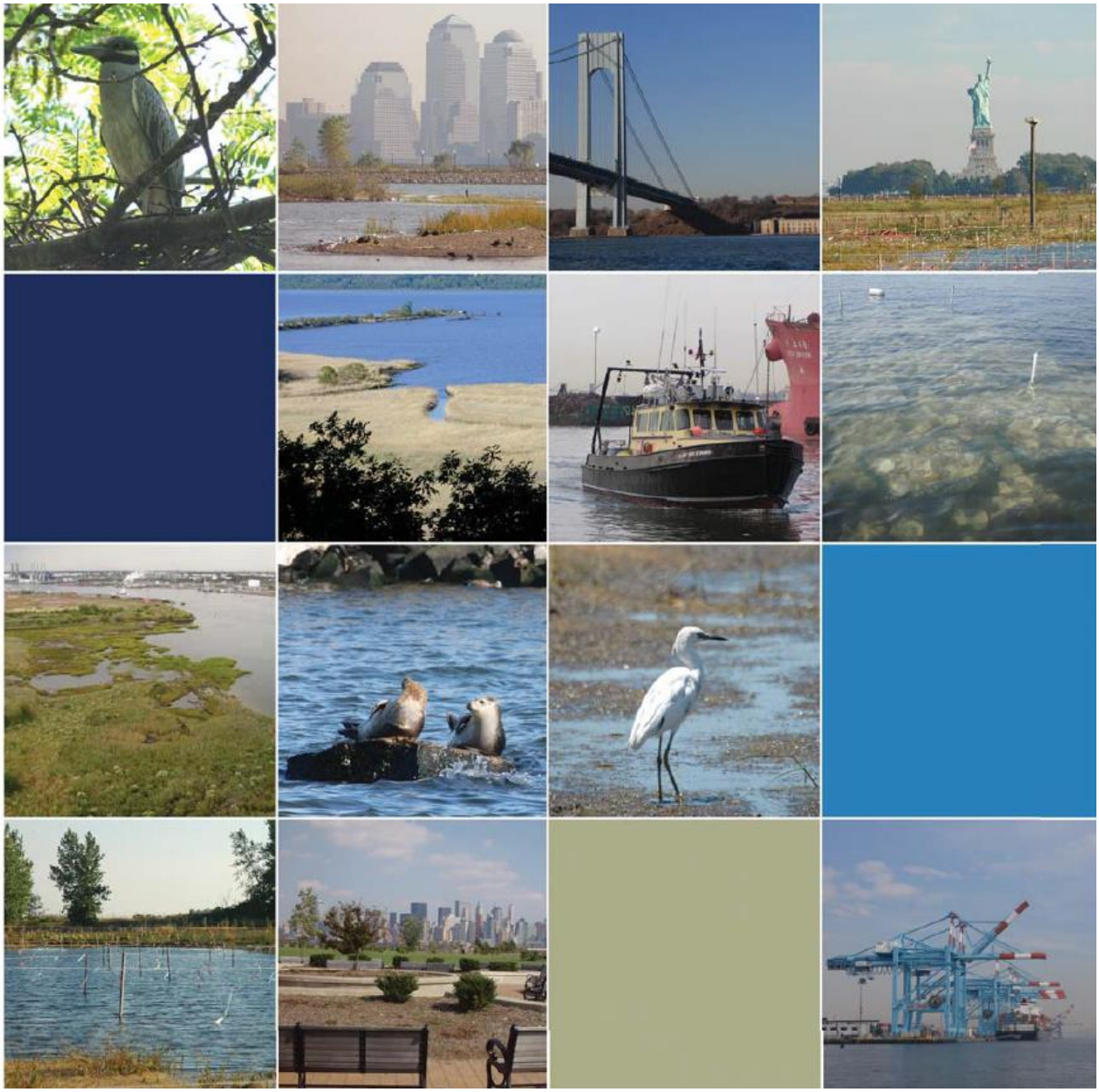
Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study

Appendix J
Cost Effectiveness/Incremental Cost Analysis (CE/ICA)

Final Integrated Feasibility Report &
Environmental Assessment
April 2020

Prepared by the New York District
U.S. Army Corps of Engineers

THE PORT AUTHORITY OF NY & NJ



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1. Introduction

The USACE ecosystem restoration mission was first authorized in the Water Resources Development Act of 1986 with the stated purpose "…to restore significant structure, function and dynamic processes that have been degraded" (ER 1165-2-501). Given this goal, USACE programs emphasize ecological outcomes (as opposed to social or economic outcomes). Generally, ecological resources may be quantified in a variety of ways ranging from habitat suitability for a focal taxa (e.g., an endangered species) to changes in physical processes (e.g., sediment delivery from geomorphic change) to changes in biological processes (e.g., carbon uptake and storage). In other USACE business lines (e.g., navigation), costs and benefits of actions are compared in monetary terms, and the benefit-cost ratio serves as a crucial decision metric. However, outputs of restoration are typically not monetized, and a different set of methods are required to inform restoration decision-making and address the issue of "Is ecosystem restoration worth the Federal investment?" In particular, cost-effectiveness and incremental cost analyses provide a technique for comparing non-monetary ecological benefits relative to the monetary costs of restoration actions (Robinson et al. 1995).

Cost-effectiveness and incremental cost analyses (CE/ICA) are analytical tools for assessing the relative benefits and costs of ecosystem restoration actions and informing decisions. Benefits and costs are assessed prior to these analyses using ecological models (e.g., the Evaluation of Planned Wetlands model) and cost engineering methods, respectively. CE/ICA may then be conducted at the site scale to compare alternatives at a single location (e.g., no action vs. dam removal vs. fish ladder) or at the system scale to compare relative merits of multiple sites (e.g., no sites vs. Site-A only vs. Site-B only vs. Site-A and Site-B). Within the USACE, the Institute of Water Resources has provided a toolkit for conducting CE/ICA, the IWR Planning Suite (**http://www.iwr.usace.army.mil/Missions/Economics/IWR-Planning-Suite/**).

Cost-effectiveness analysis provides a mechanism for examining the efficiency of alternative actions. For any given level of investment, the agency wants to identify the plan with the most return-on-investment (i.e., the most environmental benefits), and for any given level of environmental benefits, the agency wants a plan with the least cost. An "efficiency frontier" identifies all plans that efficiently provide benefits on a per cost basis (i.e., cost-effective plans, CE).

Incremental cost analysis is conducted on the set of cost-effective plans. This technique sequentially compares each plan to all higher cost plans to reveal changes in unit cost as output levels increase and eliminates plans that do not efficiently provide benefits on a per unit cost basis. Specifically, this analysis examines the slope of the cost-effectiveness frontier to isolate how the incremental unit cost ($/unit) increases as the magnitude of environmental benefit increases. Incremental cost analysis is ultimately intended to inform decision-makers about the consequences of increasing unit cost when increasing benefits (i.e., each unit becomes more expensive). Plans emerging from incremental cost analysis efficiently accomplish the objective relative to unit costs and are typically referred to as "best buys" (BB). Importantly, all "best buys" are cost-effective, but all cost-effective plans are not best buys.

The Hudson-Raritan Estuary (HRE) Ecosystem Restoration Feasibility Study is a large multi-objective, watershed-scale ecosystem restoration initiative led by the USACE, which initially resulted in 33 potential restoration sites across a diverse set of ecosystem types (e.g., coastal

marshes, urban streams, oysters), stakeholder groups (9 non-federal sponsors and dozens of interested parties), and political geographies (multiple states, Congressional districts, and municipalities). At each site, multiple alternatives were developed varying in both their costs and benefits (See other appendices). As described in the Plan Formulation Appendix, HRE restoration sites have been screened from hundreds of potential locations to 33 sites for feasibility level analysis. Following deletion of two oyster sites, 31 sites were grouped into five general system types based on geography and ecosystem type, which serve as the basis for system-scale planning. The five system types and the associated restoration sites are:

- *Jamaica Bay Perimeter*: Dead Horse Bay, Fresh Creek, Brant Point, Hawtree Point, Bayswater Point State Park, and Dubos Point

- *Jamaica Bay Marsh Islands*: Duck Point, Stony Creek, Pumpkin Patch West, Pumpkin Patch East, and Elders Center

- *Harlem River, East River and Western Long Island Sound Planning Region*: Flushing Creek, Bronx Zoo and Dam, Stone Mill Dam, Shoelace Park, Bronxville Lake, Garth Woods/Harney Road (Garth Harney), West Farm Rapids Park, Muskrat Cove, Crestwood Lake, and Westchester County Center

- *Newark Bay, Hackensack River and Passaic River Planning Region*: Oak Island Yards, Essex County Branch Brook Park, Clifton Dundee Canal Green Acres, Dundee Island Park, Kearny Point, Metromedia Tract, and Meadowlark Marsh

- *Oyster Reef Restoration*: Naval Weapons Station Earle, Bush Terminal, and Head of Jamaica Bay

The objectives of this Appendix are to:

- Annualize benefits and costs (from Appendices E and I, respectively) over a 50-year planning horizon for consistent comparison.

- Apply CE/ICA to inform site-scale recommendations for all 31 sites. Ultimately, this analysis results in a single recommended alternative at each site (e.g., Alternative-2 for Duck Point Marsh Island)

- Apply CE/ICA to inform system-scale decision-making in each region. Ultimately, this analysis identified the portfolio of restoration actions in the National Ecosystem Restoration Plan.

- Following identification of the National Ecosystem Restoration Plan, costs and benefits were “optimized” based on additional analyses. System-scale recommendations are then “confirmed” based on final costs and benefits.

2. Annualization

Restoration benefits and costs are often distributed across the planning horizon. For instance, the ecological benefits of a riparian planting scheme may not be realized until the trees reach a certain size or height threshold. Likewise, costs may be incurred differentially across the project life span such as the up-front cost of construction or annual operational costs. Annualization provides a mechanism for consistent comparison of benefits and costs, and this section describes the annualization process and outcomes. Appendices E and I provide additional detail on benefit and cost analyses, respectively.

2.1. Benefit Annualization

An analysis of the environmental benefits of each alternative was completed for each HRE study site (Appendix E). Three primary assessments were conducted to quantify environmental outcomes:

- The Evaluation of Planned Wetlands habitat model (Regional Certification obtained July 2016) was used to quantify benefits for the majority of sites. The Evaluation of Planned Wetlands model is a rapid assessment procedure which evaluates patch quality relative to six functional categories (all from 0 to 1): shoreline bank erosion, sediment stabilization, water quality, wildlife, fish, and uniqueness / heritage (Bartoldus 1994, Bartoldus et al. 1994). The uniqueness / heritage parameters are beyond the scope of USACE ecosystem restoration missions and were not used in this analysis. The five remaining categories were averaged to obtain a functional capacity index for a given site, alternative, and time period, which was subsequently multiplied by habitat area (in acres) to obtain a quality-weighted area metric (i.e., a functional capacity unit, FCU).

- Oyster reef restoration was assessed using the certified Oyster Suitability Index model (Swannack et al. 2014), which estimates habitat units associated with each site, alternative, and year.

- Fish passage connectivity benefits were quantified using the Watershed-Scale Upstream Connectivity Toolkit (National Certification in October 2018). Briefly, this model provides a procedure for quantifying benefits associated with removal of organism movement barriers within a watershed (e.g., dam removal, culvert repair, fish ladder installation) and is intended for application at the watershed-scale. The algorithm is based on four primary components: habitat quantity upstream of a dam, habitat quality upstream of a dam, the passability of a structure for a given organism, and the shape/topology of the watershed. The model combines these data to estimate quality-weighted, accessible habitat at the watershed scale (i.e., a quality-and connectivity-weighted acre or habitat unit). For HRE, benefits were computed at the Bronx Zoo Dam and Stone Mill Dam sites relative to river herring habitat and life history.

USACE policy requires analysis of the effects of sea level change on alternatives (ER 1100-2-8162). Project benefits were assessed in light of sea level change at each site. Inland sites (e.g., Bronx River) were not included due to an insensitivity to sea level. Oyster restoration sites were also not included because oysters have a wide range of depth tolerance, and sea level would

affect all alternatives equivalently (i.e., the decision would be insensitive to sea level change). This appendix only presents ecological outcomes including effects of sea level change.

All outputs were annualized (i.e., time-averaged) to reflect the average annual units over the planning horizon. Models were applied at four time periods (or target years, TY): Year-0 (TY0), Year-2 (TY2), Year-20 (TY20), and Year-50 (TY50). We assume each assessment point is the beginning of the respective year. Benefits are annualized by computing the area under the benefits curve and dividing by the length of the planning horizon (50-years), assuming a linear trajectory between all time periods. The Harlem River, East River and Western Long Island Sound sites were assessed using both the Evaluation of Planned Wetlands model and the Watershed-Scale Upstream Connectivity Toolkit, given their complementary units. At these sites, wetland units (FCUs) were combined with fish passage units (HUs) by summation. For each alternative, net benefits were computed over the future without project (FWOP) condition to reflect the change in ecological condition resulting from the restoration expenditure. This "lift" in benefits provides a consistent baseline for comparison. Table J-1 presents environmental benefits for each site, alternative, and time period as well as the average annual units and lift. For simplicity, all units will be subsequently referred to as average annual functional capacity units (AAFCUs). Additional information on alternative formulation may be found in Appendix D (Plan Formulation).

Table J-1. Benefits summary by year (in FCUs) and averaged over the planning horizon (in AAFCUs)

Site	Alternative	FCU (TY0)	FCU (TY2)	FCU (TY20)	FCU (TY50)	Average Annual Benefits (AAFCU)	Lift (AAFCU)
Dead Horse Bay	FWOP	1.2	1.2	1.2	1.2	1.2	0
	Alt4	1.2	38.3	38.3	36.6	37.1	35.8
Fresh Creek	FWOP	22.5	21.6	20.7	19.8	20.6	0
	Alt5	22.5	59	58	57.8	57.4	36.8
Brant Point	FWOP	0.6	0.6	0.6	0.4	0.5	0
	Alt2	0.6	4.1	4.1	3.9	4	3.4
Hawtree Point	FWOP	0.9	0.9	0.9	0.9	0.9	0
	Alt1	0.9	0.9	0.9	1	1	0
Bayswater State Park	FWOP	3.1	3.1	3.3	3.7	3.4	0
	Alt2	3.1	4.2	4.5	4.9	4.5	1.1
Dubos Point	FWOP	5.7	5.7	6.2	7.3	6.4	0
	Alt3	5.7	7.7	8.1	9.2	8.3	1.9
Duck Point	FWOP	3.3	3.3	2.4	0	1.9	0
	Alt1	3.3	15.2	18.5	15.7	16.7	14.8
	Alt2	3.3	21.3	27.5	22.2	24.2	22.3
	Alt3	3.3	24.2	32	26.4	28.2	26.3
Stony Creek	FWOP	4.7	4.7	3.3	0	2.6	0
	Alt1	4.7	26.6	35.1	32.1	31.9	29.3
	Alt2	4.7	21.4	24.6	18	21.6	18.9

Site	Alternative	FCU (TY0)	FCU (TY2)	FCU (TY20)	FCU (TY50)	Average Annual Benefits (AAFCU)	Lift (AAFCU)
	Alt3	4.7	16.9	19.8	15.3	17.6	14.9
Pumpkin Patch West	FWOP	0	0	0	0	0	0
	Alt1	0	9.1	11	9.3	9.9	9.9
	Alt2	0	13	13.2	12.5	12.7	12.7
	Alt3	0	16.5	20.5	16.5	18.1	18.1
Pumpkin Patch East	FWOP	0	0	0	0	0	0
	Alt1	0	18.2	24.3	21.6	21.8	21.8
	Alt2	0	11.5	15.3	12.9	13.5	13.5
	Alt3	0	15.5	19.6	16.6	17.5	17.5
Elders Center	FWOP	0	0	0	0	0	0
	Alt1	0	8.2	11	10	9.9	9.9
	Alt2	0	9.9	13.7	11.6	12	12
	Alt3	0	15.9	23.2	19.7	20.2	20.2
Flushing Creek	FWOP	4.4	4.4	4.4	4.4	4.4	0
	AltA	4.4	9.7	9.7	9.3	9.4	5.1
	AltB	4.4	12	12	11.4	11.6	7.3
	AltC	4.4	12.4	12.4	11.7	12	7.6
Bronx Zoo and Dam	FWOP	0.5	0.5	0.5	0.5	0.5	0
	AltA	0.5	2.2	2.2	2.2	2.2	1.7
	AltB	0.5	1.9	1.9	1.9	1.9	1.4
	AltC	0.5	1.6	1.6	1.6	1.6	1.1
Stone Mill Dam	FWOP	0.3	0.3	0.3	0.3	0.3	0
	AltA	0.3	19.7	19.7	19.7	19.3	19
	AltB	0.3	18	18	18	17.7	17.4
	AltC	0.3	18.1	18.1	18	17.7	17.4
Shoelace Park	FWOP	0	0	0	0	0	0
	AltA	0	5.9	5.9	5.6	5.7	5.7
	AltB	0	5.2	5.2	4.9	5	5
	AltC	0	1.7	1.7	1.6	1.7	1.7
Bronxville Lake	FWOP	0.1	0.1	0.1	0.1	0.1	0
	AltA	0.1	4.7	4.7	4.6	4.6	4.5
	AltB	0.1	4.1	4.1	3.9	4	3.8
	AltC	0.1	3	3	2.8	2.9	2.7
Garth Harney	FWOP	0.2	0.2	0.2	0.2	0.2	0
	AltA	0.2	2.8	2.8	2.7	2.7	2.5
	AltB	0.2	1.5	1.5	1.5	1.5	1.2
	AltC	0.2	0.5	0.6	0.5	0.5	0.3
	FWOP	0	0	0	0	0	0

Site	Alternative	FCU (TY0)	FCU (TY2)	FCU (TY20)	FCU (TY50)	Average Annual Benefits (AAFCU)	Lift (AAFCU)
West Farm Rapids Park	AltA	0	0.5	0.5	0.5	0.5	0.5
	AltB	0	0.4	0.4	0.4	0.4	0.4
	AltC	0	0.2	0.2	0.2	0.2	0.2
Muskrat Cove	FWOP	0	0	0	0	0	0
	AltA	0	0.7	0.7	0.6	0.7	0.6
	AltB	0	0.7	0.7	0.7	0.7	0.7
	AltC	0	0.2	0.2	0.2	0.2	0.2
Crestwood Lake	FWOP	1.1	1.1	1.1	1	1.1	0
	AltA	1.1	6.2	6.2	5.9	6	4.9
	AltB	1.1	2.5	2.5	2.4	2.5	1.4
	AltC	1.1	2.1	2.1	2	2	1
Westchester County Center	FWOP	0.6	0.6	0.6	0.6	0.6	0
	AltA	0.6	5.2	5.2	4.9	5	4.4
	AltB	0.6	2.6	2.6	2.5	2.5	1.9
	AltC	0.6	1.5	1.5	1.5	1.5	0.9
Oak Island Yards	FWOP	3.6	3.6	3.6	3.6	3.6	0
	AltA	3.6	6.7	9.2	8.6	8.4	4.8
	AltB	3.6	6.4	7.5	7.3	7.1	3.5
	AltC	3.6	6.4	8.6	8.6	8	4.4
Essex County Branch Brook Park	FWOP	19	19	19	19	19	0
	AltA	19	55.3	71.8	67.8	66.3	47.2
	AltB	19	50.4	60.2	57.4	56.6	37.5
	AltC	19	32.2	34.2	33.4	33.3	14.2
	AltD	19	38.6	43.5	41.4	41.4	22.3
Clifton Dundee Canal Green Acres	FWOP	1.4	1.4	1.4	1.4	1.4	0
	AltA	1.4	2.1	2.8	2.7	2.6	1.2
	AltB	1.4	1.4	1.5	1.5	1.5	0.1
	AltC	1.4	1.4	1.4	1.4	1.4	0
Dundee Island Park	FWOP	0.2	0.2	0.2	0.2	0.2	0
	AltA	0.2	0.5	0.7	0.7	0.6	0.4
Kearny Point	FWOP	15.1	15	15	15	15	0
	AltA	15.1	20.1	26.9	25.9	25	10
	AltB	15.1	16.9	22.4	21.7	20.9	6
	AltC	15.1	14	21.9	21.9	20.2	5.2
Metromedia Tract	FWOP	34	35.8	36.4	37	36.4	0
	AltA	34	39.4	50.8	56.4	49.9	13.5
	AltB	34	36.7	52.5	56.3	50.1	13.7
	AltC	34	38.9	52.3	54.3	49.8	13.4
	FWOP	61.2	55.8	56.2	56.7	56.4	0

Site	Alternative	FCU (TY0)	FCU (TY2)	FCU (TY20)	FCU (TY50)	Average Annual Benefits (AAFCU)	Lift (AAFCU)
Meadowlark Marsh	AltA	61.2	47.8	70.9	68.6	65.4	9.1
	AltB	61.2	49.6	72	70.8	67	10.6
	AltC	61.2	55.3	76	76.8	71.8	15.5
Naval Weapons Station Earle	FWOP	0	0	0	0	0	0
	AltA	0	2.9	2.9	2.9	2.9	2.9
	AltB	0	5.9	5.9	5.9	5.8	5.8
	AltC	0	9.8	9.8	9.8	9.6	9.6
Bush Terminal	FWOP	0	0	0	0	0	0
	AltA	0	6.8	6.8	6.8	6.7	6.7
	AltB	0	10.1	10.1	10.1	9.9	9.9
	AltC	0	19.9	19.9	19.9	19.5	19.5
Head of Jamaica Bay	FWOP	0	0	0	0	0	0
	AltA	0	1.8	1.8	1.8	1.7	1.7
	AltB	0	3.5	3.5	3.5	3.5	3.5
	AltC	0	5.4	5.4	5.4	5.2	5.2

2.2. Cost Annualization

Cost estimates were compiled for each site-scale restoration action following standard cost engineering and real estate methods (Appendix I). Sub-total first cost represents a sum of expenses related to real estate, construction, cultural resources, pre-construction engineering and design, and construction management (Accounts 01, 03-20, 18, 30, and 31, respectively). Interest during construction was computed based on sub-total first costs, construction durations and the fiscal year 2020 (October 2019) price levels and formulation rate (discount rate) of 2.75% in accordance with EGM 20-01. Monitoring and adaptive management costs were amortized over a five-year window. All costs were annualized over the 50-year planning horizon and combined with alternative-specific annual operations and maintenance costs to arrive at average annual cost (Table J-2).

Table J-2. Cost summary for all sites

Site	Alternative	Construction Duration (mon)	Sub-Total First Cost ($)	Monitoring and Adaptive Management Cost ($)	Total First Cost ($)	OMRR&R Cost ($)	Interest During Construction ($)	Average Annual Cost ($)
Dead Horse Bay	FWOP	0	0	0	0	0	0	0
	Alt4	36	82,697,602	1,848,360	84,545,962	80,000	3,361,045	3,330,851
Fresh Creek	FWOP	0	0	0	0	0	0	0
	Alt5	36	33,148,455	737,068	33,885,522	80,000	1,347,239	1,382,939
Brant Point	FWOP	0	0	0	0	0	0	0
	Alt2	36	6,425,941	155,406	6,581,347	20,000	261,167	273,007
Hawtree Point	FWOP	0	0	0	0	0	0	0
	Alt1	36	1,981,636	150,000	2,131,636	20,000	80,539	101,510
Bayswater State Park	FWOP	0	0	0	0	0	0	0
	Alt2	36	5,766,391	150,000	5,916,391	20,000	234,631	247,399
Dubos Point	FWOP	0	0	0	0	0	0	0
	Alt3	36	9,585,028	214,028	9,799,056	20,000	389,560	396,781
Duck Point	FWOP	0	0	0	0	0	0	0
	Alt1	36	20,847,701	473,882	21,321,583	50,000	847,305	869,796
	Alt2	36	23,408,019	532,104	23,940,123	50,000	951,363	970,476
	Alt3	36	28,182,992	640,688	28,823,679	50,000	1,145,430	1,158,245
Stony Creek	FWOP	0	0	0	0	0	0	0
	Alt1	36	22,218,071	515,297	22,733,369	50,000	903,000	924,034
	Alt2	36	17,973,726	416,821	18,390,547	50,000	730,499	757,065
	Alt3	36	15,770,046	365,691	16,135,738	50,000	640,936	670,374
Pumpkin Patch West	FWOP	0	0	0	0	0	0	0
	Alt1	36	14,027,060	333,372	14,360,432	50,000	583,645	614,934
	Alt2	36	20,504,279	487,409	20,991,688	50,000	853,157	875,808
	Alt3	36	26,710,462	634,999	27,345,461	50,000	1,111,390	1,125,766
	FWOP	0	0	0	0	0	0	0

Site	Alternative	Construction Duration (mon)	Sub-Total First Cost ($)	Monitoring and Adaptive Management Cost ($)	Total First Cost ($)	OMRR&R Cost ($)	Interest During Construction ($)	Average Annual Cost ($)
Pumpkin Patch East	Alt1	36	30,400,272	693,870	31,094,142	50,000	1,235,546	1,245,530
	Alt2	36	17,068,819	389,499	17,458,318	50,000	693,721	721,250
	Alt3	36	23,653,276	539,829	24,193,105	50,000	961,330	980,194
Elders Center	FWOP	0	0	0	0	0	0	0
	Alt1	36	14,516,762	347,914	14,864,676	50,000	589,999	621,457
	Alt2	36	14,303,695	342,804	14,646,500	50,000	581,339	613,069
	Alt3	36	20,411,448	489,273	20,900,721	50,000	829,574	853,506
Flushing Creek	FWOP	0	0	0	0	0	0	0
	AltA	24	8,399,122	150,000	8,549,122	80,000	222,282	404,470
	AltB	24	13,204,697	309,022	13,513,719	80,000	349,461	592,618
	AltC	24	16,113,674	378,139	16,491,813	80,000	426,447	705,583
Bronx Zoo and Dam	FWOP	0	0	0	0	0	0	0
	AltA	11	6,161,341	150,000	6,311,341	20,000	70,200	255,948
	AltB	11	4,784,598	150,000	4,934,598	20,000	54,514	204,371
	AltC	11	3,691,719	150,000	3,841,719	20,000	42,062	163,428
Stone Mill Dam	FWOP	0	0	0	0	0	0	0
	AltA	8	779,827	150,000	929,827	20,000	6,205	54,241
	AltB	8	708,351	150,000	858,351	20,000	5,637	51,572
	AltC	8	540,223	150,000	690,223	20,000	4,299	45,295
Shoelace Park	FWOP	0	0	0	0	0	0	0
	AltA	14	24,961,173	545,406	25,506,579	20,000	370,557	1,006,948
	AltB	14	18,530,516	404,768	18,935,284	20,000	275,092	760,408
	AltC	14	8,920,217	195,935	9,116,152	20,000	132,424	362,013
Bronxville Lake	FWOP	0	0	0	0	0	0	0
	AltA	13	21,281,995	464,614	21,746,610	50,000	291,415	864,975
	AltB	13	14,381,709	313,706	14,695,415	50,000	196,929	600,726

Site	Alternative	Construction Duration (mon)	Sub-Total First Cost ($)	Monitoring and Adaptive Management Cost ($)	Total First Cost ($)	OMRR&R Cost ($)	Interest During Construction ($)	Average Annual Cost ($)
	AltC	13	14,302,390	311,971	14,614,361	50,000	195,843	597,688
Garth Harney	FWOP	0	0	0	0	0	0	0
	AltA	10	7,336,979	312,399	7,649,378	20,000	75,178	305,228
	AltB	10	6,547,824	300,000	6,847,824	20,000	67,092	275,274
	AltC	10	3,917,834	300,000	4,217,834	20,000	40,144	176,858
West Farm Rapids Park	FWOP	0	0	0	0	0	0	0
	AltA	10	4,114,139	150,000	4,264,139	20,000	42,155	179,079
	AltB	10	4,056,461	150,000	4,206,461	20,000	41,564	176,920
	AltC	10	2,670,590	150,000	2,820,590	20,000	27,364	125,060
Muskrat Cove	FWOP	0	0	0	0	0	0	0
	AltA	11	7,942,235	179,193	8,121,428	20,000	90,491	348,155
	AltB	11	8,143,118	182,495	8,325,614	20,000	92,779	356,245
	AltC	11	4,186,585	150,000	4,336,585	20,000	47,700	202,470
Crestwood Lake	FWOP	0	0	0	0	0	0	0
	AltA	13	27,452,116	599,718	28,051,834	50,000	384,114	1,123,787
	AltB	13	13,666,095	298,869	13,964,964	50,000	191,222	584,571
	AltC	13	12,807,222	279,436	13,086,658	50,000	179,196	550,928
Westchester County Center	FWOP	0	0	0	0	0	0	0
	AltA	13	24,707,587	540,188	25,247,775	50,000	338,321	996,182
	AltB	13	14,692,572	321,161	15,013,732	50,000	201,186	612,653
	AltC	13	13,695,728	299,360	13,995,088	50,000	187,536	574,478
Oak Island Yards	FWOP	0	0	0	0	0	0	0
	AltA	24	18,173,963	397,189	18,571,152	50,000	459,711	753,781
	AltB	24	18,739,873	409,811	19,149,684	50,000	474,025	775,704
	AltC	24	17,702,790	387,130	18,089,921	50,000	447,792	735,543
	FWOP	0	0	0	0	0	0	0
	AltA	24	71,649,492	1,566,145	73,215,637	80,000	1,896,196	2,857,716

Site	Alternative	Construction Duration (mon)	Sub-Total First Cost ($)	Monitoring and Adaptive Management Cost ($)	Total First Cost ($)	OMRR&R Cost ($)	Interest During Construction ($)	Average Annual Cost ($)
Essex County Branch Brook Park	AltB	24	71,714,594	1,567,569	73,282,163	80,000	1,897,919	2,860,240
	AltC	24	22,130,218	483,165	22,613,383	80,000	585,674	937,928
	AltD	24	46,399,651	1,013,934	47,413,586	80,000	1,227,962	1,855,027
Clifton Dundee Canal Green Acres	FWOP	0	0	0	0	0	0	0
	AltA	24	8,881,501	171,710	9,053,210	20,000	235,048	363,553
	AltB	24	8,270,796	161,671	8,432,467	20,000	218,886	339,990
	AltC	24	7,238,061	150,000	7,388,061	20,000	191,554	300,325
Dundee Island Park	FWOP	0	0	0	0	0	0	0
	AltA	24	2,621,005	150,000	2,771,005	20,000	52,657	124,161
Kearny Point	FWOP	0	0	0	0	0	0	0
	AltA	24	50,998,310	1,113,686	52,111,997	80,000	1,349,665	2,057,073
	AltB	24	46,128,926	1,007,194	47,136,120	80,000	1,220,797	1,868,294
	AltC	24	39,470,487	861,574	40,332,061	80,000	1,044,582	1,610,156
Metromedia Tract	FWOP	0	0	0	0	0	0	0
	AltA	34	27,733,012	605,205	28,338,217	50,000	1,061,112	1,137,241
	AltB	34	45,413,789	991,882	46,405,671	80,000	1,737,608	1,860,425
	AltC	34	30,991,135	676,460	31,667,595	80,000	1,185,773	1,294,977
Meadowlark Marsh	FWOP	0	0	0	0	0	0	0
	AltA	34	63,974,334	1,398,947	65,373,280	80,000	2,447,766	2,588,139
	AltB	34	58,407,208	1,277,194	59,684,403	80,000	2,234,759	2,369,877
	AltC	34	46,725,473	1,021,716	47,747,190	80,000	1,787,796	1,911,889
Naval Weapons Station Earle	FWOP	0	0	0	0	0	0	0
	AltA	4	1,075,750	150,000	1,225,750	10,000	3,658	55,108
	AltB	5	2,099,310	150,000	2,249,310	10,000	9,524	93,239
	AltC	8	3,438,265	81,652	3,519,917	10,000	27,360	141,160
Bush Terminal	FWOP	0	0	0	0	0	0	0

Site	Alternative	Construction Duration (mon)	Sub-Total First Cost ($)	Monitoring and Adaptive Management Cost ($)	Total First Cost ($)	OMRR&R Cost ($)	Interest During Construction ($)	Average Annual Cost ($)
	AltA	4	3,105,071	118,328	3,223,398	10,000	10,557	129,449
	AltB	5	4,555,260	126,994	4,682,254	10,000	20,666	183,836
	AltC	9	8,960,603	153,319	9,113,921	10,000	81,551	350,169
Head of Jamaica Bay	FWOP	0	0	0	0	0	0	0
	AltA	3	1,098,250	150,000	1,248,250	10,000	2,488	55,898
	AltB	4	2,115,129	150,000	2,265,129	10,000	7,192	93,738
	AltC	5	3,175,638	118,758	3,294,396	10,000	14,407	132,220

3. Site-by-Site CE/ICA

At each site, multiple alternatives were developed varying in both their costs and benefits (See Appendices D, E, and I). Here, cost-effectiveness and incremental cost analysis are applied to compare alternatives at each site to identify both cost-effective (CE) and best buy (BB) alternatives. A summary figure was output for each site. Notably, Jamaica Bay Perimeter sites were analyzed and approved at the Alternative Formulation Briefing during a prior analysis (See Appendices D and E and Attachment A). As such, only the future without project (FWOP) and the recommended alternative are carried through this analysis with updated costs and benefits.

3.1. Dead Horse Bay

Alternative-4 was identified as the site-scale action with the following support:

- This alternative is a best buy at the site-scale.
- The alternative provides a very large ecological lift (36 AAFCUs) as a result of large scale regrading to form a tidal channel, removal of invasive species, and planting native wetland species.
- The alternative was recommended and approved at a 2010 Alternative Formulation Briefing based on a system-scale analysis of all potential Jamaica Bay Perimeter actions (See Attachment A).

Table J-3. Site summary for Dead Horse Bay

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt4	3,330,851	35.84	1	1	92,936	92,936	84,545,962

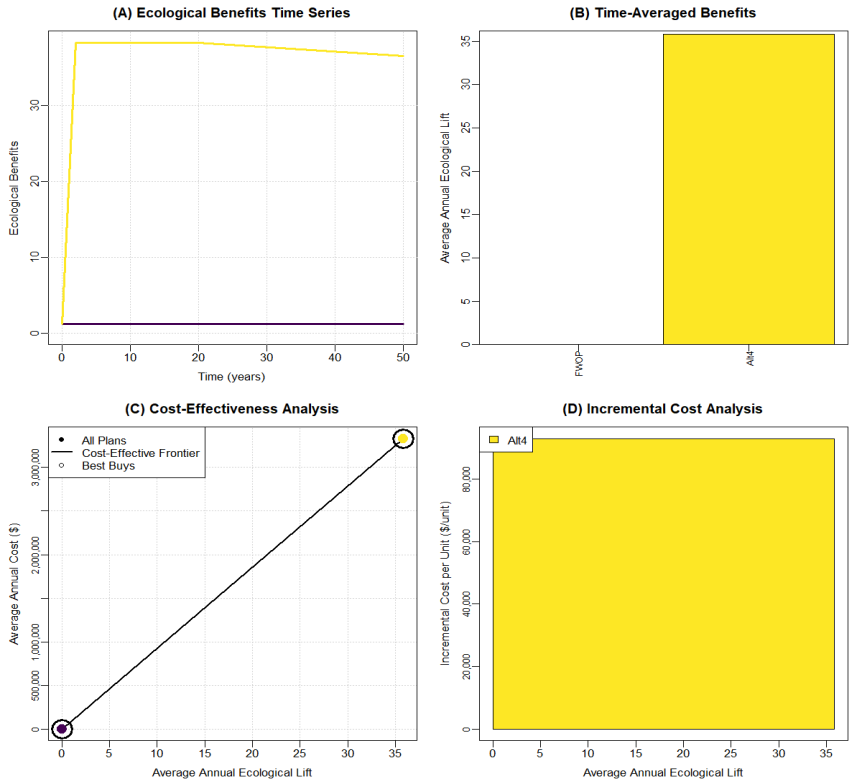

Figure J-1. CE/ICA summary for Dead Horse Bay

3.2. Fresh Creek

Alternative-5 was identified as the site-scale action with the following support:

- This alternative is a best buy at the site-scale.
- The alternative provides a very large ecological lift (37 AAFCUs) from restoration of tidal creeks and marshes along with associated buffer habitats.
- The alternative was recommended and approved at a 2010 Alternative Formulation Briefing based on a system-scale analysis of all potential Jamaica Bay Perimeter actions (See Attachment A).

Table J-4. Site summary for Fresh Creek

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt5	1,382,939	36.78	1	1	37,600	37,600	33,885,522

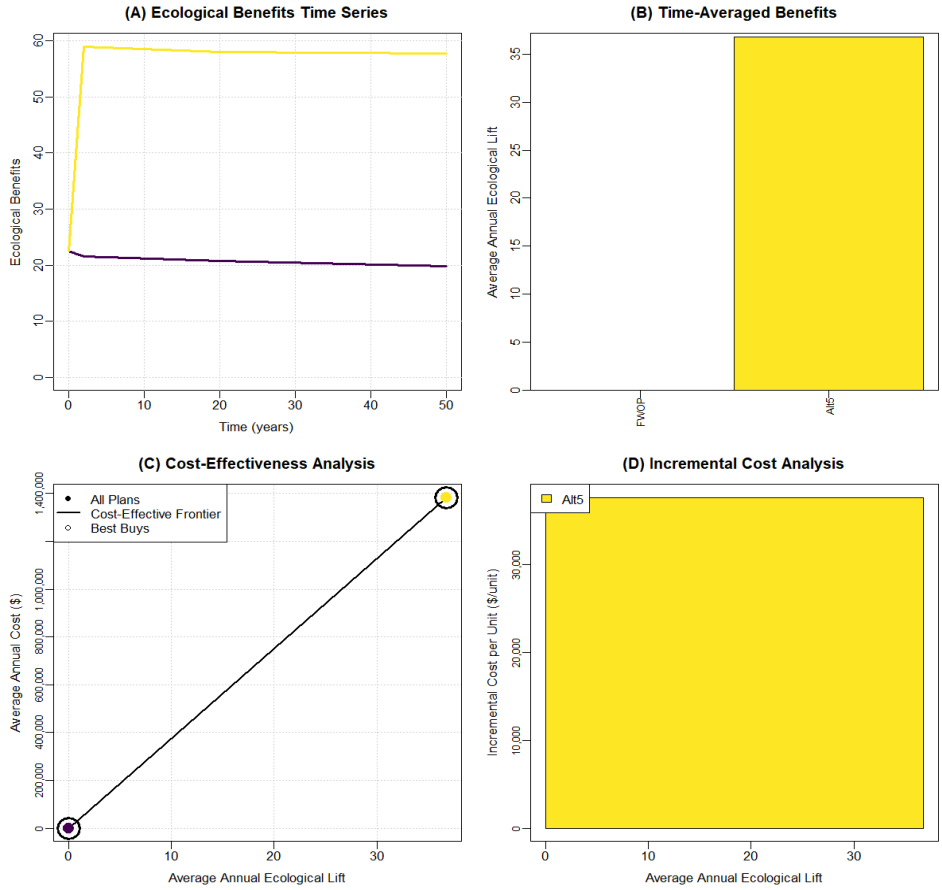

Figure J-2. CE/ICA summary for Fresh Creek

3.3. Brant Point

Alternative-2 was identified as the site-scale action with the following support:

- This alternative is a best buy at the site-scale.
- The alternative is relatively low unit cost ($79,000 / AAFCU), and actions restore ecologically important shoreline functions.
- The alternative was recommended and approved at a 2010 Alternative Formulation Briefing based on a system-scale analysis of all potential Jamaica Bay Perimeter actions (See Attachment A).

Table J-5. Site summary for Brant Point

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt2	273,007	3.45	1	1	79,195	79,195	6,581,347

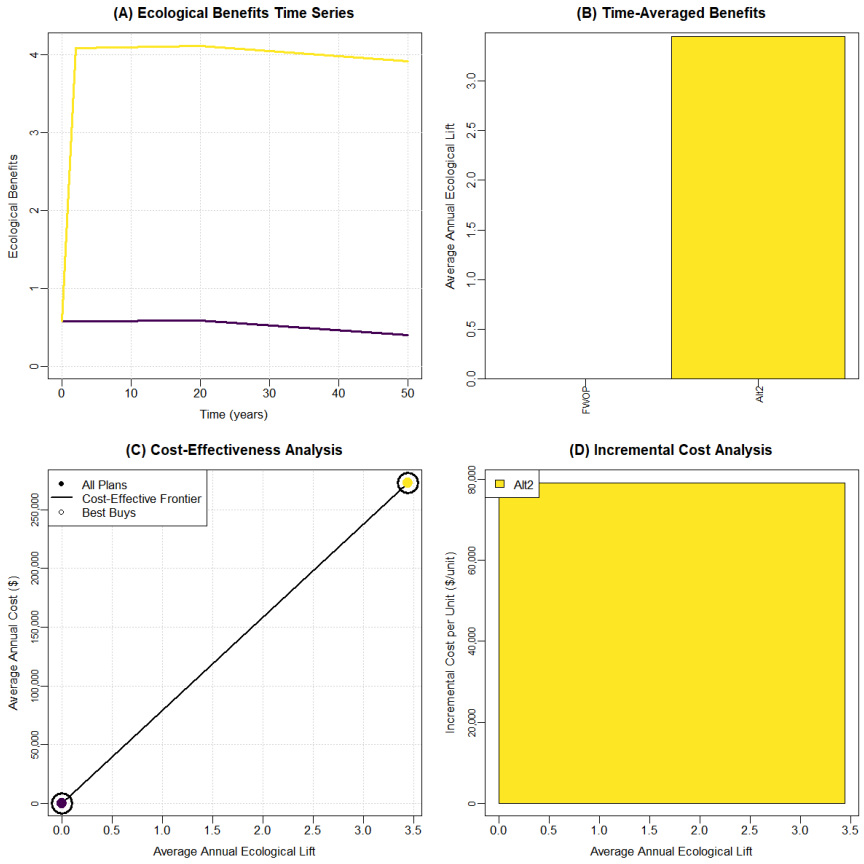

Figure J-3. CE/ICA summary for Brant Point

3.4. Hawtree Point

Alternative-1 was identified as the site-scale action with the following support:

- This alternative is a best buy at the site-scale, although unit cost is quite high ($2,242,000 / AAFCU).

- The alternative was recommended and approved at a 2010 Alternative Formulation Briefing based on a system-scale analysis of all potential Jamaica Bay Perimeter actions (See Attachment A).

Table J-6. Site summary for Hawtree Point

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt1	101,510	0.05	1	1	2,242,038	2,242,038	2,131,636

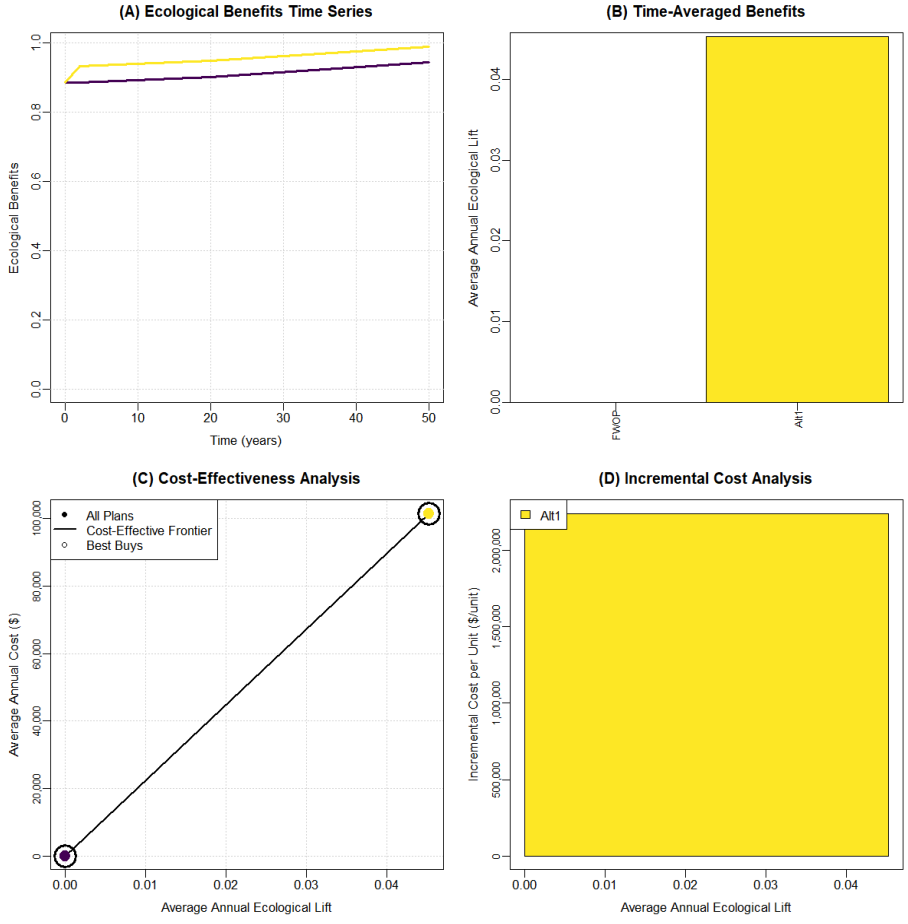

Figure J-4. CE/ICA summary for Hawtree Point

3.5. Bayswater State Park

Alternative-2 was identified as the site-scale action with the following support:

- This alternative is a best buy at the site-scale, although unit cost is quite high ($217,000 / AAFCU) and the overall lift small (1.1 AAFCU).

- The alternative was recommended and approved at a 2010 Alternative Formulation Briefing based on a system-scale analysis of all potential Jamaica Bay Perimeter actions (See Attachment A).

Table J-7. Site summary for Bayswater State Park

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt2	247,399	1.14	1	1	217,429	217,429	5,916,391

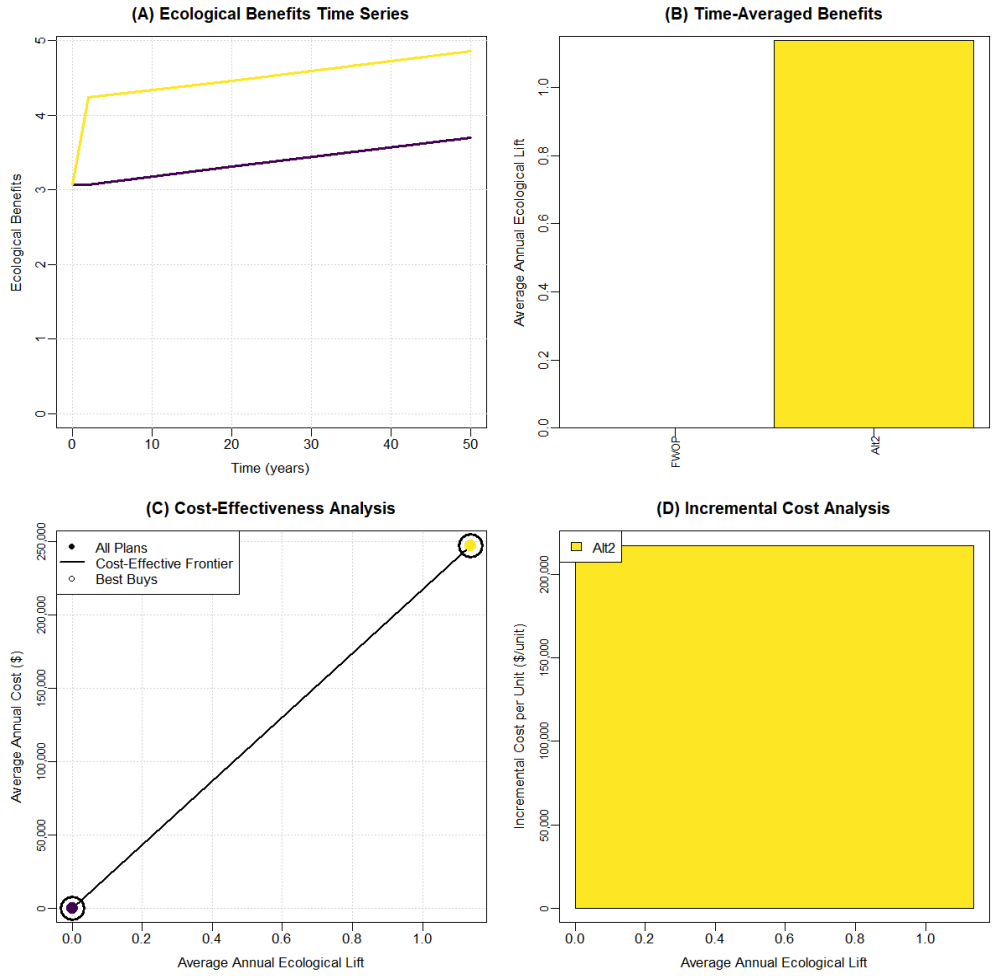

Figure J-5. CE/ICA summary for Bayswater State Park

3.6. Dubos Point

Alternative-3 was identified as the site-scale action with the following support:

- This alternative is a best buy at the site-scale, although unit cost is high ($209,000 / AAFCU) and the overall ecological lift small (1.9 AAFCU).

- The alternative was recommended and approved at a 2010 Alternative Formulation Briefing based on a system-scale analysis of all potential Jamaica Bay Perimeter actions (See Attachment A).

Table J-8. Site summary for Dubos Point

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt3	396,781	1.9	1	1	209,024	209,024	9,799,056

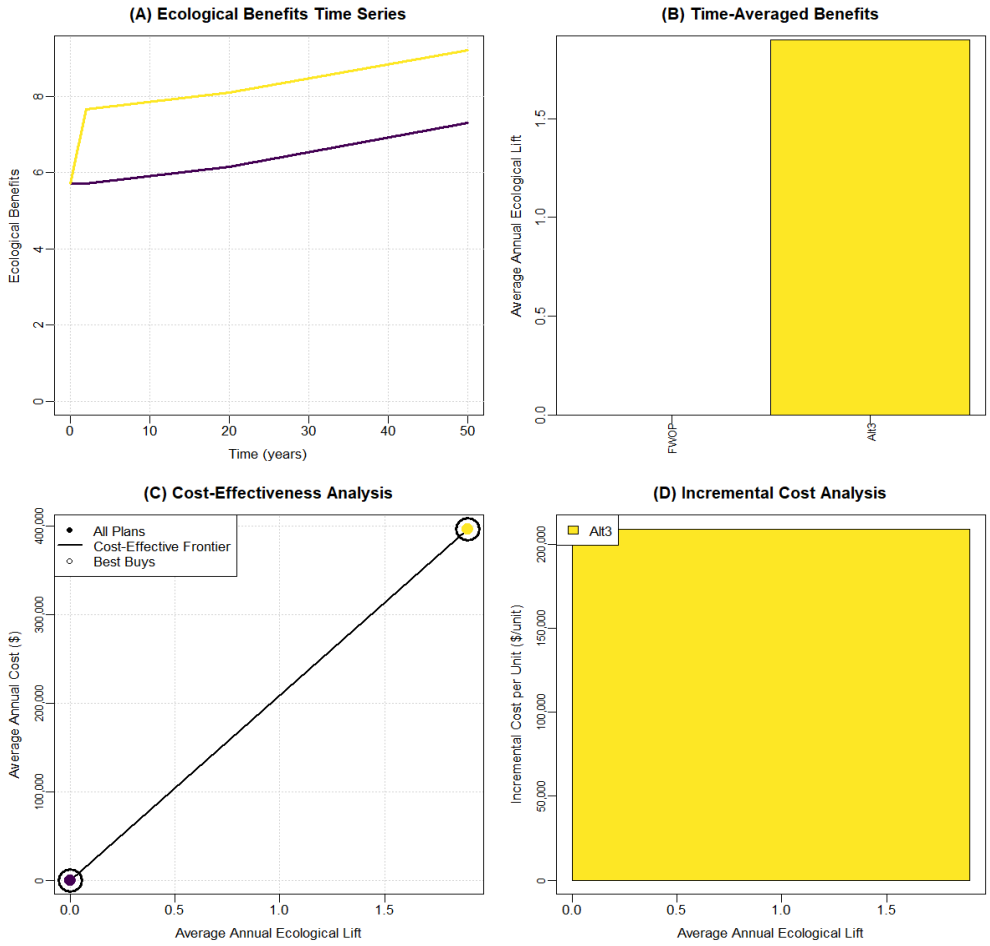

Figure J-6. CE/ICA summary for Dubos Point

3.7. Duck Point

Alternative-2 was identified as the site-scale action with the following support:

- The alternative is a best buy at the site-scale, and incremental analysis supports the alternative as a good value.

- The alternative offers the lowest unit cost of the best buy plans. Design optimization sought to increase benefits and reduce costs, which ultimately made the alternative more cost efficient (i.e., $28,627/AAFCU shown in Section 5).

- Dredged sediment is a limited asset in the Jamaica Bay system, and there is a need to beneficially use this resource efficiently for marsh island restoration. Estimated sediment volumes for the three alternatives are 96,100 yd^3, 213,776 yd^3, and 284,989 yd^3 for Alternatives 1, 2, and 3, respectively (Main Report, Section 3.8.2). Alternative 2 provides 85% of the ecological benefits of Alternative-3 at 75% of the sediment volume. Thus, Alternative-2 is preferred to Alternative-3 relative to this resource constraint.

Table J-9. Site summary for Duck Point

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt1	869,796	14.83	1	0	0	58,644	21,321,583
Alt2	970,476	22.31	1	1	43,490	43,490	23,940,123
Alt3	1,158,245	26.32	1	1	46,936	44,014	28,823,679

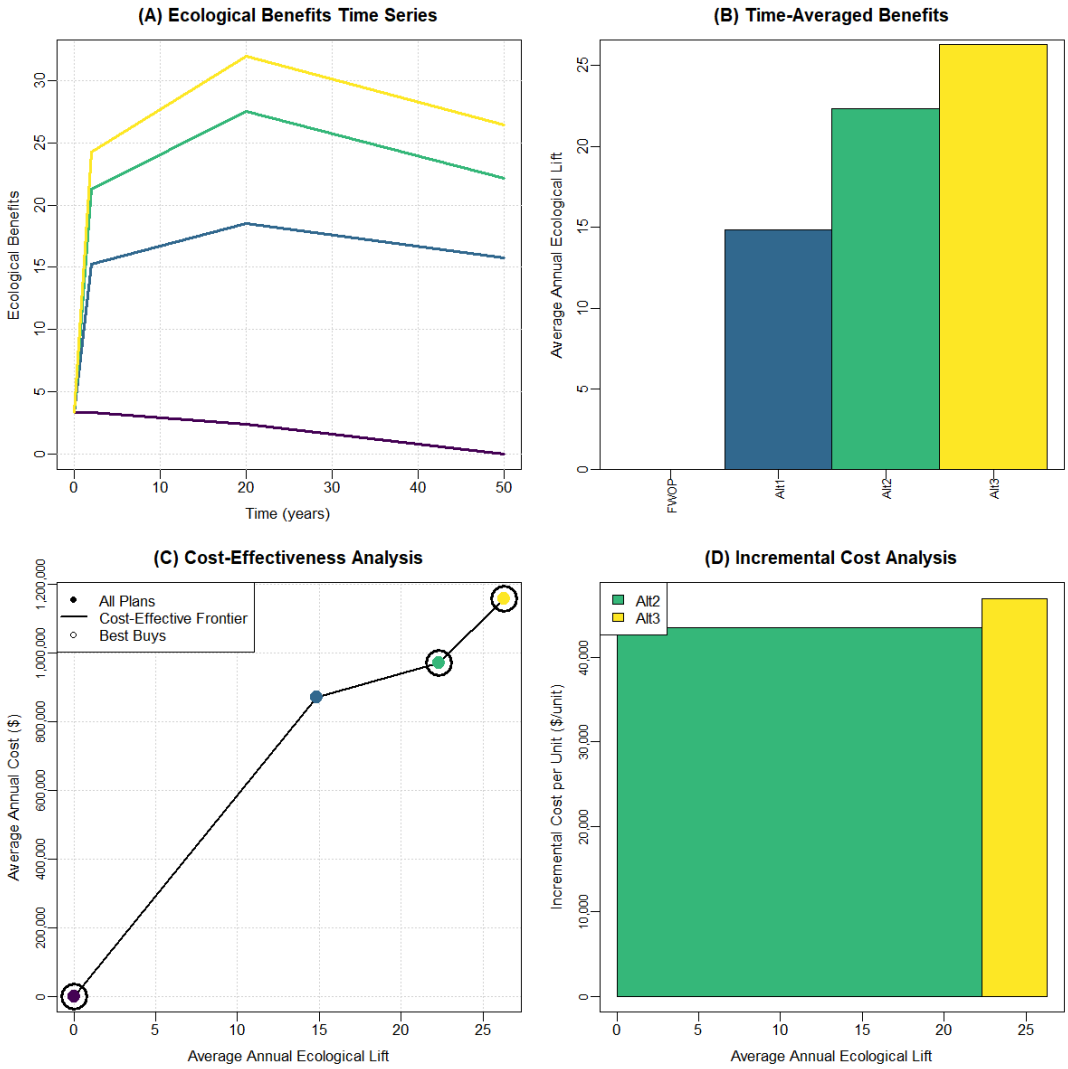

Figure J-7. CE/ICA summary for Duck Point

3.8. Stony Creek

Alternative-1 was identified as the site-scale action with the following support:

- The alternative is the only best buys of the proposed actions.
- The alternative offers high ecological benefits (29 AAFCU) at low unit cost ($31,600 / AAFCU).

Table J-10. Site summary for Stony Creek

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt3	670,374	14.94	1	0	0	44,873	16,135,738
Alt2	757,065	18.94	1	0	0	39,966	18,390,547
Alt1	924,034	29.26	1	1	31,582	31,582	22,733,369

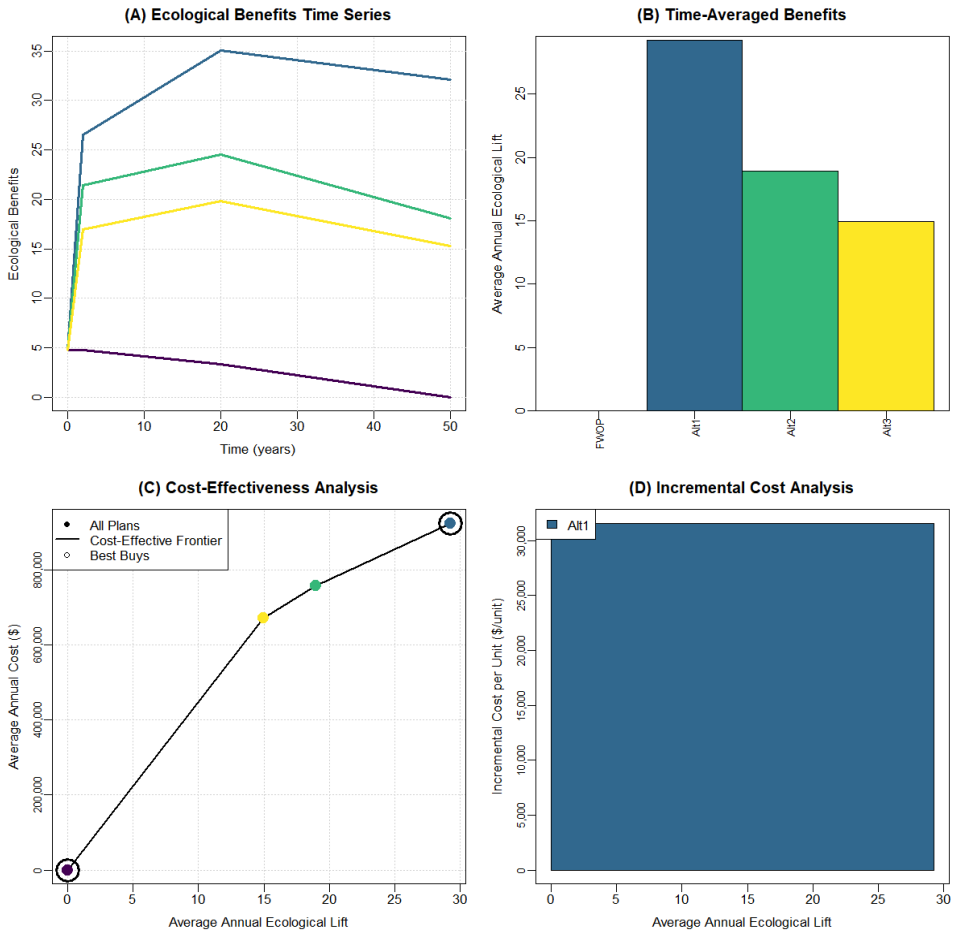

Figure J-8. CE/ICA summary for Stony Creek

3.9. Pumpkin Patch West

Alternative-2 was identified as the site-scale action as a cost-effective alternative, but not a best buy. The Planning Guidance Notebook (ER 1105-2-100, Appendix E, Page E-158) states that, "In all but the most unusual cases, the [National Ecosystem Restoration] Plan should be derived from the final set of Best Buy solutions. Other solutions, identified as non-cost effective in cost effectiveness analysis; as well as cost effective plans identified as relatively less efficient in production ('non-Best Buys') in incremental analysis, may continue to be considered for selection. In some cases, the economic and environmental models used to estimate the effects of ecosystem restoration plans are not capable of capturing the full range of such effects, or considerable uncertainty may accompany the estimates of such effects. Other evaluation criteria, such as environmental significance, acceptability, completeness, and effectiveness also impact the decision process." Alternative-2 was identified with the following support:

- The increase in cost from Alternative-1 to Alternative-3 (both best buys) is substantial (i.e., $12,985,000), while the increase from Alternative-1 to Alternative-2 is significantly reduced (i.e., $6,631,000).

- Benefits of Alternative-1 are relatively low, and the sustainability and resilience of a small marsh island is questionable under sea level rise. The larger footprint of Alternative-2 provides substantial benefits in terms of long-term efficacy of the action beyond the 50-year planning horizon.

- Dredged sediment is a limited asset in the Jamaica Bay system, and there is a need to beneficially use this resource efficiently for marsh island restoration. Estimated sediment volumes for the three alternatives are 206,810 yd^3, 327,686 yd^3, and 435,493 yd^3 for Alternatives 1, 2, and 3, respectively (Main Report, Section 3.8.2). Alternative 2 requires 107,807 yd^3 less sediment which is in-line with the maximum annual dredging volume. Thus, Alternative-2 is preferred to Alternative-3 relative to this resource constraint.

- Alternative-2 was deemed a preferable cost range for initiating design optimization given the relatively intermediate level of costs. Design optimization sought to increase benefits and reduce costs, which ultimately made the plan more cost efficient (i.e., $41,339/AAFCU shown in Section 5) than either Alternative-1 or Alternative-3.

Table J-11. Site summary for Pumpkin Patch West

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt1	614,934	9.9	1	1	62,091	62,091	14,360,432
Alt2	875,808	12.68	1	0	0	69,071	20,991,688
Alt3	1,125,766	18.07	1	1	62,520	62,285	27,345,461

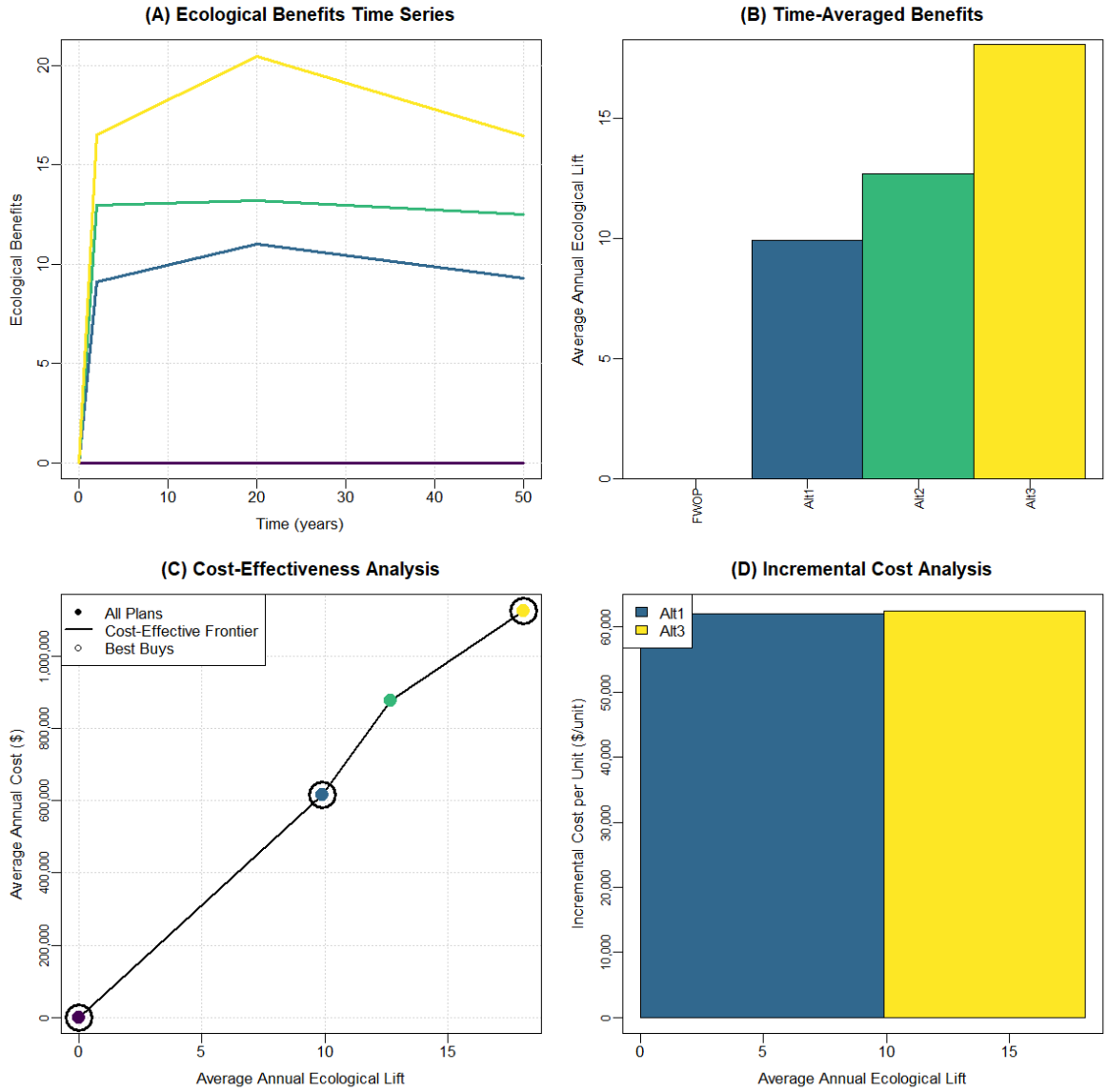

Figure J-9. CE/ICA summary for Pumpkin Patch West

3.10. Pumpkin Patch East

Alternative-3 was identified as the site-scale action as a cost-effective alternative, but not a best buy. The Planning Guidance Notebook (ER 1105-2-100, Appendix E, Page E-158) states that, "In all but the most unusual cases, the [National Ecosystem Restoration] Plan should be derived from the final set of Best Buy solutions. Other solutions, identified as non-cost effective in cost effectiveness analysis; as well as cost effective plans identified as relatively less efficient in production ('non-Best Buys') in incremental analysis, may continue to be considered for selection. In some cases, the economic and environmental models used to estimate the effects of ecosystem restoration plans are not capable of capturing the full range of such effects, or considerable uncertainty may accompany the estimates of such effects. Other evaluation criteria, such as environmental significance, acceptability, completeness, and effectiveness also impact the decision process." Alternative-3 was identified with the following support:

- The increase in total cost from Alternative-2 to Alternative-1 (both best buys) is substantial (i.e., $13,636,000), while the increase from Alternative-2 to Alternative-3 is significantly reduced (i.e., $6,735,000).

- The alternative is nearly a best buy. The incremental cost is $65,061 from Alternative-2 to Alternative-3, relative to an incremental cost of $63,450 from Alternative-2 to Alternative-1.

- Benefits of Alternative-2 are relatively low, and the sustainability and resilience of a small marsh island is questionable under sea level rise. The larger footprint of Alternative-3 provides substantial benefits in terms of long-term efficacy of the action.

- Dredged sediment is a limited asset in the Jamaica Bay system, and there is a need to beneficially use this resource efficiently for marsh island restoration. Estimated sediment volumes for the three alternatives are 432,790 yd^3, 255,123 yd^3, and 351,952 yd^3 for Alternatives 1, 2, and 3, respectively (Main Report, Section 3.8.2). Alternative 3 is 80,838 yd^3 less sediment which is more consistent with the maximum annual dredging volume. Thus, Alternative-3 is preferred to Alternative-1 relative to this resource constraint.

- Alternative-3 was deemed a preferable cost range for initiating design optimization given the relatively intermediate level of costs. Design optimization sought to increase benefits and reduce costs, which ultimately made the plan more cost efficient (i.e., $37,044/AAFCU shown in Section 5) than either Alternative-2 or Alternative-1.

Table J-12. Site summary for Pumpkin Patch East

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt2	721,250	13.51	1	1	53,380	53,380	17,458,318
Alt3	980,194	17.49	1	0	0	56,041	24,193,105
Alt1	1,245,530	21.77	1	1	63,450	57,202	31,094,142

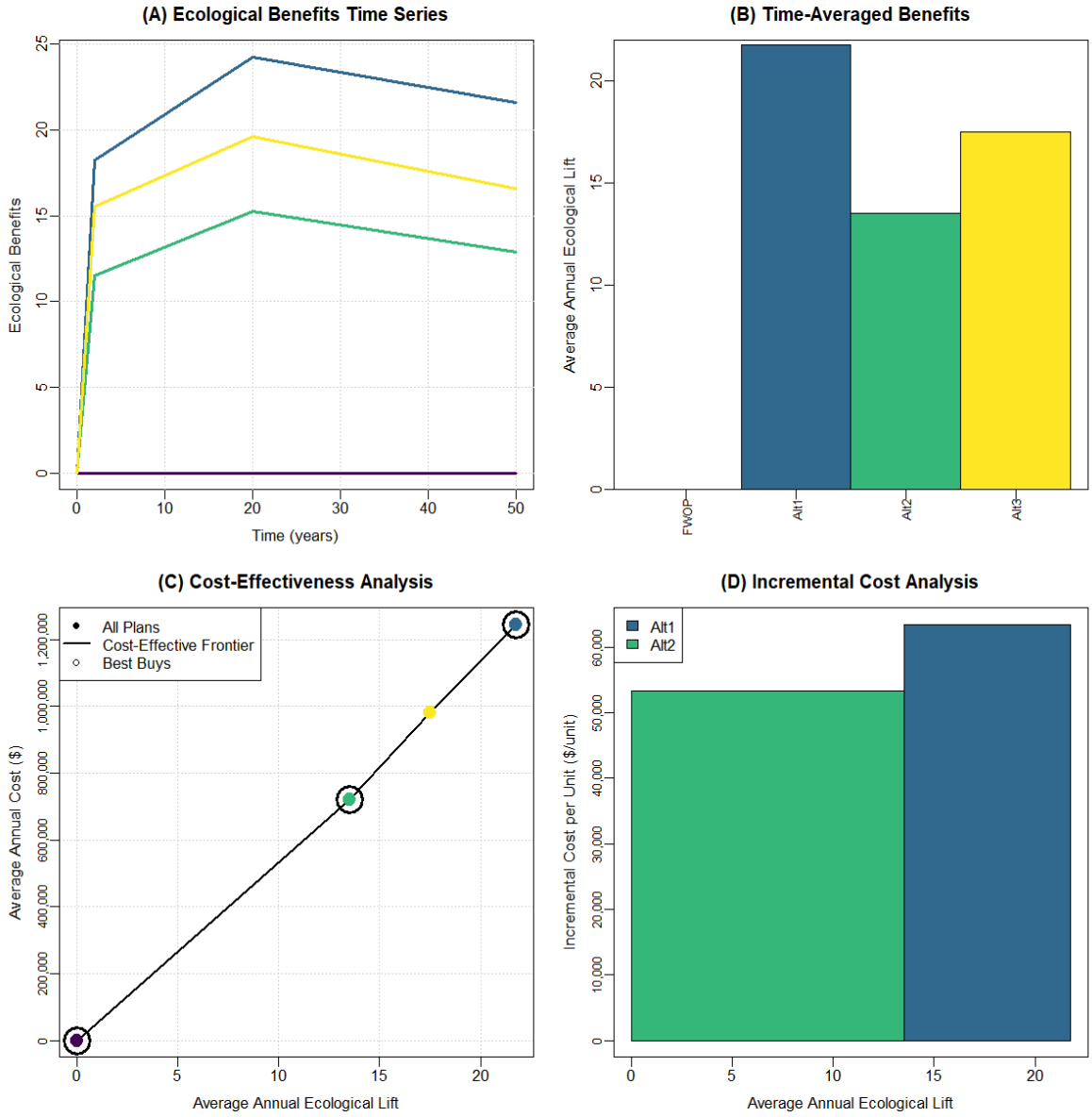

Figure J-10. CE/ICA summary for Pumpkin Patch East

3.11. Elders Center

Alternative-3 was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions.
- The alternative offers high ecological benefits (20 AAFCU) at low unit cost ($42,200 / AAFCU).

Table J-13. Site summary for Elders Center

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
Alt1	621,457	9.9	0	0	0	62,775	14,864,676
Alt2	613,069	12.04	1	0	0	50,927	14,646,500
Alt3	853,506	20.23	1	1	42,192	42,192	20,900,721

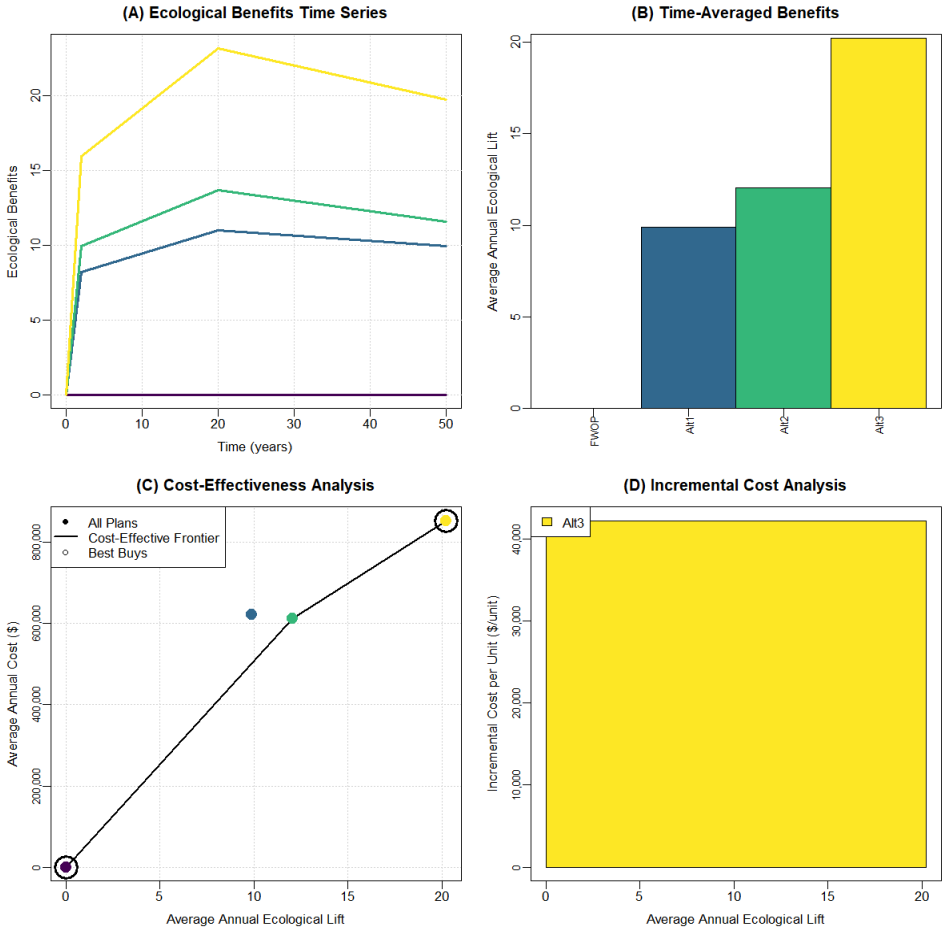

Figure J-11. CE/ICA summary for Elders Center

3.12. Flushing Creek

Alternative-B was identified as the site-scale action with the following support:

- Incremental analysis supports the alternative as a good value with large incremental benefit for small incremental cost.

- The alternative provides 95% of potential benefit at 82% of the potential cost.

Table J-14. Site summary for Flushing Creek

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltA	404,470	5.05	1	1	80,068	80,068	8,549,122
AltB	592,618	7.26	1	1	85,206	81,631	13,513,719
AltC	705,583	7.64	1	1	295,980	92,337	16,491,813

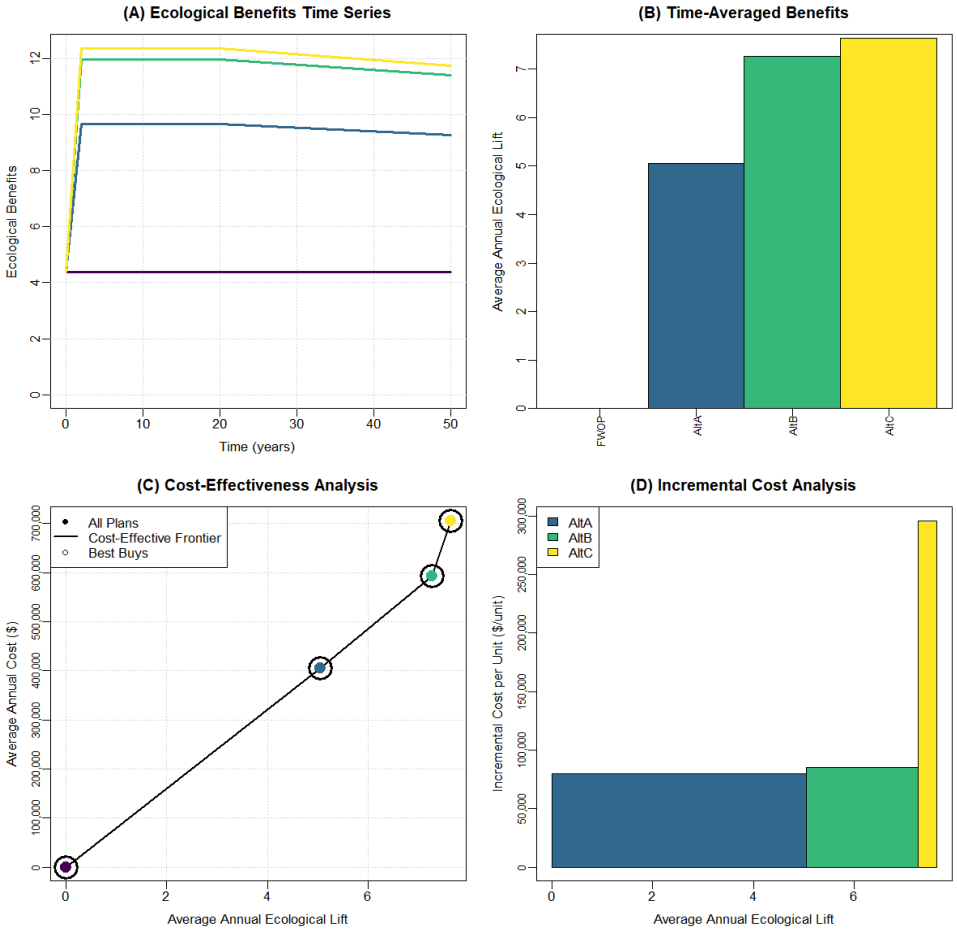

Figure J-12. CE/ICA summary for Flushing Creek

3.13. Bronx Zoo and Dam

Alternative-A was identified as the site-scale action with the following support:

- The alternative is a best buy and provides the maximum benefits at this site.

- Alternatives A, B, and C all provide fish passage benefits at this site, which are crucial to realizing the benefits at Stone Mill Dam. This site is a crucial corridor to the larger upstream ecosystem, and all alternatives meet the connectivity objectives.

- Notably, Alternative-A restores forested scrub/shrub and emergent wetlands on the east bank, which are not included in Alternatives B or C. Ecological models do not fully capture the qualitative benefits of these additional wetlands in the habitat-limited Bronx River ecosystem, where wetlands are extremely scarce.

- Additionally, Alternative-A increases the extent of shoreline wetland environments, which would increase the overall sustainability of actions at this site by further reducing bank erosion and associated downstream sediment loading.

- The additional investment over Alternative-B ($1,376,743) is worth the cost given that the site is downstream of other Bronx River sites and serves an important role connecting upstream sites to the downstream estuary (i.e., the benefits of Stone Mill Dam would not be realized without this site).

Table J-15. Site summary for Bronx Zoo and Dam

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	163,428	1.09	1	0	0	149,355	3,841,719
AltB	204,371	1.39	1	1	147,129	147,129	4,934,598
AltA	255,948	1.69	1	1	170,292	151,275	6,311,341

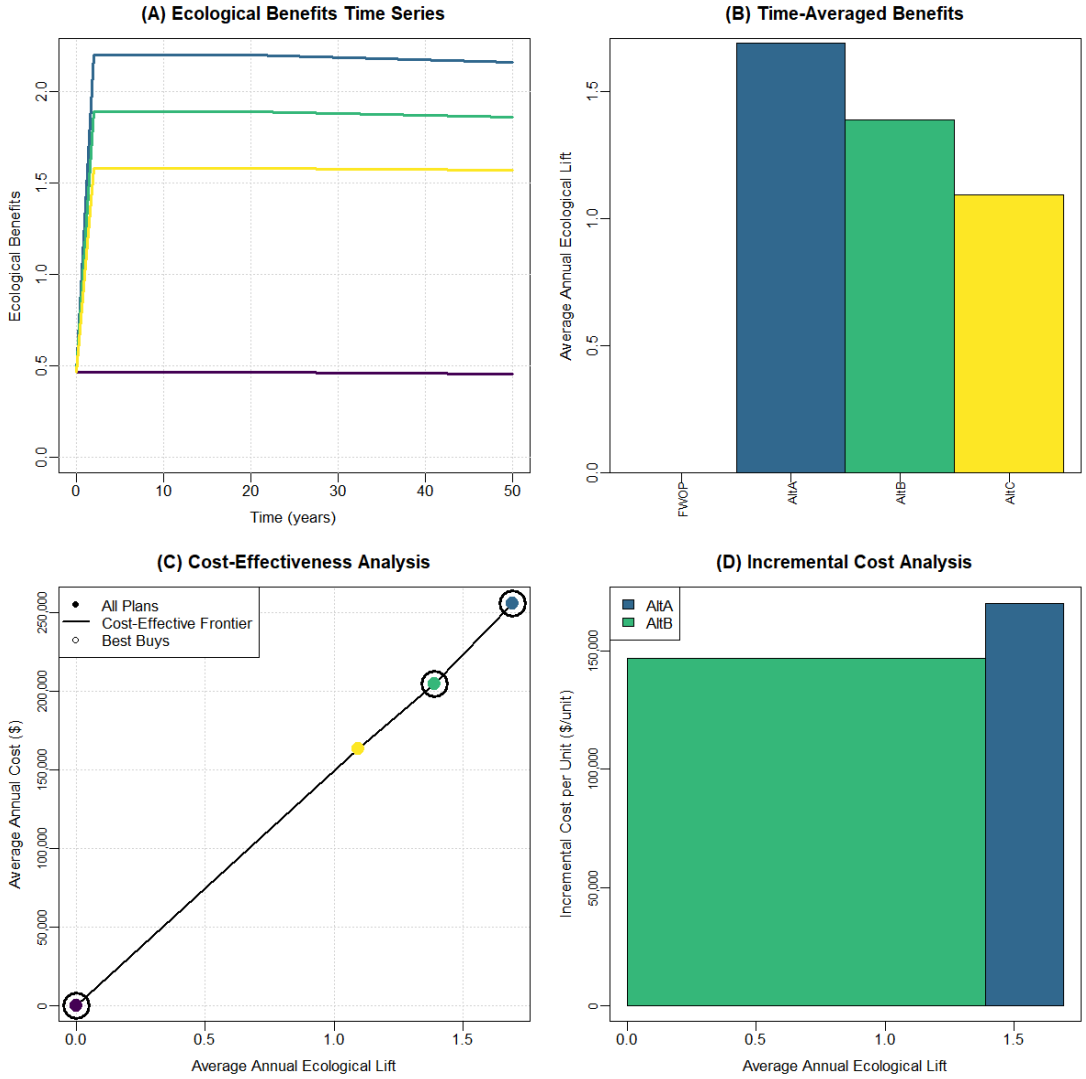

Figure J-13. CE/ICA summary for Bronx Zoo and Dam

3.14. Stone Mill Dam

Alternative-A was identified as the site-scale action with the following support:

- The alternative is a best buy with very large benefits (19 AAHUs) at very low unit cost ($2,900 / AAHU). This largest alternative is acceptable given that the unit cost is the lowest of all HRE restoration sites.

- The additional investment is deemed “worth it” given that the site is downstream of other Bronx River sites and serves an important role connecting upstream sites to the downstream estuary.

Table J-16. Site summary for Stone Mill Dam

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltB	51,572	17.36	0	0	0	2,970	858,351
AltC	45,295	17.4	1	1	2,603	2,603	690,223
AltA	54,241	19	1	1	5,587	2,855	929,827

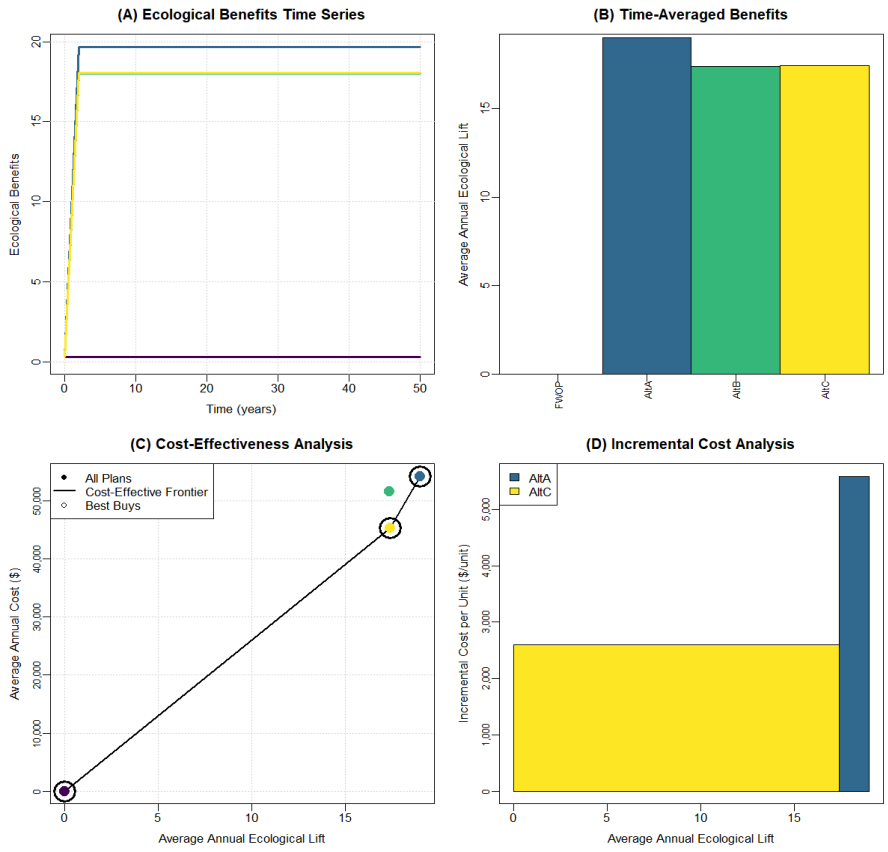

Figure J-14. CE/ICA summary for Stone Mill Dam

3.15. Shoelace Park

Alternative-B was identified as the site-scale action with the following support:

- Incremental analysis supports the alternative as a good value.
- The alternative offers the lowest unit cost of the best buy plans.

Table J-17. Site summary for Shoelace Park

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	362,013	1.66	1	0	0	217,997	9,116,152
AltB	760,408	4.97	1	1	152,923	152,923	18,935,284
AltA	1,006,948	5.73	1	1	326,004	175,771	25,506,579

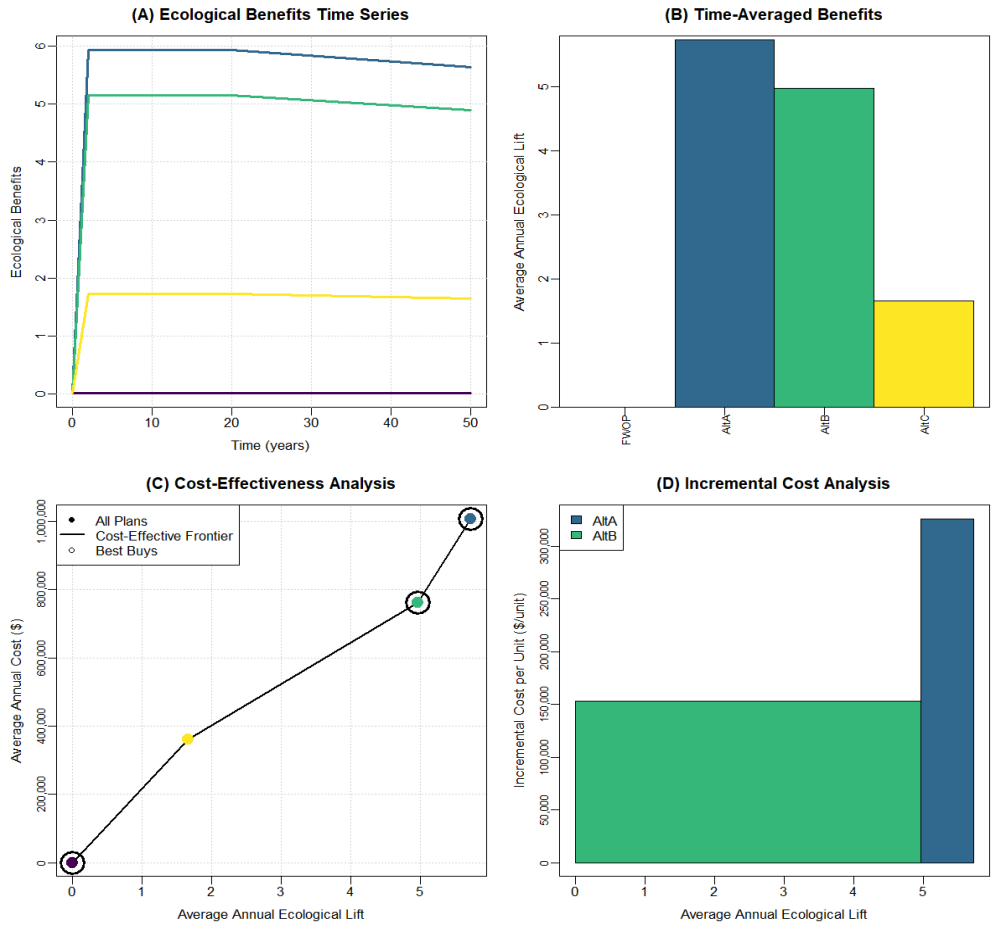

Figure J-15. CE/ICA summary for Shoelace Park

3.16. Bronxville Lake

Alternative-B was identified as the site-scale action with the following support:

- Incremental analysis supports the alternative as a good value.
- The alternative offers the lowest unit cost of the best buy plans.

Table J-18. Site summary for Bronxville Lake

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	597,688	2.74	1	0	0	218,338	14,614,361
AltB	600,726	3.82	1	1	157,057	157,057	14,695,415
AltA	864,975	4.48	1	1	400,578	192,879	21,746,610

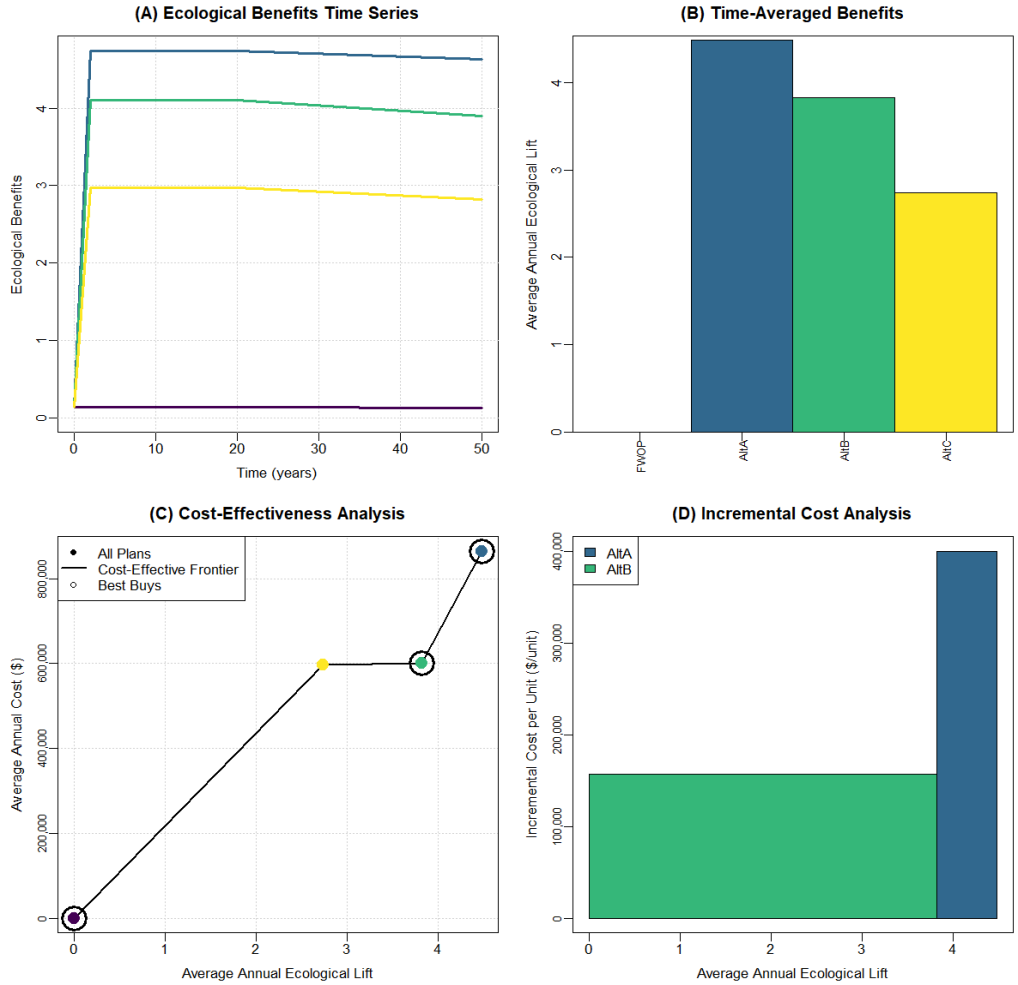

Figure J-16. CE/ICA summary for Bronxville Lake

3.17. Garth Harney

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions.
- The alternative offers the highest ecological benefits (2.5 AAFCU) possible at this site.

Table J-19. Site summary for Garth Harney

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	176,858	0.3	1	0	0	591,226	4,217,834
AltB	275,274	1.25	1	0	0	220,739	6,847,824
AltA	305,228	2.46	1	1	124,046	124,046	7,649,378

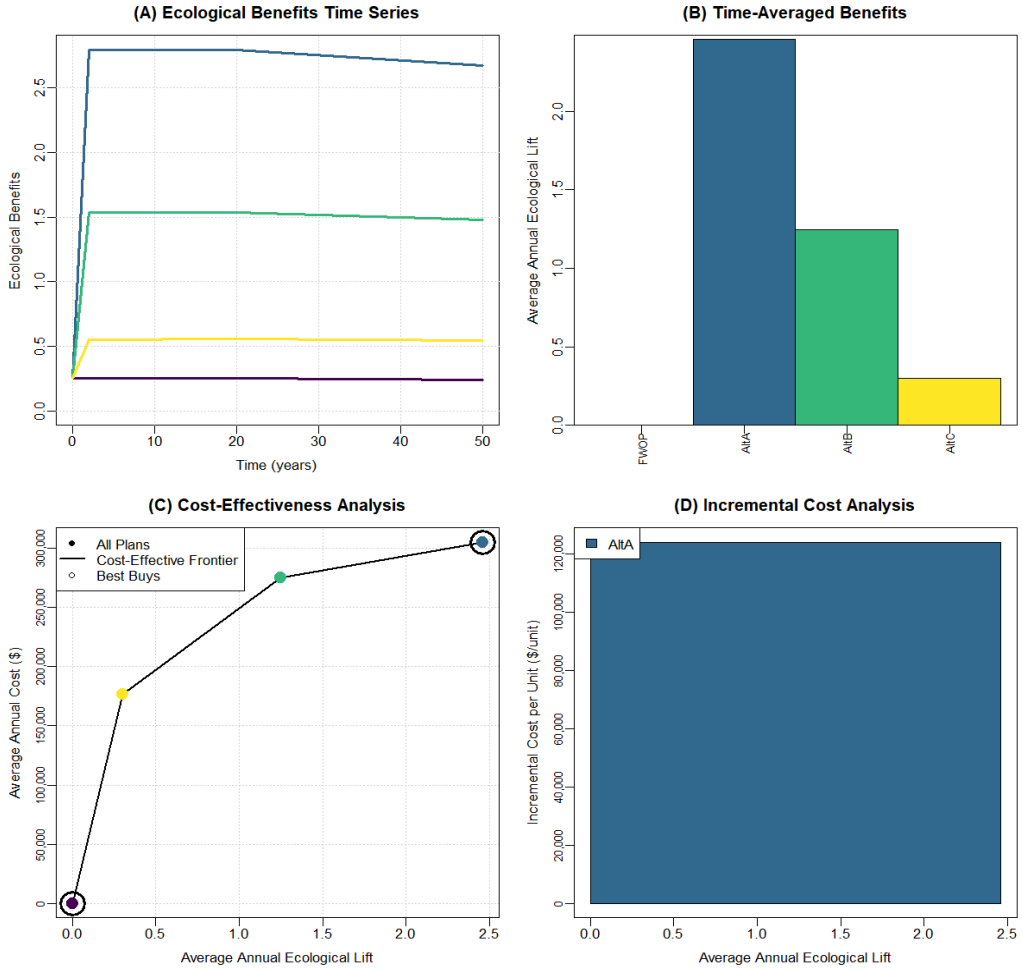

Figure J-17. CE/ICA summary for Garth Harney

3.18. West Farm Rapids Park

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions, although unit cost is high ($371,000 / AAFCU) and the overall ecological lift small (0.5 AAFCU).

Table J-20. Site summary for West Farm Rapids Park

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	125,060	0.18	1	0	0	682,198	2,820,590
AltB	176,920	0.41	1	0	0	426,385	4,206,461
AltA	179,079	0.48	1	1	370,502	370,502	4,264,139

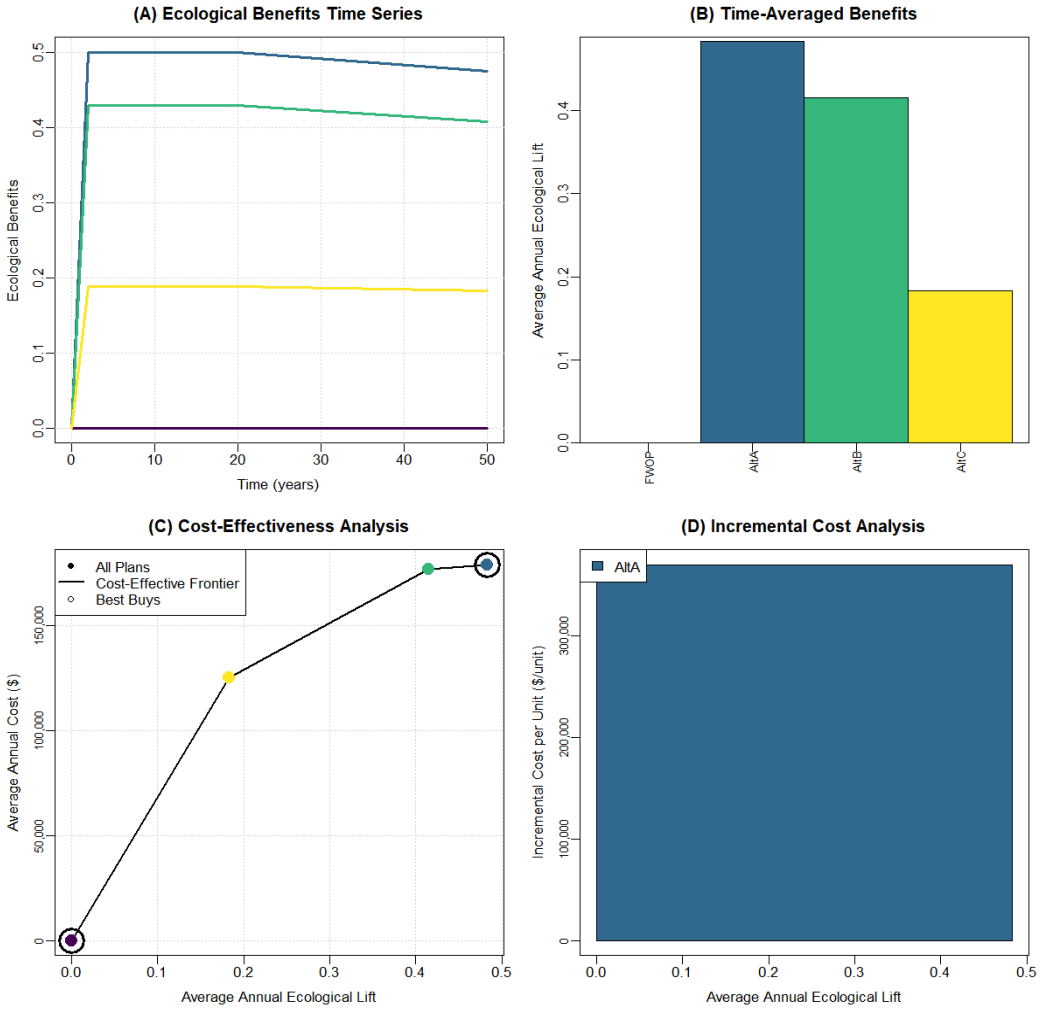

Figure J-18. CE/ICA summary for West Farm Rapids Park

3.19. Muskrat Cove

Alternative-A was identified as the site-scale action with the following support:

- Incremental analysis supports the alternative, although unit cost is very high ($536,000 / AAFCU) and the overall ecological lift small (0.7 AAFCU).

Table J-21. Site summary for Muskrat Cove

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	202,470	0.15	1	0	0	1,318,245	4,336,585
AltA	348,155	0.65	1	1	535,806	535,806	8,121,428
AltB	356,245	0.66	1	1	790,670	539,757	8,325,614

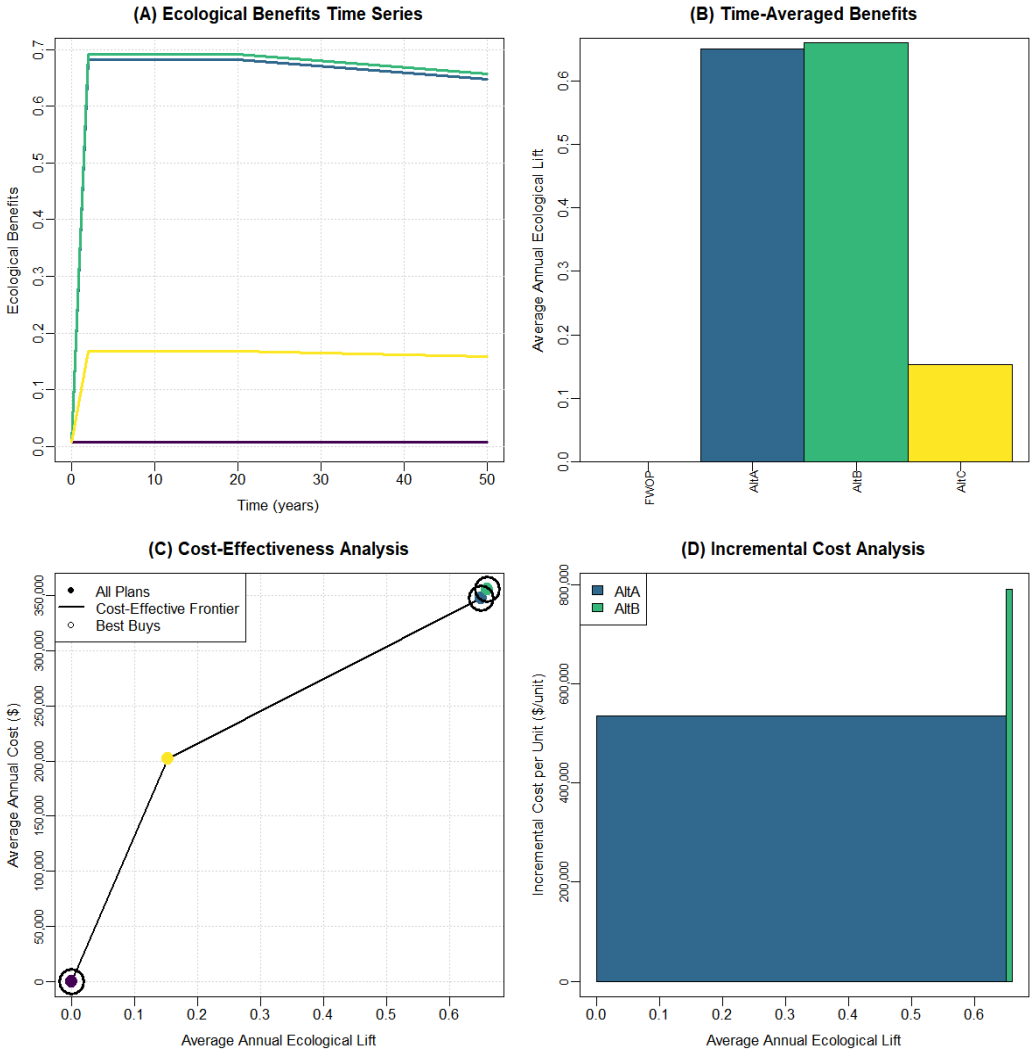

Figure J-19. CE/ICA summary for Muskrat Cove

3.20. Crestwood Lake

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions with the lowest unit cost ($228,000 / AAFCU); but highest total project cost.

Table J-22. Site summary for Crestwood Lake

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	550,928	0.96	1	0	0	571,221	13,086,658
AltB	584,571	1.41	1	0	0	415,183	13,964,964
AltA	1,123,787	4.92	1	1	228,336	228,336	28,051,834

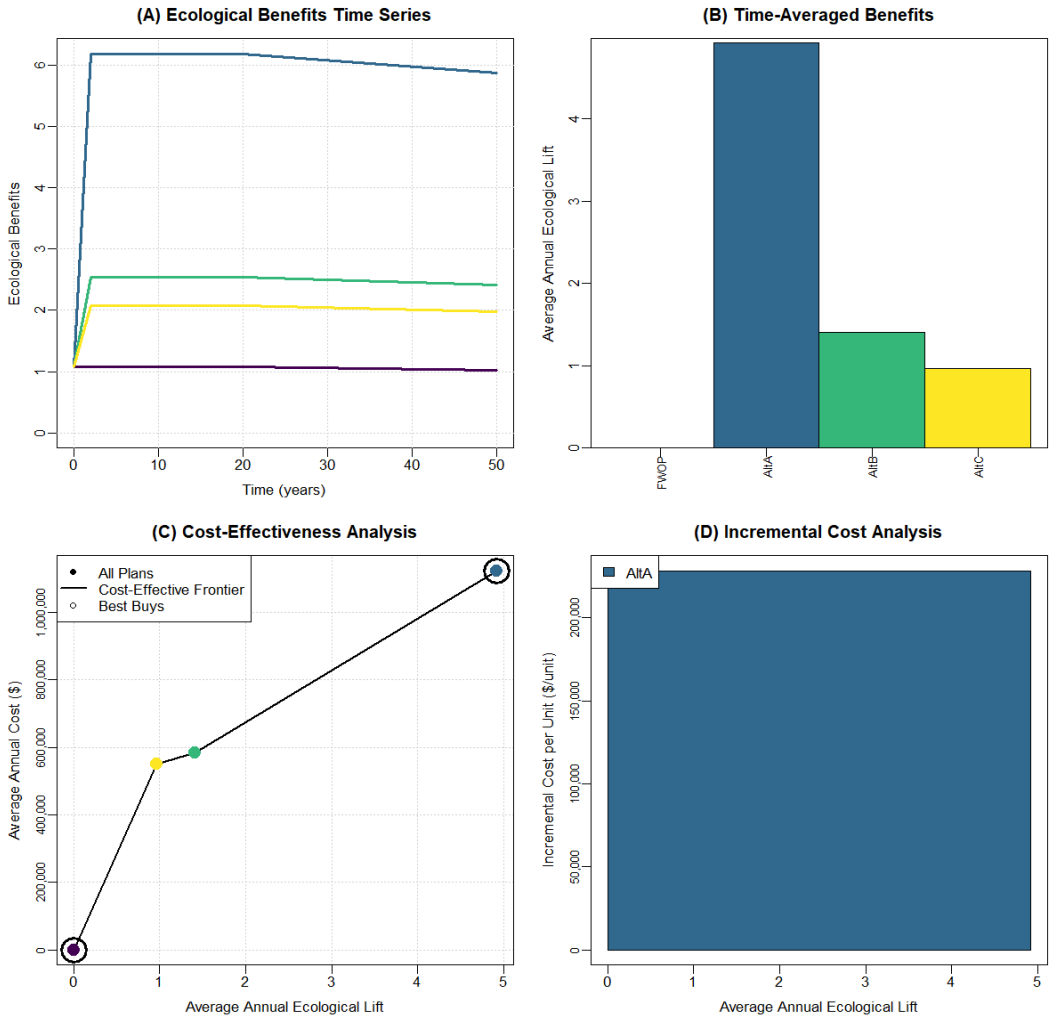

Figure J-20. CE/ICA summary for Crestwood Lake

3.21. Westchester County Center

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions with lowest unit cost ($226,000 / AAFCU); although highest total project cost.

Table J-23. Site summary for Westchester County Center

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	574,478	0.88	1	0	0	650,065	13,995,088
AltB	612,653	1.9	1	0	0	323,233	15,013,732
AltA	996,182	4.41	1	1	226,107	226,107	25,247,775

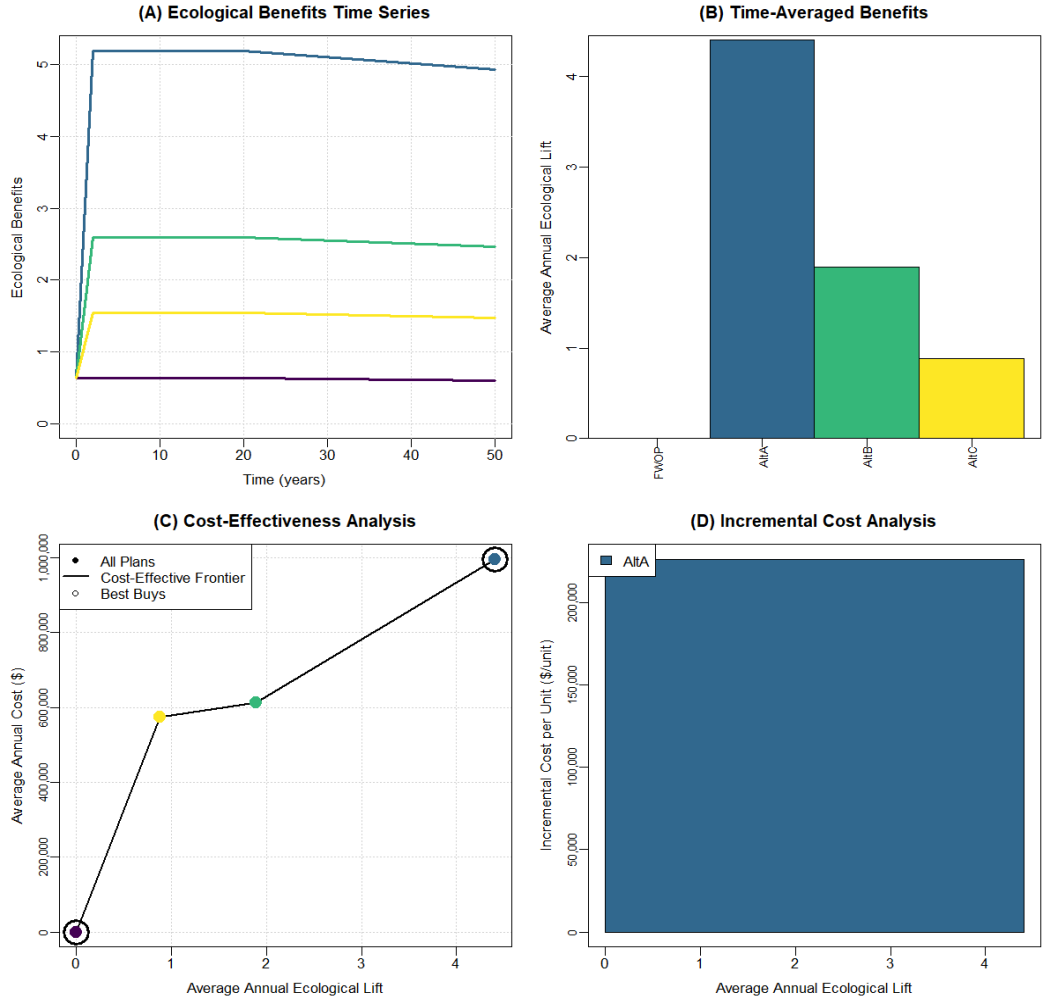

Figure J-21. CE/ICA summary for Westchester County Center

3.22. Oak Island Yards

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions.

Table J-24. Site summary for Oak Island Yards

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltB	775,704	3.52	0	0	0	220,586	19,149,684
AltC	735,543	4.42	1	0	0	166,236	18,089,921
AltA	753,781	4.8	1	1	157,019	157,019	18,571,152

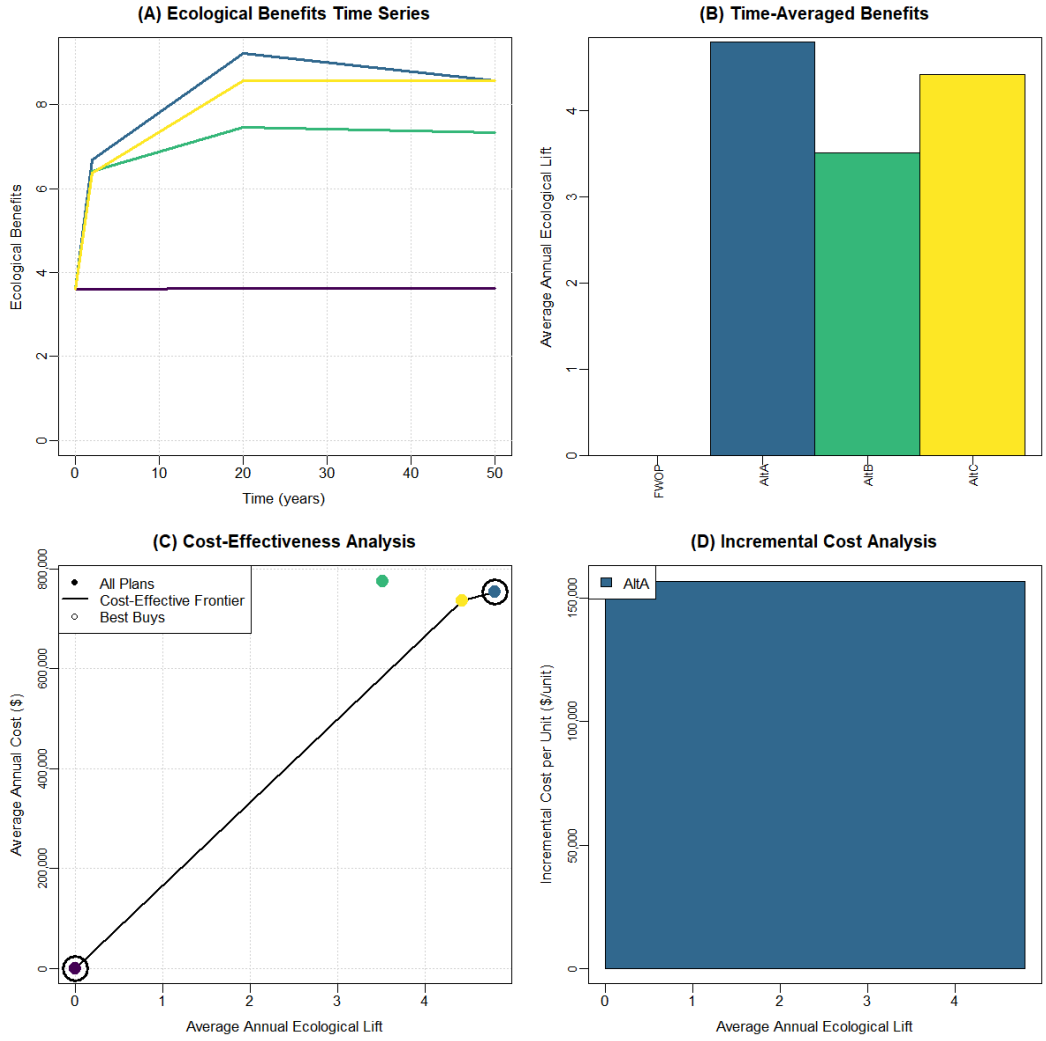

Figure J-22. CE/ICA summary for Oak Island Yards

3.23. Essex County Branch Brook Park

Alternative-D was identified as the site-scale action as a cost-effective alternative, but not a best buy. The Planning Guidance Notebook (ER 1105-2-100, Appendix E, Page E-158) states that, "In all but the most unusual cases, the [National Ecosystem Restoration] Plan should be derived from the final set of Best Buy solutions. Other solutions, identified as non-cost effective in cost effectiveness analysis; as well as cost effective plans identified as relatively less efficient in production ('non-Best Buys') in incremental analysis, may continue to be considered for selection. In some cases, the economic and environmental models used to estimate the effects of ecosystem restoration plans are not capable of capturing the full range of such effects, or considerable uncertainty may accompany the estimates of such effects. Other evaluation criteria, such as environmental significance, acceptability, completeness, and effectiveness also impact the decision process." Alternative-D was identified with the following support:

- The only best buys were the FWOP and Alternative-A, which had a large total cost ($73,215,367). The FWOP did not meet the planning objectives, given the ecological and social importance of this site. Alternative-D provided a level of affordability for the agency and cost-share sponsor, which is consistent with the Planning Guidance Notebook's example of "reasonableness of cost" as an example of other decision-making criteria used to interpret CE/ICA. Said differently, Alternative-D is recommended rather than Alternative-A in light of resource constraints. Alternative-D also facilitates the sponsor investing in multiple sites in the region, which cumulatively provide benefits at a larger scale.

- Alternative-D meets the planning objectives for the site, while omitting features from Alternative-A that increase cost significantly. For instance, Alternative-A includes bank and slope stabilization as well as sediment basins, which provide additional benefits but are relatively costly. Alternative-D preserves the key ecological features (e.g., wetlands, channels, and buffering habitats), which directly address the planning objectives.

- Alternative-D provides a large amount of ecological benefit (22 AAFCU) at an intermediate level of expense relative to the other alternatives. Alternative-D provides 57% more benefits than Alternative-C, which was also cost-effective.

- Alternative-D was deemed a preferable cost range for initiating design optimization given the relatively intermediate level of costs. Design optimization sought to increase benefits and reduce costs, which ultimately made the plan more cost efficient (i.e., $73,529/AAFCU shown in Section 5).

- The incremental cost of Alternative-D ($83,028) is deemed worth the investment at the regional scale, given the ecological and regional importance of this site as part of the Passaic River Urban Waters Federal Partnership.

- The increased incremental cost of Alternative-D is also worth the investment in light of regional considerations. Essex County Branch Brook Park addresses planning objectives

related to freshwater resources, and the cost savings of Alternative-D over Alternative-A facilitates investment at other sites in the region addressing estuarine ecosystems (a separate planning objective). Said differently, the increased incremental cost of Alternative-D allows the larger HRE recommendation to better meet system-wide planning objectives including both freshwater and estuarine resources.

- At a regional scale, multiple sites also lead to system-scale functions not adequately captured in the patch-scale EPW models. For instance, multiple restoration locations provide additional connectivity benefits to migratory birds. As such, a smaller alternative (Alternative-D) facilitates investment at multiple sites, given resource constraints.

Table J-25. Site summary for Essex County Branch Brook Park

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	937,928	14.21	1	0	0	66,003	22,613,383
AltD	1,855,027	22.34	1	0	0	83,028	47,413,586
AltB	2,860,240	37.54	0	0	0	76,190	73,282,163
AltA	2,857,716	47.22	1	1	60,518	60,518	73,215,637

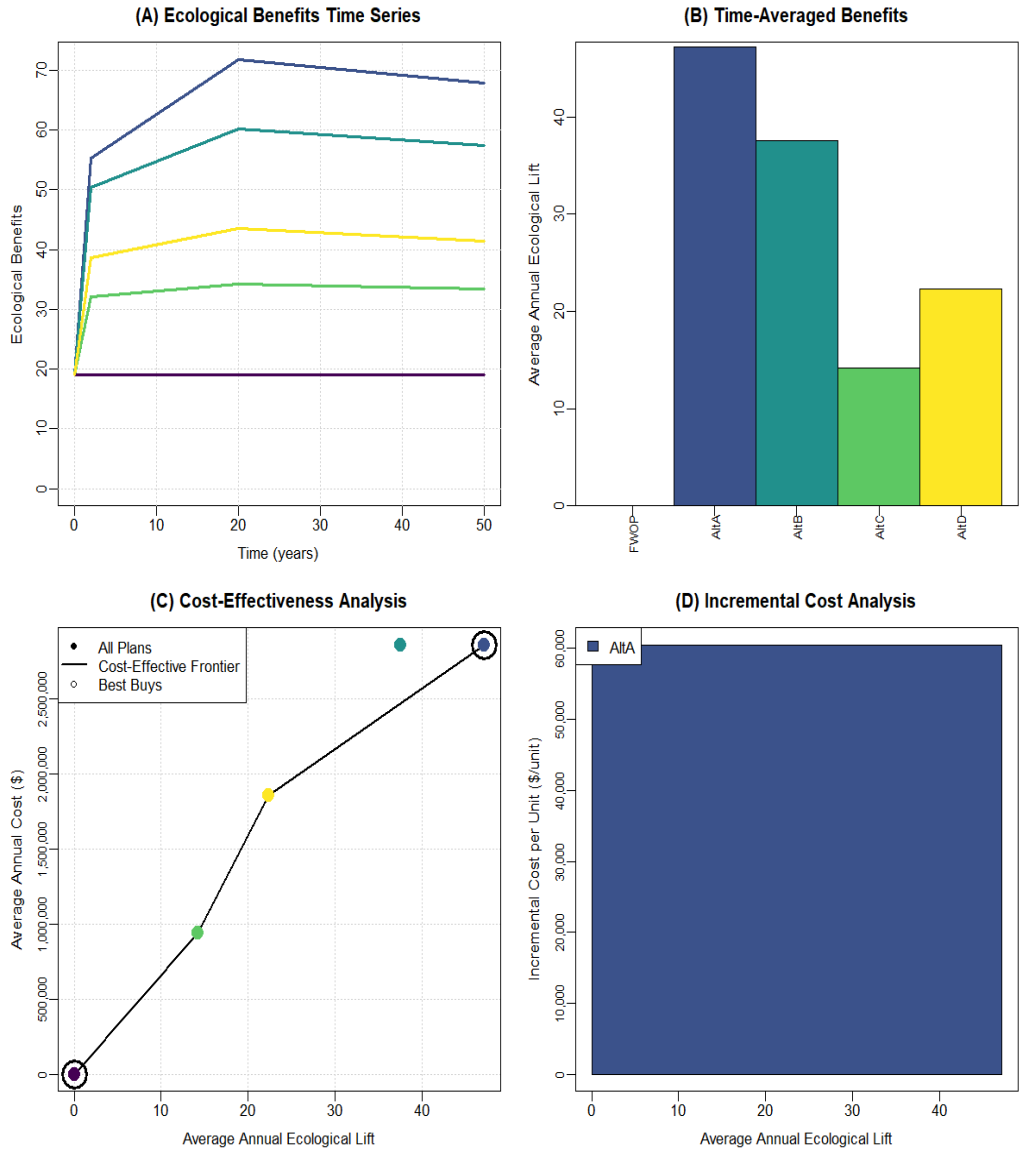

Figure J-23. CE/ICA summary for Essex County Branch Brook Park

3.24. Clifton Dundee Canal Green Acres

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions, although unit cost is high ($291,000 / AAFCU).

Table J-26. Site summary for Clifton Dundee Canal Green Acres

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	300,325	0	0	0	0	0	7,388,061
AltB	339,990	0.1	1	0	0	3,576,000	8,432,467
AltA	363,553	1.25	1	1	290,902	290,902	9,053,210

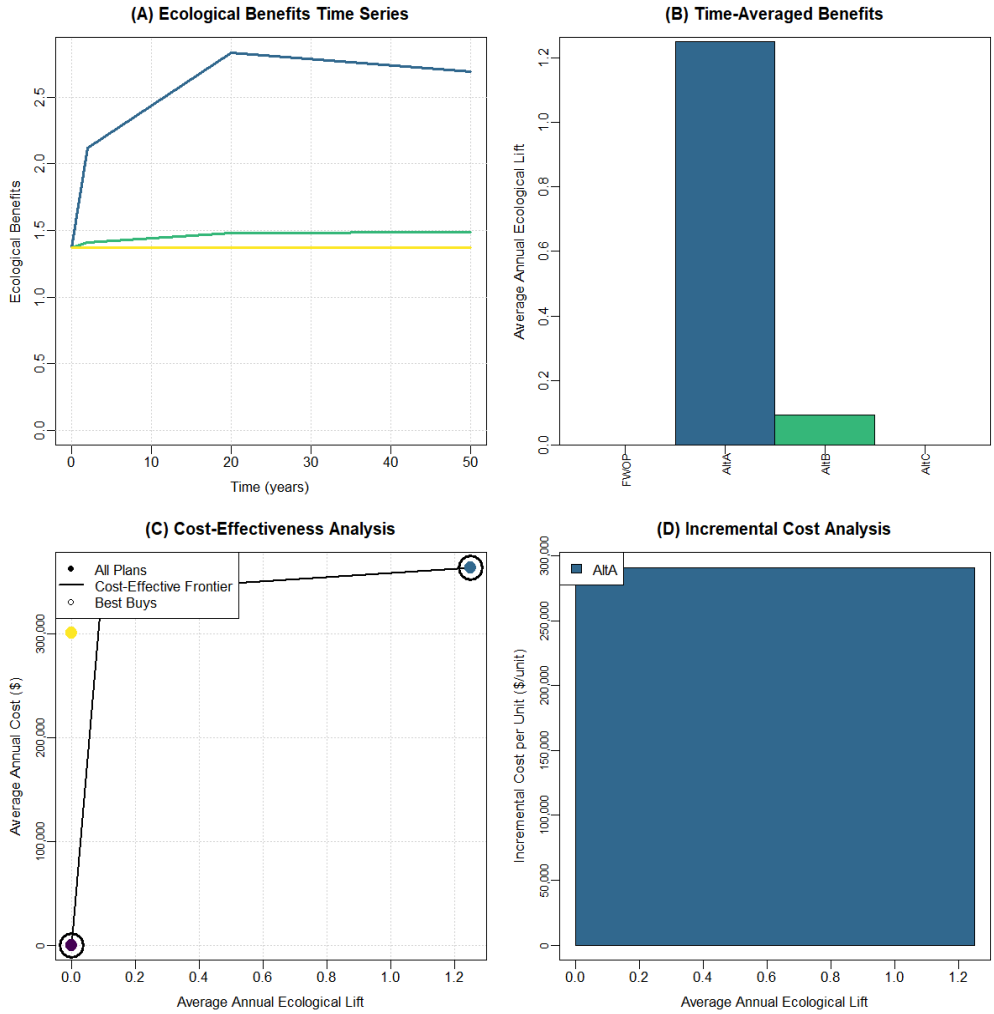

Figure J-24. CE/ICA summary for Clifton Dundee Canal Green Acres

3.25. Dundee Island Park

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy, although unit cost is high ($287,000 / AAFCU).

Table J-27. Site summary for Dundee Island Park

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltA	124,161	0.43	1	1	286,974	286,974	2,771,005

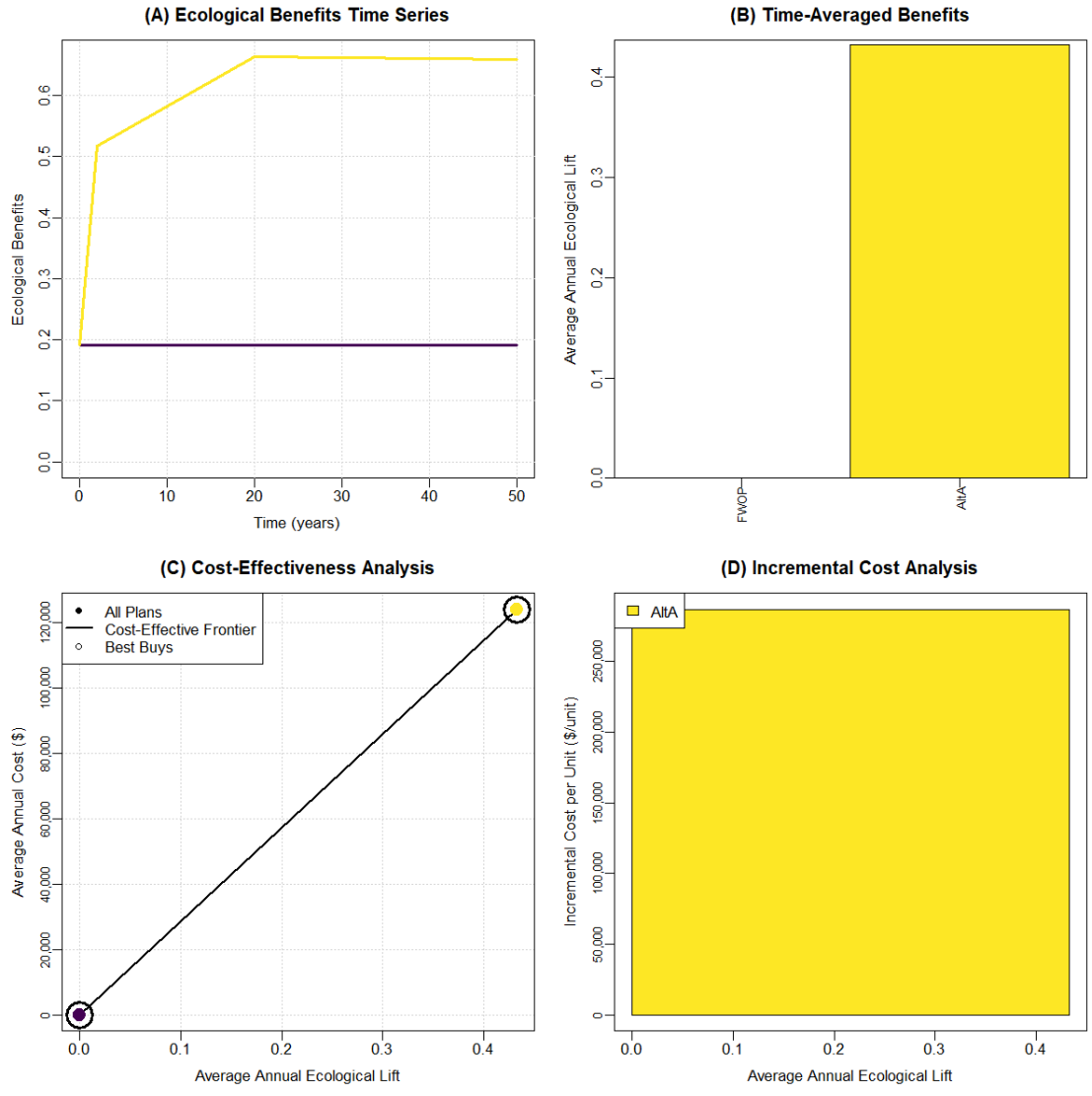

Figure J-25. CE/ICA summary for Dundee Island Park

3.26. Kearny Point

Alternative-A was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions with the lowest unit cost ($205,000 / AAFCU), although total project cost is high.

Table J-28. Site summary for Kearny Point

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	1,610,156	5.21	1	0	0	308,821	40,332,061
AltB	1,868,294	5.98	1	0	0	312,589	47,136,120
AltA	2,057,073	10.04	1	1	204,899	204,899	52,111,997

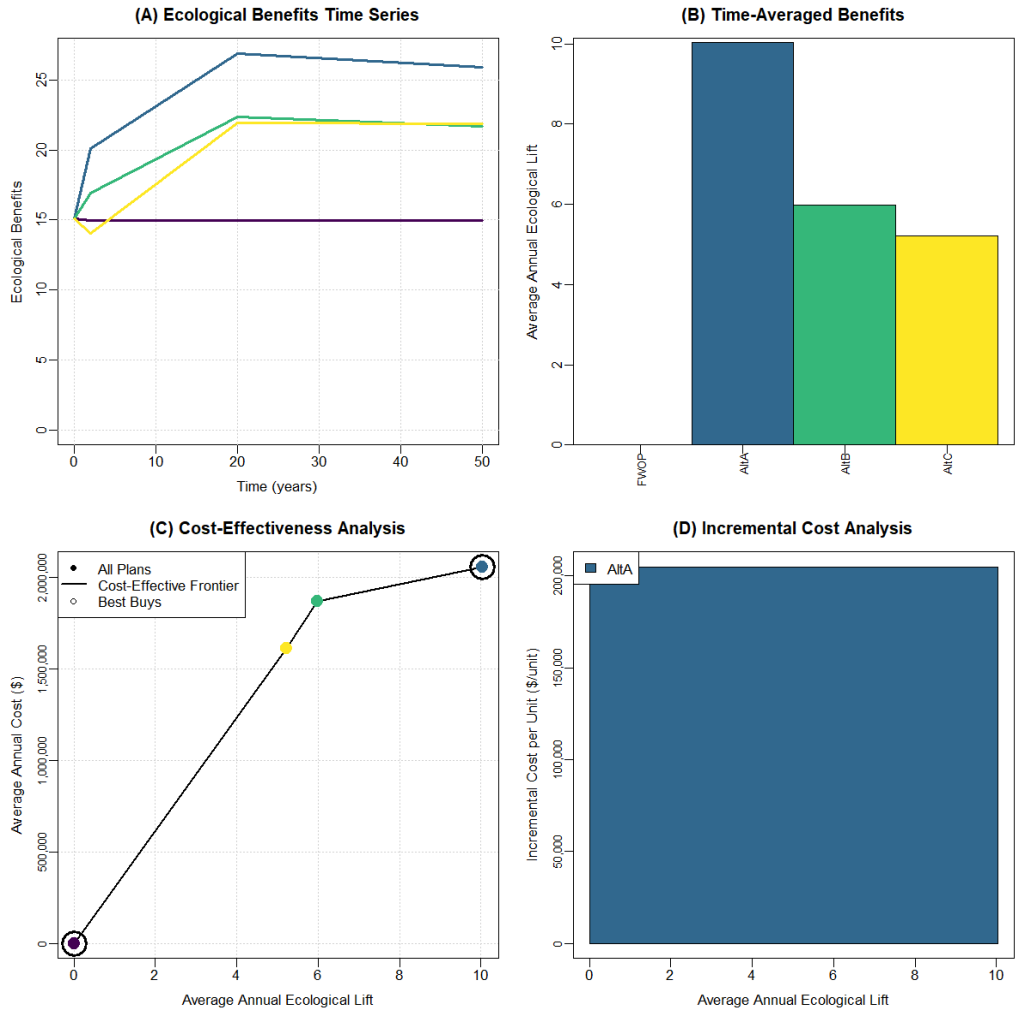

Figure J-26. CE/ICA summary for Kearny Point

3.27. Metromedia Tract

Alternative-A was identified as the site-scale action with the following support:

- Incremental analysis supports the alternative as a good value.
- The alternative offers the lowest unit cost of the best buy plans.

Table J-29. Site summary for Metromedia Tract

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltC	1,294,977	13.44	0	0	0	96,360	31,667,595
AltA	1,137,241	13.45	1	1	84,525	84,525	28,338,217
AltB	1,860,425	13.72	1	1	2,687,279	135,564	46,405,671

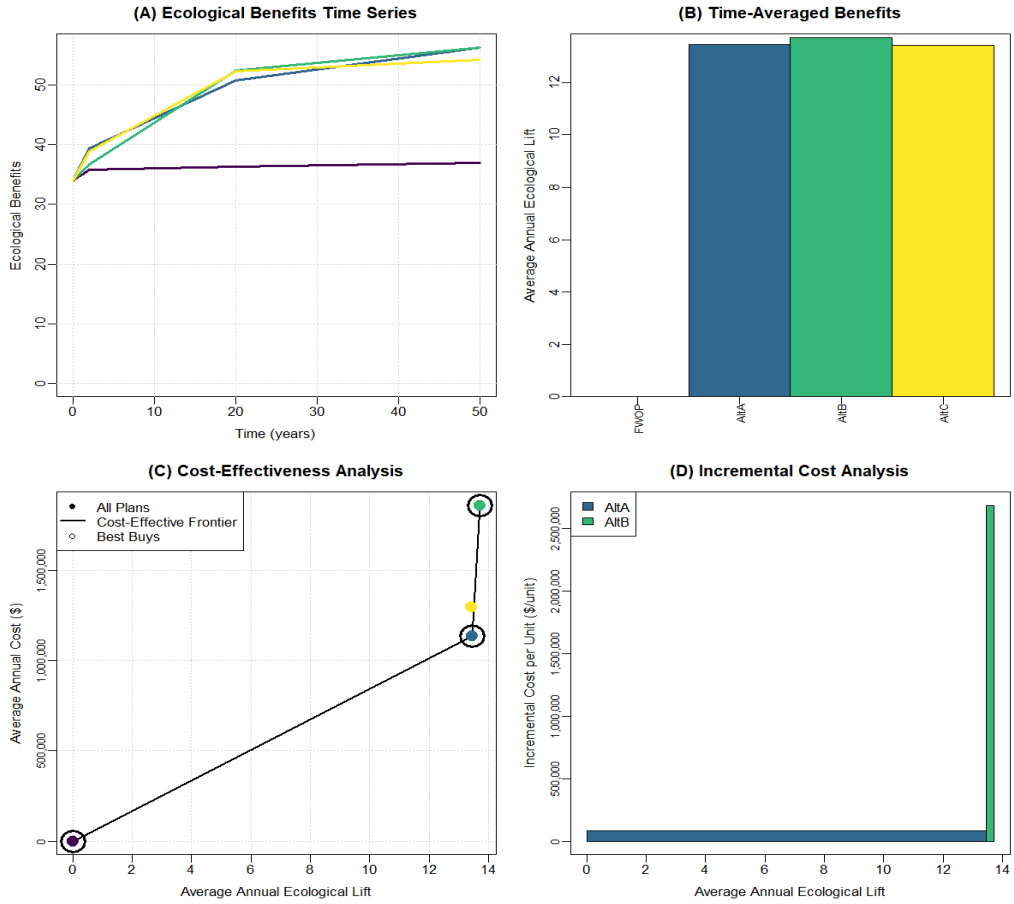

Figure J-27. CE/ICA summary for Metromedia Tract

3.28. Meadowlark Marsh

Alternative-C was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions.
- The alternative offers high ecological benefits (15 AAFCU) at low unit cost ($123,600 / AAFCU).

Table J-30. Site summary for Meadowlark Marsh

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltA	2,588,139	9.07	0	0	0	285,395	65,373,280
AltB	2,369,877	10.62	0	0	0	223,171	59,684,403
AltC	1,911,889	15.47	1	1	123,589	123,589	47,747,190

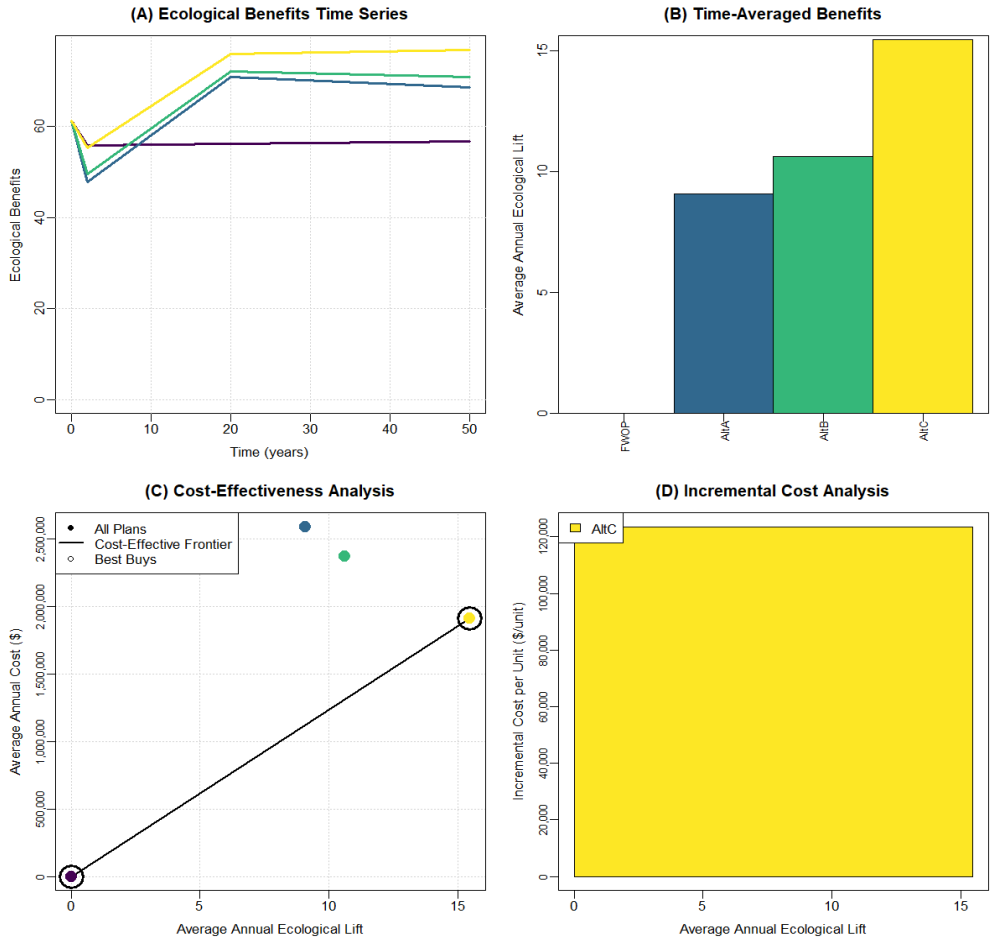

Figure J-28. CE/ICA summary for Meadowlark Marsh

3.29. Naval Weapons Station Earle

Alternative-C was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions.
- The alternative offers high ecological benefits (10 AAHU) at low unit cost ($14,700 / AAHU).

Table J-31. Site summary for Naval Weapons Station Earle

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltA	55,108	2.88	1	0	0	19,149	1,225,750
AltB	93,239	5.75	1	0	0	16,208	2,249,310
AltC	141,160	9.58	1	1	14,731	14,731	3,519,917

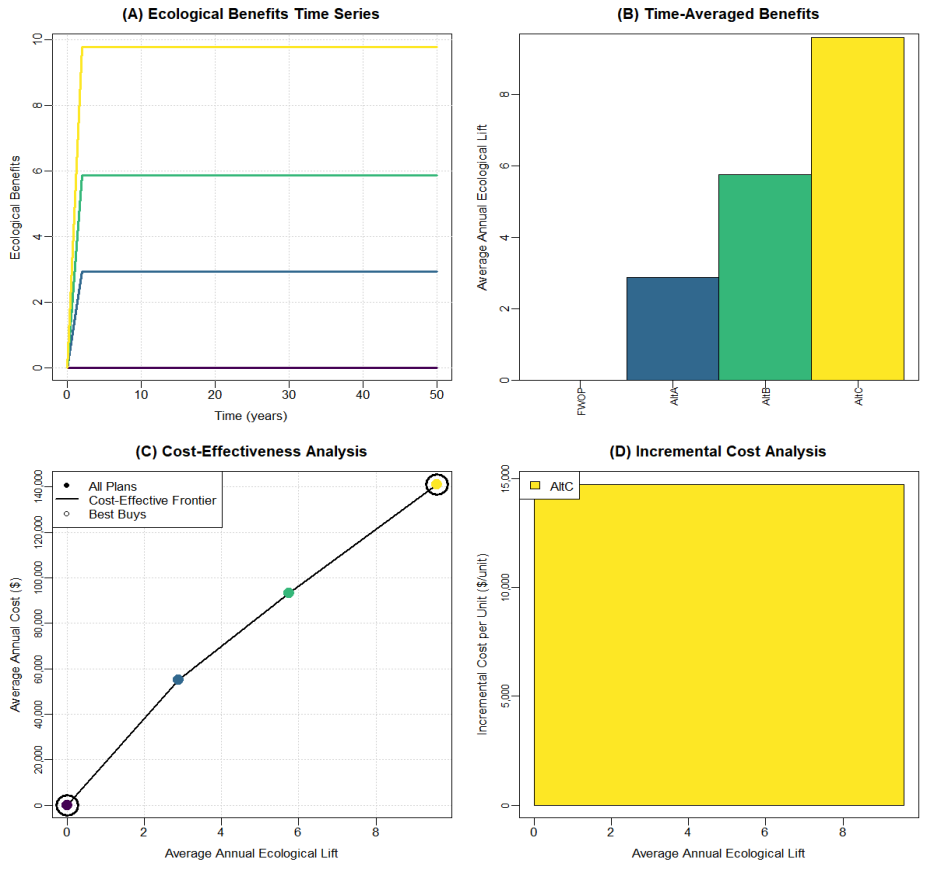

Figure J-29. CE/ICA summary for Naval Weapons Station Earle

3.30. Bush Terminal

Alternative-C was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions.
- The alternative offers high ecological benefits (20 AAHU) at low unit cost ($18,000 / AAHU).

Table J-32. Site summary for Bush Terminal

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltA	129,449	6.7	1	0	0	19,310	3,223,398
AltB	183,836	9.87	1	0	0	18,621	4,682,254
AltC	350,169	19.5	1	1	17,956	17,956	9,113,921

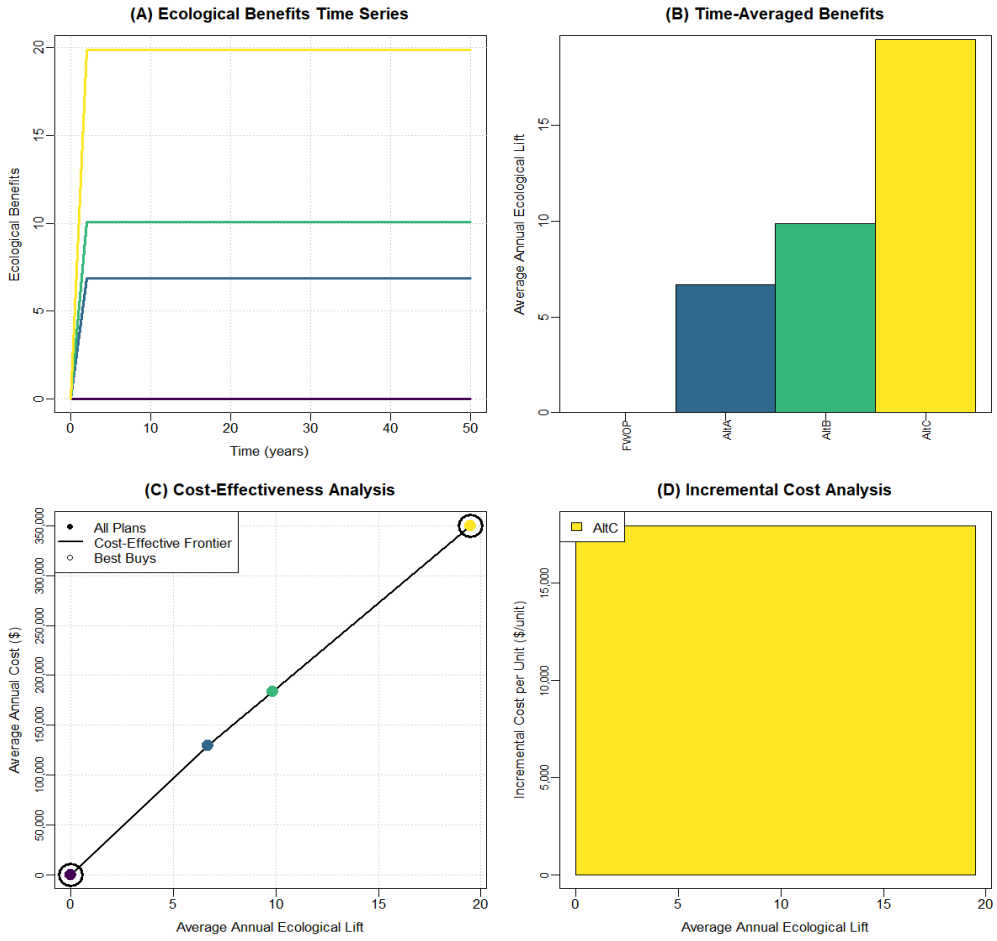

Figure J-30. CE/ICA summary for Bush Terminal

3.31. Head of Jamaica Bay

Alternative-C was identified as the site-scale action with the following support:

- The alternative is the only best buy of the proposed actions.
- The alternative offers important oyster reef habitat, which is scarce in Jamaica Bay.
- The low unit cost ($31,600 / AAHU) is a good value.

Table J-33. Site summary for Head of Jamaica Bay

Alternative	Avg Ann Cost ($)	Lift (AAFCU)	CE?	BB?	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)
FWOP	0	0	1	1	0	0	0
AltA	55,898	1.73	1	0	0	32,270	1,248,250
AltB	93,738	3.46	1	0	0	27,063	2,265,129
AltC	132,220	5.25	1	1	25,201	25,201	3,294,396

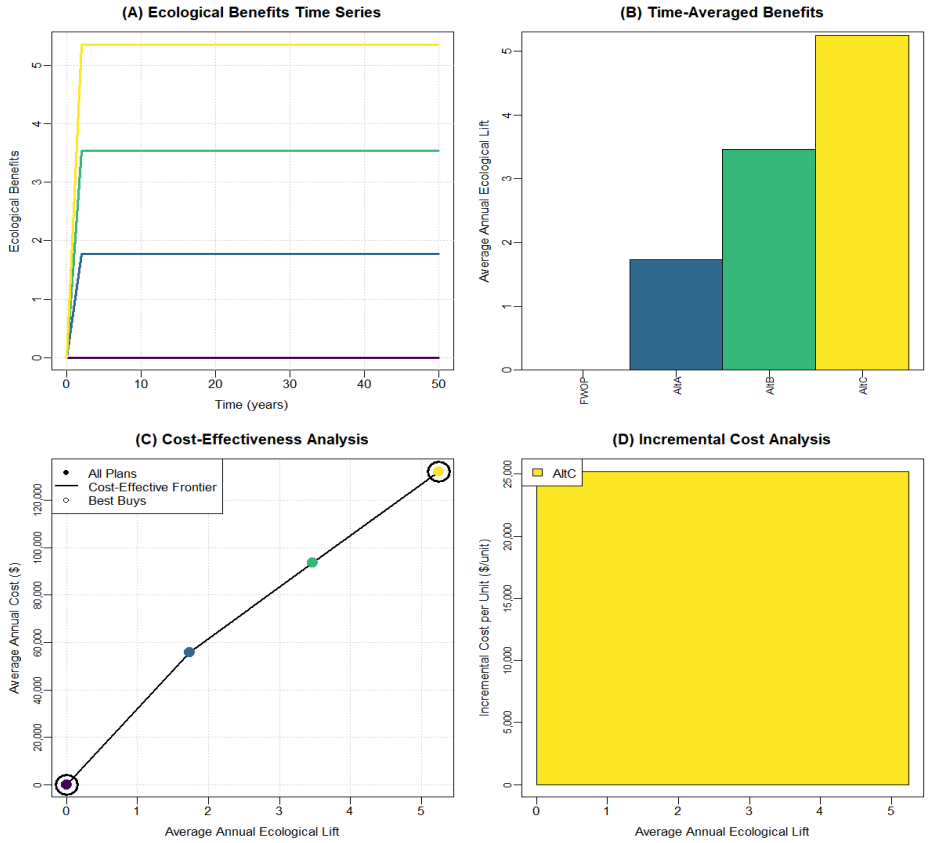

Figure J-31. CE/ICA summary for Head of Jamaica Bay

3.32. Summary of Site-Scale Recommendations

This analysis has focused on the development of recommended alternatives at each of the 31 proposed restoration sites. The following table summarizes the ecological benefits and monetary costs associated with each site-scale recommendation.

Table J-34. Summary of site-scale recommendations prior to system-scale analysis and plan optimization

System	Site	Alternative	Lift (AAFCU)	Avg Ann Cost ($)	Unit Cost ($/AAFCU)	Total Cost ($)
Jamaica Bay Perimeter	Dead Horse Bay	Alt4	35.84	3,330,851	92,936	84,545,962
	Fresh Creek	Alt5	36.78	1,382,939	37,600	33,885,522
	Brant Point	Alt2	3.45	273,007	79,195	6,581,347
	Hawtree Point	Alt1	0.05	101,510	2,242,038	2,131,636
	Bayswater State Park	Alt2	1.14	247,399	217,429	5,916,391
	Dubos Point	Alt3	1.9	396,781	209,024	9,799,056
Jamaica Bay Marsh Islands	Duck Point	Alt2	22.31	970,476	43,490	23,940,123
	Stony Creek	Alt1	29.26	924,034	31,582	22,733,369
	Pumpkin Patch West	Alt2	12.68	875,808	69,071	20,991,688
	Pumpkin Patch East	Alt3	17.49	980,194	56,041	24,193,105
	Elders Center	Alt3	20.23	853,506	42,192	20,900,721
Harlem River, East River and Western Long Island Sound	Flushing Creek	AltB	7.26	592,618	81,631	13,513,719
	Bronx Zoo and Dam	AltA	1.69	255,948	151,275	6,311,341
	Stone Mill Dam	AltA	19	54,241	2,855	929,827
	Shoelace Park	AltB	4.97	760,408	152,923	18,935,284
	Bronxville Lake	AltB	3.82	600,726	157,057	14,695,415
	Garth Harney	AltA	2.46	305,228	124,046	7,649,378
	West Farm Rapids Park	AltA	0.48	179,079	370,502	4,264,139
	Muskrat Cove	AltA	0.65	348,155	535,806	8,121,428
	Crestwood Lake	AltA	4.92	1,123,787	228,336	28,051,834
	Westchester County Center	AltA	4.41	996,182	226,107	25,247,775
Newark Bay, Hackensack River and Passaic River	Oak Island Yards	AltA	4.8	753,781	157,019	18,571,152
	Essex County Branch Brook Park	AltD	22.34	1,855,027	83,028	47,413,586
	Clifton Dundee Canal Green Acres	AltA	1.25	363,553	290,902	9,053,210

System	Site	Alternative	Lift (AAFCU)	Avg Ann Cost ($)	Unit Cost ($/AAFCU)	Total Cost ($)
	Dundee Island Park	AltA	0.43	124,161	286,974	2,771,005
	Kearny Point	AltA	10.04	2,057,073	204,899	52,111,997
	Metromedia Tract	AltA	13.45	1,137,241	84,525	28,338,217
	Meadowlark Marsh	AltC	15.47	1,911,889	123,589	47,747,190
Oyster Reef Restoration	Naval Weapons Station Earle	AltC	9.58	141,160	14,731	3,519,917
	Bush Terminal	AltC	19.5	350,169	17,956	9,113,921
	Head of Jamaica Bay	AltC	5.25	132,220	25,201	3,294,396

4. System-Scale CE/ICA

The preceding analyses have focused on site-scale outcomes of restoration with minimal consideration of system-wide effects of actions at multiple sites. This section analyzes system-wide restoration outcomes for each planning region. All combinations of restoration sites are considered for each of the five system types (e.g., Jamaica Bay Marsh Islands). Each system is then subjected to three types of analyses, all of which intend to clarify the agency's recommendation and explain the logic behind the challenging issue of "How much ecosystem restoration is worth the Federal investment?"

4.1. Methods

Three distinct methods are applied to inform system-scale recommendations (all of which are summarized in McKay et al. (in revision for *Anthropocene*)):

- System-scale CE/ICA: Plans are developed and analyzed for each system type relative to ecological benefits and costs.

- Secondary decision factors: "Unintended consequences" of each system-scale plan are assessed relative to environmental justice, ecosystem services, stakeholder support, and USACE technical significance.

- Decision summaries: Data are synthesized and summarized to inform decision-making.

4.1.1. System-Scale Plan Development

Site-level recommendations are combined into regional plans including all combinations of sites. Each plan represents a different combination of sites (e.g., No sites vs. A-only vs. B-only vs. A+B). These analyses compute CE/ICA outcomes for all five systems. All possible site combinations were computed for each planning set; however, some planning sets have more sites and thus many more combinations of sites (e.g., 10 sites in the Harlem River, East River and Western Long Island Sound planning region can be combined into 1,024 unique plans). These analyses output data for each system type and serve as a basis for system-wide decision-making. Notably, all ecological benefits used in these analyses include the effects of sea level change, where appropriate.

4.1.2. Secondary Decision Factors

USACE policy instructs teams to recommend a restoration plan that cost-effectively delivers ecological benefits. In particular, the Planning Guidance Notebook (ER 1105-2-100) directs teams to consider all monetary and non-monetary costs and benefits and recommend a plan that "*reasonably maximize[s] overall project benefits*" (ER 1105-2-100, Appendix C, Page C-5, emphasis added here). Furthermore, "the results of incremental analysis must be synthesized with other decision-making criteria (for example, significance of outputs, acceptability, completeness, effectiveness, risk and uncertainty, reasonableness of costs) to help the planning team select and recommend a particular plan" (ER 1105-2-100, Appendix E, Page E-153). The following five issues are then highlighted to help teams interpret CE/ICA outputs and justify project recommendations (ER 1105-2-100, Appendix E, Page E-157):

- *Curve Anomalies* -Inflection points in the response of benefits and costs (from CE/ICA) can indicate non-linear changes in the agency's return on investment.

- *Output Targets* -Some studies have specific quantitative goals such as restoration of a specific amount of habitat restoration agreed to as part of a broader, multi-stakeholder planning agreement.

- *Output Thresholds* -Some ecological systems may exhibit well-defined threshold responses (e.g., minimum patch size for a key focal taxa), which can serve as a basis for selecting a particular plan.

- *Cost Affordability* -Implementation funding can be a constraint from either a legislative threshold (e.g., maximum investment under a particular authority) or practical threshold (e.g., maximum investment affordable to both USACE and cost-share sponsors).

- *Unintended Effects* -"Decisions to recommend a particular cost effective or best buy plan are not made in isolation. Other factors that matter in terms of selecting one alternative over another could include, for example, land ownership, effects on other outputs, and effects on nearby stakeholders. It is possible that the unintended consequences could be just as important as the primary project purpose of ecosystem restoration. The importance and magnitude of these unintended effects will of course vary from study to study."

The first four of these factors are largely derived from close examination of CE/ICA and contextual knowledge of the decision (e.g., local ecological knowledge, negotiation with non-Federal sponsor). However, unintended effects are more challenging to capture and are often addressed narratively in the discussion of what level of investment is appropriate. In this section, we take a more rigorous view of unintended effects by building a more quantitative view of this concept.

Urban ecosystems often produce important social and economic outcomes, which may be important considerations for decision-making. While not the focal point of plan formulation, these other social effects may be secondary goals, provide context regarding the unintended, positive consequences of restoration, and assist decision-makers in making judgments about whether a larger restoration plan is "worth the investment." Four key factors were identified as important context for HRE decision-making: environmental justice, ecosystem services, stakeholder support, and USACE technical significance.

Environmental Justice: The study area is one of the most demographically diverse regions in the United States, and equitable allocation of the benefits and costs of ecosystem management have become key issues in restoration and conservation (e.g., 1 of 16 goals of the Convention on Biological Diversity is "to promote equity and benefit-sharing," CBD 2017) as well as federal project planning (Executive Order 12898). Although social equity encapsulates many factors, we focus on the distributional aspect of restoration benefits (Montambault et al. 2018). We computed two proxies for social equity issues at each restoration site: total population and classification as environmental justice communities. First, total population near restoration sites was assessed for a one-mile "halo" surrounding the project area (Figure J-32). Total population

was summed for any census block wholly or partially contained within this one-mile boundary (2010 Census data).

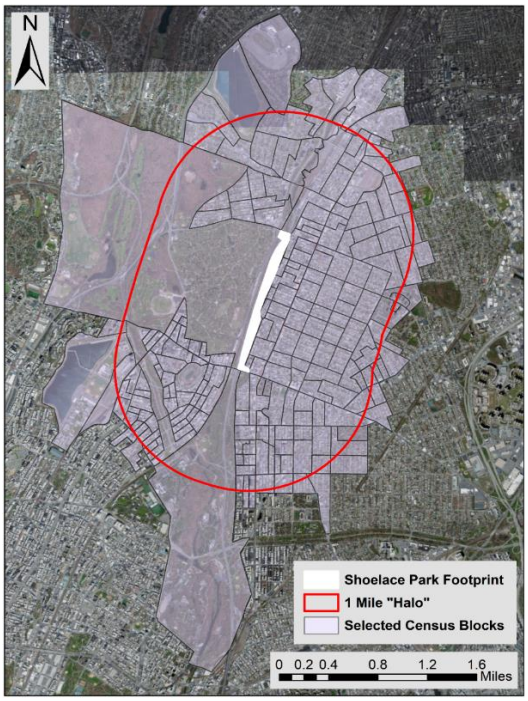

Figure J-32. Method of isolating a one-mile "halo" around each restoration site for census estimates (example from Shoelace Park).

Second, we identified each adjacent community's status as a Potential Environmental Justice Area (PEJA). Environmental justice is "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies" (EPA 2017). The New York State Department of Environmental Conservation identifies PEJAs as census block groups meeting one or more of the following criteria (NYSDEC 2018): 51.1% or more of the population are members of minority groups in an urban area, 33.8% or more of the population are members of minority groups in a rural area, or 23.59% or more of the population in an urban or rural area have incomes below the federal poverty level. Using the census blocks identified above, population of minority residents (any group other than non-Hispanic White alone; Colby and Ortman 2015) and population with income less than the federal determination of poverty (US Census Bureau 2017) was compiled, and data were summarized in the binary context of PEJA or non-PEJA based on the state criteria. This criteria allowed for prioritization based not only on the benefits produced by a project, but also the equitable allocation of those benefits among watershed residents. Notably, restoration projects may have temporary negative effects on these communities (e.g., construction noise and traffic), but these effects were deemed acceptable in light of positive long-term outcomes.

Ecosystem Services: Urban ecosystems have many users and functions, particularly in the population-dense New York City metropolitan area. Citizens and project sponsors are often interested in the "benefits people obtain from ecosystems" (i.e., ecosystem services, Millennium Ecosystem Assessment 2005), which can include diverse outcomes such as recreational access

and water quality improvement. While many services may be monetized (e.g., Elmqvist et al. 2015), some ecosystem services may not be monetized in the context of a particular project for technical, logistical, application, or policy constraints (Wainger et al. 2010). Here, we stop short of valuation of ecosystem services and instead compute benefit relevant indicators (Olander et al. 2018). Furthermore, the environmental outputs considered in USACE project evaluation are typically not monetized.

Given the economic-basis for ecosystem services, we coarsely divided our benefit relevant indicators into components related to supply and demand. As a proxy for demand, we used the total population of adjacent communities described above. The area one mile from the site was selected as a boundary based on a resident's ability to access some of the services (e.g., walking to a forested area to enjoy cooler temperatures on a hot summer day).

As a proxy for supply of ecosystem services, we developed a semi-quantitative scoring system for each of five services with direct or indirect links to USACE missions: flood risk, navigation, recreation, thermal regulation, and water quality. These five categories were chosen based on the team's perception of relevance to the USACE mission along with priorities of cost-share sponsors and prior ecosystem services analyses in the city (e.g., McPhearson et al. 2013, Hansen et al. 2015). This analysis intends to operationalize the ideas of integrated water resource management by presenting decision-makers with information relevant to other agency missions. For each service, we developed a consistent 0-20 scoring system along with accompanying narrative descriptions of scores (Figure J-33). These "constructed metrics" were indirect and qualitative, but useful for informing decision-making (Keeney and Gregory 2005). We adapted the general categorical-numerical format of the Rapid Bioassessment Protocols from stream assessment (Barbour et al. 1999) because of team familiarity with the basic assessment structure. All sites were jointly scored by two team members (McKay and Kohtio) for futures without and with the recommended restoration alternatives. The net effect of restoration actions was summed across ecosystem services as an overarching score. Notably, some services were defined to differentiate between HRE sites across system types (e.g., Bronx River vs. Jamaica Bay).

Category	Optimal 20 19 18 17 16	Suboptimal 15 14 13 12 11	Marginal 10 9 8 7 6	Poor 5 4 3 2 1 0	No Action	Future w/Project
Flood risk management	Measurable reduction in flood levels significantly reducing risk for residents and damages	Clear qualitative reduction in the flood risk	Minor, site-specific reductions in flood risk outcomes	Negligible or zero effect on flood risk outcomes		
Navigation	High proximity to navigation projects. Site actively performs a functional role for the navigation mission (e.g., sediment disposal).	High proximity to navigation projects. Site indirectly improves the navigation mission (e.g., sediment retention).	Low proximity to navigation projects. No obvious current connection to navigation activities.	Active interference with navigation projects or mission.		
Recreational opportunities	Meets all four objectives from the CRP (2009): direct access, indirect access, vistas, upland access routes	Meets 3 of 4 categorical objectives from the CRP	Meets 2 of 4 categorical objectives from the CRP	Meets 1 of 4 categorical objectives from the CRP (or zero objectives)		
Air & Thermal Regulation	Project area is 75-100% vegetated	Project area is 50-75% vegetated	Project area is 25-50% vegetated	Project area is 0-25% vegetated		
Improve Water Quality	Significant, quantitative contribution to sediment settling, nutrient uptake, and carbon retention	Major, qualitative contribution to sediment settling, nutrient uptake, and carbon retention	Minor, indirect benefits to sediment settling, nutrient uptake, and carbon retention	Little (if any) effect on sediment settling, nutrient uptake, and carbon retention outcomes		

Figure J-33. Qualitative scoring system applied to assess ecosystem services

Stakeholder Support: The HRE study area has a large community of engaged and interested parties, including nine cost-share sponsors, numerous coordinating entities (e.g., Federal permitting agencies), and dozens of stakeholder groups. All proposed restoration sites have significant local and regional support, but some sites clearly have more formal institutional support (e.g., the Bronx River's designation in the Urban Waters Federal Partnership). We identified two proxies for stakeholder support. First, mirroring the ecosystem service metrics, we developed a scoring system for "plan recognition" (Figure J-34), which describes a site's contribution to existing watershed plans (based on a similar metric in EC-11-2-206). Second, we use the number of cost share sponsors at each site as a metric for formal stakeholder support.

Category	Optimal 20 19 18 17 16	Suboptimal 15 14 13 12 11	Marginal 10 9 8 7 6	Poor 5 4 3 2 1 0	Future w/Project
Plan Recognition	Contributes to multi-agency comprehensive watershed or basin plan which is Federal priority as demonstrated in laws or specifically authorized programs. Numerous supportive organizations with significant political will.	Contributes to multi-entity regional watershed or basin plan, but largely led by one or a few partners. Significant priority to multiple groups.	Supportive of local actions of a small number of partners. Minor contribution to broader watershed actions.	No contribution to broader watershed planning.	

Figure J-34. Qualitative scoring system applied to assess stakeholder support

Technical significance: USACE defines the significance of an ecosystem relative to institutional, public, and technical dimensions. The former two categories are partially addressed by criteria related to ecosystem services, environmental justice, and stakeholder support. However, technical significance is also a crucial factor in determining the competitiveness of a USACE project in the budgeting process. We adapted the USACE technical significance scoring system used in budget prioritization (EC-11-2-206, USACE 2014) as a qualitative metric of site significance. Each category was rescaled from 0-20 for consistency with other secondary factors (Figure J-35), and sites were jointly scored by two team members based on project documentation in December 2017. All sites were scored to reflect the net outcome between the futures without and with a restoration project. These values are used as an analog to "ecological lift" applied during cost-effectiveness analysis. Notably, the scale of each metric was adapted from the budget criteria to reflect equal weighting among the six criteria (i.e., all scales are 0-20 with a maximum score of 120).

Category	Optimal 20 19 18 17 16	Suboptimal 15 14 13 12 11	Marginal 10 9 8 7 6	Poor 5 4 3 2 1 0	Future w/Project
Habitat Scarcity	Habitat is extremely scarce, and restoration substantially reduces local scarcity (e.g., >50% over current reach condition).	Habitat is extremely scarce, and restoration reduces local scarcity (e.g., 25-50% over current reach condition).	Habitat is somewhat scarce, and project reduces local scarcity (e.g., 0-25% over current condition).	Habitat is common and/or project does not measurably reduce local scarcity.	
Special Status Species	Many species of concern are directly benefitted.	Multiple species of concern are likely benefited.	Benefits to ecosystem function. Indirect benefits to imperiled taxa.	No improvement to habitat for species of concern.	
Connectivity	Makes critical direct physical connection between existing habitat areas or establishes a network of interconnected habitat.	Creates a nodal connection between existing habitat areas.	Restores suitability of existing connection. Expands area within corridor or home range.	Provides minor expansion to existing habitat.	
Hydrologic Character	Quantifiable improvement in the natural hydrologic condition	Meaningful qualitative contribution to hydrologic character outcome, but signs of degradation remain	Minor positive effect on hydrologic impairment	Negligible or zero effect on hydrology	
Geomorphic Condition	Quantifiably restores the attainable geomorphic processes/form including appropriate diversity and dynamics	Meaningful qualitative contribution to key geomorphic processes and form	Minor positive effect on geomorphic impairment (e.g., via form not function)	Negligible or zero effect on geomorphic form or function	
Self-Sustaining	Physical or ecological processes are self-reinforcing with no operational or maintenance needs.	Physical or ecological processes requiring possible maintenance.	Physical or ecological processes require clear operational or maintenance actions (> 1 year frequency).	Project does not function without significant operation and maintenance (sub-annual frequency).	

Figure J-35. Qualitative scoring system applied to assess technical significance

4.2.3. Decision Summary

Cost-effectiveness and incremental cost analysis (CE/ICA) is a valuable tool for interpreting the consequences of projects with non-monetary outcomes (e.g., ecosystem restoration projects). However, these analyses require the decision-maker to impose judgment, values, and context to determine the appropriate level of investment and select a plan. Many ecosystem management problems produce multiple lines of evidence and ask decision-makers to synthesize diverse data and information to make informed choices regarding complex issues (Linkov et al. 2011). A variety of decision support tools are growing in prominence in the restoration and conservation communities, and we applied three different methods of summarizing results for decision-makers. The positive and negative consequences of different restoration plans are then presented relative to these summaries, and a system-scale alternative is recommended.

- Visual summaries of primary objectives: CE/ICA was visually summarized with only the primary objectives included (i.e., ecological benefits and costs) at the system-scale. CE/ICA figures allowed users to understand the relative increase in benefits compared with costs for each alternative and capture non-linearities in both analyses.

- Compilation of secondary decision factors: Secondary criteria are then presented to quantify the value of individual sites relative to other decision factors (primarily Other Social Effects).

- Consequences tables: Primary and secondary outcomes are then collected for the final array of management alternatives at the system-scale. Decision matrices provide an opportunity for deep exploration of the relative merits of a plan (Gregory and Keeney 2002, Gregory et al. 2012), and these tables often include not only raw data, but summary values more indicative of decision-making.

4.2. Jamaica Bay Perimeter

Six Jamaica Bay Perimeter sites were combined into 64 potential plans, which were examined with CE/ICA (Figure J-36).

- Three sites provide the majority of the ecological benefits (Fresh Creek, Brant Point and Dead Horse Bay).

- Key breakpoints in incremental cost are observed with the addition of Brant Point, Dubos Point, and Hawtree Point. The increased incremental cost with the addition of Hawtree Point is extreme (i.e., an order of magnitude increase in $/AAFCU).

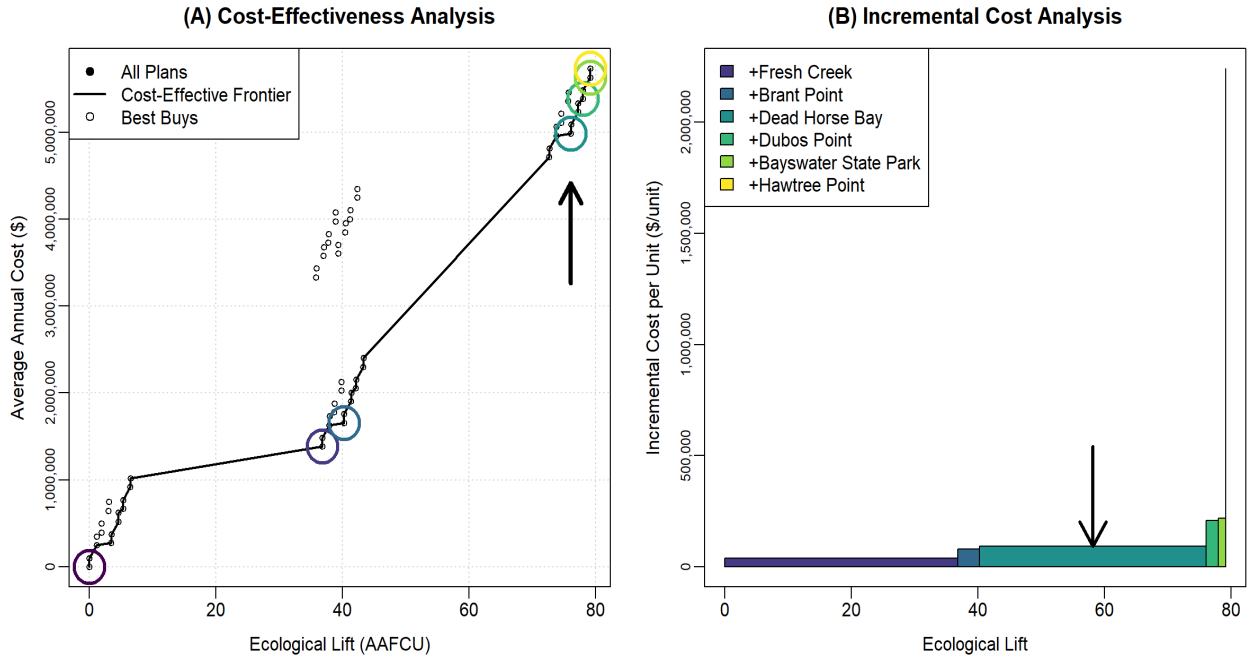

Figure J-36. Cost-effectiveness and incremental cost analyses for the Jamaica Bay perimeter planning region. Arrows indicate the recommended plan.

Secondary decision factors provide further insight into the difference between sites (Figure J-37), notably the following.

- Fresh Creek is consistently highlighted as important with respect to these criteria. The site has a large neighboring population (i.e., over 120,000 residents). The site provides the largest “lift” relative to ecosystem services and USACE technical significance criteria.

- Fresh Creek, Brant Point, Bayswater State Park, and Dubos Point all qualify as PEJA communities.

- Dead Horse Bay and Hawtree Point provide a large “lift” in ecosystem services.

- Dubos Point has a relatively small “lift” in ecosystem services".

- Bayswater State Park is the only single-sponsor site with all other sites supported by multiple entities.

- Hawtree Point notably lags behind in plan recognition and technical significance.

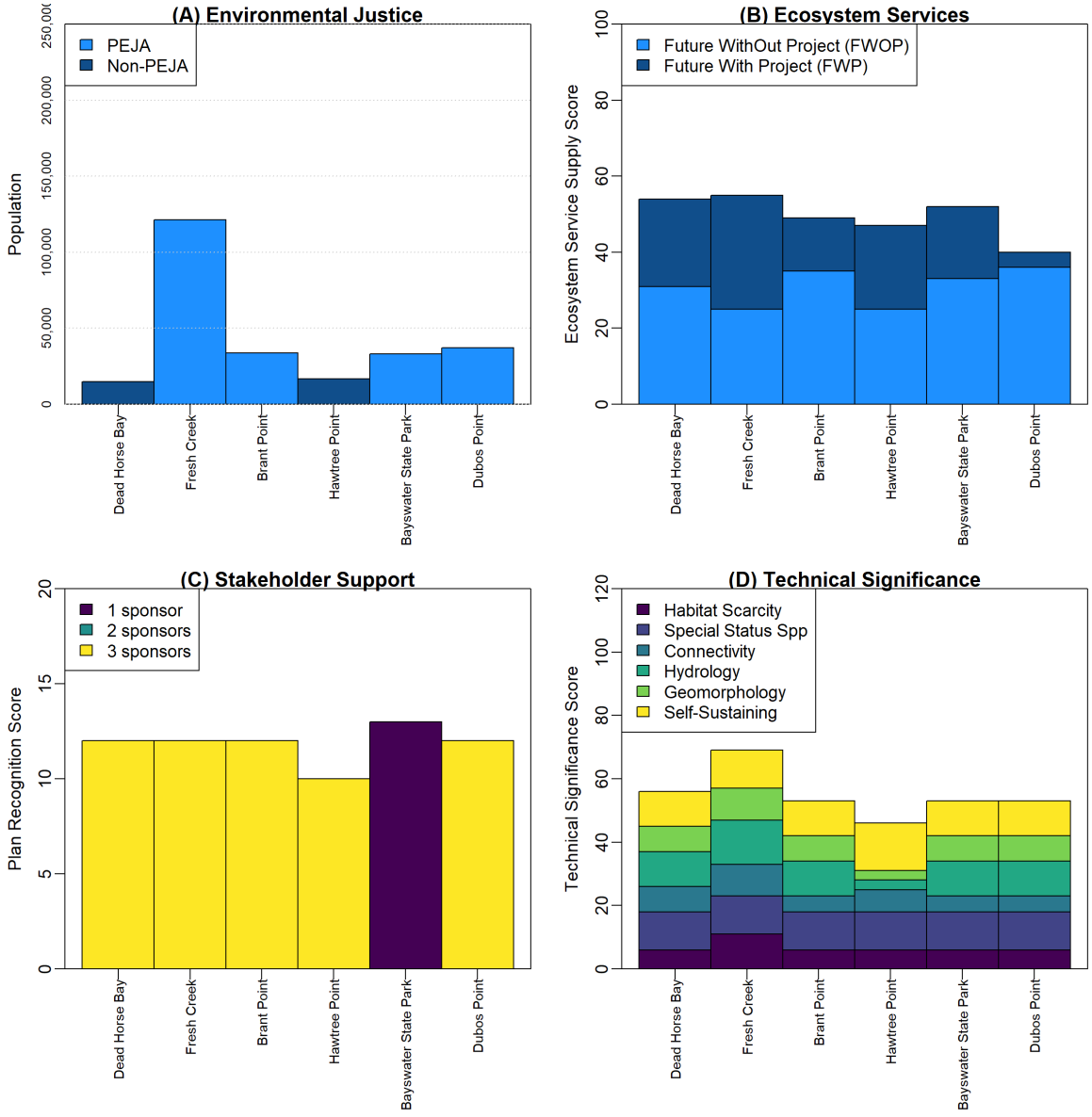

Figure J-37. Secondary decision factors for the Jamaica Bay perimeter planning region

Table J-35. Array of best buy plans for the Jamaica Bay Perimeter Planning Region

Plan	Ecological Lift (AAFCU)	Annualized Cost ($)	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)	Total Population	Number of PEJAs	Net Ecosystem Services Score (sum)	Plan Recognition Score (sum)	USACE Technical Significance (sum)
FWOP	0	0	0	0	0	0	0	0	0	0
+Fresh Creek	36.8	1,382,939	37,600	37,600	33,885,522	121,308	1	30	12	69
+Brant Point	40.2	1,655,946	79,195	41,164	40,466,869	154,941	2	44	24	122
+Dead Horse Bay	76.1	4,986,797	92,936	65,557	125,012,831	169,704	2	67	36	178
+Dubos Point	78	5,383,579	209,024	69,050	134,811,887	206,727	3	71	48	231
+Bayswater State Park	79.1	5,630,978	217,429	71,184	140,728,278	239,702	4	90	61	284
+Hawtree Point	79.1	5,732,488	2,242,038	72,426	142,859,915	256,504	4	112	71	330

Based on these analyses, three plans were considered for the final decision array. Smaller plans would not meet the planning objectives and would likely be unacceptable to stakeholders and sponsors.

- *Base Plan (Fresh Creek + Brant Point + Dead Horse Bay)* -**Recommendation**: When considering only benefits/outputs (increases in the net quantity and/or quality of desired ecosystem resources), a plan reasonably maximizes the restoration of the Planning Region would include all sites up to Dead Horse Bay (i.e., Fresh Creek, Brant Point, Dead Horse Bay). This plan costs $125.0M and produces 76.1 average annual functional capacity units (AAFCU). The plan also generally occurs at a "break point" in incremental cost as recommended in ER 1105-2-100. While smaller plans have lower incremental cost per incremental unit, this plan is deemed "worth it" due to the relatively small incremental cost of this step (i.e., $93,000/AAFCU) and the low unit cost of the plan as a whole (i.e., $66,000/AAFCU). The plan includes 2 of 4 PEJAs and captures more than half of the potential benefits related to ecosystem services, plan recognition, and technical significance.

- *Moderate Plan (Base Plan + Dubos Point)*: This plan incorporates Fresh Creek, Brant Point, Dead Horse Bay, and Dubos Point. The plan has a total first cost of $134.8M and produces 78.0 AAFCUs. This plan incorporates the PEJA around Dubos Point, but also leads to a substantial increase in the unit cost. The OSE benefits associated with wetland restoration at Dubos Point include providing the local PEJA community with increased passive recreation opportunities, enjoyment of improved resources and natural flood risk management measures.

- *Save the Bay Plan (Base Plan + Dubos Point + Bayswater State Park)*: This plan reasonably maximizes benefits to the ecologically unique Jamaica Bay ecosystem by including all sites except Hawtree Point (i.e., Fresh Creek, Brant Point, Dead Horse Bay, Dubos Point, Bayswater Point State Park). This plan addresses the significant ecological degradation that has occurred in the unique Jamaica Bay system, while avoiding the costly Hawtree Point site. This plan costs $140.7M, produces 79.1 AAFCUs, and includes all PEJAs. The Bayswater Point site is a high visibility public park and represents an important contribution to public education and patronage opportunities. Bayswater Point State Park is a pivotal link and plays an important role due to its key location ensuring connectivity to adjacent critical habitat between Jamaica Bay City Park and Rockaway Community Park and Dubos Point. In addition, this restoration would be integrated with planned public access improvements implemented by NYS Department of Parks. While higher cost, the plan is deemed "worth it" given the distinctiveness of the Bay ecosystem, the need for connectivity of critical habitat, the unique role the USACE plays in the Bay, and the effect of these projects on system-wide functionality in other business lines.

4.3. Jamaica Bay Marsh Islands

Five Jamaica Bay marsh islands were combined into 32 potential plans, which were examined with CE/ICA (Figure J-38).

- Incremental cost increases are relatively linear and without any major “breakpoints”.
- The maximum incremental cost increase is low relative to other planning regions.

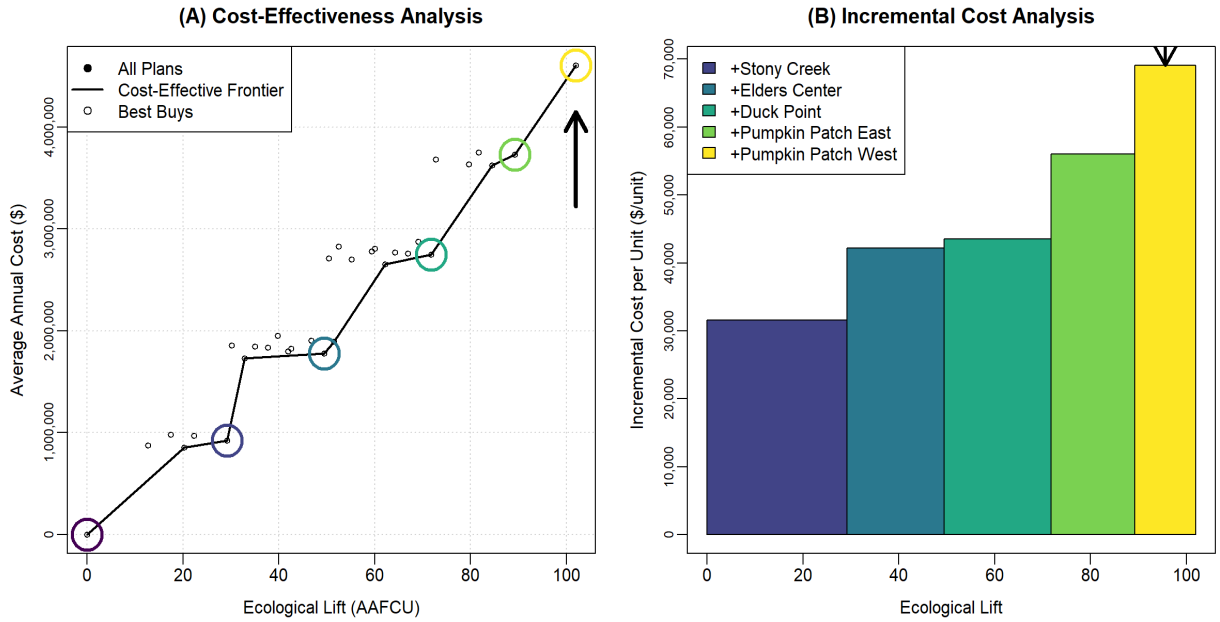

Figure J-38. Cost-effectiveness and incremental cost analyses for the Jamaica Bay marsh islands planning region. Arrows indicate the recommended plan.

Secondary decision factors provide further insight into the ecological value of these sites (Figure J-39), notably the following.

- Islands are relatively isolated based on the population metrics used here. However, marsh islands are highly used by recreational boating and fishing communities.
- All islands provide large increases in ecosystem services.
- Marsh islands are high visibility sites, particularly given their historical decline and scarcity.
- Marsh islands directly address all of the USACE technical significance criteria.

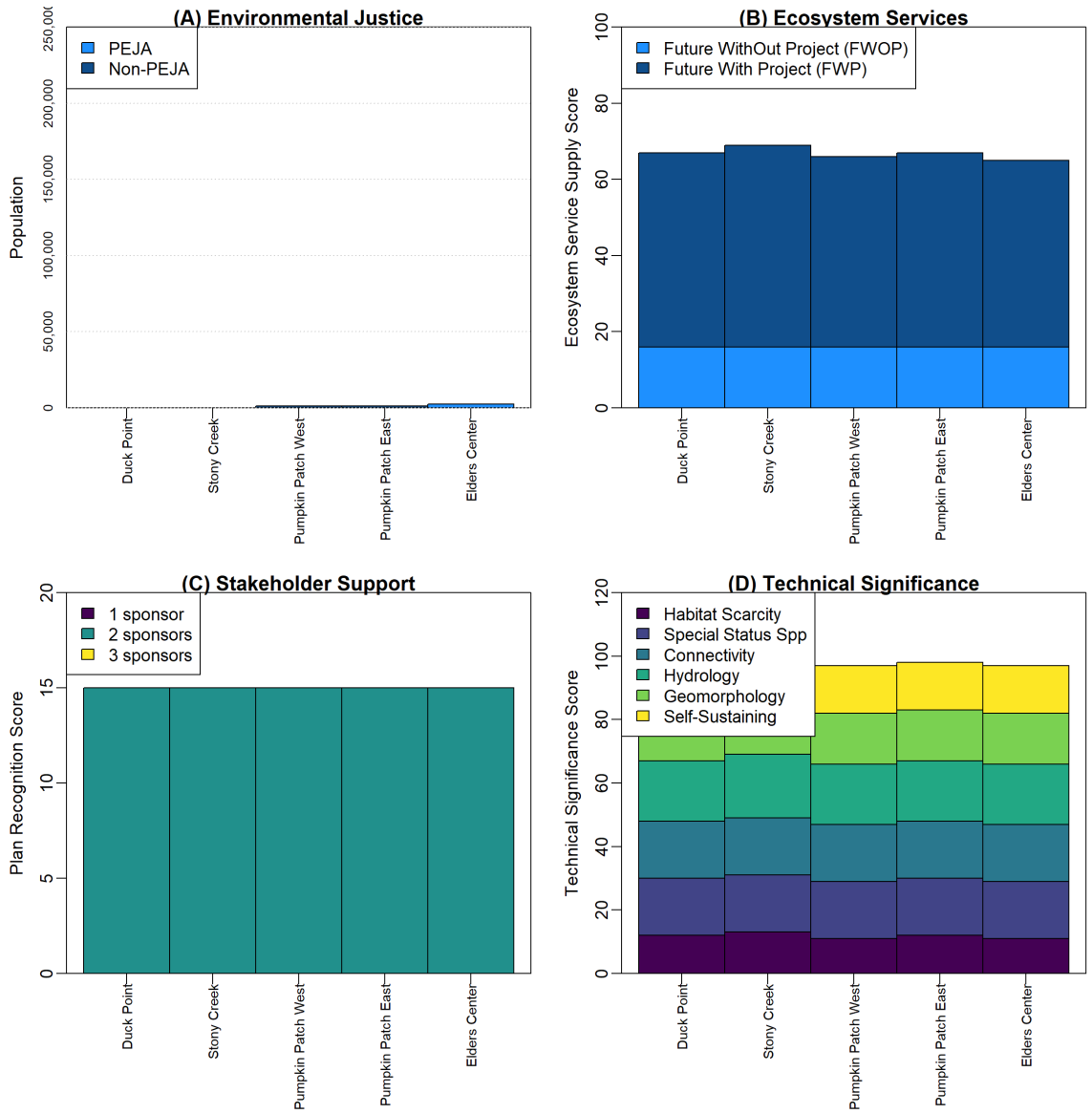

Figure J-39. Secondary decision factors for the Jamaica Bay marsh islands planning region.

Table J-36. Array of best buy plans for the Jamaica Bay Marsh Islands Planning Region

Plan	Ecological Lift (AAFCU)	Annualized Cost ($)	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)	Total Population	Number of PEJAs	Net Ecosystem Services Score (sum)	Plan Recognition Score (sum)	USACE Technical Significance (sum)
FWOP	0	0	0	0	0	0	0	0	0	0
+Stony Creek	29.3	924,034	31,582	31,582	22,733,369	19	1	53	15	100
+Elders Center	49.5	1,777,540	42,192	35,919	43,634,090	2,480	2	102	30	197
+Duck Point	71.8	2,748,016	43,490	38,272	67,574,213	2,499	3	153	45	295
+Pumpkin Patch East	89.3	3,728,210	56,041	41,753	91,767,318	3,836	3	204	60	393
+Pumpkin Patch West	102	4,604,018	69,071	45,150	112,759,006	5,173	3	254	75	490

Only the largest plan was preserved for the final decision array. Smaller plans would not meet the planning objectives and would likely be unacceptable to stakeholders and sponsors.

- *Base Plan (Stony Creek + Elders Center + Duck Point + Pumpkin Patch -East + Pumpkin Patch -West)* -**Recommendation**: The plan that reasonably maximizes environmental benefits includes all the marsh island sites evaluated (i.e., Stony Creek, Elders Center, Duck Point, Pumpkin Patch -East, Pumpkin Patch -West). This plan costs $112.8M and produces 102.0 AAFCUs. Marsh Islands function as a system of projects, and there are significant synergies to including all five islands in the recommendation. This plan also directly addresses the loss of an ecosystem that only the USACE is capable of addressing, given the agency's role in coastal resiliency and regional sediment management through its Civil Works Mission. These sites provide an enormous array of ecosystem services and directly address the USACE technical significance criteria as well as contribute to a primary objective to restore this critical marsh island habitat that has been significantly lost. A resilient marsh ecosystem provides coastal storm risk management services to adjacent communities through wind fetch reduction and wave attenuation. The collection of sites are also recommended because of their systemic functioning and larger-scale effect on Bay-wide hydrodynamics (not accounted for in the purely ecological benefits presented here). Furthermore, the relatively low unit cost (less than $50,000 / unit) and high visibility of these sites (e.g., by every passenger to John F. Kennedy airport and visitor to the National Park) make these sites an efficient investment.

4.4. Harlem River, East River and Western Long Island Sound

Ten sites in the Harlem River, East River and Western Long Island Sound Planning Region were combined into 1,024 potential plans, which were examined with CE/ICA (Figure J-40).

- Two major groupings of plans emerge in the cost-effectiveness analysis, which represent the inclusion (or exclusion) of Stone Mill Dam.

- Key breakpoints in incremental cost are observed with the addition of Flushing Creek, Garth-Harney, Bronx Zoo and Dam, Shoelace Park, Westchester County Center, and West Farm Rapids Park. Incremental costs increase greatly above plans including Westchester County Center.

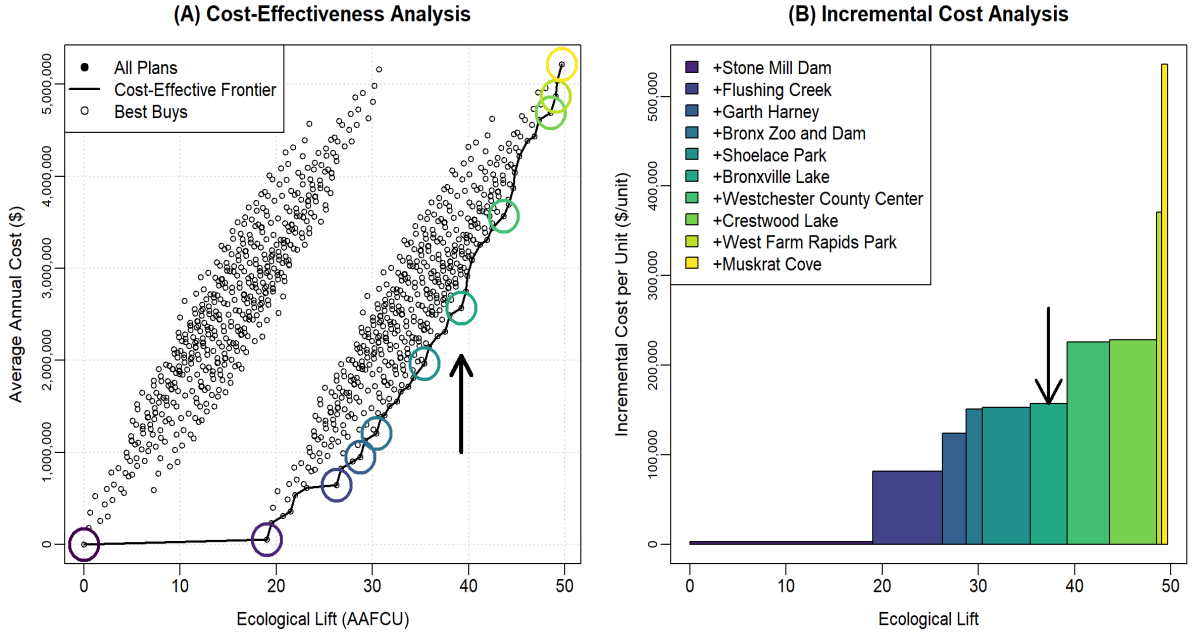

Figure J-40. Cost-effectiveness and incremental cost analyses for the Harlem River, East River and Western Long Island Sound Planning Region. Arrows indicate the recommended plan.

Secondary decision factors provide further differentiation between these sites (Figure J-41), notably the following.

- All communities within New York City have extremely large populations (i.e., >100,000 neighboring residents) and qualify as PEJAs. One site, Shoelace Park, has more than 228,000 nearby residents, which makes roughly equal to the 100th largest city in the Nation. Westchester County sites also have large nearby populations (i.e., >39,000) relative to parts of the United States (e.g., population of Vicksburg, Mississippi is < 25,000).

- Ecosystem service scores are quite different across sites, with larger footprint sites generally providing more services (e.g., Shoelace Park, Bronxville Lake, Crestwood Lake, Westchester County Center). Notably, the Stone Mill Dam restoration provides no increase

in ecosystem services due to negligible effects on flood risk, navigation, and other services outcomes in a small footprint.

- Stakeholder support is very high for sites in the Harlem River, East River and Western Long Island Sound region given the Bronx River's status in the Urban Waters Federal Partnership and intersection with missions of partner agencies (e.g., stormwater management).

- Technical significance is variable across sites with West Farm Rapids Park and Muskrat Cove notably lower than other locations.

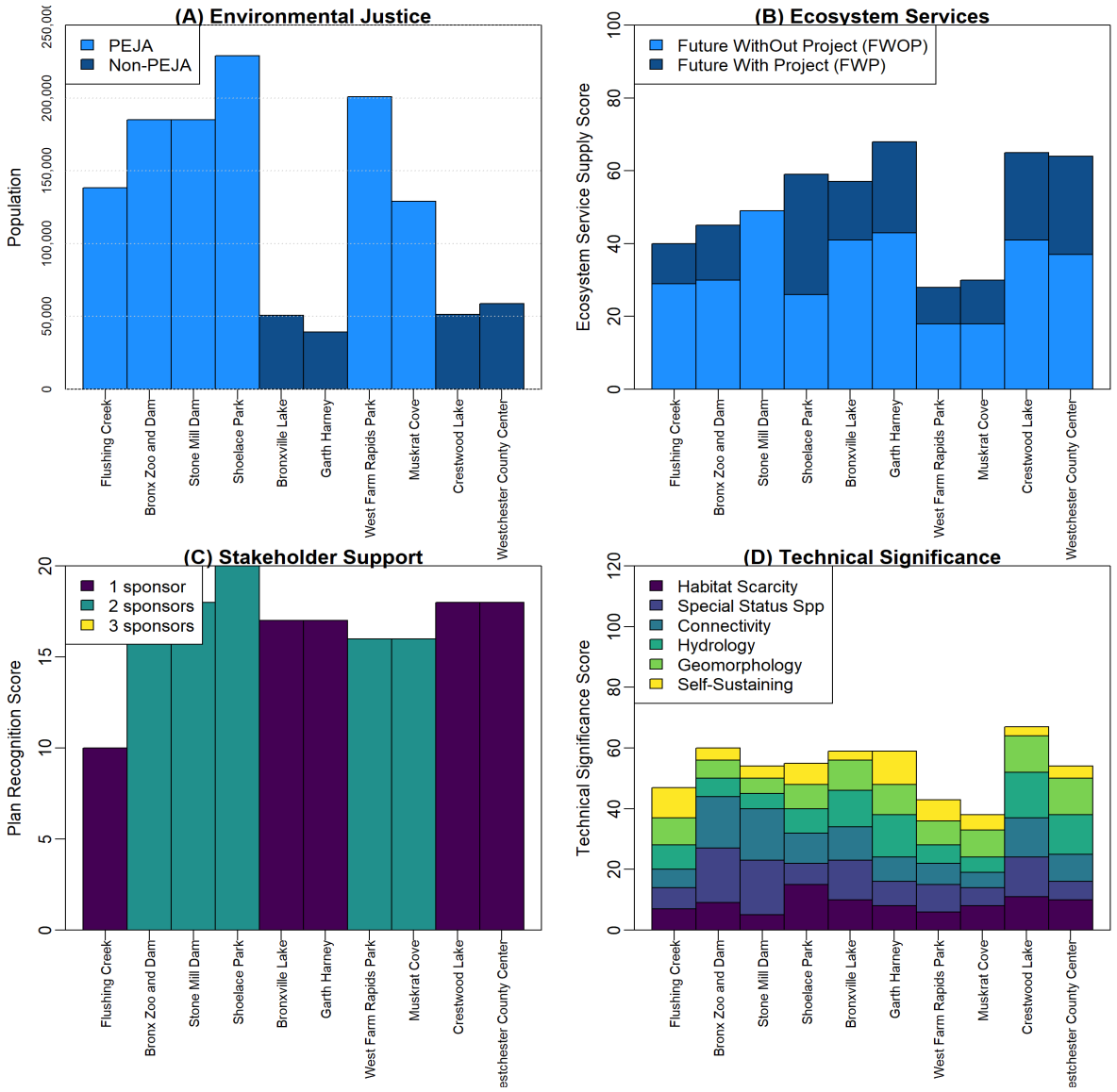

Figure J-41. Secondary decision factors for the Harlem River, East River and Western Long Island Sound Planning Region.

Table J-37. Array of best buy plans for the Harlem River, East River and Western Long Island Sound Planning Region

Plan	Ecological Lift (AAFCU)	Annualized Cost ($)	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)	Total Population	Number of PEJAs	Net Ecosystem Services Score (sum)	Plan Recognition Score (sum)	USACE Technical Significance (sum)
FWOP	0	0	0	0	0	0	0	0	0	0
+Stone Mill Dam	19	54,241	2,855	2,855	929,827	185,029	1	0	18	54
+Flushing Creek	26.3	646,859	81,631	24,634	14,443,546	323,440	2	11	28	101
+Garth Harney	28.7	952,087	124,046	33,151	22,092,924	362,759	2	36	45	160
+Bronx Zoo and Dam	30.4	1,208,035	151,275	39,723	28,404,265	547,821	3	51	63	220
+Shoelace Park	35.4	1,968,443	152,923	55,631	47,339,549	776,691	4	84	83	275
+Bronxville Lake	39.2	2,569,169	157,057	65,525	62,034,964	827,429	4	100	100	334
+Westchester County Center	43.6	3,565,351	226,107	81,747	87,282,739	886,260	4	127	118	388
+Crestwood Lake	48.5	4,689,137	228,336	96,611	115,334,573	937,570	4	151	136	455
+West Farm Rapids Park	49	4,868,216	370,502	99,312	119,598,713	1,138,402	5	161	152	498
+Muskrat Cove	49.7	5,216,371	535,806	105,022	127,720,140	1,267,513	6	173	168	536

Based on these analyses, three plans were considered for the final decision array. Smaller plans would not meet the planning objectives and would likely be unacceptable to stakeholders and sponsors.

- *Base Plan (Stone Mill Dam + Flushing Creek + Garth Harney + Bronx Zoo and Dam + Shoelace Park + Bronxville Lake)* -**Recommendation**: When considering only environmental outputs, a plan that reasonably maximizes benefits would include all sites up to Bronxville Lake. This plan costs $62.0M and produces 39.2 habitat units, and the plan generally occurs at a "break point" in incremental cost as recommended in ER 1105-2-100. This plan is extremely efficient and obtains 79% of the total potential benefits at 48% of the total potential cost. The plan also captures a large portion of secondary benefits (i.e., 4 of 6 PEJAs, 827,000 nearby residents, 58% of the net ecosystem services score, multiple top priority sites). Bronxville Lake is cost-shared with Westchester County and also represents a second site for this sponsor.

- *Basin-Wide Restoration Plan (Base Plan + Westchester County Center)*: This plan provides a larger restoration contribution to the highly degraded Bronx River ecosystem and includes all sites up to Westchester County Center. This plan costs $87.3M and produces 43.6 habitat units. Westchester County Center is a public facility, which would provide key educational opportunities and demonstrate the USACE's commitment to urban ecosystem restoration. This site is also a major contribution to ecosystem services and technical significance.

- *Urban Waters Federal Partnership Plan (Base Plan + Westchester County Center + Crestwood Lake)*: This plan maximizes benefits to the Bronx River ecosystem by including all sites up to Crestwood Lake. The plan has a total first cost of $115.3M and produces 48.5 habitat units. Crestwood Lake is a key provider of ecosystem services in the Bronx River, given its large floodplain habitat and key role in restoring hydrologic processes at all subsequent sites downstream in general and Bronxville Lake in particular. The Bronx River is a focal site in the Urban Waters Federal Partnership, and the inclusion of this site provides another high visibility ecosystem restoration project in a basin where natural systems are extremely scarce.

4.5. Newark Bay, Hackensack River and Passaic River

Seven sites in the Newark Bay, Hackensack River and Passaic River Planning Region were combined into 128 potential plans, which were examined with CE/ICA (Figure J-42).

- Three major groups of sites emerged from incremental cost analysis. First, plans including only Essex County Branch Brook Park and Metromedia Tract are extremely efficient. Second, plans increasingly including Meadowlark Marsh, Oak Island Yards, and Kearny Point have steadily increasing incremental cost. Third, plans including Dundee Island Park and Clifton Dundee Canal Green Acres have steep increases in incremental cost.

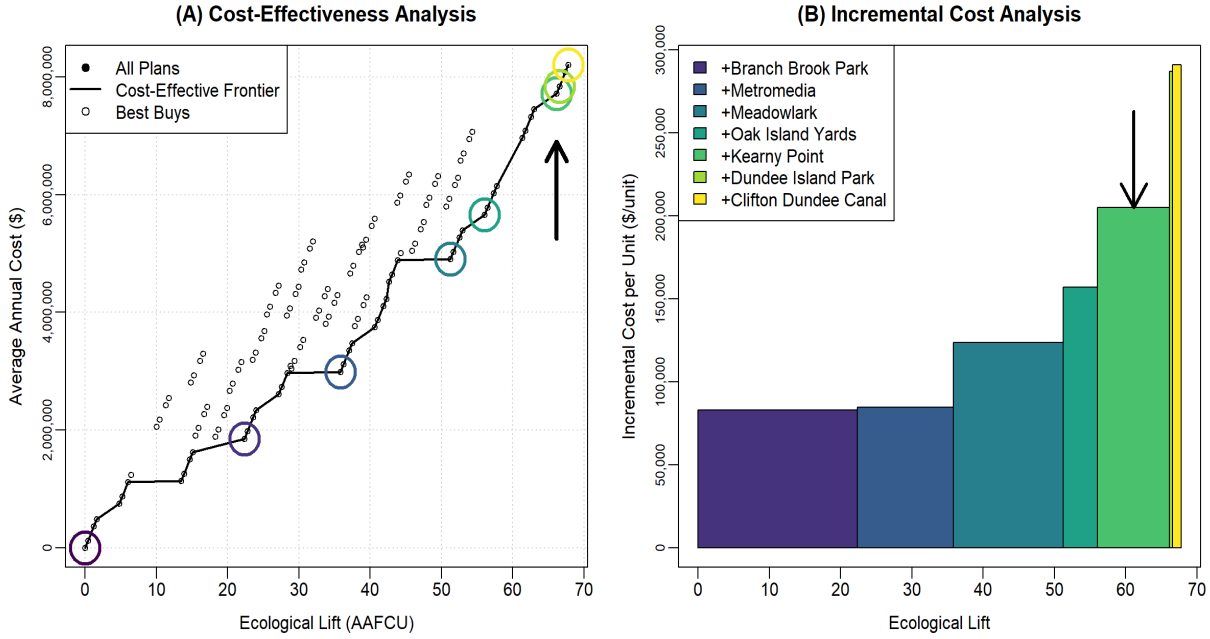

Figure J-42. Cost-effectiveness and incremental cost analyses for the Newark Bay, Hackensack River and Passaic River Planning Region. Arrows indicate the recommended plan.

Secondary decision factors provide further differentiation between these sites (Figure J-43), notably the following.

- Essex County Branch Brook Park, Clifton Dundee Canal Green Acres, and Dundee Island Park have large populations (i.e., >50,000 neighboring residents), while Oak Island Yards, Essex County Branch Brook Park, Dundee Island Park, and Kearny Point qualify as PEJAs.

- Essex County Branch Brook Park, Metromedia Tract, and Meadowlark Marsh consistently have higher ecosystem service scores than other sites.

- Stakeholder support is very high for Oak Island Yards, Essex County Branch Brook Park, Clifton Dundee Canal Green Acres, Dundee Island Park, and Kearny Point given the Passaic River's status in the Urban Waters Federal Partnership. However, Metromedia Tract and Meadowlark Marsh have additional cost-share sponsors.

- Technical significance is variable across sites with Kearny Point, Metromedia Tract, and Meadowlark Marsh notably higher than other locations (and Clifton Dundee Canal Green Acres and Dundee Island Park notably lower).

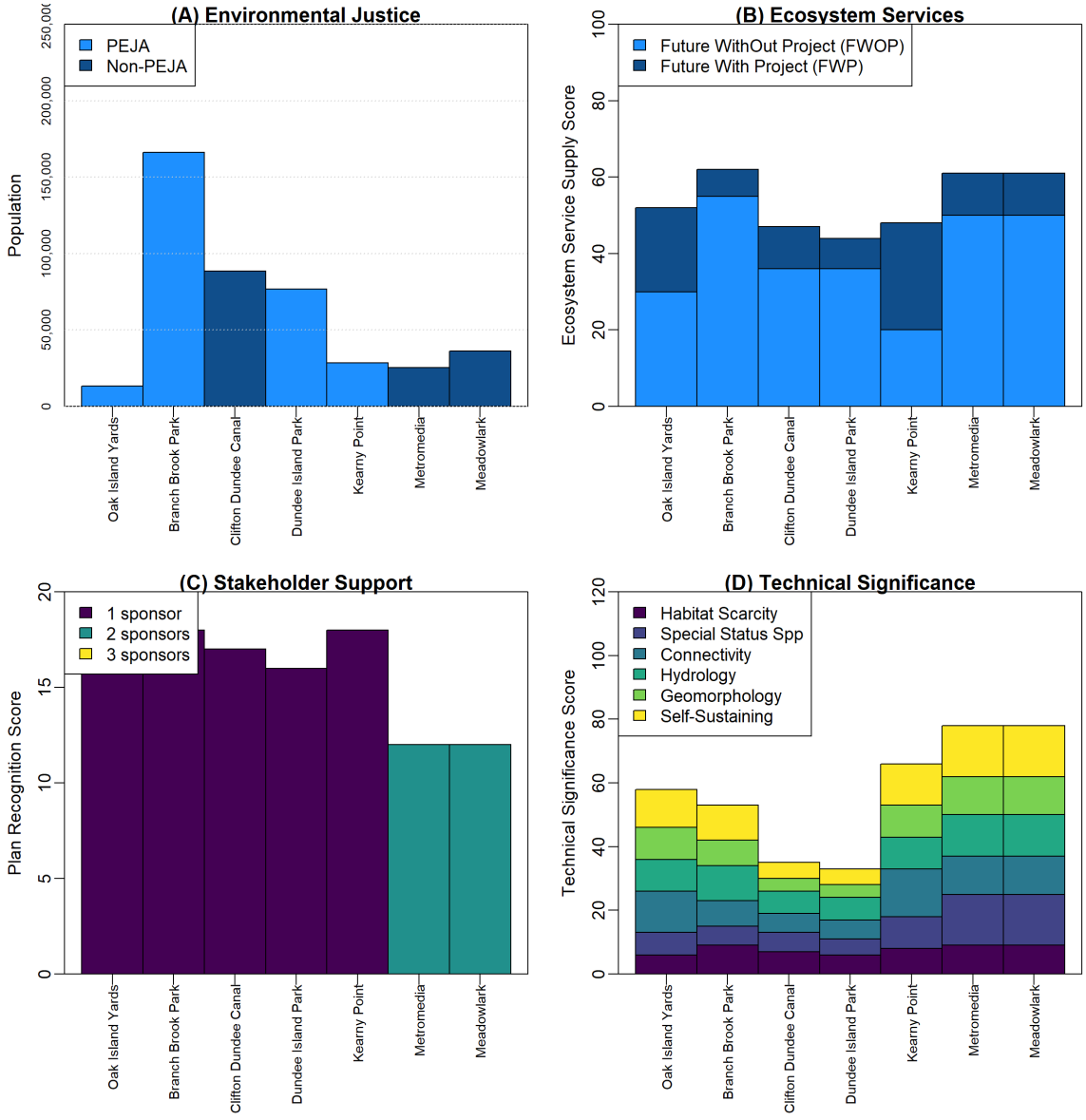

Figure J-43. Secondary decision factors for the Newark Bay, Hackensack River and Passaic River Planning Region.

Table J-38. Array of best buy plans for the Newark Bay, Hackensack River and Passaic River Planning Region

Plan	Ecological Lift (AAFCU)	Annualized Cost ($)	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)	Total Population	Number of PEJAs	Net Ecosystem Services Score (sum)	Plan Recognition Score (sum)	USACE Technical Significance (sum)
FWOP	0	0	0	0	0	0	0	0	0	0
+Essex County Branch Brook Park	22.3	1,855,027	83,028	83,028	47,413,586	166,302	1	7	18	53
+Metromedia Tract	35.8	2,992,268	84,525	83,591	75,751,803	191,559	1	18	30	131
+Meadowlark Marsh	51.3	4,904,157	123,589	95,661	123,498,993	227,920	1	29	42	209
+Oak Island Yards	56.1	5,657,938	157,019	100,914	142,070,145	241,171	2	51	60	267
+Kearny Point	66.1	7,715,010	204,899	116,706	194,182,142	269,789	3	79	78	333
+Dundee Island Park	66.5	7,839,171	286,974	117,813	196,953,146	346,424	4	87	94	366
+Clifton Dundee Canal Green Acres	67.8	8,202,724	290,902	121,004	206,006,357	434,928	4	98	111	401

Based on these analyses, four plans were considered for the final decision array. Smaller plans would not meet the planning objectives and would likely be unacceptable to stakeholders and sponsors.

- *Minimal Plan (Essex County Branch Brook Park + Metromedia Tract)*: When considering only environmental outputs and costs, a plan including Essex County Branch Brook Park and Metromedia Tract emerges. The plan has total first cost of $75.8M and produces 35.8 AAFCUs. This plan is very efficient by producing 53% of potential benefit in the region at 37% of the cost. However, a single action in the Passaic and Hackensack Watersheds would likely be unacceptable to stakeholders and cost-share sponsors.

- *Base Plan (Essex County Branch Brook Park + Metromedia Tract + Meadowlark Marsh)*: The minimally acceptable base plan would include Essex County Branch Brook Park, Metromedia Tract, and Meadowlark Marsh. The plan has total first cost of $123.5M and produces 51.3 AAFCUs. Metromedia Tract and Meadowlark Marsh are both ecologically important to the Meadowlands wetland ecosystem. These sites leverage prior restoration efforts by connecting high functioning habitat thus creating a contiguous expanse of wetlands in the region. Local, state, and federal partners have previously identified this site as a key multi-agency priority. By including Meadowlark Marsh, this plan incorporates all sites making major contributions to ecosystem services.

- *Multi-Watershed Restoration Plan (Essex County Branch Brook Park + Metromedia Tract + Meadowlark Marsh + Oak Island Yards)*: This plan reasonably maximizes ecological benefits (56.1 AAFCU, total first costs $142.1M). Oak Island Yards contains Newark's largest extent of tidal marsh, tidal creeks, and emergent wetland, and this project would return this site to a less degraded, more natural condition. This site is near the confluence of the largest concentration of wetlands in the region, which make it important for ecological connectivity. Oak Island Yards also contains a unique habitat type (salt panne), which is undervalued by EPW. Oak Island Yards is a Tier 2 site and would be deferred until the lower 8.2 miles of the Lower Passaic River is remediated. Including this site is important to demonstrate the joint program and governmental partnership with EPA's Superfund program sequencing restoration following the remedial action for the Lower Passaic River. This site is also important for the Urban Waters Federal Partnership showcasing our coordination with USEPA as Co-Lead Agency. This plan includes two of four PEJAs.

- *Urban Waters Federal Partnership Plan (Essex County Branch Brook Park + Metromedia Tract + Meadowlark Marsh + Oak Island Yards + Kearny Point)* -**Recommendation**: This plan includes all sites up to Kearny Point. The plan addresses the significant ecological degradation that has occurred in the Newark Bay, Hackensack River and Passaic River system, while avoiding extremely costly sites (i.e., Dundee Island Park, Clifton Dundee Canal Green Acres). This plan includes three of four PEJAs, and makes a strong contribution to the Passaic River focal site of the Urban Waters Federal Partnership. This plan costs $215.1M, produces 66.1 AAFCUs. This plan includes three of four PEJAs, and makes a strong contribution to the Passaic River focal site of the Urban Waters Federal Partnership. Kearny Point would be deferred for implementation until the lower 8.2 mile cleanup of the Passaic River was completed by EPA.

4.6. Oyster Reef Restoration

Three oyster reefs were combined into 8 potential plans, which were examined with CE/ICA (Figure J-44).

- Incremental cost increases are relatively linear and without any major “breakpoints”.
- The maximum incremental cost increase is low ($25,000/AAFCU), and the unit cost is low ($18,000/AAFCU) relative to other planning regions.

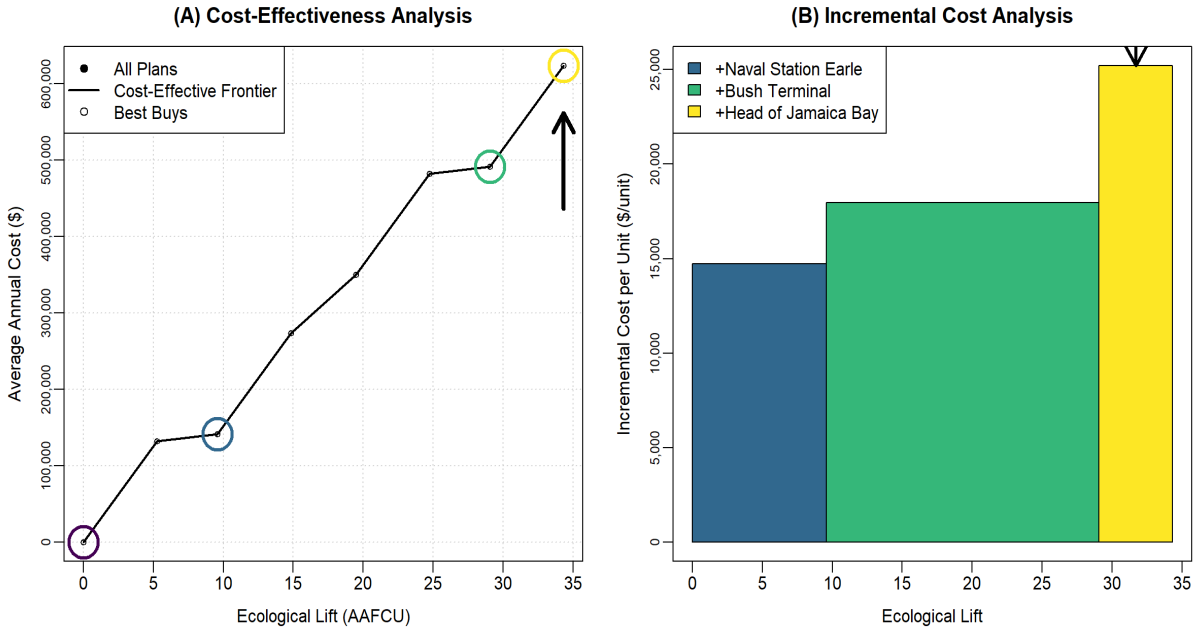

Figure J-44. Cost-effectiveness and incremental cost analyses for the oyster reef restoration. Arrows indicate the recommended plan.

Secondary decision factors provide little differentiation between these sites (Figure J-45), notably the following.

- Oyster reef restoration sites are relatively isolated from residents with the notable exception of Bush Terminal.
- Oyster reef restoration is highly supported by all stakeholders as evidenced by large-scale, multi-agency initiatives such as the “Billion Oyster Project.”

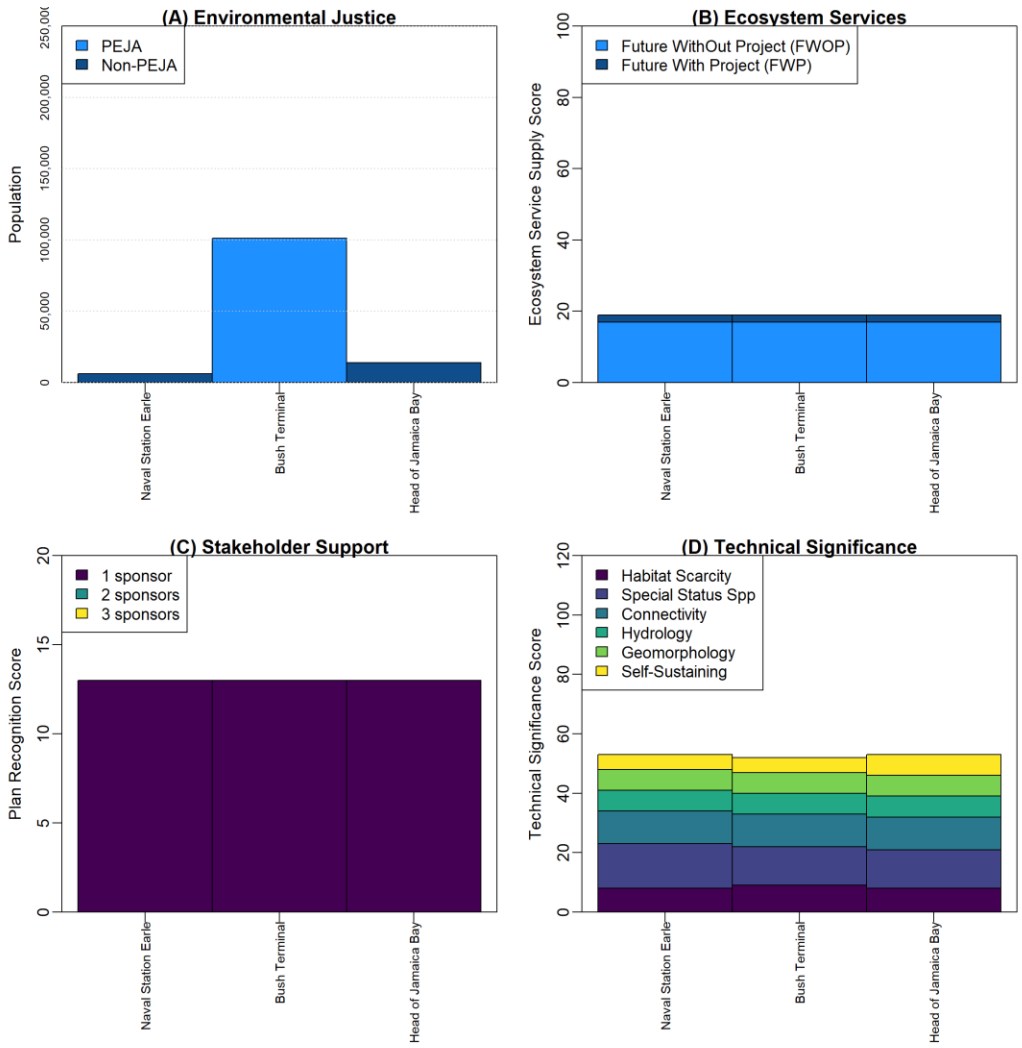

Figure J-45. Secondary decision factors for the oyster reef restoration.

Based on these analyses, one plan was considered for the final decision array. Smaller plans would not meet the planning objectives and would likely be unacceptable to stakeholders and sponsors.

- *Base Plan* -**Recommendation**: In light of only environmental outcomes, a reasonable plan would include all oyster reef sites (i.e., Naval Weapons Station Earle, Bush Terminal and Head of Jamaica Bay). This plan costs $15.9M and produces 34.3 habitat units. This plan directly addresses the loss of an ecosystem that has declined to less than 1% of its historical range. Furthermore, the relatively low unit cost (less than $20,000 / unit) and high visibility of these sites (e.g., the Billion Oyster Project) make these sites an efficient investment. This recommendation also significantly contributes to the regional Comprehensive Restoration Plan targets of 2,000 acres by 2050.

Table J-39. Array of best buy plans for oyster reef restoration

Plan	Ecological Lift (AAFCU)	Annualized Cost ($)	Incremental Cost ($/AAFCU)	Unit Cost ($/AAFCU)	Total Cost ($)	Total Population	Number of PEJAs	Net Ecosystem Services Score (sum)	Plan Recognition Score (sum)	USACE Technical Significance (sum)
FWOP	0	0	0	0	0	0	0	0	0	0
+Naval Weapons Station Earle	9.6	141,160	14,731	14,731	3,519,917	6,131	0	2	13	53
+Bush Terminal	29.1	491,329	17,956	16,893	12,633,838	107,202	1	4	26	105
+Head of Jamaica Bay	34.3	623,549	25,201	18,163	15,928,235	121,184	1	6	39	158

4.7. Summary of System-Scale Recommendations

This analysis has focused on the development of recommended plans at the system-scale. The following tables summarize the ecological benefits and monetary costs associated with these 22 recommended sites at both site-and system-scales.

Table J-40. Summary of site-scale recommendations before plan optimization

System	Site	Alt	Lift (AAFCU)	Avg Ann Cost ($)	Unit Cost ($/AAFCU)	Total Cost ($)
Jamaica Bay Perimeter	Dead Horse Bay	Alt4	35.84	3,330,851	92,936	84,545,962
	Fresh Creek	Alt5	36.78	1,382,939	37,600	33,885,522
	Brant Point	Alt2	3.45	273,007	79,195	6,581,347
Jamaica Bay Marsh Islands	Duck Point	Alt2	22.31	970,476	43,490	23,940,123
	Stony Creek	Alt1	29.26	924,034	31,582	22,733,369
	Pumpkin Patch West	Alt2	12.68	875,808	69,071	20,991,688
	Pumpkin Patch East	Alt3	17.49	980,194	56,041	24,193,105
	Elders Center	Alt3	20.23	853,506	42,192	20,900,721
Harlem River, East River and Western Long Island Sound	Flushing Creek	AltB	7.26	592,618	81,631	13,513,719
	Bronx Zoo and Dam	AltA	1.69	255,948	151,275	6,311,341
	Stone Mill Dam	AltA	19	54,241	2,855	929,827
	Shoelace Park	AltB	4.97	760,408	152,923	18,935,284
	Bronxville Lake	AltB	3.82	600,726	157,057	14,695,415
	Garth Harney	AltA	2.46	305,228	124,046	7,649,378
Newark Bay, Hackensack River and Passaic River	Oak Island Yards	AltA	4.8	753,781	157,019	18,571,152
	Essex County Branch Brook Park	AltD	22.34	1,855,027	83,028	47,413,586
	Kearny Point	AltA	10.04	2,057,073	204,899	52,111,997
	Metromedia Tract	AltA	13.45	1,137,241	84,525	28,338,217
	Meadowlark Marsh	AltC	15.47	1,911,889	123,589	47,747,190
Oyster Reef Restoration	Naval Weapons Station Earle	AltC	9.58	141,160	14,731	3,519,917
	Bush Terminal	AltC	19.5	350,169	17,956	9,113,921
	Head of Jamaica Bay	AltC	5.25	132,220	25,201	3,294,396

Table J-41. Summary of system-scale recommendations before plan optimization

Region	Ecological Lift (AAFCU)	Annualized Cost ($)	Unit Cost ($/AAFCU)	Total Cost ($)	OMRR&R Cost ($)	Total Population	Number of PEJAs
Jamaica Bay Perimeter	76	4,986,797	65,557	125,012,831	180,000	169,704	2
Jamaica Bay Marsh Islands	102	4,604,018	45,150	112,759,006	250,000	5,173	3
Harlem River, East River and Western Long Island Sound	39	2,569,169	65,525	62,034,964	210,000	827,429	4
Newark Bay, Hackensack River and Passaic River	66	7,715,010	116,706	194,182,142	340,000	269,789	3
Oyster Reef Restoration	34	623,549	18,163	15,928,235	30,000	121,184	1
TOTAL	318	20,498,544	64,525	509,917,177	1,010,000	1,393,279	13

5. Confirmation of the Recommended Plan following Optimization

Following the Agency Decision Milestone, all benefits and costs were verified at each site. During this process, two sites were removed from the recommendation for logistical and administrative reasons:

- *Brant Point*: Jamaica Bay Perimeter planning activities initially assumed independence from other USACE projects without final approval (i.e., Chief's Reports). However, the East Rockaway planning study was approved during final stages of HRE planning (August 2019). Brant Point is included in the natural and nature-based features for the East Rockaway project. Restoration plans will be folded into designs for this ongoing project and not recommended for HRE.

- *Kearny Point*: During the planning process, remedial actions were conducted at the site by other agencies which preclude USACE actions at the site, and thus, this site is not recommended for further action.

Restoration designs were optimized at the remaining 20 sites with accompanying reassessment of ecological benefits and costs. Three analyses were conducted to ensure that changes in benefits and costs did not alter the recommended agency action described in Section 4. First, ecological benefits and costs were annualized for the final restoration designs. Second, changes in unit cost were examined on a site-by-site basis. Third, the effects of optimization were considered by re-conducting the system-scale CE/ICA. Together, these assessments confirm the National Ecosystem Restoration Plan, which is summarized in Section 6.

5.1. Optimized Benefits and Costs

Restoration designs were optimized at the remaining 20 sites with accompanying reassessment of ecological benefits and costs. Following methods from Section 2.1, benefits were annualized. Table J-41 presents optimized values associated with the recommended alternative.

Table J-42. Summary of ecological benefits for the optimized restoration designs

Site	Alternative	FCU (TY0)	FCU (TY2)	FCU (TY20)	FCU (TY50)	Average Annual Benefits (AAFCU)	Lift (AAFCU)
Dead Horse Bay	Alt4	1.2	30.3	31.5	34.2	31.5	30.3
Fresh Creek	Alt5	22.5	57	57.9	59.7	57.5	36.9
Duck Point	Alt2	3.3	25.8	32.9	31	30.3	28.4
Stony Creek	Alt1	4.7	33.5	43.4	41.1	40	37.3
Pumpkin Patch West	Alt2	0	15.5	19.8	19.4	18.4	18.4
Pumpkin Patch East	Alt3	0	18.6	24	22.9	22.1	22.1
Elders Center	Alt3	0	18.5	24	21.2	21.6	21.6
Flushing Creek	AltB	4.4	12.8	12.7	12.9	12.6	8.3
Bronx Zoo and Dam	AltA	0.5	2.4	2.4	2.3	2.3	1.9
Stone Mill Dam	AltA	0.3	19.9	19.9	19.9	19.5	19.2
Shoelace Park	AltB	0	10	10	9.5	9.6	9.6
Bronxville Lake	AltB	0.1	4.1	4.1	3.9	4	3.8
Garth Harney	AltA	0.2	4.7	4.7	4.5	4.5	4.3
Oak Island Yards	AltA	3.7	4.7	7.2	6.9	6.6	2.8
Essex County Branch Brook Park	AltD	19	42.6	48.4	45.9	45.9	26.9
Metromedia Tract	AltA	34	46.3	60.5	60.1	57.0	20.6
Meadowlark Marsh	AltC	52.1	43.6	60.4	62.2	57.4	14.6
Naval Weapons Station Earle	AltC	0	9.8	9.8	9.8	9.6	9.6
Bush Terminal	AltC	0	19.9	19.9	19.9	19.5	19.5
Head of Jamaica Bay	AltC	0	5.4	5.4	5.4	5.2	5.2

Cost estimates were revised for the optimized designs. Project first costs were estimated using standard cost engineering methods (Appendix I). Average annual economic costs were computed based on project first cost, interest during construction, and OMRR&R. Monitoring and adaptive management costs were amortized over a five year period. Total OMRR&R costs were amortized over a 10-year period (Years 6-15) with exceptions for sites with long-term repair needs. Fully funded costs were projected to the mid-point of construction (Appendix I). Table J-42 presents optimized costs for the recommended alternatives.

Table J-43. Summary of costs for the optimized restoration designs

Site	Alt	Total Monitoring Cost ($)	Total Adaptive Management Cost ($)	Project First Cost ($)	Total OMRR&R Cost ($)	Annual Economic Cost ($)	Fully Funded Cost ($)
Dead Horse Bay	Alt4	128,137	285,853	40,750,432	162,486	1,566,406	68,645,000
Fresh Creek	Alt5	244,626	273,065	33,914,507	182,006	1,291,116	44,377,000
Duck Point	Alt2	167,494	392,470	21,401,095	169,394	813,568	27,271,000
Stony Creek	Alt1	167,494	548,540	23,220,043	188,380	887,316	27,976,000
Pumpkin Patch West	Alt2	135,387	272,670	20,124,334	154,797	761,952	31,897,000
Pumpkin Patch East	Alt3	135,387	304,480	21,581,125	156,827	818,662	38,856,000
Elders Center	Alt3	135,387	292,514	19,582,641	156,333	741,493	28,318,000
Flushing Creek	AltB	129,188	80,638	16,151,862	166,006	615,187	19,786,000
Bronx Zoo and Dam	AltA	165,863	718,045	10,993,425	1,059,705	425,882	13,020,000
Stone Mill Dam	AltA	104,696	128,231	4,658,650	665,011	182,857	5,606,000
Shoelace Park	AltB	165,863	835,374	20,713,053	1,504,484	796,204	27,969,000
Bronxville Lake	AltB	165,863	863,094	15,400,018	189,524	582,270	22,389,000
Garth Harney	AltA	165,863	741,432	10,322,520	772,468	396,596	13,134,000
Oak Island Yards	AltA	101,044	102,760	15,440,769	154,172	587,309	25,906,000
Branch Brook Park	AltD	190,965	3,986,573	52,027,663	317,423	1,976,173	75,928,000
Metromedia	AltA	184,854	860,698	31,106,080	185,055	1,181,233	43,087,000
Meadowlark	AltC	184,854	444,980	29,668,449	181,274	1,129,412	46,351,000
Naval Station Earle	AltC	78,278	372,771	8,508,329	298,238	328,007	10,354,000
Bush Terminal	AltC	147,972	468,082	6,935,486	361,673	267,098	9,514,000
Head of Jamaica Bay	AltC	78,278	386,866	5,683,652	426,253	221,761	7,276,000

5.2. Site-Scale Confirmation of the Recommended Plan

Table J-44 summarizes changes in the ecological lift, average annual costs, and unit costs of each site. This table also shows percent change in unit cost and notes any sites where unit costs increased. Fifteen sites showed decreased unit cost, where either benefits increased, costs declined, or changes occurred in both). Declines in unit cost increased the competitiveness of these sites, which were previously justified in Section 4. As such, these sites are assumed to be even more competitive and are easily confirmed as part of the recommended plan. Unit costs increased at five sites, but these increases are acceptable for the following site-specific reasons. Notably, all increases in costs and benefits should be considered relative to other project uncertainties (e.g., contingency estimates ranging from 21-37%, ecological model outputs, sea level change, etc.).

- *Bronx Zoo and Dam*: Benefits increased at this location as a result of design optimization, but costs increased substantially as well. Cost changes were the result of adding toe protection features and these costs would have consistently affected the relative ranking of alternatives at this site. The increase in unit cost is justifiable at this location given the dependency of other restoration actions on this site. For instance, the large fish passage benefits of Stone Mill Dam cannot be realized without Bronx Zoo and Dam restoration. Furthermore, the increase in costs were attributable in part to increases in monitoring and adaptive management of a fish ladder, which has broader benefits to regional tributary reconnection as a "living laboratory."

- *Stone Mill Dam*: Unit cost increased substantially at this location, but this unit cost remains the lowest cost of any HRE site.

- *Oak Island Yards*: Benefits and costs declined at this marsh restoration site. Specifically, prior assumptions about site excavation volumes were modified and led to a reduction in benefits. However, this Passaic River site is in the Urban Waters Federal Partnership, and the benefits are justifiable relative to the costs.

- *Naval Weapons Station Earle*: Unit cost increased substantially at this location, but unit cost remains low relative to other HRE sites and oyster reef restoration represents a unique ecological outcome.

- *Head of Jamaica Bay*: Unit cost increased substantially at this location, but unit cost remains low relative to other HRE sites and oyster reef restoration represents a unique ecological outcome.

Table J-44. Summary of initial and optimized benefits and costs

Site	Alt	Initial Lift (AAFCU)	Final Lift (AAFCU)	Initial Avg Ann ($)	Final Avg Ann ($)	Initial Unit Cost ($/AAFCU)	Final Unit Cost ($/AAFCU)	Change in Unit Cost (%)
Dead Horse Bay	Alt4	35.8	30.3	3,330,851	1,566,406	92,936	51,766	-44.3
Fresh Creek	Alt5	36.8	36.9	1,382,939	1,291,116	37,600	34,979	-7.0
Duck Point	Alt2	22.3	28.4	970,476	813,568	43,490	28,627	-34.2
Stony Creek	Alt1	29.3	37.3	924,034	887,316	31,582	23,778	-24.7
Pumpkin Patch West	Alt2	12.7	18.4	875,808	761,952	69,071	41,339	-40.2
Pumpkin Patch East	Alt3	17.5	22.1	980,194	818,662	56,041	37,044	-33.9
Elders Center	Alt3	20.2	21.6	853,506	741,493	42,192	34,334	-18.6
Flushing Creek	AltB	7.3	8.3	592,618	615,187	81,631	74,537	-8.7
Bronx Zoo and Dam	AltA	1.7	1.9	255,948	425,882	151,275	225,959	+49.4
Stone Mill Dam	AltA	19.0	19.2	54,241	182,857	2,855	9,504	+232.9
Shoelace Park	AltB	5.0	9.6	760,408	796,204	152,923	82,585	-46.0
Bronxville Lake	AltB	3.8	3.8	600,726	582,270	157,057	152,232	-3.1
Garth Harney	AltA	2.5	4.3	305,228	396,596	124,046	92,951	-25.1
Oak Island Yards	AltA	4.8	2.8	753,781	587,309	157,019	206,576	+31.6
Branch Brook Park	AltD	22.3	26.9	1,855,027	1,976,173	83,028	73,529	-11.4
Metromedia	AltA	13.5	20.6	1,137,241	1,181,233	84,525	57,325	-32.2
Meadowlark	AltC	15.5	14.6	1,911,889	1,129,412	123,589	77,325	-37.4
Naval Station Earle	AltC	9.6	9.6	141,160	328,007	14,731	34,230	+132.4
Bush Terminal	AltC	19.5	19.5	350,169	267,098	17,956	13,696	-23.7
Head of Jamaica Bay	AltC	5.2	5.2	132,220	221,761	25,201	42,268	+67.7

5.3. System-Scale Confirmation of the Recommended Plan

A second method for confirming the recommended plan was applied by re-conducting CE/ICA at the system-scale for each planning region. The relative ranking of alternatives and associated incremental costs may then be reconsidered in light of optimized benefits and costs. The following section presents side-by-side comparisons for each region and associated discussion on a regional basis.

Jamaica Bay Perimeter: Reduced unit costs at Fresh Creek and Dead Horse Bay make these sites more competitive at a system-scale. Final incremental costs were significantly lower than initial estimates.

Table J-45. Comparison of incremental cost analyses for initial and optimized actions in Jamaica Bay Perimeter Planning Region

Initial Plan	Initial Lift (AAFCU)	Initial Annualized Cost ($)	Initial Incremental Cost ($/AAFCU)	Final Plan	Final Lift (AAFCU)	Final Annualized Cost ($)	Final Incremental Cost ($/AAFCU)
FWOP	0	0	0	FWOP	0	0	0
+Fresh Creek	36.8	1,382,939	37,600	+Fresh Creek	36.9	1,291,116	34,979
+Brant Point	40.2	1,655,946	79,195	+Dead Horse Bay	67.2	2,857,522	51,766
+Dead Horse Bay	76.1	4,986,797	92,936	+Brant Point	70.6	3,130,529	79,195
+Dubos Point	78	5,383,579	209,024	+Dubos Point	72.5	3,527,310	209,024
+Bayswater State Park	79.1	5,630,978	217,429	+Bayswater State Park	73.7	3,774,709	217,429
+Hawtree Point	79.1	5,732,488	2,242,038	+Hawtree Point	73.7	3,876,220	2,242,038

Jamaica Bay Marsh Islands: Reduced unit costs at all five marsh islands make these sites more attractive. Final incremental costs were significantly lower than initial estimates.

Table J-46. Comparison of incremental cost analyses for initial and optimized actions in Jamaica Bay marsh islands Planning Region

Initial Plan	Initial Lift (AAFCU)	Initial Annualized Cost ($)	Initial Incremental Cost ($/AAFCU)	Final Plan	Final Lift (AAFCU)	Final Annualized Cost ($)	Final Incremental Cost ($/AAFCU)
FWOP	0	0	0	FWOP	0	0	0
+Stony Creek	29.3	924,034	31,582	+Stony Creek	37.3	887,316	23,778
+Elders Center	49.5	1,777,540	42,192	+Duck Point	65.7	1,700,884	28,627
+Duck Point	71.8	2,748,016	43,490	+Elders Center	87.3	2,442,376	34,334
+Pumpkin Patch East	89.3	3,728,210	56,041	+Pumpkin Patch East	109.4	3,261,038	37,044
+Pumpkin Patch West	102	4,604,018	69,071	+Pumpkin Patch West	127.9	4,022,991	41,339

Harlem River, East River and Western Long Island Sound: Increased unit cost at Stone Mill Dam had no change in the relative ranking of sites. In fact, Stone Mill Dam remains the most competitive site in the urban stream planning set. Conversely, Bronx Zoo and Dam declined in the relative ranking of sites because of increased unit cost. However, the benefits of Stone Mill Dam cannot be realized without action at the downstream Bronx Zoo and Dam site. Table J-48 shows the results of incremental cost analysis when accounting for the dependency between actions at Bronx Zoo and Dam and Stone Mill Dam. Although costs increased at Bronx Zoo and Dam, the combination of these sites is the most competitive action from a portfolio standpoint. Thus, the recommended plan includes all site up to and including Bronx Zoo and Dam.

Table J-47. Comparison of incremental cost analyses for initial and optimized actions in the Harlem River, East River and Western Long Island Sound Planning Region

Initial Plan	Initial Lift (AAFCU)	Initial Annualized Cost ($)	Initial Incremental Cost ($/AAFCU)	Final Plan	Final Lift (AAFCU)	Final Annualized Cost ($)	Final Incremental Cost ($/AAFCU)
FWOP	0	0	0	FWOP	0	0	0
+Stone Mill Dam	19	54,241	2,855	+Stone Mill Dam	19.2	182,857	9,504
+Flushing Creek	26.3	646,859	81,631	+Flushing Creek	27.5	798,045	74,537
+Garth Harney	28.7	952,087	124,046	+Shoelace Park	37.1	1,594,249	82,585
+Bronx Zoo and Dam	30.4	1,208,035	151,275	+Garth Harney	41.4	1,990,845	92,951
+Shoelace Park	35.4	1,968,443	152,923	+Bronxville Lake	45.2	2,573,114	152,232
+Bronxville Lake	39.2	2,569,169	157,057	+Bronx Zoo and Dam	47.1	2,998,996	225,959
+Westchester County Center	43.6	3,565,351	226,107	+Westchester County Center	51.5	3,995,178	226,107
+Crestwood Lake	48.5	4,689,137	228,336	+Crestwood Lake	56.4	5,118,965	228,336
+West Farm Rapids Park	49	4,868,216	370,502	+West Farm Rapids Park	56.9	5,298,044	370,502
+Muskrat Cove	49.7	5,216,371	535,806	+Muskrat Cove	57.6	5,646,199	535,806

Table J-48. Incremental cost analysis of optimized actions with dependency between fish passage actions in the Harlem River, East River and Western Long Island Sound Planning Region

Final Plan with Site Dependencies	Final Lift (AAFCU)	Final Annualized Cost ($)	Final Incremental Cost ($/AAFCU)
FWOP	0	0	0
+Stone Mill Dam + Bronx Zoo and Dam	21.1	608,739	28,850
+Flushing Creek	29.4	1,223,926	74,537
+Shoelace Park	39.0	2,020,130	82,585
+Garth Harney	43.3	2,416,726	92,951
+Bronxville Lake	47.1	2,998,996	152,232

Newark Bay, Hackensack River and Passaic River: Design optimization led to a significant increase in unit cost for Oak Island Yards (i.e., +31.6%). The incremental cost of including Oak Island Yards is now $206,576 / AAFCU. This represents a large "step" from the plan including Meadowlark Marsh, which has an incremental cost of $77,325 / AAFCU. Kearny Point was removed from consideration based on ongoing remedial actions by other entities as described at the beginning of Section 5. However, Oak Island Yards is still recommended for inclusion in the National Ecosystem Restoration plan. Including this site is important to demonstrate the joint program and governmental partnership with EPA's Superfund program sequencing restoration following the remedial action for the Lower Passaic River. This site is also important for the Urban Waters Federal Partnership showcasing our coordination with USEPA as Co-Lead Agency. This plan also benefits a second PEJA, and thus, there are substantial social benefits of including this restoration action.

Table J-49. Comparison of incremental cost analyses for initial and optimized actions in Newark Bay, Hackensack River and Passaic River Planning Region

Initial Plan	Initial Lift (AAFCU)	Initial Annualized Cost ($)	Initial Incremental Cost ($/AAFCU)	Final Plan	Final Lift (AAFCU)	Final Annualized Cost ($)	Final Incremental Cost ($/AAFCU)
FWOP	0	0	0	FWOP	0	0	0
+Branch Brook Park	22.3	1,855,027	83,028	+Metromedia	20.6	1,181,233	57,325
+Metromedia	35.8	2,992,268	84,525	+Branch Brook Park	47.5	3,157,406	73,529
+Meadowlark	51.3	4,904,157	123,589	+Meadowlark	62.1	4,286,818	77,325
+Oak Island Yards	56.1	5,657,938	157,019	+Kearny Point	72.1	6,343,891	204,899
+Kearny Point	66.1	7,715,010	204,899	+Oak Island Yards	75	6,931,200	206,576
+Dundee Island Park	66.5	7,839,171	286,974	+Dundee Island Park	75.4	7,055,360	286,974
+Clifton Dundee Canal	67.8	8,202,724	290,902	+Clifton Dundee Canal	76.7	7,418,913	290,902

Oyster Reef Restoration: The relative ranking of oyster reef sites were altered based on design optimization. However, all sites continue to provide low unit cost for a high value ecological resource that is extremely scarce in the region. Thus, the recommended plan remains to include all three oyster reef sites.

Table J-50. Comparison of incremental cost analyses for initial and optimized actions in oyster reef restoration

Initial Plan	Initial Lift (AAFCU)	Initial Annualized Cost ($)	Initial Incremental Cost ($/AAFCU)	Final Plan	Final Lift (AAFCU)	Final Annualized Cost ($)	Final Incremental Cost ($/AAFCU)
FWOP	0	0	0	FWOP	0	0	0
+Naval Weapons Station Earle	9.6	141,160	14,731	+Bush Terminal	19.5	267,098	13,696
+Bush Terminal	29.1	491,329	17,956	+Naval Weapons Station Earle	29.1	595,105	34,230
+Head of Jamaica Bay	34.3	623,549	25,201	+Head of Jamaica Bay	34.3	816,866	42,268

6. Summary of the National Ecosystem Restoration Plan

Per the Planning Guidance Notebook (ER 1105-2-100, Appendix E, Page E-163), the National Ecosystem Restoration Plan "meets planning objectives and constraints and reasonably maximizes environmental benefits while passing tests of cost effectiveness and incremental cost analyses, significance of outputs, acceptability, completeness, efficiency, and effectiveness" with additional factors related to partnership context and reasonableness of costs.

This appendix has sequentially presented the development of the National Ecosystem Restoration Plan for the Hudson-Raritan Estuary. This recommendation was developed based on multiple planning steps and analyses, specifically:

- An initial array of 33 restoration sites was proposed in the Draft Feasibility Report (February 2017), each with multiple alternatives. Two sites were removed from the analysis due to actions by others. Benefits and costs from the remaining 31 sites were reviewed, error-checked, and verified. These benefits and costs were annualized over a 50-year planning horizon for consistent comparison across the diverse study area (Appendix J, Section 2).

- Cost-effectiveness and incremental costs analyses (CE/ICA) were conducted at the site-scale with annualized benefits and costs, and a recommended alternative was identified for each proposed restoration site (Appendix J, Section 3).

- Site-scale recommendations were combined into system-scale plans for five planning sets: Jamaica Bay Perimeter; Jamaica Bay Marsh Islands; Harlem River, East River and Western Long Island Sound Region; Newark Bay, Hackensack River and Passaic River Region, and Oyster Reef Restoration. CE/ICA was applied to these system-wide plans. Additionally, secondary decision criteria were qualitatively assessed and used to support the plan recommendation rationale and describe the significance of the restoration site and action. Twenty-two sites were recommended (i.e., nine were eliminated) based on these analyses (Appendix J, Section 4).

- Two sites were removed from the recommendation for logistical and administrative reasons, and designs were optimized for the remaining twenty sites. Finalized benefits and costs were re-annualized for consistent comparison, and analyses were conducted to confirm the recommendation of twenty restoration sites (Appendix J, Section 5).

These analyses ultimately led to the National Ecosystem Restoration Plan, which is summarized in Tables 51-52. This plan "reasonably maximizes" ecological benefits in a cost-effective and cost-efficient manner. The plan recommends twenty nationally significant sites, which provide a substantial contribution to the overall ecological integrity of the Hudson-Raritan Estuary. The project first cost of these actions is $408.2M ($587.7M fully funded), which provide 341 habitat units in lift. Across all sites, the unit cost is $45,600/unit.

Table J-51. Site-by-site summary of the National Ecosystem Restoration Plan

Site	Ecological Lift (AAFCU)	Monitoring Cost ($)	Adaptive Management Cost ($)	Project First Cost ($)	Annual Economic Cost ($)	Unit Cost ($/AAFCU)	Fully Funded Cost ($)	Total OMRR&R Cost ($)
Dead Horse Bay	30.3	128,137	285,853	40,750,432	1,566,406	51,766	68,645,000	162,486
Fresh Creek	36.9	244,626	273,065	33,914,507	1,291,116	34,979	44,377,000	182,006
Duck Point	28.4	167,494	392,470	21,401,095	813,568	28,627	27,271,000	169,394
Stony Creek	37.3	167,494	548,540	23,220,043	887,316	23,778	27,976,000	188,380
Pumpkin Patch West	18.4	135,387	272,670	20,124,334	761,952	41,339	31,897,000	154,797
Pumpkin Patch East	22.1	135,387	304,480	21,581,125	818,662	37,044	38,856,000	156,827
Elders Center	21.6	135,387	292,514	19,582,641	741,493	34,334	28,318,000	156,333
Flushing Creek	8.3	129,188	80,638	16,151,862	615,187	74,537	19,786,000	166,006
Bronx Zoo and Dam	1.9	165,863	718,045	10,993,425	425,882	225,959	13,020,000	1,059,705
Stone Mill Dam	19.2	104,696	128,231	4,658,650	182,857	9,504	5,606,000	665,011
Shoelace Park	9.6	165,863	835,374	20,713,053	796,204	82,585	27,969,000	1,504,484
Bronxville Lake	3.8	165,863	863,094	15,400,018	582,270	152,232	22,389,000	189,524
Garth Harney	4.3	165,863	741,432	10,322,520	396,596	92,951	13,134,000	772,468
Oak Island Yards	2.8	101,044	102,760	15,440,769	587,309	206,576	25,906,000	154,172
Branch Brook Park	26.9	190,965	3,986,573	52,027,663	1,976,173	73,529	75,928,000	317,423
Metromedia	20.6	184,854	860,698	31,106,080	1,181,233	57,325	43,087,000	185,055
Meadowlark	14.6	184,854	444,980	29,668,449	1,129,412	77,325	46,351,000	181,274
Naval Station Earle	9.6	78,278	372,771	8,508,329	328,007	34,230	10,354,000	298,238
Bush Terminal	19.5	147,972	468,082	6,935,486	267,098	13,696	9,514,000	361,673
Head of Jamaica Bay	5.2	78,278	386,866	5,683,652	221,761	42,268	7,276,000	426,253

Table J-52. Regional summary of the National Ecosystem Restoration Plan

Region	Ecological Lift (AAFCU)	Unit Cost ($/AAFCU)	Project First Cost ($)	Fully Funded Cost ($)	OMRR&R Cost ($)
Jamaica Bay Perimeter	67	42,541	74,664,939	113,022,000	344,492
Jamaica Bay Marsh Islands	128	31,463	105,909,238	154,318,000	825,732
Harlem River, East River and Western Long Island Sound	47	63,659	78,239,529	101,904,000	4,357,197
Newark Bay, Hackensack River and Passaic River	65	75,066	128,242,961	191,272,000	837,923
Oyster Reef Restoration	34	23,794	21,127,467	27,144,000	1,086,164
TOTAL	341	45,607	408,184,134	587,660,000	7,451,508

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Attachment A: Jamaica Bay Perimeter (2010 Analysis)

The Jamaica Bay Perimeter sites were originally assessed via CE/ICA, recommended, and approved at a 2010 USACE Alternative Formulation Briefing. In 2010, 32 restoration alternatives (including no action) for the original eight Tier 1 Jamaica Bay sites were analyzed. Restoration costs were calculated in terms of present worth using the 2010 rate of 4.875% and annualized. Annualized costs and average annual restoration outputs were used in CE/ICA. Notably, all ecological outputs in 2010 were calculated by summing five categorical outputs from the Evaluation of Planned Wetlands model, which was revised as the average of five categories in the main text of Appendix J (above). All logical permutations of 32 restoration alternatives at eight sites resulted in 46,080 possible combinations of actions (i.e., "plans"). Of 46,080 plans, 187 plans were identified as cost effective and 11 plans as Best Buys (Figure J-A.1). Each of the best buys incorporated additional sites into the plan. To emphasize the incremental relationship between these plans, best buys are depicted as the prior plan + the new site (e.g., Plan 3 = "Plan 2 + Fresh Creek"). The 11 Best Buy Plans along with their respective average costs and incremental costs per additional output are presented in Figure J-s A.2 and A.3.

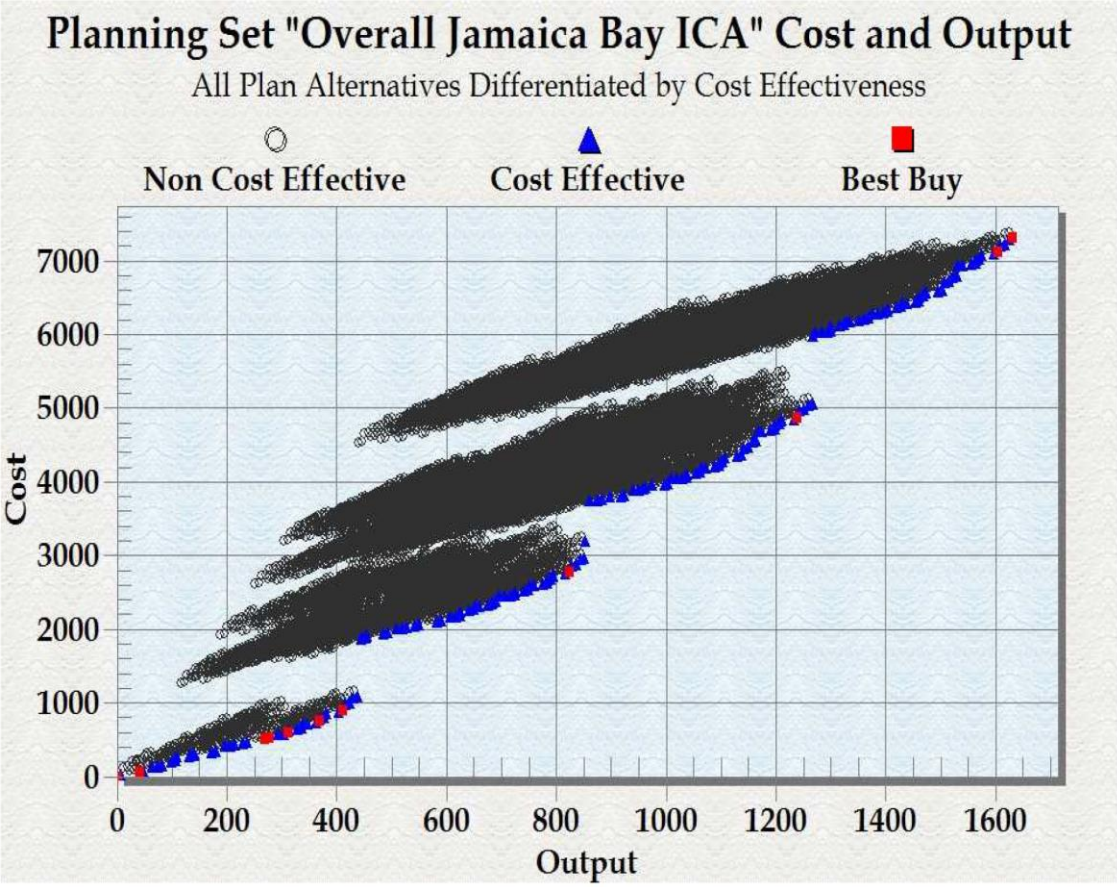

Figure J-A.1. Cost-effectiveness analysis of Jamaica Bay Perimeter sites (2010 analysis)

No.	Plan Description	AAFCU	Annual Cost ($1000)	Avg. Cost ($1000)/ AAFCU	Incremental Cost per AAFCU ($)
1	No Action	0	0	0	0
2	Bayswater State Park Tidal Channel with Coastal Dunes	41	54	1.32	1.32
3	Plan 2 + Fresh Creek Tidal Marsh with basin filling to Jamaica Bay	249	498	2.00	2.13
4	Plan 3 + Bayswater State Park T groin	284	516	2.04	2.31
5	Plan 4 + Dubos Point Tidal Channel with continuous toe protection	342	597	2.15	2.71
6	Plan 5 + Hawtree Point Coastal Dunes	348.5	754	2.16	2.77
7*	Plan 5 + *Fresh Creek Basin Filling to Jamaica Bay and Detention Basin*	386.5	893	2.31	3.66
8	Plan 7 + Dead Horse Bay tidal creek and trash removal	799.5	2,767	3.46	4.54
9	Plan 8 + Paerdegat Fringe marsh with basin fill to Jamaica Bay	1214.5	4,870	4.01	5.07
10*	Plan 9 + Spring Creek tidal channel marsh system and coastal dunes	1,546.5	7,113	4.60	6.77
11*	Plan 10 + Brant Point Tidal Marsh with shore protection	1,573.5	7,308	4.64	7.22

*Best Buy Plans

Figure J-A.2. Best buys plans for Jamaica Bay Perimeter sites (2010 analysis)

The CE/ICA identified two break points, where there is a marked increase in incremental costs, beyond the general range of preceding costs, from which three plans of interest were identified (Best Buy Plans 7, 10, 11). The first break point was at Best Buy Plan 7, which includes Fresh Creek, Hawtree Point, Bayswater State Park, and Dubos Point. The second break point was at Best Buy Plan 10, which includes all elements of Best Buy Plan 7 as well as Dead Horse Bay, Paerdegat Basin, and Spring Creek. The last remaining plan, Best Buy Plan 11, includes all elements of Best Buy Plan 10 as well as Brant Point. Ultimately, Best Buy Plan 11 was recommended and approved at the 2010 Alternative Formulation Briefing. Since 2010, restoration opportunities at Paerdegat Basin and Spring Creek are no longer available due to execution in other programs. Six sites were subsequently preserved for the HRE Final Feasibility Report: Dead Horse Bay, Fresh Creek, Brant Point, Hawtree Point, Bayswater State Park, and Dubos Point.

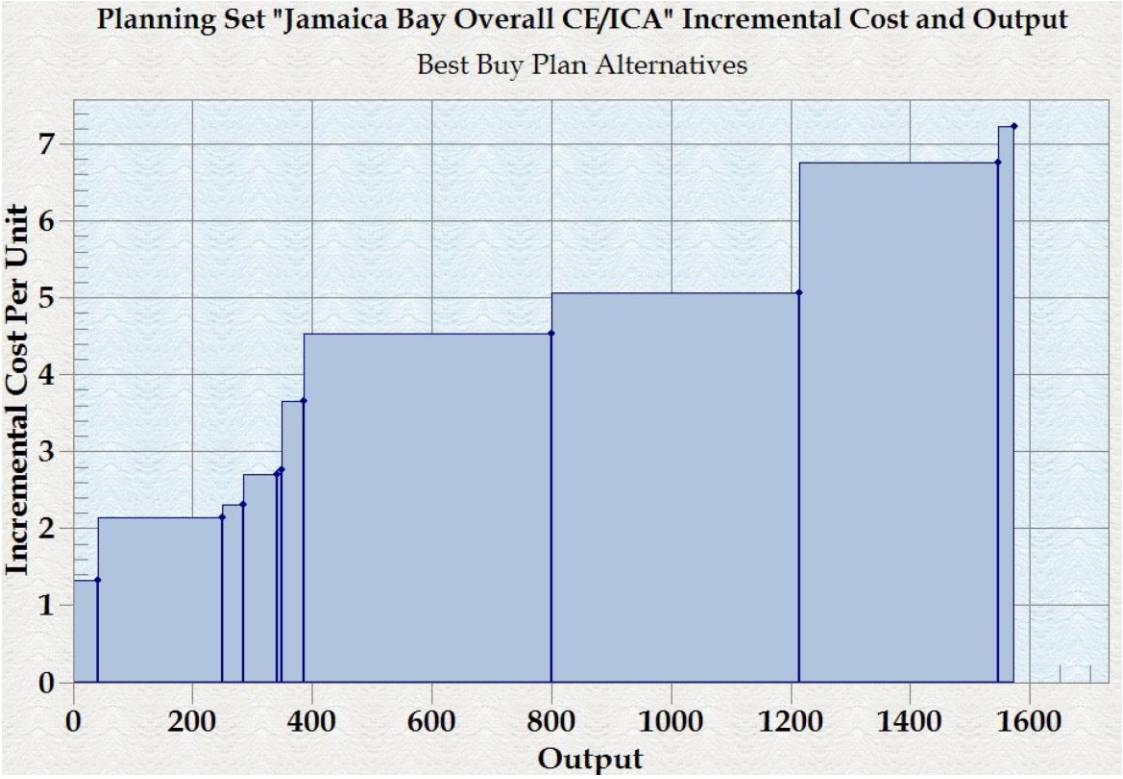

Figure J-A.3. Incremental cost analysis for Jamaica Bay Perimeter sites (2010 analysis). Bars are sequentially ordered from Plan 2 through Plan 11.