0	**12**	**8**
Shooters Island	10.5	622.4	10	62.2	**13**	**9**
Rahway 1135	4	110.0	2	55.0	**11**	**10**

The Equimarginal Principle/Diminishing Marginal Utility

Acres Built	TU	DMU
0	0	
5000	1	1
8000	1.95	0.95
10800	2.83	0.88
13250	3.58	0.75
15200	4.23	0.65



For demonstration purposes, let's work with a smaller goal of 800 acres

Acres Built	Total Utility	Marginal Utility
0	0	
275	1	1
450	1.95	0.95
575	2.83	0.88
700	3.58	0.75
800	4.23	0.65

Effect of Marginal Utility on Benefit Scores for Wetlands

Site	Z score	Acreage	Cumulative Acreage*	DMU factor	Adjusted Z Score
LSP	675131	150	150	x 1	675131
Kearny Point	318307	60	210		318307
Dead Horse Bay	227674	130	340	x 0.95	216290
Spring Creek	161283	150	490	x 0.88	141929
Gerritsen Creek	45425	36	526		39974
Brant Point	5733	8	534		5045
Anderson Creek	3916	35	569		3446
Turtle Cove	3139	15	584	x 0.75	2354
Lincoln Park West	1117	45	629		838
Rahway 1135	253	4	633		190

* Assume that sites will be implemented in order of benefit score

CRR Process Evaluation

- Benefits
  - Transparent
  - Collaboratively defined goals and benefits
  - Able to analyze large area with many different types of habitats in short time frame

- Potential Issues
  - Conceptual plan for a site may differ from that of post authorization analysis
  - Limited resources allow for limited conceptual plan development

Summary: Why are we using this process for the HRE Program?

- HRE study area is too large for traditional feasibility recommendation:
  - traditional reports = snapshots
  - not appropriate for the broad regional scale
  - need comprehensive overview for most effective restoration
  - existing methods did not capture all the metrics needed for HRE (watershed approach)
- Program needed as form of adaptive management:
  - monitor progress toward addressing HRE Problems
  - updates to HRE restoration agenda based on results
  - venue for collaborative planning and stakeholder input

Questions?