Appendix P
New Haven Harbor, CT
Navigation Improvement Project
Environmental Benefit Evaluation of the Proposed Sandy Point Salt Marsh Beneficial Use Project Feature

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1.0 BENEFICIAL USE

The US Army Corps of Engineers (USACE) proposed New Haven Harbor Navigation Improvement Project includes dredging about 4.28 Million cubic yards of ordinary improvement material (i.e., silt and sand) and removing 43,500 cy of rock to deepen the channel, turning basin and maneuvering area from -35 feet MLLW to -40 feet MLLW with incidental widening of the channel and channel bend at the breakwaters. As part of the feasibility study, several options were identified for the placement of dredged material. The Federal base plan includes a variety of beneficial use (BU) placements that represent the least costly alternatives and meet the environmental standards. In addition the feasibility study identified a beneficial use alternative for the dredged material that is not a least cost option. This alternative involves using dredged material from the New Haven Harbor improvement project to create salt marsh north of Sandy Point within the New Haven Harbor system. The Connecticut Port Authority, the improvement project Non-Federal Sponsor, supports the proposed placement that is not a least cost option.

The purpose of this appendix is to describe the salt marsh creation resource significance and quantify the environmental benefits to demonstrate that the incremental cost of the beneficial use disposal alternative is reasonable in relation to the environmental benefits to be achieved.

2.0 SALT MARSH RESOURCE SIGNIFICANCE

USACE decisions with respect to the restoration of environmental resources in restoration projects are based on the technical, institutional, and public significance of the affected resources. This section summarizes the significance of salt marsh resources using these criteria.

Institutional Recognition: Institutional recognition is demonstrated through the establishment of laws, restrictions, plans and policy statements by public agencies, tribes or private groups that acknowledge the importance of the environmental resource. The Clean Water Act, Section 404(b)(1) Guidelines institutionally recognize salt marshes as Special Aquatic Sites. Salt marshes provide valuable nesting, spawning, nursery, cover, and foraging habitat for aquatic and semi-aquatic animals, nutrient transformation functions, and aquatic productivity enhancement. The degraded state of this habitat has substantial adverse environmental effects on the value of this site as coastal habitat. Connecticut Coastal Zone Management laws and regulations recognize the importance of salt marsh and estuarine habitats.

Public Recognition: Public significance is demonstrated when some segment of the general public recognizes the importance of an environmental resource. Public recognition of the importance of salt marsh resources is embodied in requests from Federal, State, and local agencies to beneficially use dredged material to create habitat for fish and wildlife resources.

Technical Recognition: Elements of technical significance include habitat scarcity, habitat connectivity, and effects on special status species. Technical significance is demonstrated by scientific or technical knowledge or judgment concluding the importance of a resource.

Habitat Scarcity - Salt marshes have declined significantly due to development, agriculture, and water-control activities. Loss estimates for salt marshes from the mid-1950s to the mid-1970s are as much as 400,000 acres (Tiner, 1984). The loss of wetlands due to human development is well documented. Deegan and Buchsbaum 2005 state:

Loss of coastal wetlands due to residential and industrial development has been severe in the United States. Recent estimates suggest that about 54% of the nation's original 915,000 km2 of wetlands (freshwater and coastal) have been lost (Tiner, 1984), and over half of the nation's original salt marshes and mangrove forests have been destroyed (Watzin and Gosselink, 1992). A particularly intense period of loss occurred between 1950 and 1970.

The authors also note that degradation in habitat quality is just as harmful as reduction in quantity. Increased siltation, loss of salinity, eutrophication, food web disruption and hydrologic changes have deleterious effects on the quantity and diversity of biota.

Connectivity - Connectivity is a measure of the degree of habitat or population fragmentation; ranging from "connected and sustainable," to "fragmented," to "isolated." There would be a high degree of connectivity between the created marsh habitat and New Haven Harbor and Long Island Sound. This would allow for the marsh area to be used extensively by ecological resources within the system.

Special Status Species – salt marsh habitat can be created and provide important habitat for salt marsh sparrow, which are species of concern.

Biodiversity - Salt marshes are highly productive habitats that contribute to biodiversity. These wetlands serve as spawning habitat and nurseries for many invertebrates and fish as well as nesting and feeding habitat for a variety of birds and mammals. The loss of salt marshes has contributed to the declining populations of many species that rely on a complex mosaic of coastal habitats and can only exist in the narrow estuarine band along the coast.

3.0 ENVIRONMENTAL BENEFITS

3.1 Introduction

The USACE used the Assessment of Wildlife Habitat Value of New England Salt Marsh model (NESMM) to quantify the ecological benefits gained from using the dredged material to create a salt marsh at Sandy Point. The model was used to evaluate the habitat value of salt marsh creation alternatives and the long term value of the marsh creation under different sea level change (SLC) scenarios.

Two different alternative marsh sizes were examined: a 58-acre marsh and a 30-acre marsh. Both sizes included habitat components that were 90% salt marsh habitat and 10% open water/intertidal flat habitat. The 90% marsh habitat component was further evaluated by varying the percentages of high marsh and low marsh sub-habitats within the salt marsh area. For both marsh sizes, the creation of marsh habitats that were 98% high marsh/2% low marsh, 75% high marsh/25% low marsh, and 50% high marsh/50% low marsh were evaluated.

One of the goals of the New Haven Harbor dredging project is to increase beneficial use of dredged material to the maximum extent practicable to avoid open water placement. The maximum size of the salt marsh creation area (approximately 58 acres) was determined based on outlining a reasonable seaward perimeter which avoided impacting existing infrastructure (e.g., marinas and boat ramp) and locating the created salt marsh within the protected area afforded by the Sandy Point spit. To verify that the maximum size was suitable for an environmental benefits point of view a smaller size creation project (30 acres) was also assessed using the model.

The salt marsh creation project will result in the replacement of subtidal habitat and intertidal mudflat habitat with a combination of high marsh, low marsh, and tidal creek (i.e., open water and mudflat) habitat. The harbor contains an abundance of shallow estuarine subtidal habitat and intertidal mudflat habitat, while the harbor has lost most of its salt marsh habitat due to filling that occurred prior to the 1970s. For the purposes of the benefits evaluation, the loss of the habitat value of the existing condition is considered minimal relative to the environmental benefit to be gained.

3.2 Model Description

The NESMM is a marsh assessment tool that was developed by the US Environmental Protection Agency (USEPA). This model is approved for use by the USACE Ecosystem Restoration PCX.

See: https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=View&Id=25.

NESMM is a standalone assessment tool based on wildlife habitat values of coastal wetlands. The model quantifies salt marsh health and function through the valuation of marsh characteristics and the presence of habitat types. While other habitat evaluation tools use marsh functions as metrics (e.g., nutrient removal) to assess wetland sites, the NESMM focuses on marsh habitat types, marsh morphology, and landscape setting.

The marsh habitat type was chosen to be used as the framework for the environmental model for a number of reasons. First, providing wildlife habitat is one of the most important functions shared by all marshes. Salt marshes are thought to be amongst the most productive ecosystems in the world, providing substantial biodiversity, supporting numerous species from all of the major groups of organisms, and providing both seasonal and year around habitat for many terrestrial and aquatic species. Of particular importance are wetlands or classes of wetlands that provide habitat for threatened and endangered species. Second, the area of available habitat within a marsh is a metric that is well suited for assessment. Aerial photographic interpretation of the habitat types in the marsh system coupled with ground-truthing can be accomplished easily. Additionally, forecasts of types of habitats in restored and/or created marsh are typically planned out in restoration efforts, so the applicable data is available. Finally, wetland protection or restoration goals based on wildlife habitat targets are generally well received and understood by the public, particularly when the species of interest, such as large birds and mammals, are included in the project goals.

The NESMM quantifies habitat values based on marsh characteristics and the presence of habitat types that contribute to use by terrestrial species. The model's developers identified 79 birds, 20 mammals, and 6 amphibian and reptile species that utilize New England salt marsh habitat at some life stage. Habitat requirements of these species were determined through a search of published literature, unpublished reports, anecdotal information from wetland ecologists and personal observations of the model's creators. From the available information, the developers identified common habitat types associated within salt marshes, or those that were reported as being used by at least 3 bird or mammal species. These habitat types, as well as the habitat requirements of salt marsh fauna, form the basis of the salt marsh assessment model.

The model consists of eight wetland and landscape components that are used to assess and evaluate salt marsh wildlife habitat values (Table 3.1). Several of the components are directly based on the different habitat types found in and around marshes or ecosystems that are linked to salt marshes. Other components reflect the anthropogenic alteration of these habitats. The remaining components take into account the size, morphology, and landscape positions of the marsh, which may be important to territorial species and those that require adjacent upland habitats. The eight components are (1) marsh habitat types, (2) marsh morphology, (3) marsh size, (4) degree of anthropogenic modification, (5) vegetative heterogeneity, (6) surrounding land use, (7) connectivity, and (8) vegetation types. Each component, in turn, consists of several categories. For example, the "Habitat Type" component consists of ten categories including shallow open water, tidal flats, pannes, wooded islands, and low marsh. A complete description of each habitat component and the overall framework of this model are included in McKinney and Wigand (2006).

The model user assigns a rating of low, moderate, high or absent to each model category. The rating is given a numerical score and a weighting factor to reflect faunal habitat requisites, which can be found in Table 3.2. For example, one category of the habitat component involves the presence of shallow water. If open shallow water habitat makes up >20% of the marsh, the category is given a numeric score of "5". If open shallow water habitat is absent from a salt marsh, the category is given a "0". The value of each category is multiplied by a weighting factor. The output produced by the USEPA model is a numerical score, an overall relative wildlife habitat assessment score for the marsh, which is calculated by summing subtotals for each of eight habitat components of the model (McKinney et al. 2009a). The maximum wildlife habitat assessment score possible from the NESMM is 784, with small, impaired marshes receiving values below 100. The values and weighting factors assigned to each model component are shown in the table below (McKinney et al. 2009a).

The scores and weighting factors for each component were developed and tested on a group of 16 salt marshes in Narragansett Bay, Rhode Island. The study and resulting conclusions are described in two peer reviewed papers: "Assessing the wildlife habitat value for New England salt marshes: I. Model and application" and "Assessing the wildlife habitat value of New England salt marshes: II. Model testing and validation."

Table 3.1.

New England Salt Marsh Model wetland assessment components and their associated categories.

Component	Categories	Criteria
I. Salt Marsh Size Class	Very small (under 5 ha) Small (5 – 25 ha) Medium-sized (26 – 125 ha) Large (126 – 200 ha) Very large (over 200 ha)	Marsh area
II. Salt Marsh Morphology	Salt meadow marsh Meadow / fringe marsh Wide fringe marsh Narrow fringe marsh Marine fringe marsh	Marsh morphology
III. Salt Marsh Habitat Types	Shallow open water Tidal flats Low marsh Trees overhanging water High marsh Pools Pannes Wooded islands Marsh-upland border Phragmites	Presence or abundance
IV. Extent of Modification	Little to no ditching Moderate ditching Severe ditching Little to no tidal restriction Moderate tidal restriction Severe tidal restriction	Degree of modification
V. Salt Marsh Vegetation	Aquatic plants Emergents Shrubs Trees Vines	Presence or abundance
VI. Vegetative Heterogeneity	High heterogeneity Moderate heterogeneity Low heterogeneity	Number of habitat edges
VII. Surrounding Land Cover	Open water Natural land Maintained open land Developed land	Presence or area
VIII. Connectivity	Sand or cobble beach Coastal dunes or overwash Other salt marsh wetland Brackish wetland or pond Freshwater wetland or pond Upland meadow Upland forest	Presence or area

Table 3.2.
Values and weighting factors associated with each habitat category
in the New England Salt Marsh Model.

a) Pre-classification components

Component	Category	Weighting factor	Criteria (value): High (5)	High/mod. (4)	Moderate (3)	Mod./low (2)	Low (1)
Size class	–	10	> 200 ha	126–200 ha	26–125 ha	5–25 ha	< 5 ha
Morphology	–	10	Salt meadow	Meadow/fringe	Wide or marine fringe	–	Narrow fringe

b) Assessment components

Component	Category	Weighting factor	Criteria (value): High (5)	Moderate (3)	Low (1)	Absent (0)
Habitat type	shallow open water	7	>20% of marsh unit	10–20% of marsh unit	<10% of marsh unit	absent
	tidal flats	8	>30% of marsh unit	5–30% of marsh unit	<5% of marsh unit	absent
	low marsh	8	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	trees overhanging water	5	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	high marsh	8	>40% of marsh unit	5–40% of marsh unit	<5% of marsh unit	absent
	wooded islands	6	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	phragmites	4	>3% of marsh unit	1–3% of marsh unit	<1% of marsh unit	absent
	pools	8	>10 pools/ha	2–10 pools/ha	<2 pools/ha	absent
	pannes	5	>10 pannes/ha	2–10 pannes/ha	<2 pannes/ha	absent
	marsh-upland border[a]	8				
	width		width >8 m	width 2–8 m	width <2 m	–
	length		>65% of perimeter	50–65% of perimeter	<50% of perimeter	–
	composition		>70% shrubs	50–70% shrubs	<50% shrubs	–
Anthropogenic modification	ditching	9	little to no ditching	moderate ditching	severe ditching	–
	tidal restriction	7	little to no restriction	moderate restriction	severe restriction	–
Vegetation	aquatic plants	2	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	emergents	3	>90% of marsh unit	75–90% of marsh unit	<75% of marsh unit	absent
	shrubs	3	>20% of marsh unit	5–20% of marsh unit	<5% of marsh unit	absent
	trees	4	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	vines	1	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
Vegetative heterogeneity	–	6	5 edge habitats	3–4 edge habitats	1 or 2 edge habitats	–
Surrounding land use	open water	6	>35% of buffer[b]	25–35% of buffer	<25% of buffer	–
	natural land	9	>25% of buffer	10–25% of buffer	<10% of buffer	–
	maintained open	5	<5% of buffer	5–15% of buffer	>15% of buffer	–
	developed land	9	<5% of buffer	5–35% of buffer	>35% of buffer	–
Connectivity[c]		9				
	habitat types in buffer[d]		>4	3–4	1–2	–
	average size		>3 ha	1–3 ha	<1 ha	–
	proportion of buffer		>30% of buffer	15–30% of buffer	<15% of buffer	–

3.3 Model Requirements

The USEPA designed the model to be an easily accessible tool to be used by field biologists and resource managers to perform office-based assessments that could be run in a relatively short amount of time using readily available data and software. The model designers intended that output produced by the model would be used to make planning and management decisions, such as "(1) prioritizing marshes for protection and restoration, (2) identify ecologically important marshes that could potentially harbor high biodiversity, and (3) monitor changes in habitat value over time, for example during the course of salt marsh restoration" (McKinney et al. 2009a). The input data necessary for the application of the model is "at a minimum, aerial photographs showing each salt marsh to be assessed and the surrounding landscape at least 1km around each site are required to carry out the assessment. Digital land use and land cover in a GIS will aid in determining surrounding land use and associated habitats. Office-based aerial photo delineation to assess habitat type, vegetative structure, and vegetative heterogeneity should, if possible, be supplemented with field assessment" (USEPA, 2008). Software and hardware required to run the EPA model are commonly available in an office setting. An Excel or any simple spread sheet software package can be used to calculate habitat assessment scores. A matrix, including the assessment components, and their associated weighting factors and scores, is available in McKinney et al (2009).

There is no formal training associated with the USEPA model. Since the basis of the model is to assess marsh quality through available habitats, the model user must have an understanding of and the ability to recognize habitat types present in a salt marsh. The user must be able to differentiate, either from aerial photography or through field visits, vegetative structures and habitat types. The user must also be able to estimate the extent of habitat or vegetation types that make up each study site.

3.4 Application of the NESSM Model to the Sandy Point Salt Marsh Creation Area

The NESMM was used to calculate environmental benefits that would be derived from creation efforts at the Sandy Point site within New Haven Harbor (New Haven and West Haven, CT) using a 50-year period of analysis for the created marsh. The model was run for two size alternatives, a 58 acre salt marsh and a 30 acre salt marsh (Figure 3.1), using existing tidal conditions in New Haven Harbor (Table 3.3) and considering SLC (Table 3.4). For all scenarios the design dedicated 90% of the area to salt marsh and 10% of the area to tidal creek/mudflat habitat. The tidal creek/mudflat portion of the area is incorporated into the design to allow for the existing connection between New Haven Harbor and Old Field Creek (which feeds a salt marsh to the west of the site) to remain. One alternative evaluated for both the 30 acre alternative and 58 acre alternative salt marsh areas was creating primarily (98%) high marsh to maximize the marsh's capacity to hold dredged material. Alternatives using salt marsh habitat ratios of 50% high marsh/50% low marsh and 75% high marsh/25% low marsh (assuming the same quantity of placement) were also run to evaluate habitat value under differing marsh configurations.

Figure 3.1: Salt marsh creation alternatives for the New Haven Harbor Navigation Improvement Project.

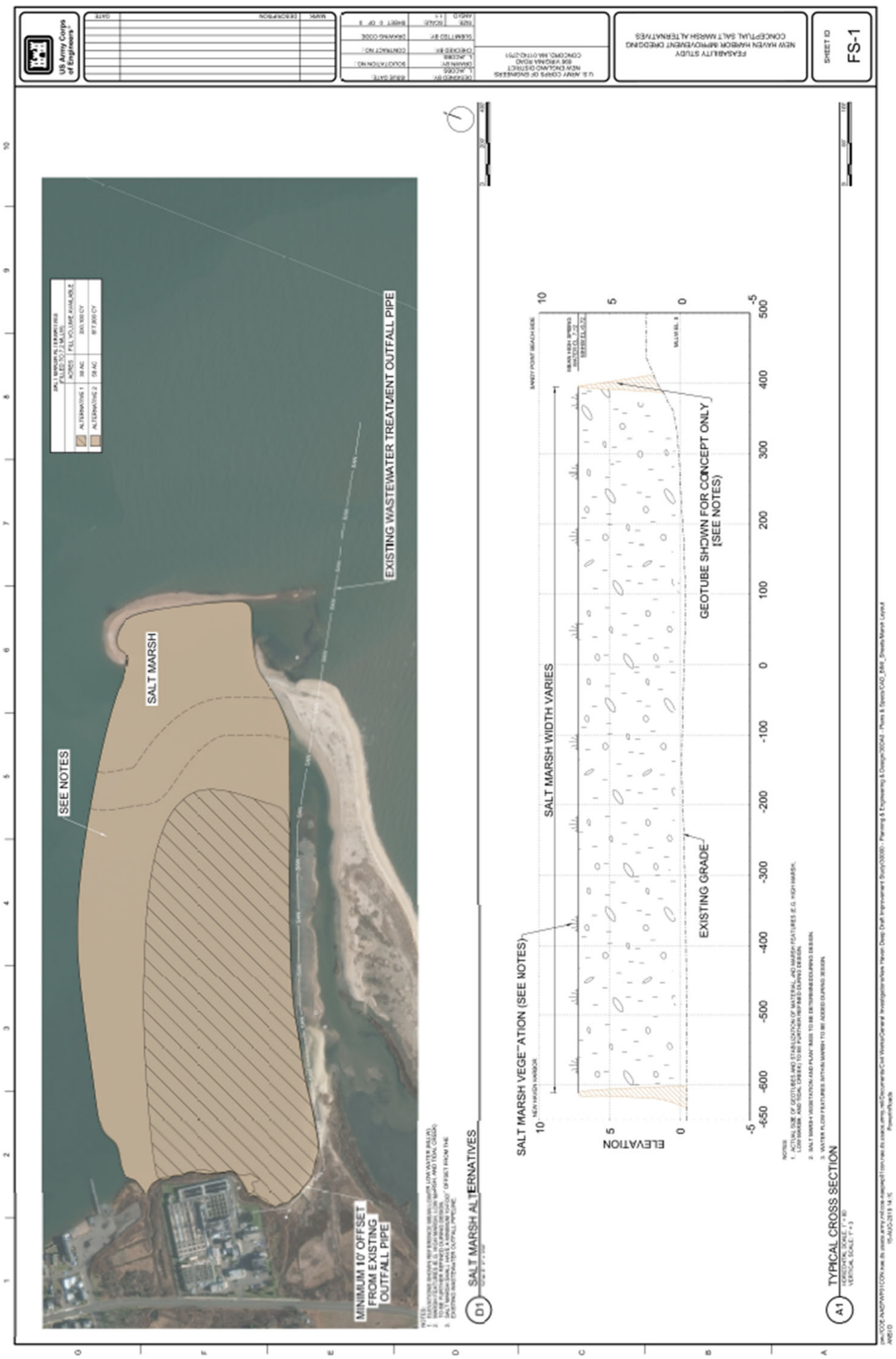

Table 3.3
New Haven Harbor Existing Tide Range – NOAA Station 8465705

Condition	**Elevation (feet, MLLW)**	**Elevation (feet, NAVD88)**
Mean Spring High Water (MSHW)	7.22	3.60
Mean Higher High Water (MHHW)	6.71	3.09
Mean High Water (MHW)	6.39	2.77
NAVD88	3.62	0.00
Mean Sea Level (MSL)	3.32	-0.30
Mean Tide Level (MTL)	3.32	-0.30
Mean Low Water (MLW)	0.24	-3.38
Mean Lower Low Water	0.00	-3.62

Table 3.4
USACE Sea Level Change Rates – Future Scenarios

Estimated Relative Sea Level Change
from 2023 To 2073
8467150, Bridgeport, CT
NOAA's 2006 Published Rate: 0.00840 feet/yr
All values are expressed in feet

Year	USACE Low	USACE Int	USACE High
2023	0.00	0.00	0.00
2025	0.02	0.03	0.06
2030	0.06	0.10	0.24
2035	0.10	0.18	0.43
2040	0.14	0.26	0.64
2045	0.19	0.35	0.87
2050	0.23	0.44	1.12
2055	0.27	0.54	1.38
2060	0.31	0.64	1.67
2065	0.35	0.74	1.97
2070	0.40	0.85	2.29
2073	0.42	0.92	2.50

Marsh Creation and SLC Scenarios

Both the 30-acre and 58-acre alternatives were considered under three sea level change (SLC) scenarios: high, intermediate, and low over the 50-year period of analysis.

30-Acre and 58-acre Marsh Creation, Low and Intermediate SLC Conditions

When comparing the existing (2019) tidal data (Table 3) and the predicted SLC data (Table 4) over a 50-year period, it was determined that under the low and intermediate SLC scenarios, the NESMM values for both alternatives would not change. Both the low and intermediate SLC values were less than a 1 foot change over a 50-year period. This change in water elevation would remain within the range of high marsh conditions and not significantly change marsh species composition. The with project condition represents the future under the low and intermediate SLC conditions. The high SLC scenario, which has a 2.5 foot rise in sea level over 50 years, would impact the marsh species composition and the sensitivity of the results to the high SLC was evaluated with the NESMM and is also presented below.

A discussion of the SLC scenarios and their calculations can be found in Section 5 of the Appendix E - Coastal Engineering. The existing tidal data is shown in Table 3 and predicted SLC data is shown in Table 4. The NESMM was not used to assess current conditions in the project area as the area is currently shallow subtidal habitat and intertidal mudflat habitat. Therefore, the "marsh" habitat value under current conditions was given an overall score of 0.

Data used to quantify the "with project" condition values were based upon projected habitat types that are being considered in the New Haven Harbor Navigation Improvement Project Integrated Feasibility Report and Environmental Impact Statement (IFR/EIS) (USACE 2018). The values were developed using anticipated site conditions once salt marsh creation efforts have been completed and are based upon the best professional judgment of USACE biologists. The inherent weakness of forecasting future conditions is that there is no way to guarantee that optimal conditions will be established at the salt marsh site. This uncertainty can be mitigated with the establishment of monitoring and adaptive management programs, as is required by USACE policy and has been included in the New Haven Harbor IFR/EIS.

30-Acre Marsh Creation, With Project Conditions

Alternative A. 30-acre created salt marsh, consisting primarily (98%) of high marsh, received a NESMM score of 382, which accounts for 49% of the highest possible score an evaluated marsh can achieve (Table 5).

Alternative B. A 30-acre created salt marsh, consisting of a 75% high marsh and 25% low marsh and as a sensitivity check a 30-acre created salt marsh consisting of 50% high marsh and 50% low marsh both received a NESMM score of 414, which accounts for 53% of the highest possible score (Table 5).

Each of the eight NESMM components that comprise the model are discussed below.

Size Class: This component received a score of 20 out of a possible 50 for all 30-acre scenarios. This is due to the marsh being in the "small" sized category (5-25 ha).

Morphology: This component received a score of 50 out of a possible 50 for all 30-acre scenarios. This is due to the marsh being designed as a salt meadow marsh.

Habitat Type: The "Habitat Type" component assesses the presence of 10 distinct microhabitats found within a salt marsh (i.e. shallow open water, tidal flats, pannes, trees over hanging water, high marsh, phragmites, pools, marsh-upland border, wooded islands, and low marsh) by assigning values and weighting factors to the percentage of each microhabitat present at the site. This component received a score of 76 out of a possible 319 for the primarily (98%) high marsh scenario. This value is due to the marsh being primarily high marsh. The scenarios of 75% high marsh/25% low marsh and 50% high marsh/50% low marsh received a score of 108 out of a possible 319. The higher score is a result of the low marsh percentage being greater than 15% and therefore causing the model to rate the marsh higher (the model plateau at which ratings change based upon the percentage of low marsh is at 15% low marsh).

Modification: This component received a score of 80 out of a possible 80 for all scenarios. This is due to the marsh being designed as a salt meadow marsh with no ditching or tidal restrictions.

Surrounding Land: This component received a score of 81 out of a possible 145 for all scenarios. This value is a function of the varying percentages of land use that surround the 30 acre marsh footprint. As the majority of surrounding land use would be open water and natural land, the component scores fairly high compared to the maximum.

Connectivity: This component received a score of 27 out of a possible 45 for all scenarios. This value is a function of the number of habitat types present in the adjacent lands. As with the surrounding land use component, the connectivity component scores fairly high compared to the maximum due to the proximity of open water, beach, and natural land habitat adjacent to the perimeter of the marsh.

Vegetative Heterogeneity: The "Vegetative Heterogeneity" component accounts for the abundance and diversity of vegetative edges. This component received a score of 30 out of a possible 30 for all scenarios. This is due to the marsh being designed as a salt meadow marsh that is adjacent to both open water habitat and natural land habitat.

Vegetation: The model assigns value to the composition of the salt marsh plant community through the "Vegetation" component. The percentage of five plant groups (aquatic plants, emergents, shrubs, trees, and vines) within the marsh unit is captured in this component. This component received a score of 18 out of a possible 65 for all scenarios. The value is due to the footprint being designed as primarily salt marsh as opposed to a mix of salt marsh, islands, upland, and open water.

58-Acre Marsh Creation, With Project Conditions

Alternative A. A 58-acre created salt marsh, consisting primarily (98%) of high marsh, received a NESMM score of 426, which accounts for 54% of the highest possible score an evaluated marsh can achieve (Table 5).

Alternative B. A 58-acre created salt marsh, consisting of 75% high marsh/25% low marsh and as a sensitivity check a 50% high marsh/50% low marsh, both received a NESMM score of 458, which accounts for 58% of the highest possible score an evaluated marsh can achieve (Table 5). The same score achieved by the 2 latter scenarios is a result of both scenarios having low marsh percentages greater than 15% (the model plateau at which ratings change based upon the percentage of low marsh is at 15% low marsh).

Each of the eight NESMM components that comprise the model are discussed below.

Size Class: This component received a score of 30 out of a possible 50 for all three scenarios. This is due to the marsh being in the "medium" sized category.

Morphology: This component received a score of 50 out of a possible 50 for all three scenarios. This is due to the marsh being designed as a salt meadow marsh.

Habitat Type: This component received a score of 92 out of a possible 319 for the predominately (98%) high marsh scenario. The value is due to the marsh being designed as primarily salt marsh as opposed to a mix of upland, marsh, island, and open water habitats. The 75%/25% and the 50%/50% high marsh/low marsh scenarios both obtained scores of 124 for habitat type. The increased score was the result of the greater than 15% low marsh quantity.

Modification: This component received a score of 80 out of a possible 80 for all three scenarios. This is due to the marsh being designed as a salt meadow marsh with no ditching or tidal restrictions.

Surrounding Land: This component received a score of 99 out of a possible 145 for all three scenarios. This value is a function of the varying percentages of land use that surround the 58 acre marsh footprint. As the majority of surrounding land use would be open water and natural land, the component scores fairly high compared to the maximum. All 58-acre marsh alternatives scored 16 points higher in this component than the 30-acre alternatives due to the larger ratio of marsh to open water.

Connectivity: This component received a score of 27 out of a possible 45 for all scenarios. This value is a function of number of habitat types present in the adjacent lands. As with the surrounding land use component, the connectivity component scores fairly high compared to the maximum due to the proximity of open water, beach, and natural land habitat adjacent to the perimeter of the marsh.

Vegetative Heterogeneity: The "Vegetative Heterogeneity" component accounts for the abundance and diversity of vegetative edges. This component received a score of 30 out of a possible 30 for all scenarios. This is due to the marsh being designed as a salt meadow marsh that is adjacent to both open water habitat and natural land habitat.

Vegetation: The model assigns value to the composition of the salt marsh plant community through the "Vegetation" component. The percentage of five plant groups (aquatic plants, emergents, shrubs, trees, and vines) within the marsh unit is captured in this component. This component received a score of 18 out of a possible 65 for all scenarios. The relatively low value is due to the marsh being designed as exclusively salt marsh meadow habitat.

Sensitivity Analysis to High SLC Conditions

30-Acre Marsh Creation, High SLC Conditions

The 30-acre created salt marsh was evaluated under high SLC conditions. In this scenario it was assumed that a sea level rise of 2.5 feet was realized and no natural marsh accretion had occurred. Therefore the site was evaluated as consisting primarily (99%) of low marsh. This scenario received a NESMM score of 374, which accounts for 48% of the highest possible score an evaluated marsh can achieve (Table 5). Each of the eight NESMM components that comprise the model are discussed below.

Size Class: This component received a score of 20 out of a possible 50. This is due to the marsh being in the "small" category (5-25 ha).

Morphology: This component received a score of 50 out of a possible 50. This is due to the marsh being designed as a salt meadow marsh.

Habitat Type: This component received a score of 68 out of a possible 319. The relatively low value is due to the predicted marsh being primarily (~99%) low marsh under high SLC conditions. However, as salt marshes have the ability to adapt to SLC through accretion processes, this scenario of changing from predominately high marsh to predominately low marsh over a lengthy time period (i.e., 50 years) is unlikely.

Modification: This component received a score of 80 out of a possible 80. This is due to the marsh being designed as a salt meadow marsh with no ditching or tidal restrictions.

Surrounding Land: This component received a score of 81 out of a possible 145. This value is a function of the varying percentages of land use that surround the 30 acre marsh footprint. As the majority of surrounding land use would be open water and natural land, the component scores fairly high compared to the maximum. While SLC values predict changes to marsh habitat types on the marsh surface, no changes in surrounding lands are expected.

Connectivity: This component received a score of 27 out of a possible 45. This value is a function of number of habitat types present in the adjacent lands. As with the surrounding land use component, the connectivity component scores fairly high compared to the maximum due to the proximity of open water, beach, and natural land habitat adjacent to the perimeter of the marsh. No changes to surrounding land are expected under the High SLC scenario.

Vegetative Heterogeneity: The "Vegetative Heterogeneity" component accounts for the abundance and diversity of vegetative edges. This component received a score of 30 out of a possible 30. This is due to the marsh being designed as a salt meadow marsh that is adjacent to both open water habitat and natural land habitat. While the high SLC scenario predicts changes in the salt marsh from high marsh dominant to low marsh dominant, the marsh would still be considered a salt meadow marsh.

Vegetation: This component received a score of 18 out of a possible 65. The relatively low value is due to the marsh being theoretically composed of primarily (99%) low marsh under the High SLC scenario.

58-Acre Marsh Creation, High SLC Conditions

A 58-acre created salt marsh under high SLC conditions, consisting primarily (~99%) of low marsh, received a NESMM score of 418, which accounts for 53% of the highest possible score an evaluated marsh can achieve (Table 5). Each of the eight NESMM components that comprise the model are discussed below.

Size Class: This component received a score of 30 out of a possible 50. This is due to the marsh being in the "medium" category.

Morphology: This component received a score of 50 out of a possible 50. This is due to the marsh being a salt meadow marsh.

Habitat Type: This component received a score of 84 out of a possible 319. The value is due to the predicted marsh being primarily low marsh under high SLC conditions, which (based upon how the NESMM values habitat diversity) is of lesser value than a marsh with a mix of habitat types. However, as salt marshes have the ability to adapt to SLC through accretion processes, this scenario of changing from predominately high marsh to predominately low marsh over a lengthy time period (i.e., 50 years) would depend on the extent to which the marsh is able to keep pace with sea level rise. While some transition to low marsh may occur, the change of the marsh habitat from "salt meadow" to intertidal flat and/or open water is not expected.

Modification: This component received a score of 80 out of a possible 80. This is due to the marsh being designed as a salt meadow marsh with no ditching or tidal restrictions.

Surrounding Land: This component received a score of 99 out of a possible 145. This value is a function of the varying percentages of land use that surround the 30 acre marsh footprint. As the majority of surrounding land use would be open water and natural land, the component scores fairly high compared to the maximum. While SLC values predict changes to marsh habitat types on the marsh surface, no changes in surrounding lands are expected as the 2.50 increase in sea level is below the existing elevations

Connectivity: This component received a score of 27 out of a possible 45. This value is a function of number of habitat types present in the adjacent lands. As with the surrounding land use component, the connectivity component scores fairly high compared to the maximum due to the proximity of open water, beach, and natural land habitat adjacent to the perimeter of the marsh. No changes to surrounding land are expected under the High SLC scenario.

Vegetative Heterogeneity: The "Vegetative Heterogeneity" component accounts for the abundance and diversity of vegetative edges. This component received a score of 30 out of a possible 30. This is due to the marsh being designed as a salt meadow marsh that is adjacent to both open water habitat and natural land habitat. While the high SLC scenario predicts changes in the salt marsh from high marsh dominant to low marsh dominant, the marsh would still be considered a salt meadow marsh.

Vegetation: This component received a score of 18 out of a possible 65. The relatively low value is due to the marsh being primarily (~99%) low marsh under the High SLC scenario.

4.0 ENVIRONMENTAL BENEFITS SUMMARY

To assess the ecological benefits gained from salt marsh creation, USACE used the NESMM (a marsh assessment tool) to evaluate the habitat value of the salt marsh creation alternative. Results are presented below in Table 4.1. The with project conditions represent the future under the low and intermediate SLC scenarios. A sensitivity analysis is also provided for the high scenario.

Two salt marsh sizes were evaluated one that maximizes placement (beneficial use) of the dredged material and a smaller size. The ratios of high marsh to low marsh habitat within each of the marsh sizes were also varied in an attempt to maximize ecological benefits based on the NESMM. These results show that adjusting the ratios of high to low marsh from 50% to 75% did not change the NESMM score.

The creation of a 58-acre salt marsh with a 75% high marsh 25% low marsh scenario produced the highest NESMM score (458) under the with project conditions, while the creation of a 30-acre salt marsh with the same habitat ratio produced a NESMM score of 414. It should be noted that because of existing conditions surrounding the site, the maximum score of any salt marsh configuration at Sandy Point was calculated to be 633. Therefore, the 58-acre salt marsh with a 75% high marsh 25% low marsh scenario accounts for 72% of the highest score possible.

Applying the high SLC scenario to the salt marsh creation project predicted that the salt marsh would likely change in form from a high-marsh dominated salt marsh meadow to a low-marsh dominated salt marsh meadow, indicating the environmental benefits of the marsh creation would not change significantly over the 50-year period of analysis as NESSM score only decreased by about one percent.

Table 4.1

Scores for each Sandy Point salt marsh creation area scenario under the with project conditions* and the predictive high sea level change (SLC) conditions.

Habitat Component	Max.** NESSM Score Possible	30 acres With Project Conditions (50% high marsh design)	30 acres With Project Conditions (75% high marsh design)	30 acres With Project Conditions (98% high marsh design)	30 acres High SLC Conditions Sensitivity Analysis	58 acres With Project Conditions (50% high marsh design)	58 acres With Project Conditions (75% high marsh design)	58 acres With Project Conditions (98% high marsh design)	58 acres High SLC Conditions Sensitivity Analysis
% salt marsh	-	90	90	90	90	90	90	90	90
% open water - mudflat	-	10	10	10	10	10	10	10	10
% high marsh	-	50	75	98	1	50	75	98	1
% low marsh	-	50	25	2	99	50	25	2	99
Size Class	50.0	20	20	20	20	30	30	30	30
Morphology	50.0	50	50	50	50	50	50	50	50
Habitat Type	319.0	108	108	76	68	124	124	92	84
Modification	80.0	80	80	80	80	80	80	80	80
Surrounding Land	145.0	81	81	81	81	99	99	99	99
Connectivity	45.0	27	27	27	27	27	27	27	27
Vegetative Heterogeneity	30.0	30	30	30	30	30	30	30	30
Vegetation	65.0	18	18	18	18	18	18	18	18
Total	**784****	**414**	**414**	**382**	**374**	**458**	**458**	**426**	**418**
Percent of Maximum	100%	53%	53%	49%	48%	58%	58%	54%	53%

*With project conditions represent both the low and intermediate SLC predictive conditions.
**Due to adjacent land use that cannot be modified, the maximum score for a salt marsh within the footprint under consideration is 633 (81% of the model's maximum score).

5.0 INCREMENTAL COST OF SALT MARSH CREATION AND BENEFIT

The cost to create the salt marsh is not a least cost disposal alternative. Use of the dredged material to create the salt marsh requires mobilizing a hydraulic dredge, placement of geotubes to provide for containment, contouring of the surface of the marsh, and post construction monitoring. Using the dredged material to create the salt marsh helps to limit the material going the Central Long Island Sound Disposal Site (CLDS). Project costs are the additional costs to create the salt marsh alternatives instead of disposing the material at CLDS. Costs are annualized over a 50-planning period (see Table 5.1).

Table 5.1
Project Costs

Sandy Point Salt Marsh Creation Beneficial Use of Dredged Material		
Quantity of Dredged Material	330,100 cy (Plan A & B)	657,000 cy (Plan C &D)
Acres	30	58
Project First Cost* (Cost above disposal at CLDS)	$5,676,000	$7,443,000
IDC (2-years) **	$157,000	$206,000
Total Includes IDC	$5,833,000	$7,649,000
Average Annual Equivalent (AAEQ) Cost	$216,000	$283,000
Average Annual Equivalent (AAEQ) O&M Cost	$15,000	$15,000
Average Annual Equivalent (AAEQ) Total	$231,000	$298,000
* Cost October 2019 price level, ** FY20 Discount Rate 2.75%		

Cost Effectiveness and Incremental-Cost Analysis

Cost effectiveness and incremental-cost analysis is an alternative to benefit-cost analysis used when the primary outputs/benefits of alternative plans are not measured in dollars. Cost effectiveness ensures that the least cost alternative is identified for each possible level of output, or NESMM units in this case. The incremental cost analysis reveals changes in costs as output units increase and allows an assessment of whether the increase in units is worth the additional cost (identifies diminishing returns). This process does not identify a unique optimal solution, rather it informs and supports selecting an alternative.

Five alternatives are considered in the cost effectiveness and incremental-cost analysis (CEICA).

The initial review of the plans shows that five alternatives, are cost-effective plans (economically justifiable). These alternatives are cost effective because there are no other alternatives that provides similar habitat units at less cost (see Table 5.2).

Table 5.2
Cost Effective Plans

Alternative	Description	CY	Output NESMM Score
No Action Alternative			0
Alternative A	30 acre 75% HM	330,100	414
Alternative B	30 acre 98% HM	330,100	382
Alternative C	58 acre 75 % HM	657,000	458
Alternative D	58 acre 98% HM	657,000	426

Best buy plans are a subset of cost effective plans. For each best buy plan there are no other plans that will give the same level of output at a lower incremental cost. There are three best buy plans: No Action, Alternative A, and Alternative C. See Table 5.3 below and Figure 5.1 Best Buy Plans.

Table 5.3
Best Buy Plans

Alternative	Description	Output NESMM Score	AAEQ Cost ($)	Cost Effective
No Action Alternative		0	0	Best Buy
Alternative A	30 acre 75% HM	414	231,000	Best Buy
Alternative B	30 acre 98% HM	382	231,000	Non-Cost Effective
Alternative C	58 acre 75 % HM	458	298,000	Best Buy
Alternative D	58 acre 98% HM	426	298,000	Non-Cost Effective

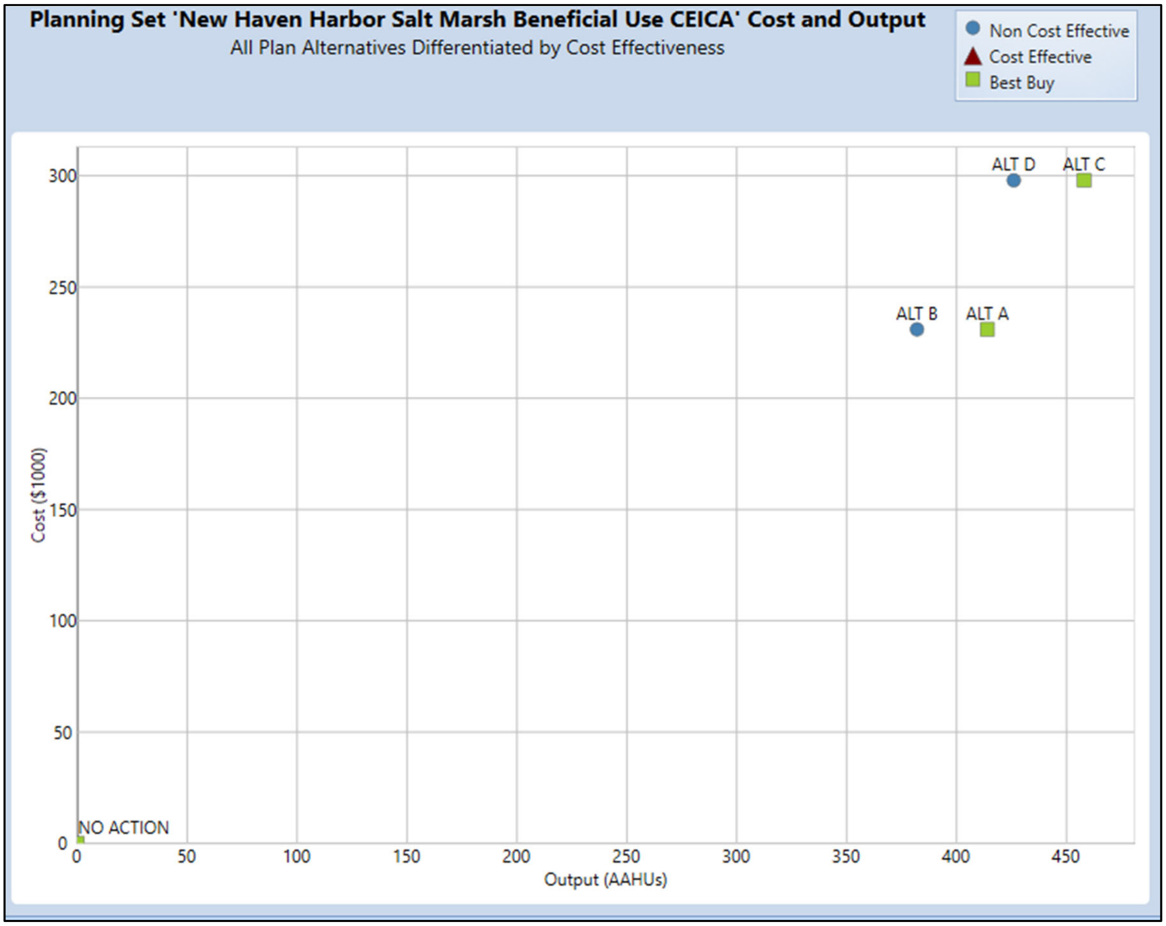

Figure 5.1: Best Buy Plans

The incremental cost per NESMM unit is the change in cost divided by the change in NESMM unit, or incremental output when proceeding to plans with higher levels of output. In this study, the incremental cost curve consists of three points (the three Best Buy Plans). See Figure 5.2. Alterative A would provide an additional 414 NESMM units over the No Action Alternative at an AAEQ cost of $558/unit. Alternative C would provide additional 44 NESMM units over Alternative A at an incremental AAEQ cost of $1,523 per NESMM unit. Although the incremental cost per unit in moving from Plan A to Plan C is higher that the going from the No Action to Plan A, it is worth the increase to obtain the additional environmental benefits provided by the larger 58 acre marsh and take full advantage of the beneficial use of dredged material.

Alternative C is the recommended alternative and provides 58 acres of salt marsh habitat (458 NESMM units) at an AAEQ cost of $650/NESMM unit or an AAEQ of $5,100/acre and significantly decrease the quantity of material going to Central Long Island Sound by 657,000 cy of dredged material.

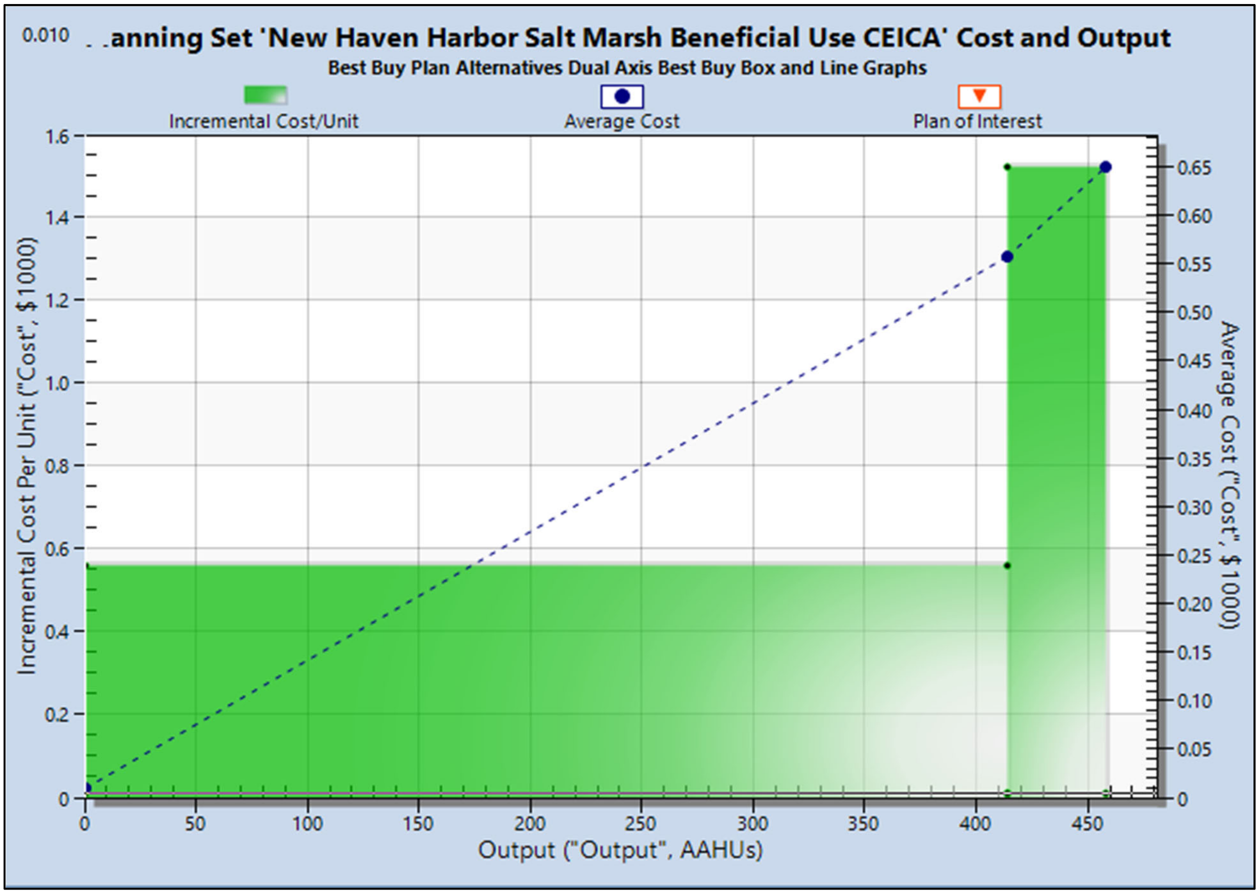

Figure 5.2: Incremental Cost

6.0 REFERENCES

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