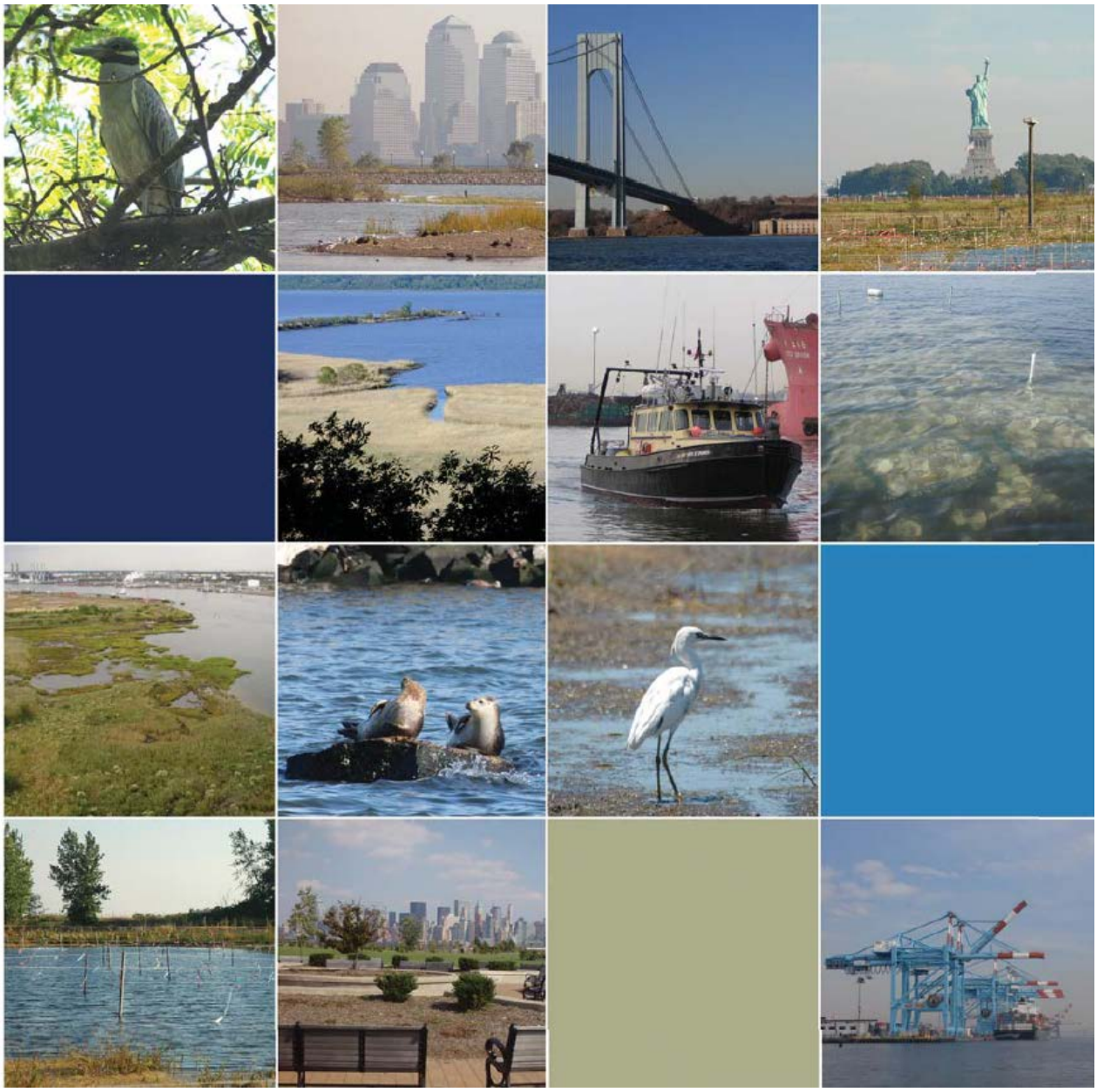
Hudson Raritan- Estuary Ecosystem Restoration Feasibility Study

Appendix M:

COST EFFECTIVENESS AND INCREMENTAL COST ANALYSIS

Draft Integrated Feasibility Report & Environmental Assessment
February 2017

Prepared by the New York District, North Atlantic Division, U.S. Army Corps of Engineers



Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study
Appendix M: Cost Effectiveness And Incremental Cost Analysis

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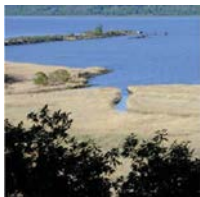

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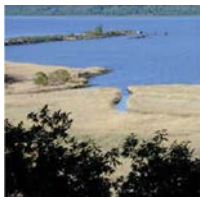


1 Introduction

This Hudson Raritan Estuary (HRE) Ecosystem Restoration Draft Integrated Feasibility Report and Environmental Assessment (FR/EA) used the Institute for Water Resources Planning Suite (IWR Planning Suite 2.0.6.1) to evaluate and compare sites with multiple plan alternatives in order to select the Tentatively Selected Plan (TSP). The suite is a water resources investment decision support tool, built by the Unites States Army Corps of Engineers (USACE) Institute for Water Resources for the formulation and evaluation of ecosystem restoration alternative plans. The cost effectiveness/incremental cost analysis (CE/ICA) approach is consistent with the Principles and Guidelines planning paradigm.

CE/ICA was conducted on estuarine and freshwater riparian sites with multiple alternatives at 16 sites in the Lower Passaic River (with exception of Dundee Island Park), Hackensack River, Bronx River and Flushing Creek (Table 1-1). CE/ICA was also conducted for the six (6) Jamaica Bay Perimeter/Shoreline sites in order to select the recommended plan in 2010.

Table 1-1: Restoration Sites Where CE/ICA was Conducted

Waterbody	Recommended Restoration	Site
Jamaica Bay Planning Region (2010)		
Jamaica Bay	Estuarine Habitat Restoration – Shoreline/Perimeter	• Dead Horse Bay • Fresh Creek • Hawtree Point • Bayswater State Park • Dubos Point • Brant Point
Harlem River, East River, and Western Long Island Sound Planning Region		
Flushing Creek	Estuarine Habitat Restoration	• Flushing Creek
Bronx River	Freshwater Riverine Habitat Restoration	• River Park/West Farm Rapids Park • Bronx Zoo and Dam • Shoelace Park • Muskrat Cove • Bronxville Lake • Crestwood Lake • Garth Woods/Harney Road • Westchester County Center
Newark Bay, Hackensack River, and Passaic River Planning Region		
Hackensack River	Estuarine Habitat Restoration	• Metromedia Tract • Meadowlark Marsh
Lower Passaic River	Tier 2 Estuarine Habitat Restoration	• Oak Island Yards • Kearny Point
	Freshwater Riverine Habitat Restoration	• Essex County Branch Brook Park • Dundee Island Park • Clifton Dundee Canal Green Acres

1.1 Estuarine Restoration - Jamaica Bay Shoreline Perimeter Sites

In 2010, 32 restoration alternatives (including no action) for the original eight (8) Tier 1 Jamaica Bay sites (Appendix E-1) were analyzed through the IWR PLAN Decision Support Software. Each of these eight (8) sites (also including Spring Creek South and Paerdegat Basin) contributes to the overall degradation of the Jamaica Bay area and their restoration would work towards solving the water resources problems in the planning region.

Elements that affected the performance of restoration measures over the course of the 50 target years included tidal energy, shore protection measures, maturity periods of habitat types, and proposed habitat proportions for each of the 32 restoration measures. Restoration implementation costs (Appendix L) were calculated using base construction costs (USACE, 2003). Annualized costs and average annual restoration outputs (Appendix E-1) were input into IWR-PLAN (Attachment A).

No two (2) alternatives from one site were included in a plan (i.e., Dubos Point No Action and Dubos Point Tidal Channel could not logically both be included within one plan). Consequently, from 32 restoration alternatives among eight (8) sites, IWR-PLAN identified 46,080 possible combinations. Best Buy Plans and Cost Effective Plans were identified and provided in Attachment A. Of the 46,080 possible combinations, 187 were identified as cost effective. For each plan identified as cost effective, no other plan provides the same output for less cost.

Of the 187 Cost Effective Plans, IWR-PLAN identified 11 Best Buy Plans through an Incremental Cost Analysis (ICA). Each of the Best Buy Plans indicate additional sites added to each plan. The primary difference between most of the plans was the inclusion of more restoration sites. For instance, Best Buy Plan 2 recommends a tidal channel with coastal dunes at Bayswater State Park. The next plan, Number 3, includes the same restoration alternative at Bayswater State Park and adds a tidal marsh at Fresh Creek with basin filling. To emphasize the incremental relationship between these plans, Best Buy Plan 3 was depicted as “Plan 2 + Fresh Creek”. An ICA revealed changes in costs as output levels increase, and allowed an assessment of whether the increase in output was worth the additional cost. The 11 Best Buy Plans along with their respective average costs and incremental costs per additional output are presented in Table 2-1.

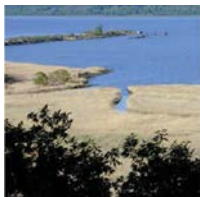
The CE/ICA through IWR-PLAN software identified two break points, where there is a marked increase in incremental costs, beyond the general range of preceding costs, from which three Plans of Interest were identified (Best Buy Plans 7, 10, 11) (Table 2-1). The first break point was at Best Buy Plan 7, which includes a suite of tidal creek systems, fringe marsh systems, basin filling and recontouring, coastal dune restoration, and shore protection in the form of toe dike protection, tidal pools, and natural plantings at Fresh Creek, Hawtree Point, Bayswater State Park, and Dubos Point for a total habitat output of 386.5 Average Annual Functional Capacity Units (AAFCU)s with a project first cost of $16,603,000, at an average annual cost of $893,000. The second break point was at Best Buy Plan 10, which includes all the elements of Best Buy Plan 7, and extends the suite of restoration measures to the sites of Dead Horse Bay, Paerdegat Basin, and Spring Creek, for a total habitat output of 1,546.5 AAFCUs with a project first cost of $132,381,000, at an average annual cost of $7,113,000. The last remaining plan, Best Buy Plan 11, includes all the elements of Best Buy Plan 10 and adds wetland restoration and shore protection at Brant Point. This conclusion is illustrated in Figures 2-1 and 2-2, which displays the incremental cost per additional output for each plan in graphic form, first in point plot form and then in box graph form. In the following section, these results are evaluated to determine which one is the tentatively selected plan.

1.2 Estuarine and Freshwater Riparian Restoration Sites

CE/ICA was conducted on individual sites to determine which alternative was considered the "Best Buy Plan" and the most cost effective for each site. Costs were amortized at the FY2017 discount rate of 2.875 percent over a 50 year period of analysis (Cost Appendix L). The 50 year total wetland AAFCU scores were the benefit metric that was assessed in CE/ICA (Alternatives Development Appendix E). Site locations were assessed for plan efficiency and effectiveness by comparing the AAFCU output performance and the cost of management measures of various scales, including a no action plan. The alternative scales used for each site were A, B, and C; with A typically being expected to provide the greatest ecological uplift, followed by B, and then C which is expected to provide the least ecological uplift.

The cost effectiveness analysis ensures that the least cost plan was identified for each possible level of environmental output; and that for any level of investment, the maximum level of AAFCU output is identified. The Best Buy and cost effective plans are identified by an algorithm that measures plans along a frontier of higher output with lower costs. Incremental Cost Analysis calculates the cost per additional AAFCU of the Best Buy plans only, which allows for comparison of Best Buy plans across the site study area.

In most cases, the TSP was identified as the Best Buy Plan which had the least cost per AAFCU. If two (2) alternatives were identified as the Best Buy plans, Stream Visual Assessment Protocol (SVAP) results were considered to select the TSP alternative. Tables 2-2 through 2-16 presents the results of the CE/ICA outputs for each alternative, the Best Buy and cost effective plans and the recommended alternative selected at each of the 16 sites.



2 CE/ICA Results

2.1 Jamaica Bay Planning Region

Table 2-1: CE/ICA Results for Jamaica Bay Shoreline Perimeter Restoration Sites

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

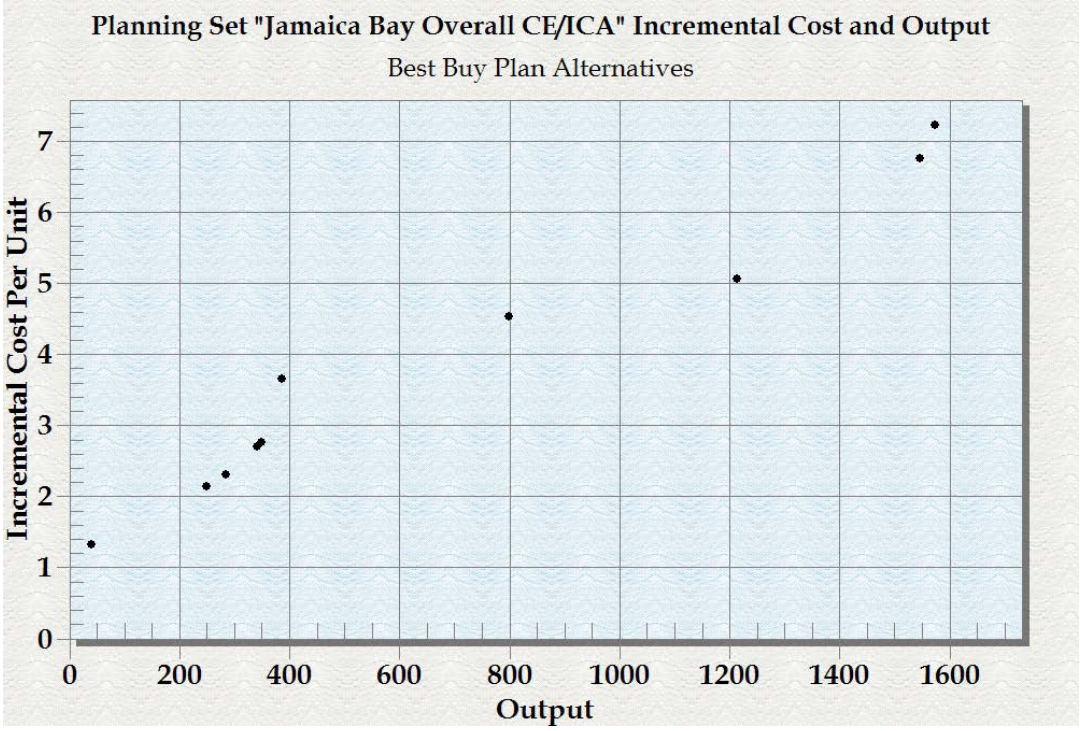


Figure 2-1: Jamaica bay Cost and Output

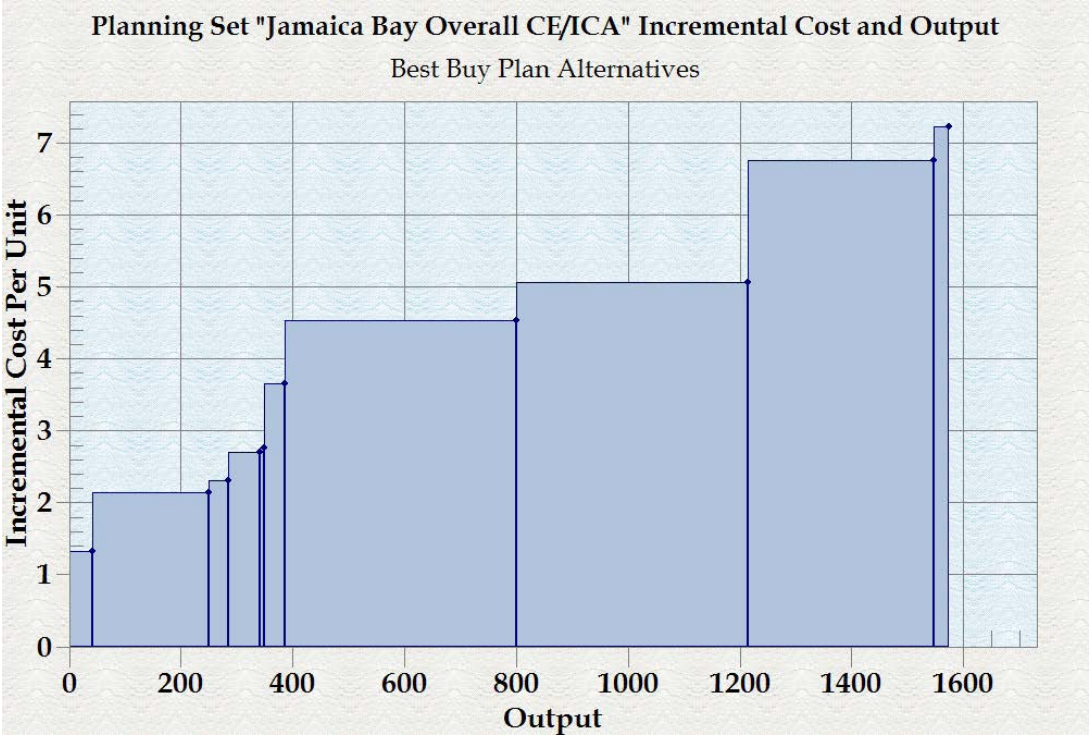


Figure 2-2: Jamaica Bay Incremental Cost and Output

2.2 Harlem River, East River, and Western Long Island Sound Planning Region

Table 2-2: Flushing Creek

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000/AAFCU)	Best Buy Plans
Alternative B	16.9	691.00	40.89	X
Alternative A	12.5	233.00	18.64	X
Alternative C	17.7	789.00	44.57	X

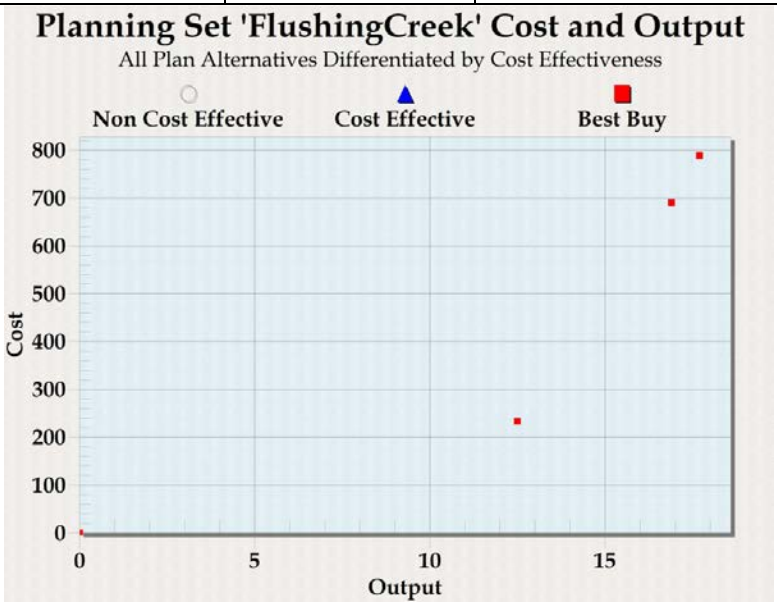


Figure 2-3 Flushing Bay Cost & Output

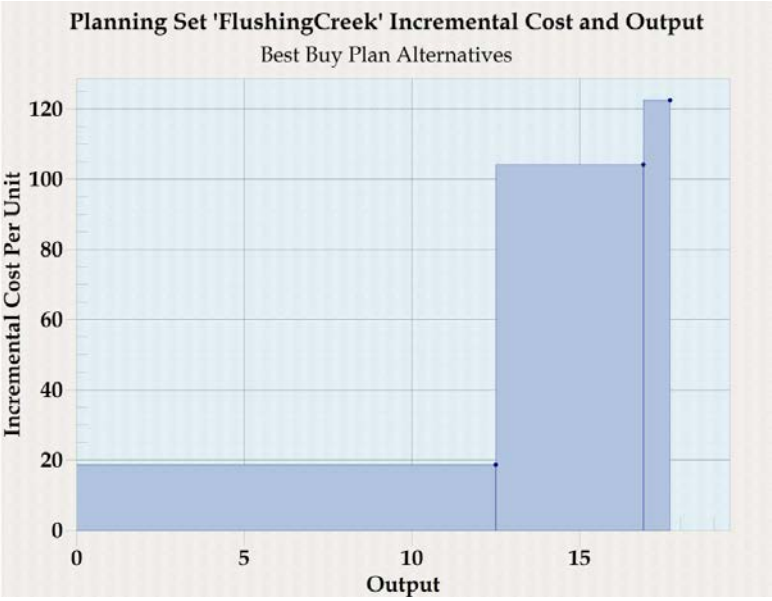


Figure 2-4: Flushing Creek Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Flushing Creek.

Table 2-3: Bronx River Park/West Farm Rapids Park

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	0.07	95.93	1,390.26	
Alternative B	0.38	152.87	403.36	X
Alternative A	0.38	154.78	407.33	X

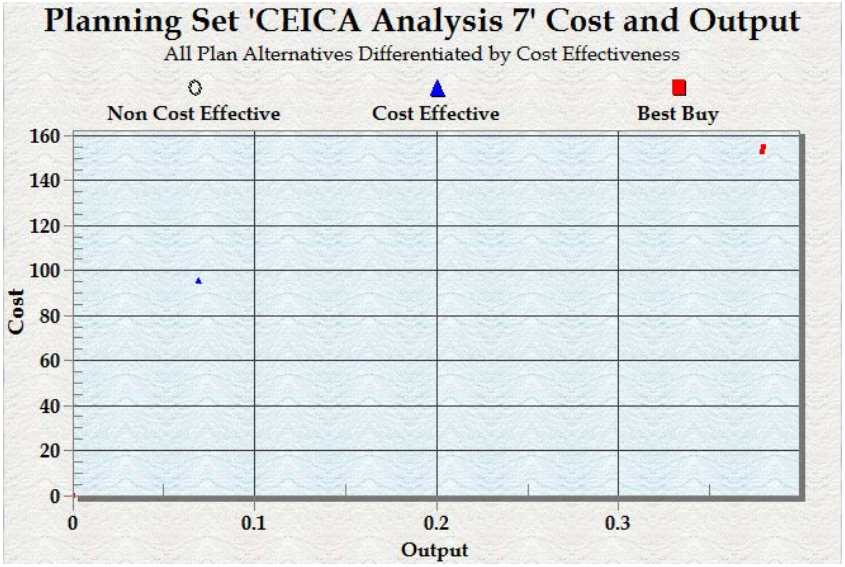


Figure 2-5: Bronx River Park/West Farm Rapids Park Cost & Output

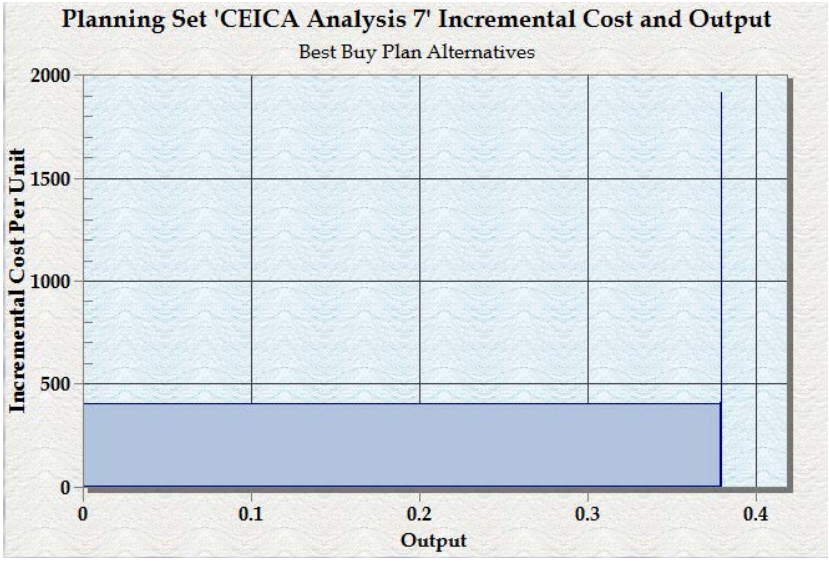


Figure 2-6: Bronx River Park/ West Farm Rapids Park Incremental Cost & Output

Recommendation: Alternative B is the most cost effective plan for Bronx River Park/West Farm Rapids Park.

Table 2-4: Bronx Zoo and Dam

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	1.37	147.14	107.48	X
Alternative B	1.69	189.41	111.94	X
Alternative A	2.04	242.59	119.03	X

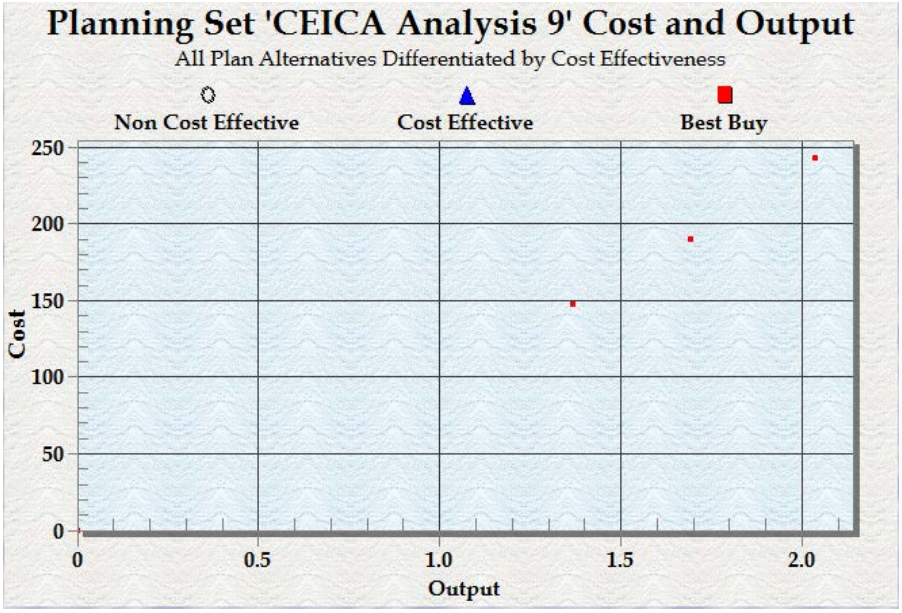


Figure 2-7: Bronx Zoo and Dam Cost & Output

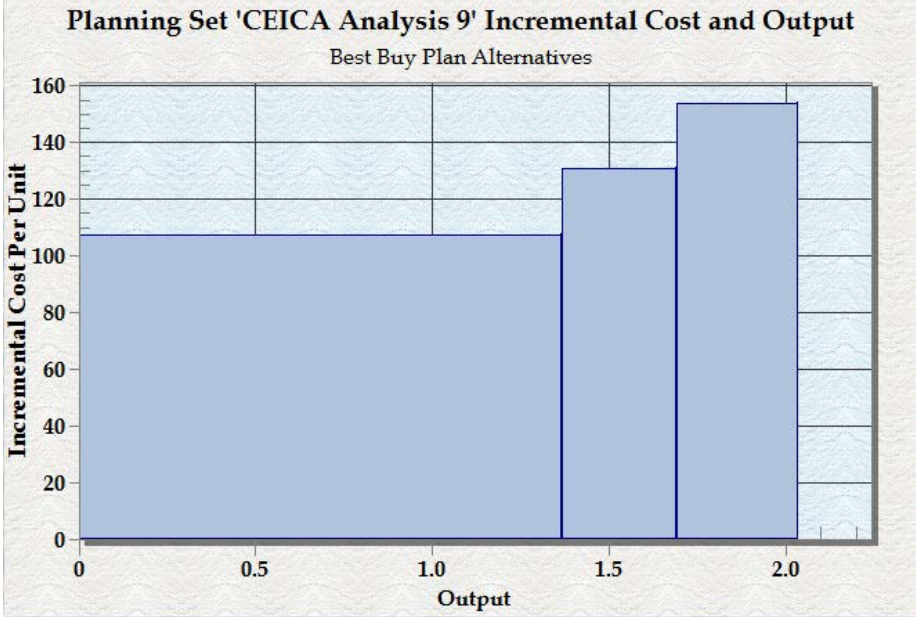


Figure 2-8: Bronx Zoo and Dam Incremental Cost & Output

Recommendation: Alternative C is the most cost effective plan for Bronx Zoo and Dam.

Table 2-5: Shoelace Park

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	0.36	338.23	929.21	
Alternative B	0.46	713.78	1,544.97	
Alternative A	3.30	959.25	290.33	X

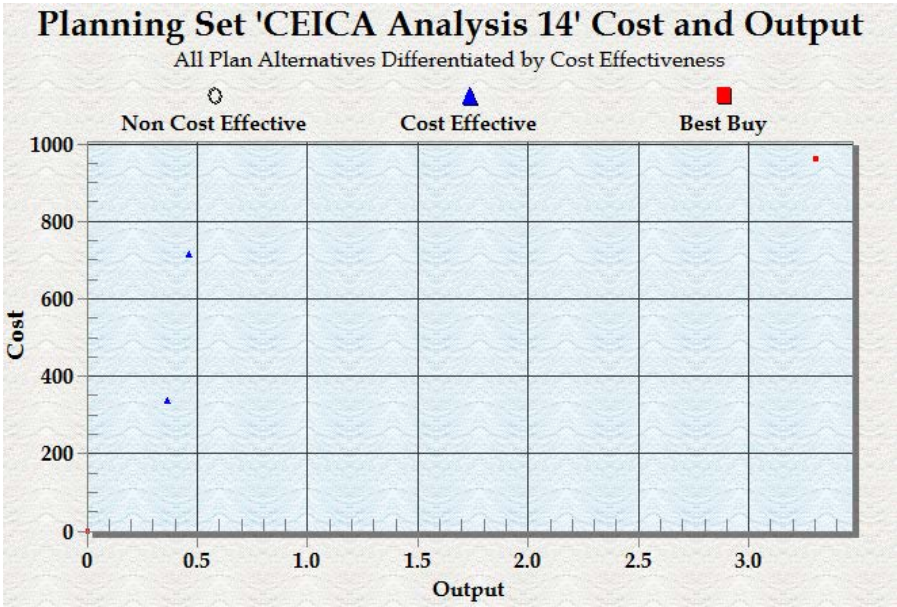


Figure 2-9: Shoelace Park Cost & Output

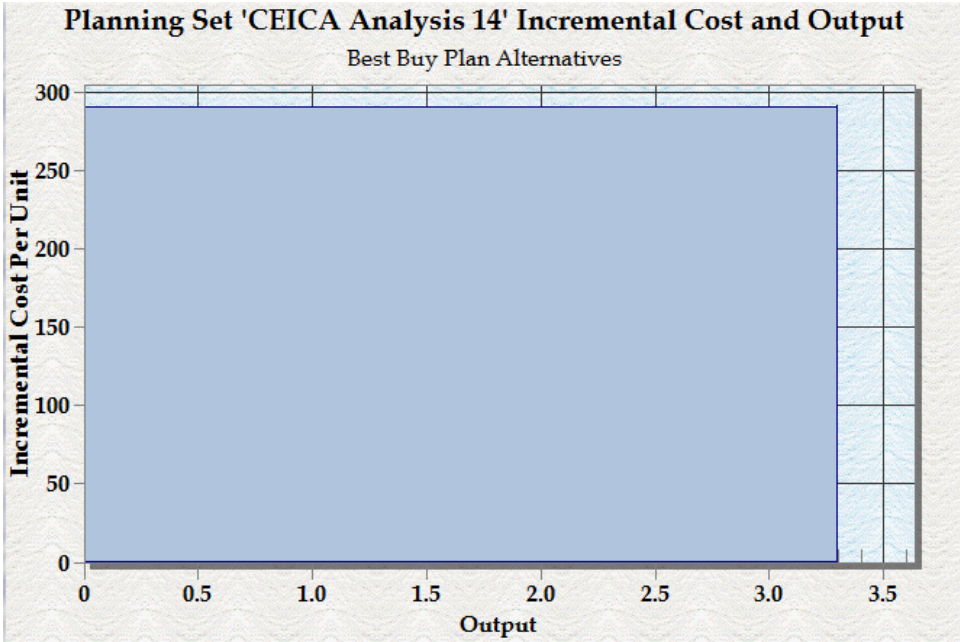


Figure 2-10: Shoelace Park Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Shoelace Park.

Table 2-6: Muskrat Cove

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	0.10	156.50	1,647.35	
Alternative A	0.76	300.70	397.22	X
Alternative B	0.77	308.75	403.07	X

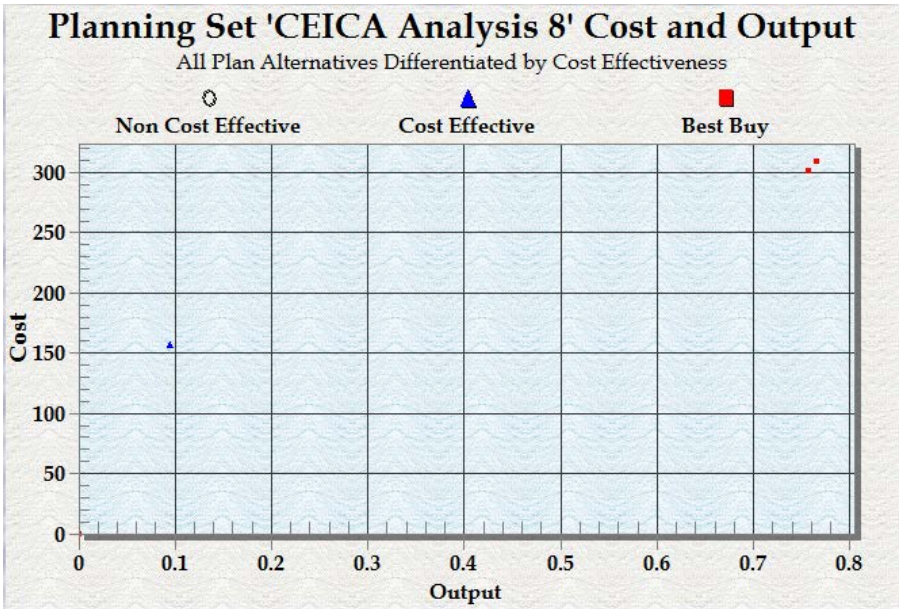


Figure 2-11: Muskrat Cove Cost & Output

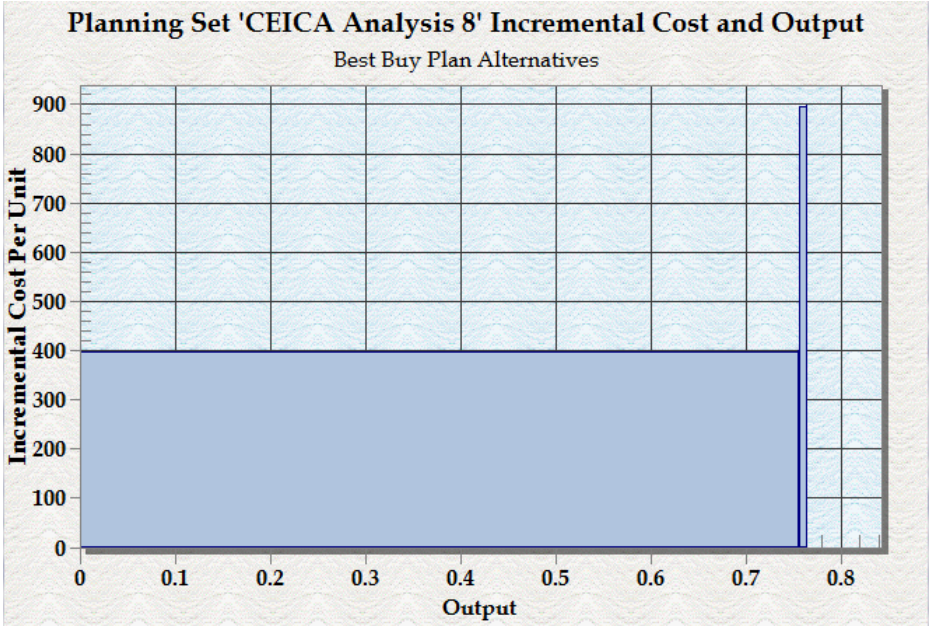


Figure 2-12: Muskrat Cover Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Muskrat Cove.

Table 2-7: Bronxville Lake

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	1.61	503.17	311.94	
Alternative B	5.34	555.97	104.08	X
Alternative A	7.47	813.50	108.92	X

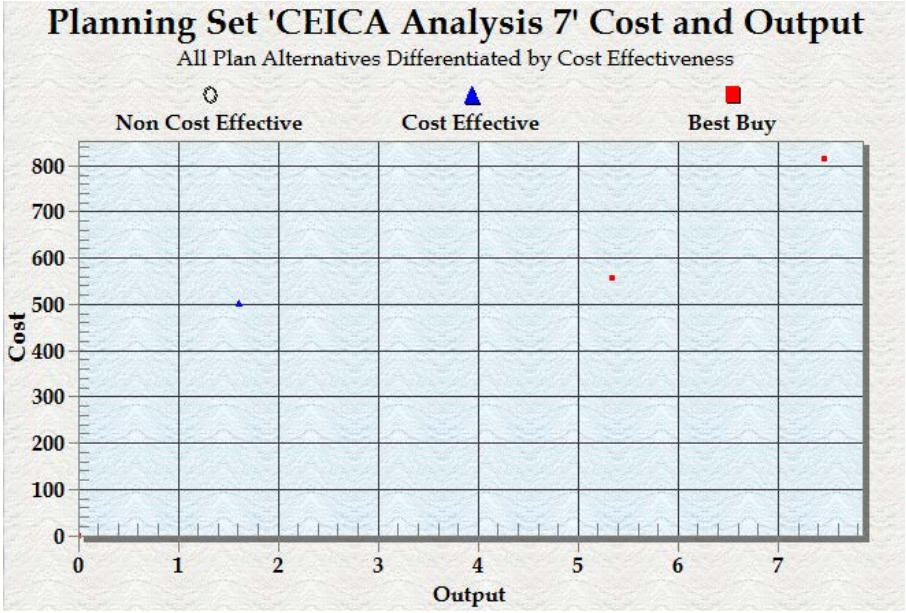


Figure 2-13: Bronxville Lake Cost & Output

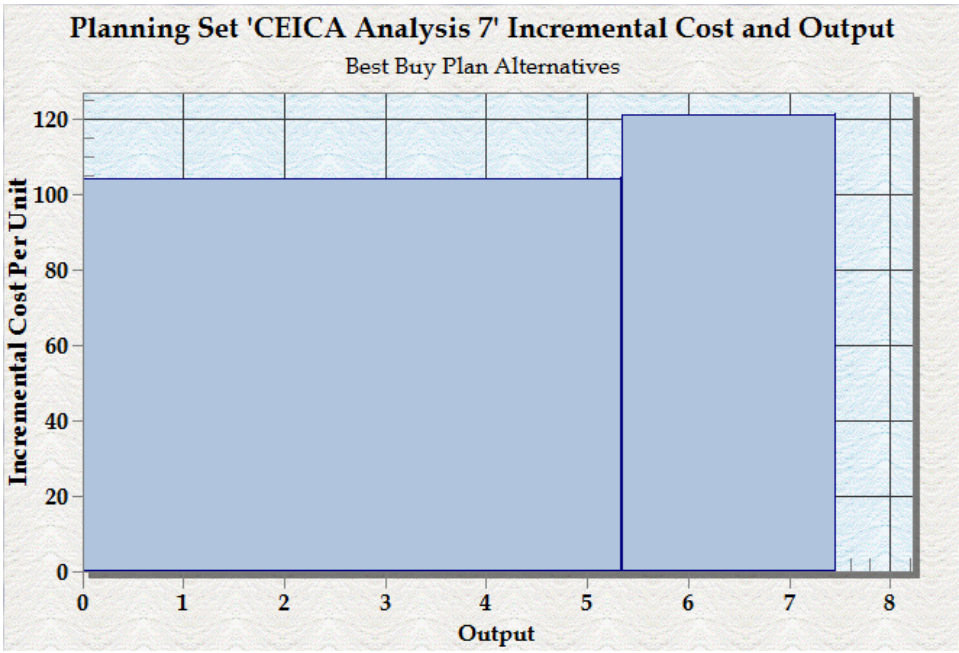


Figure 2-14: Bronxville Lake Incremental Cost & Output

Recommendation: Alternative B is the most cost effective plan for Bronxville Lake.

Table 2-8: Crestwood Lake

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	5.19	482.51	93.06	
Alternative B	6.15	536.33	87.15	
Alternative A	13.27	1,058.97	79.82	X

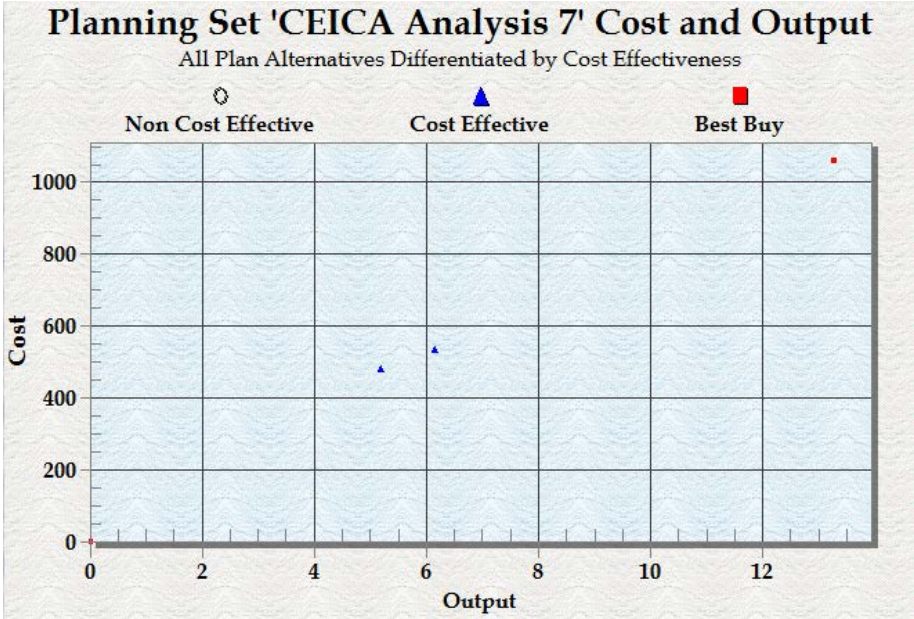


Figure 2-15: Crestwood Lake Cost & Output

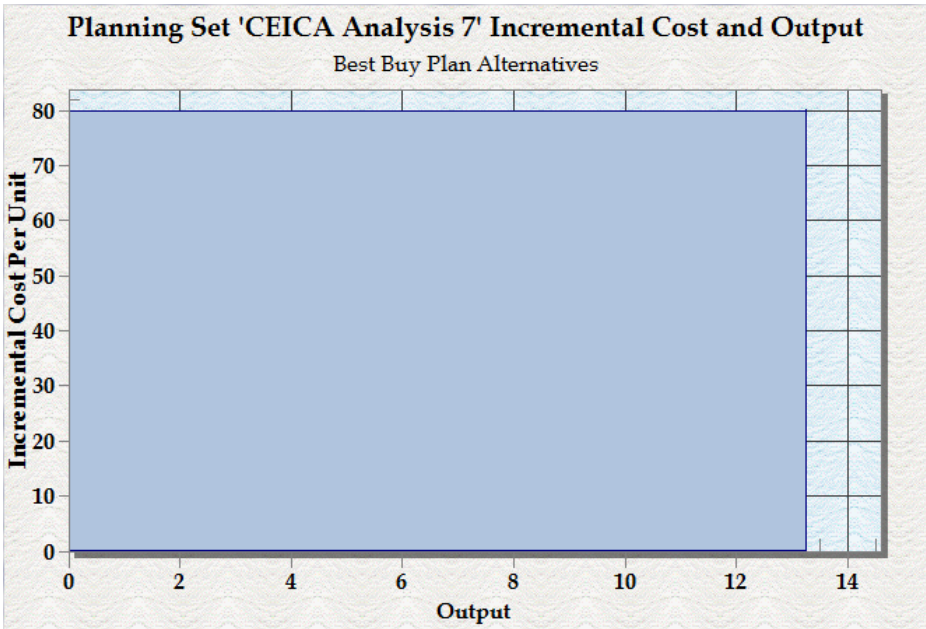


Figure 2-16: Crestwood Lake Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Crestwood Lake.

Table 2-9: Garth Woods/Harney Road

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	2.26	143.49	63.41	X
Alternative B	2.44	248.63	101.81	
Alternative A	3.23	275.83	85.47	X

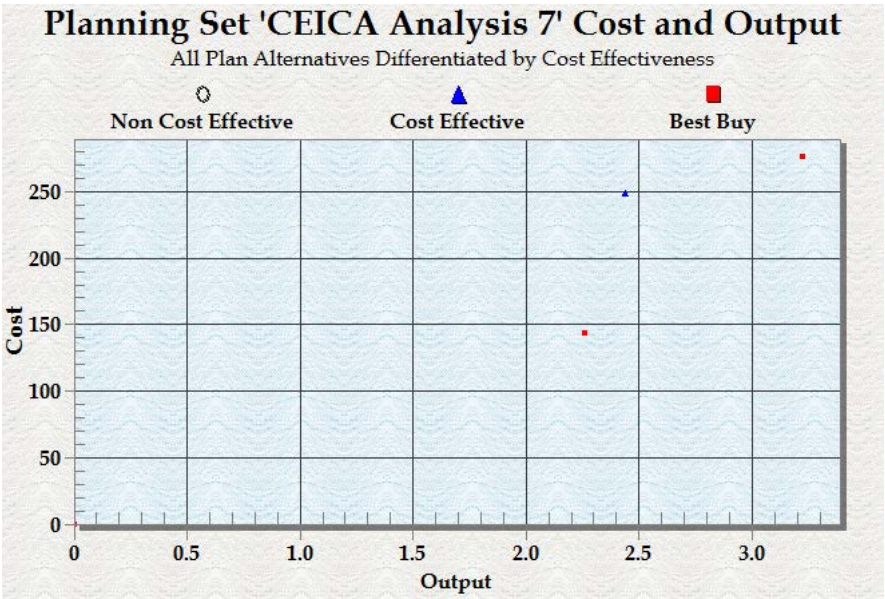


Figure 2-17: Garth Woods/Harney Road Cost & Output

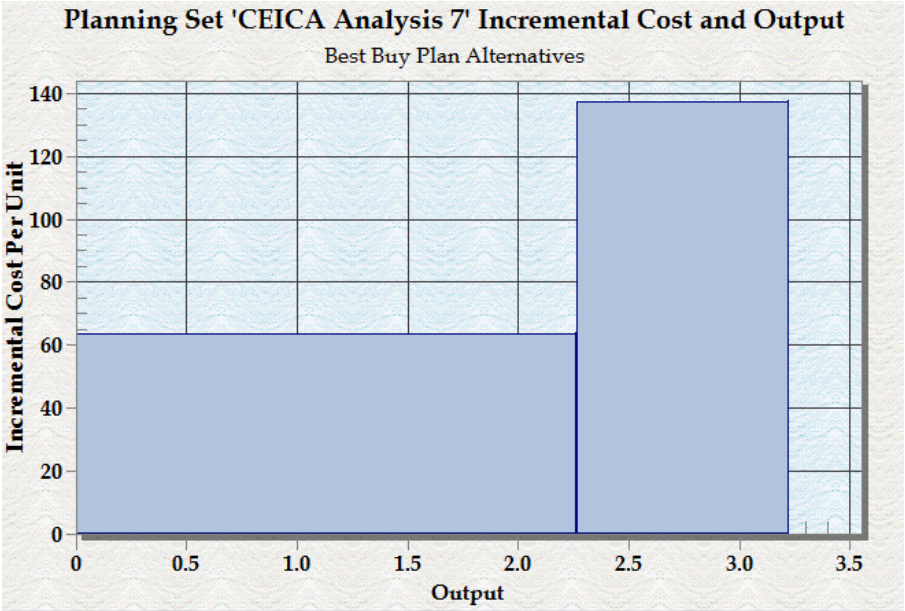


Figure 2-18: Garth Woods/Harney Road Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Garth Woods/Harney Road.

Table 2-10: Westchester County Center

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	6.11	515.57	84.35	
Alternative B	7.26	555.59	76.54	X
Alternative A	9.64	940.87	97.58	X

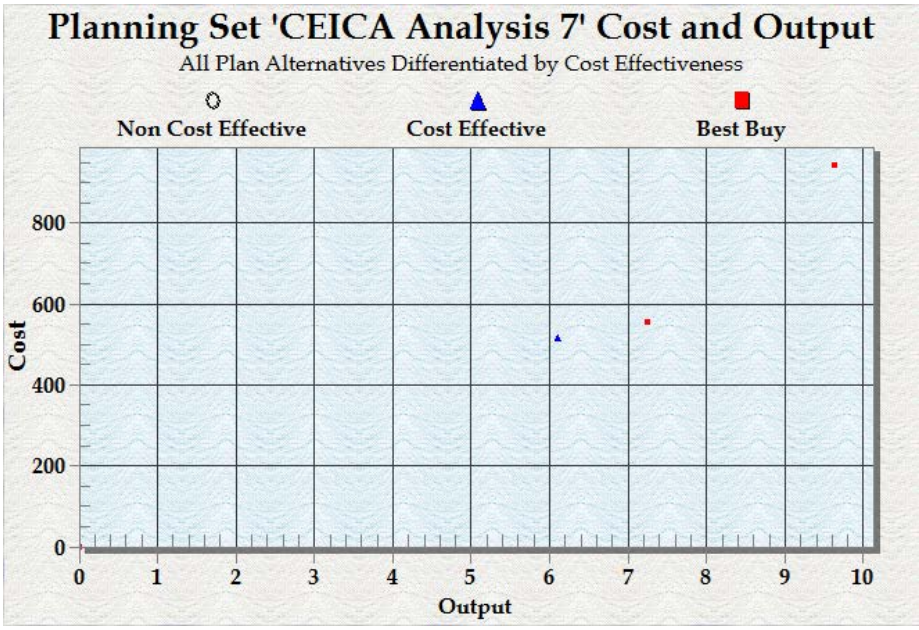


Figure 2-19: Westchester County Center Cost & Output

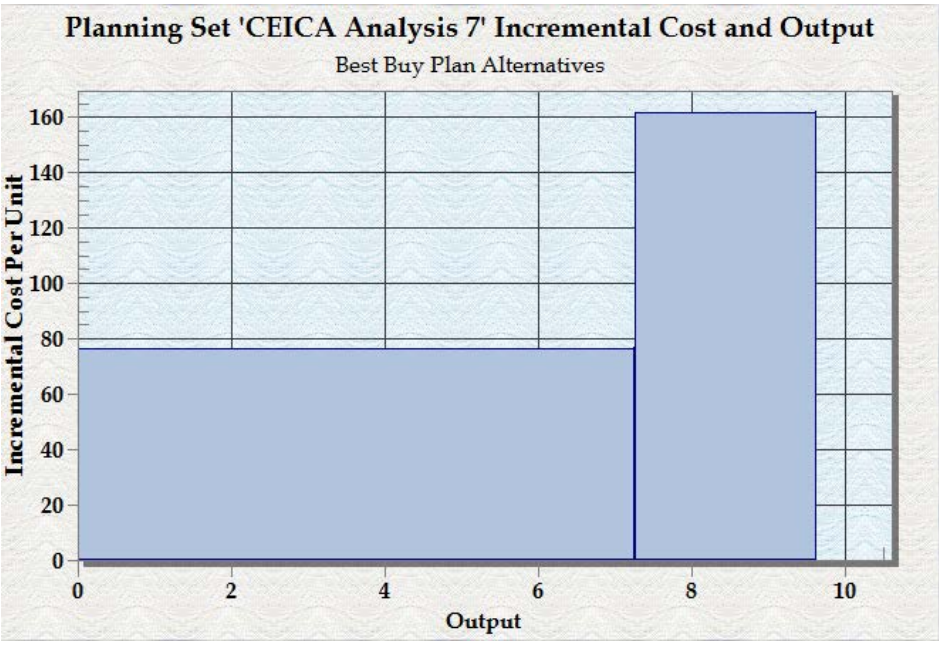


Figure 2-20: Westchester County Center Incremental Cost & Output

Recommendation: Alternative B is the most cost effective plan for Westchester County Center.

2.3 Newark Bay, Hackensack River, and Passaic River Planning Region

Table 2-11: Metromedia Tract

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative A	187.11	1,852.00	6.87	X
Alternative C	198.37	1,446.00	7.30	X
Alternative B	202.72	1,968.00	9.71	X

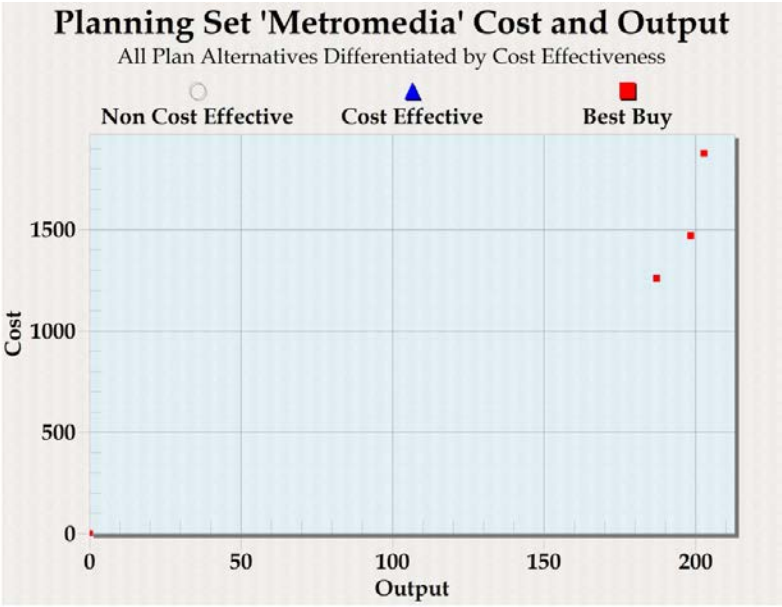


Figure 2-21 Metromedia Tract Cost & Output

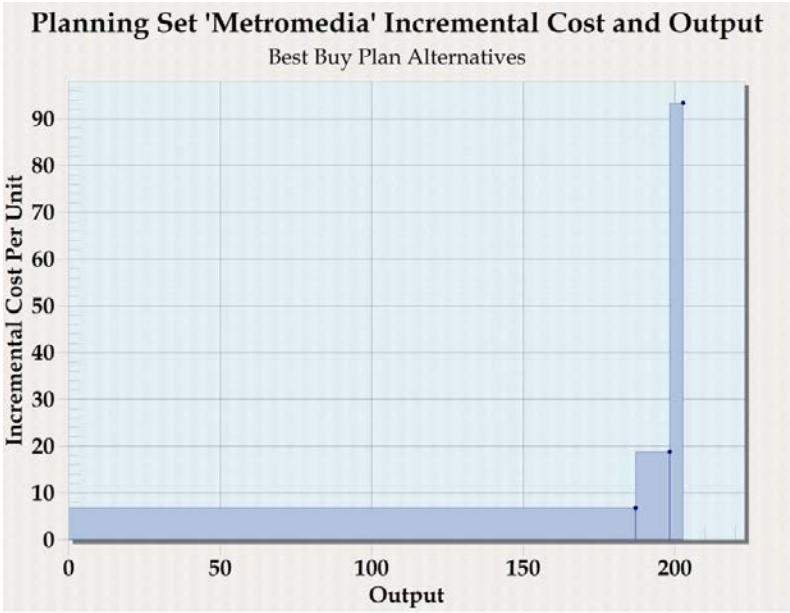


Figure 2-22: Metromedia Tract Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Metromedia Marsh.

Table 2-12: Meadowlark Marsh

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	294.22	1,618.87	5.50	X
Alternative A	306.20	2,475.32	8.08	
Alternative B	307.25	2,191.65	7.13	X

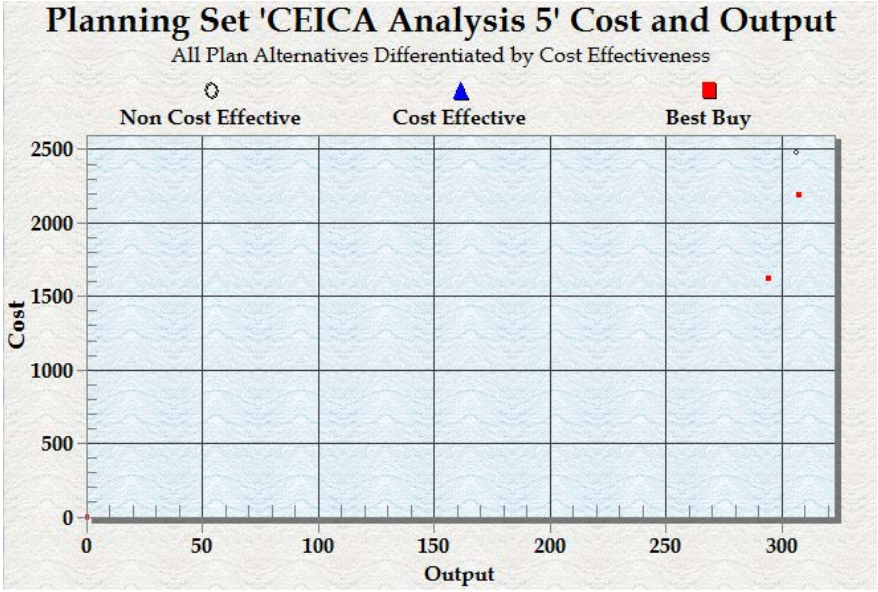


Figure 2-23: Meadowlark Marsh Cost & Output

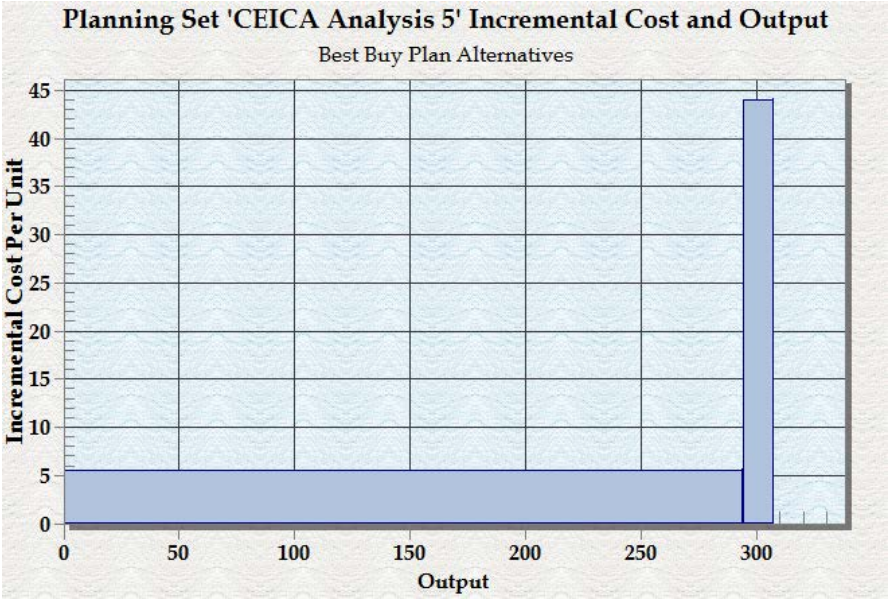


Figure 2-24: Meadowlark Marsh Incremental & Output

Recommendation: Alternative C is the most cost effective plan for Meadowlark Marsh.

Table 2-13: Oak Island Yards

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative B	29.03	1,146.38	39.49	
Alternative C	29.54	1,077.51	36.48	X
Alternative A	30.77	1,134.14	36.86	X

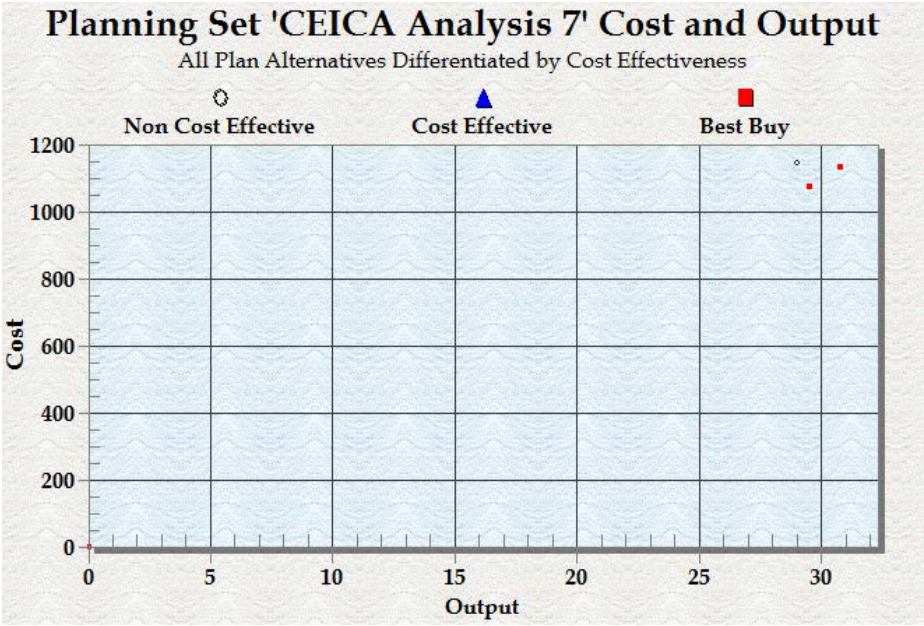


Figure 2-25: Oak Island Cost & Output

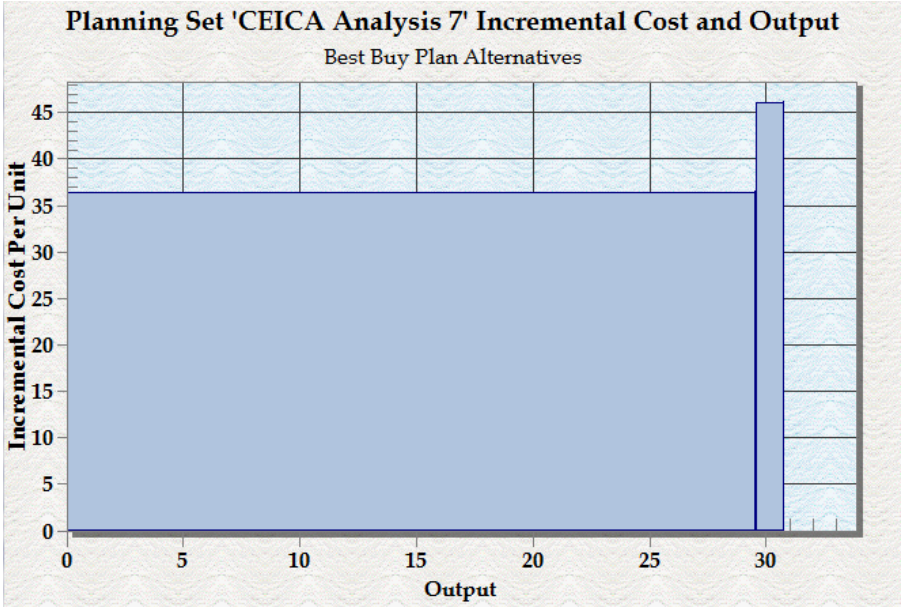


Figure 2-26: Oak Island Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Oak Island Yards.

Table 2-14: Kearny Point

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	125.27	2,245.67	17.93	X
Alternative B	135.01	2,934.64	21.74	
Alternative A	145.00	3,172.84	21.88	X

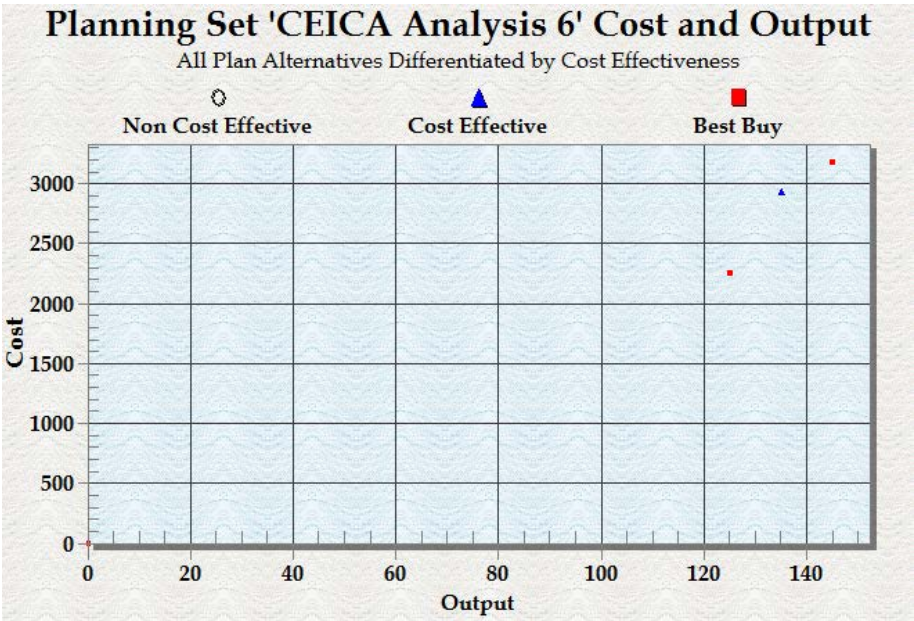


Figure 2-27: Kearny Point Cost & Output

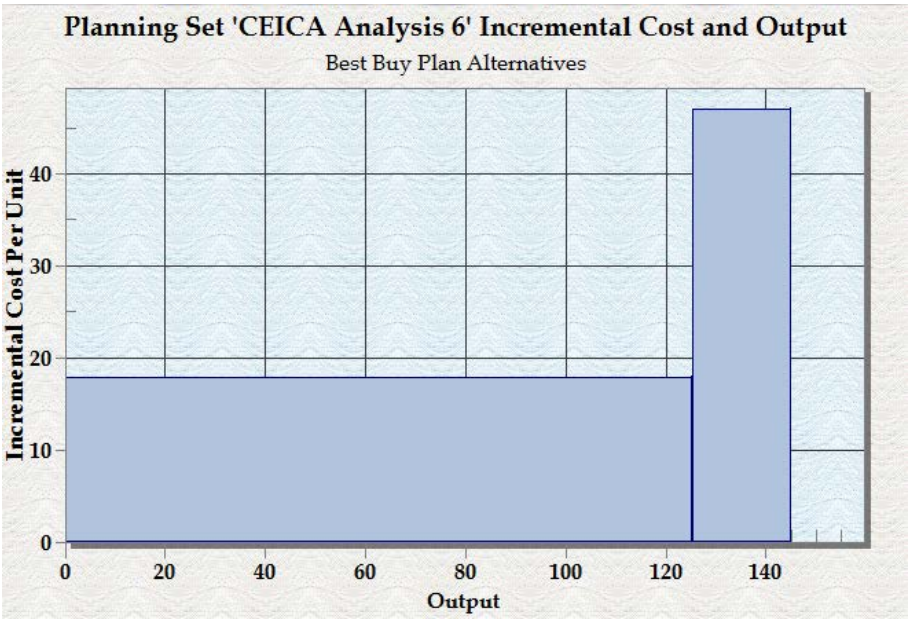


Figure 2-28: Kearny Point Incremental Cost & Output

Recommendation: Alternative C is the most cost effective plan for Kearny Point.

Table 2-15: Essex County Branch Brook Park

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)/AAFCU	Best Buy Plans
Alternative C	99.69	849.61	8.52	X
Alternative B	103.31	2,887.29	27.95	
Alternative A	142.81	2,898.93	20.30	X

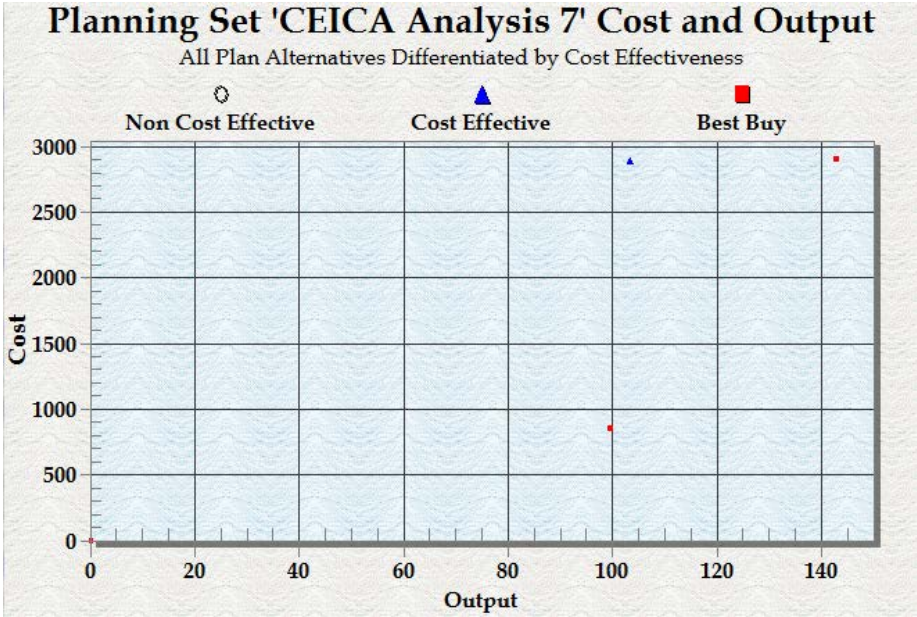


Figure 2-29: Essex County Branch Brook Park Cost & Output

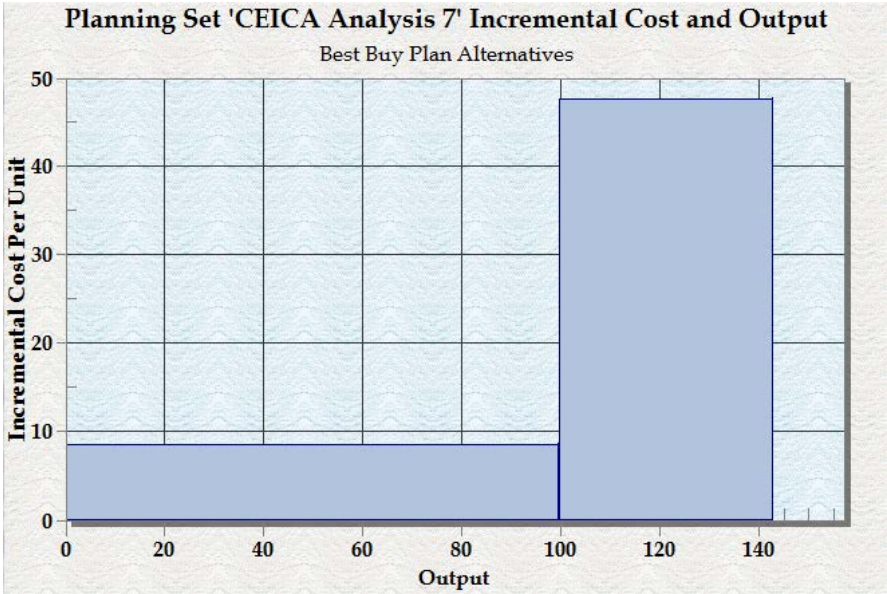


Figure 2-30: Essex County Branch Brook Park Incremental Cost & Output

Recommendation: Alternative C is the most cost effective plan for Essex County Branch Brook Park.

Table 2-16: Clifton Dundee Canal Green Acres Site

	50 year AAFCU	Annual Cost ($1000)	Average Annual Cost ($1000)AAFCU	Best Buy Plans
Alternative C	6.73	364.65	54.18	
Alternative B	8.37	411.33	49.14	
Alternative A	14.43	457.25	31.69	X

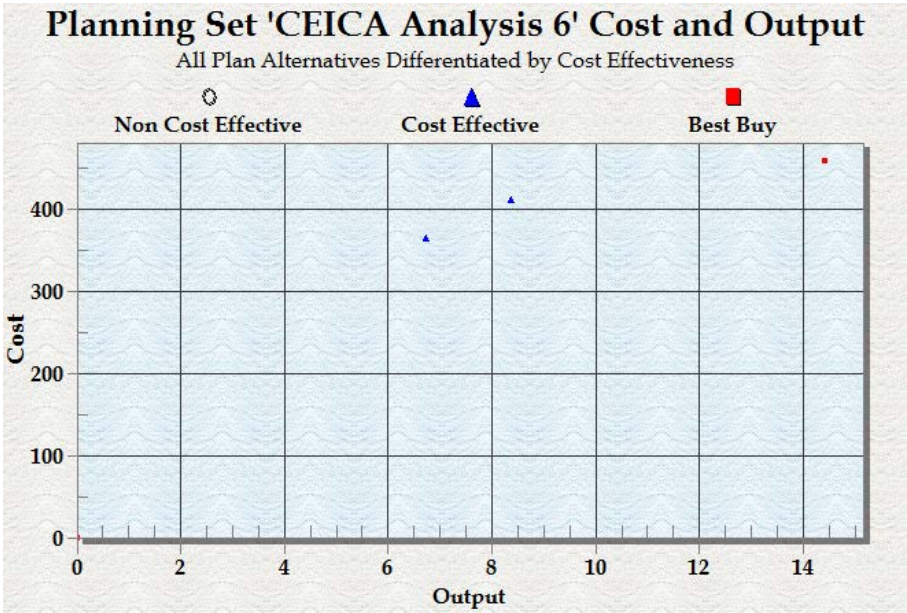


Figure 2-31 Clifton Dundee Canal Green Acres Site Cost & Output

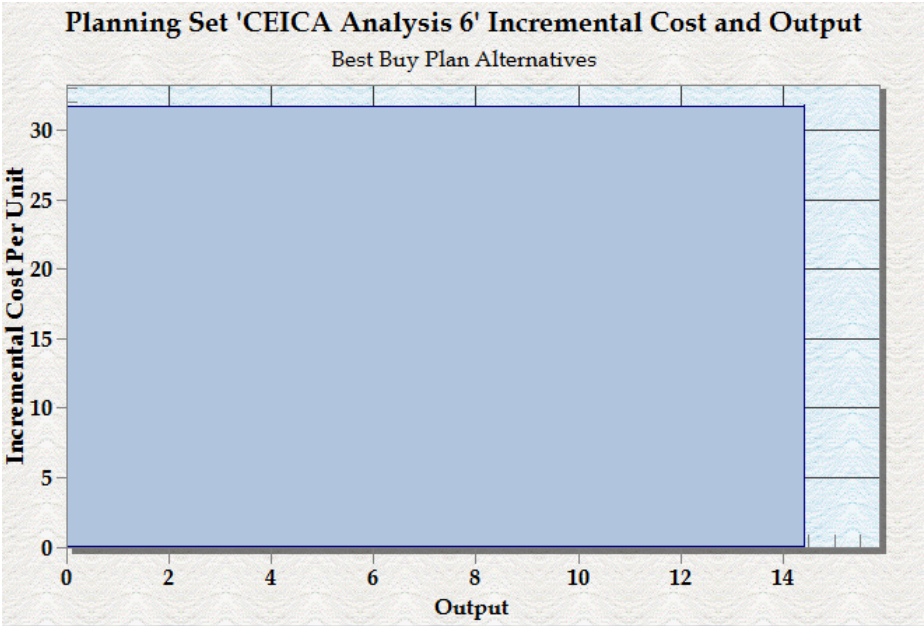


Figure 2-32: Clifton Dundee Canal Green Acres Incremental Cost & Output

Recommendation: Alternative A is the most cost effective plan for Clifton Dundee Canal Green Acres.

ATTACHMENT A

JAMAICA BAY, MARINE PARK, AND PLUMB BEACH ECOSYSTEM RESTORATION "SOURCE" FEASIBILITY STUDY

CE/ICA BACK-UP

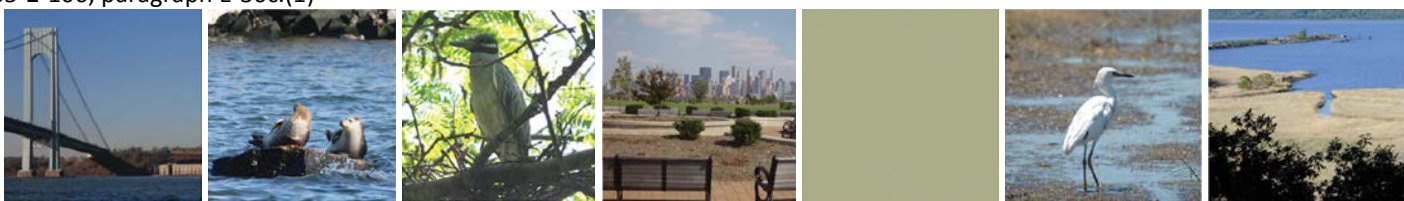
JAMAICA BAY PERIMETER SITES
INPUTS USED IN THE 2008 COST EFFECTIVENESS/INCREMENTAL COST ANALYSIS

In accordance with planning guidance, the outputs, expressed in Functional Capacity Units (FCU), were computed on an average annual basis, taking into consideration that the outputs achieved may vary over time.[1] Average Annual Functional Capacity Units (AAFCUs), Implementation Costs (Cost Appendix L) and annual costs outlined in the table below.

Alt No	Alternative Description	Peak Output (FCUs)	Avg. Ann. Output (AAFCU)	Implemen-tation Cost ($1000)	Annual Cost ($1000)
	Dead Horse Bay No Action	0	0	0	
1	Dead Horse Bay Fringe Marsh	161	116	$23,615	$1,269
2	Dead Horse Bay (1) + Trash removal	231	166	$26,197	$1,407
3	Dead Horse Bay Tidal Creek	359	334	$31,864	$1,712
4	Dead Horse Bay (3) + Trash removal	444	413	$34,885	$1,874
	Fresh Creek No Action	0	0	0	0
1	Fresh Creek Tidal Marsh	96	88	$5,057	$272
2	Fresh Creek (1) + channel filling	129	119	$5,231	$281
3	Fresh Creek (1) + Basin head filling	136	126	$8,388	$451
4	Fresh Creek (1) + Basin filling to Jamaica Bay	230	208	$8,259	$444
5	Fresh Creek (4) + Detention Basin	266	246	$10,850	$583
	Hawtree Point No Action	0	0	0	0
1	Hawtree Point Coastal Dune restoration	7.5	6.5	$327	$18
	Bayswater State Park No Action	0	0	$0	$0
1	Bayswater Tidal Channel with coastal dunes	57	41	$1,007	$54
2	Bayswater Tidal Channel with tidal pool	82	76	$2,507	$135
3	Bayswater Tidal Channel with T groin protection	74	69	$3,751	$202
	Dubos Point No Action	0	0	0	0
1	Dubos Point Tidal Channel	33	24	$1,464	$79
2	Dubos Point (1) + limited toe protection	38	27	$2,192	$118
3	Dubos Point (1) + continuous toe protection	62	58	$2,919	$157
	Brant Point No Action	0	0	0	0
1	Brant Point Tidal Marsh	17	12	$2,091	$112
2	Brant Point (1) with shore protection	34	27	$3,641	$195

Elements that affected the performance of restoration measures over the course of the 50 target years included tidal energy, shore protection measures, maturity periods of habitat types, and proposed habitat proportions for each of the alternatives. Since ecosystem restoration outputs are not monetary, they were not discounted. Restoration costs were calculated in terms of present worth (at

[1] ER 1105-2-100, paragraph E-36c.(1)



the time 2008) using the current rate of 4 7/8% and annualized. Annualized costs and average annual restoration outputs were input into the IWR-PLAN.

Incremental Cost of Best Buy Plan Combinations (Ordered By Output)

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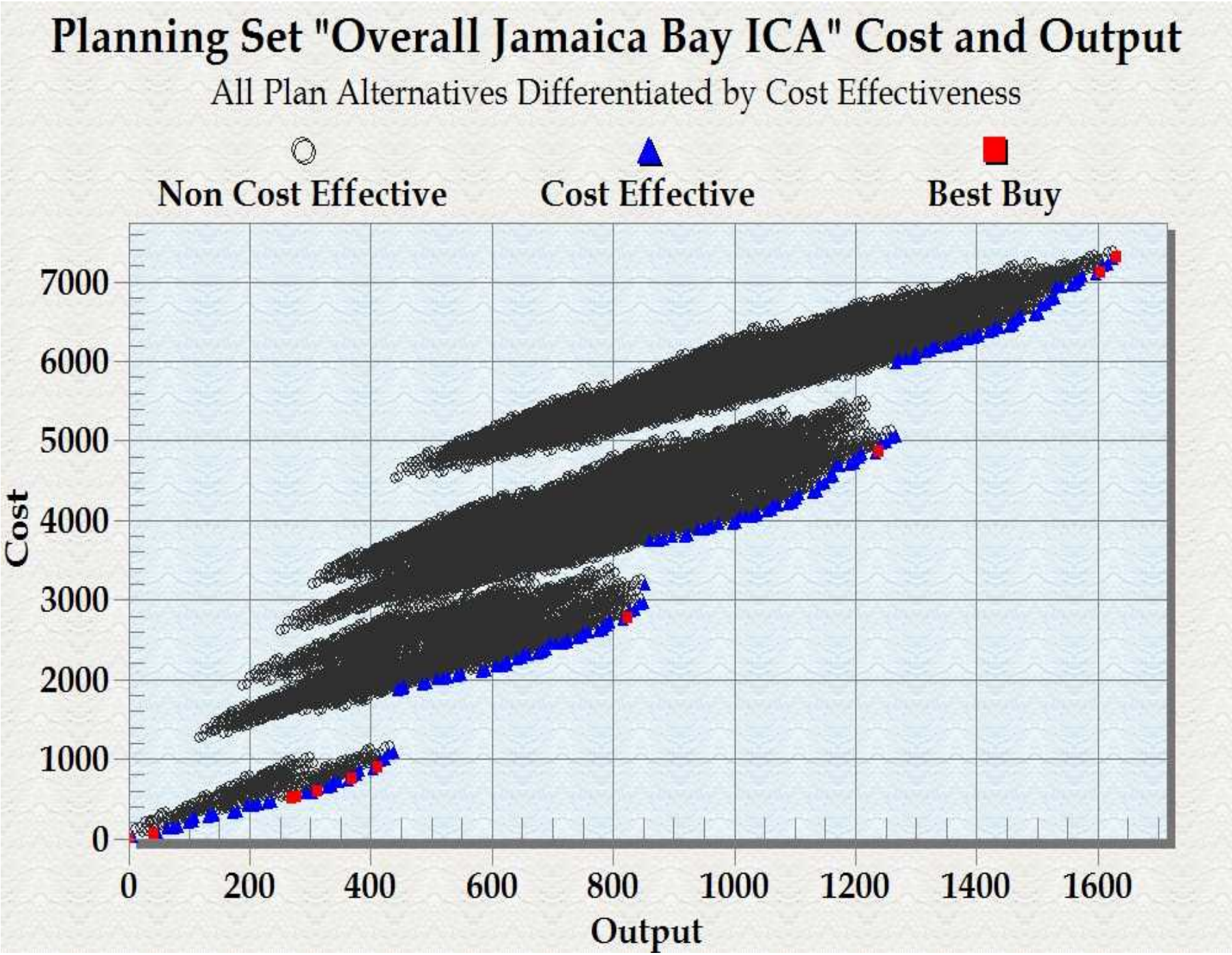
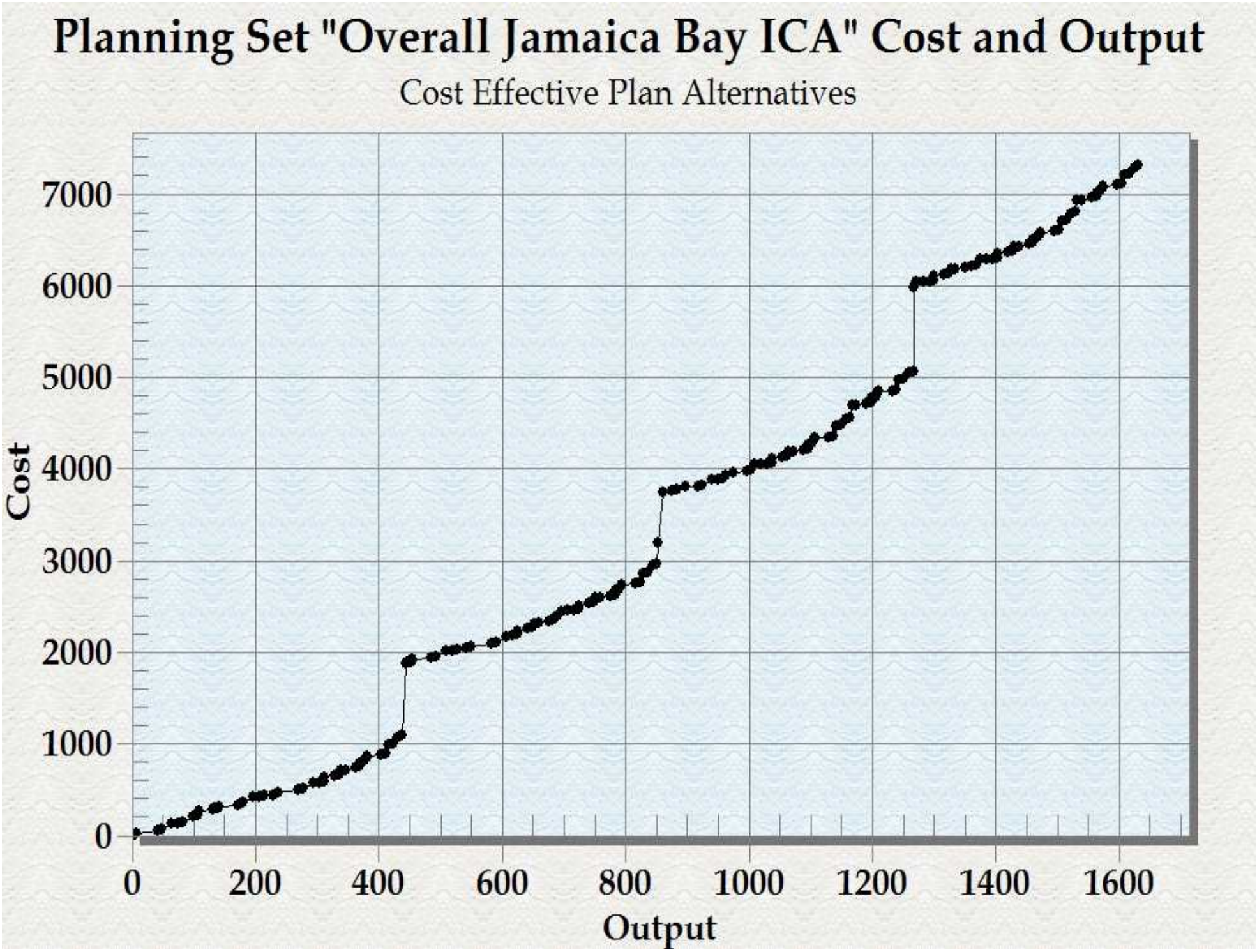
Planning Set: Overall Jamaica Bay ICA

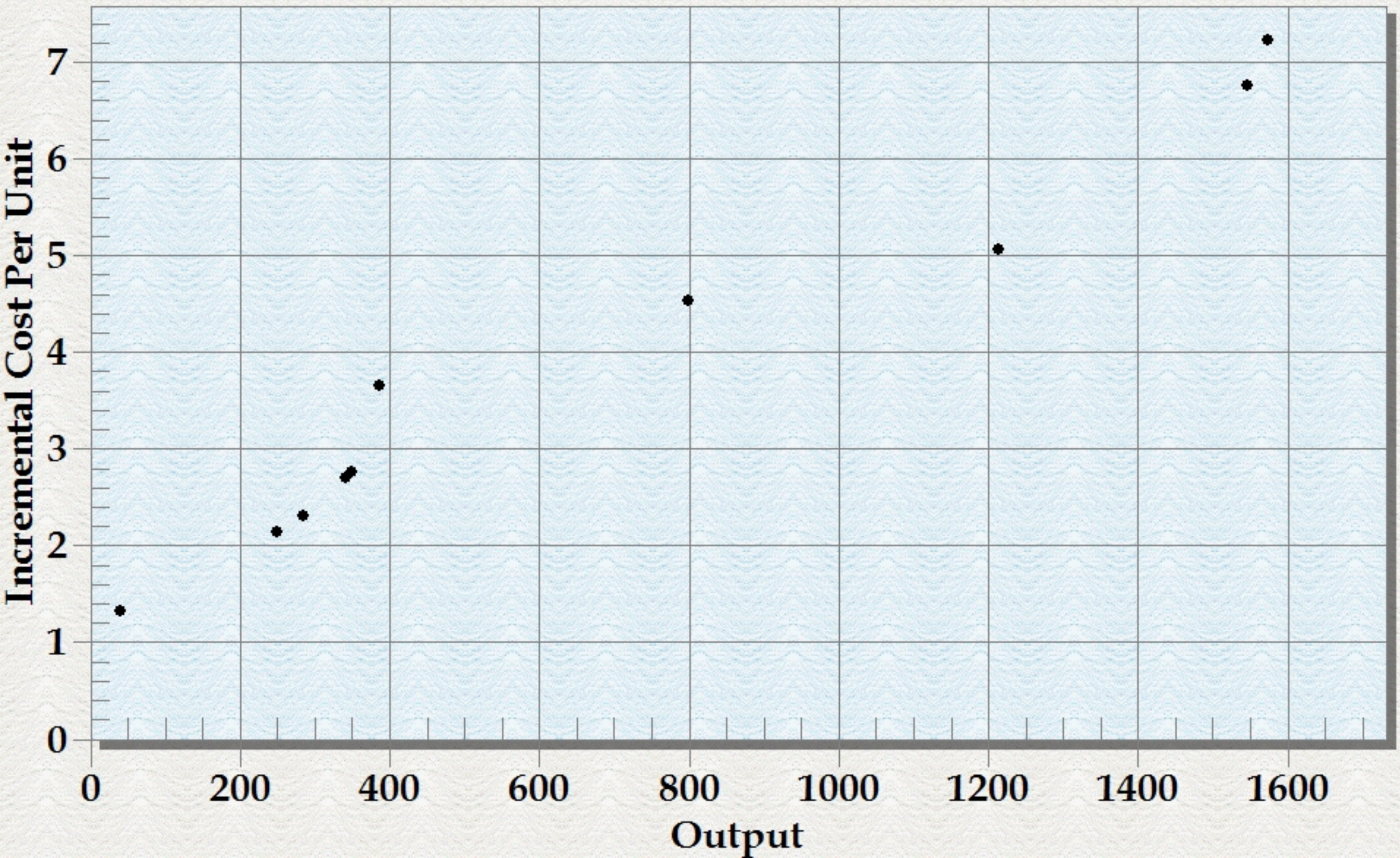
Counter	Plan Alternative	Output (AAFCU)	Cost ($1000)	Average Cost ($1000 / AAFCU)	Incremental Cost ($1000)	Inc. Output (AAFCU)	Inc. Cost Per Output
1	No Action Plan	0.00	0.00				
2	A0B0C0D0E0F1G0H0	41.00	54.00	1.3171	54.0000	41.0000	1.3171
3	A0B0C4D0E0F1G0H0	249.00	498.00	2.0000	444.0000	208.0000	2.1346
4	A0B0C4D0E0F2G0H0	284.00	579.00	2.0387	81.0000	35.0000	2.3143
5	A0B0C4D0E0F2G3H0	342.00	736.00	2.1520	157.0000	58.0000	2.7069
6	A0B0C4D0E1F2G3H0	348.50	754.00	2.1636	18.0000	6.5000	2.7692
7	A0B0C5D0E1F2G3H0	386.50	893.00	2.3105	139.0000	38.0000	3.6579
8	A4B0C5D0E1F2G3H0	799.50	2,767.00	3.4609	1,874.0000	413.0000	4.5375
9	A4B3C5D0E1F2G3H0	1,214.50	4,870.00	4.0099	2,103.0000	415.0000	5.0675
10	A4B3C5D3E1F2G3H0	1,546.50	7,113.00	4.5994	2,243.0000	332.0000	6.7560
11	A4B3C5D3E1F2G3H2	1,573.50	7,308.00	4.6444	195.0000	27.0000	7.2222

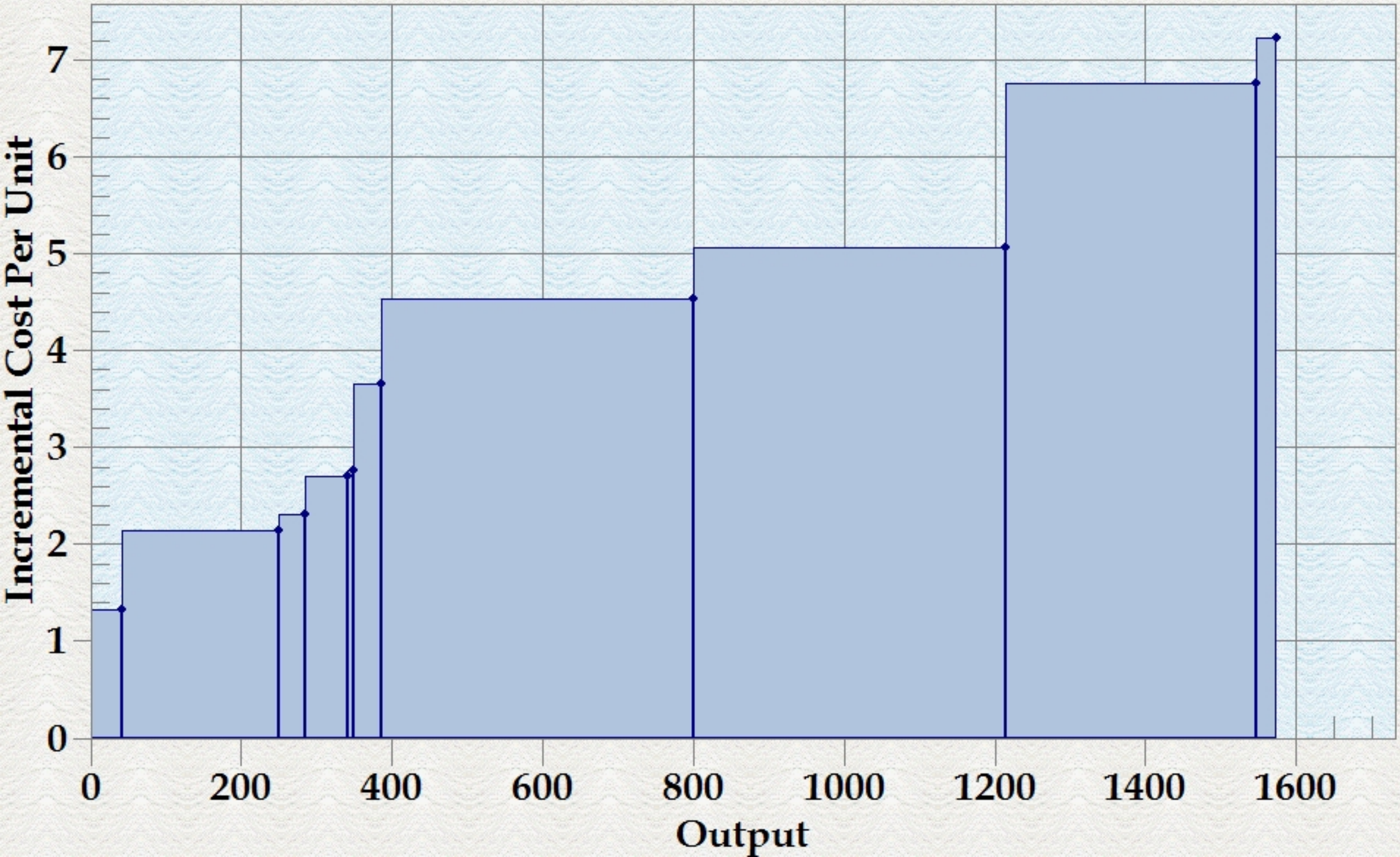

Planning Set "Overall Jamaica Bay ICA" Cost and Output
All Plan Alternatives Differentiated by Cost Effectiveness
Non Cost Effective
Cost Effective
Best Buy
Cost
7000
6000
5000
4000
3000
2000
1000
0
0
200
400
600
800
1000
1200
1400
1600
Output


Planning Set "Overall Jamaica Bay ICA" Cost and Output
Cost Effective Plan Alternatives
Cost
0
1000
2000
3000
4000
5000
6000
7000
0
200
400
600
800
1000
1200
1400
1600
Output

Planning Set "Jamaica Bay Overall CE/ICA" Incremental Cost and Output

Best Buy Plan Alternatives



Planning Set "Jamaica Bay Overall CE/ICA" Incremental Cost and Output

Best Buy Plan Alternatives