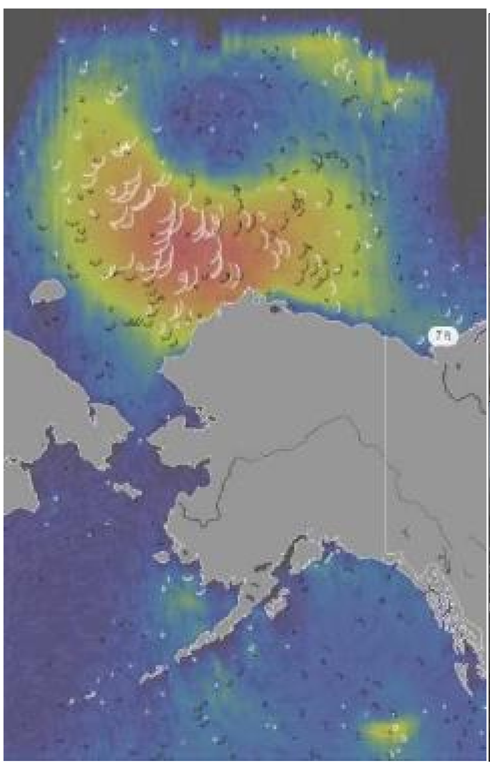
U.S. Army Corps of Engineers
Alaska District

Barrow Alaska Coastal Erosion Feasibility Study



Economic Analysis Technical Appendix

November 2019

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BARROW ALASKA
COASTAL EROSION FEASIBILITY STUDY

ECONOMIC ANALYSIS TECHNICAL APPENDIX

Alaska District

U.S. Army Corps of Engineers

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1.0 PREFACE

The United States Army Corps of Engineers (USACE) has partnered with the North Slope Borough (NSB) to conduct the Barrow Alaska Coastal Erosion Feasibility Study. The study is being conducted under authority provided by Section 116 of the Energy and Water Development Appropriations Act of 2010 (PL 111-85) as amended. Section 116 provides authority for the Secretary of the Army to carry out structural and non-structural projects for storm damage prevention and reduction, coastal erosion, and ice and glacial damage in Alaska.

This feasibility study is a USACE 3x3x3 SMART Planning feasibility study being conducted in response to a request from the NSB to resume a previous study effort by the USACE. The previous study effort, the Barrow Coastal Storm Damage Reduction Feasibility Study, culminated in a Technical Report in 2010, and is referred to as the 2010 study. Consistent with USACE SMART Planning principles, the current feasibility study is utilizing existing and available information from the 2010 study, combined with new data to support plan formulation and risk informed identification of a recommended plan.

This economic analysis technical appendix documents methods and results of economic studies conducted as part of the current feasibility study. Specifically, the appendix includes:

1) Description of the study area
2) Documentation of existing socioeconomic conditions in the study area
3) **Economic Evaluation Iteration 1**
    a. Documentation of expected without project National Economic Development (NED) damages and evaluation of potential NED effects of alternatives
    b. Overview of alternatives to reduce coastal erosion and flooding risk
    c. Documentation of planning level cost estimates for alternatives
    d. Evaluation of expected Regional Economic Development (RED) effects of alternatives
    e. Evaluation of expected Other Social Effects (OSE) of alternatives
    f. Documentation of evaluation framework to assess community resilience under without project conditions and expected Community Resilience Effects (CRE) with each alternative
    g. Documentation of Cost Effectiveness and Incremental Cost Analyses (CE/ICA) to support recommendation of a recommended plan in accordance with Section 116 of the Energy and Water Development Act of 2010 and its associated USACE implementation guidance.
    h. Findings and Conclusions from Iteration 1
4) **Economic Evaluation Iteration 2**
5) Optimization of Measures Carried Forward for further Evaluation
    a. Sensitivity Analyses
6) Identification of recommended plan
7) Description of significance of the recommended plan CRE for the study area
8) Documentation of local sponsor ability to pay analysis (see Attachment 2)

2.0 SUMMARY OF RESULTS

This section summarizes key results from this Economic Analysis Technical Appendix.

The NED benefits analysis for the alternatives under consideration was performed based primarily upon price level and interest rate updates of the 2010 study. Additionally, previous damage categories and methodologies were reviewed for current applicability. A new emergency flood fighting cost model was developed, reviewed, and approved for use in the current study to capture significant annual flood fighting costs of the North Slope Borough from annual storms under without project conditions.

As directed by the Section 116 USACE Implementation Guidance, when there is no NED Plan and/or the selection of a plan other than the NED Plan is based in part or whole on non-monetary units, the selection must be supported by a CE/ICA, consistent with established evaluation procedures in Engineering Regulation (ER) 1105-2-100, Appendix E. The Section 116 Authority affords the opportunity to formulate and select a plan based upon all four economic accounts. The PDT developed a CE/ICA framework, which evaluated and compared alternative plans in terms of their contribution to community resilience. For this study, community resilience was defined in terms of multiple variables that spanned the four accounts, including direct damages, social/cultural effects, life safety risk, employment and income effects, and environmental risk. Based upon existing information from the 2010 study and recent information obtained from the NSB, the community resilience evaluation framework was employed to estimate Community Resilience Units for the alternatives. The IWR Planning Suite software was utilized to perform the CE/ICA.

Through multiple iterations of the CE/ICA framework, a final array of eight action Alternatives A through H were identified from the initial array of Alternatives 2 through 6. Based upon this process, three plans (A, B, and C) were identified that had positive NED net benefits. Alternative A maximized net benefits and was identified as the NED plan. In consideration of the potential benefits across all four accounts and under the authority of Section 116, the PDT utilized the CE/ICA framework to inform selection of a plan based upon the derived Community Resilience Units. This consideration resulted in the selection of Alternative H as the recommended plan. This plan would provide risk reduction along the full length of the project area with a revetment in Reaches 1, 2, and 3 and would raise and armor Stevenson Street in Reaches 4, 5 and 6 to provide risk reduction, while minimizing the intersection of the project footprint with existing property and infrastructure. Based upon current design, the recommended plan would have a total construction cost (first cost plus contingency) of approximately $320.6 million. The PDT and sponsor judged the cost to be worth the improvements to community resilience in Barrow that would result from implementation of the recommended plan.

3.0 STUDY AREA

Barrow, Alaska is the northernmost community in North America, lying north of 71 degrees north latitude (Figure 1). Barrow is the economic, social, and cultural center for the NSB, which includes almost all of Alaska north of the 68th Parallel and has a population of about 9,800 persons[1] spread over 89,000 square miles, an area about the size of the State of Oregon. Barrow, incorporated in 1958, currently has about 4,500 residents[1], accounting for nearly half of the Borough's population.

[1] 2016 State Demographer estimate.

Figure 1 – State of Alaska Location Map

Barrow is located on the Chukchi Sea coast, 10 miles south of Point Barrow from which it takes its name. It lies 725 air miles from Anchorage and encompasses 18.4 square miles of land and 2.9 square miles of water. The climate of Barrow is arctic. Annual precipitation is light, with rainfall averaging 5 inches and annual snowfall averaging 20 inches. Temperatures range from -56 to 78 degrees Fahrenheit, with an average temperature of 40 degrees Fahrenheit during summer. The sun does not set between May 10th and August 2nd each summer and does not rise between November 18th and January 24th each winter. The daily minimum temperature is below freezing 324 days of the year. Prevailing winds are easterly and average 12 mph. The Chukchi Sea is typically ice-free from mid-June through October.

There are documented coastal erosion and flooding risks in the study area that pose threats to economic, social/cultural, and environmental systems in the community. The primary focus of the economic study of coastal flooding and erosion damages is the 5-mile stretch of coast beginning in the neighborhood of Barrow and extending northwest through the neighborhood of Browerville, along Stevenson Street past the South Salt and Middle Salt lagoons, up to and including the Naval Arctic Research Laboratory (NARL) facility (Figure 2). The Barrow and Browerville neighborhoods are the most populous and contain both residential and nonresidential structures and most of the city's infrastructure.

Figure 2 – Study Area

4.0 SOCIOECONOMIC CHARACTERISTICS

Barrow has the largest population in the NSB and is the economic center of the region. Borough, state, and federal agencies are the largest employers in the city. Numerous businesses provide support services to oil field operations. Tourism and arts and crafts provide some cash income. Seven residents hold commercial fishing permits. Subsistence production is an important component of the local economy and social structure, as many residents rely upon subsistence food sources. Whale, seal, polar bear, walrus, duck, caribou, grayling, and whitefish are harvested from the coast or nearby rivers and lakes for local subsistence.

Barrow is in the North Slope Census Area. The following paragraphs summarize population, housing, income, and employment statistics for Barrow. Most of the information is based upon data from the U.S. Census and Alaska Department of Labor and Workforce Development's 2016 Population Overview.

4.1 Population

Barrow's population was steady over the period between 2010 and 2016, with a high of 4,548 in 2015, a low of 4,436 in 2012, and a 2016 population of 4,469. Figure 3 shows the population change in Barrow over the period of 1880-2005. The most recent detailed demographic data for Barrow is from the U.S. Census American Community Survey program for 2016 (2016 Census). At that time, 71percent of the population was reported as Alaska Native alone (64 percent) or in combination with one or more races (7 percent). Of the remaining population, the largest racial groups were reported as white (12 percent) and Asian (12 percent). Table 1 provides a summary of the racial composition of the Barrow population in 2016.

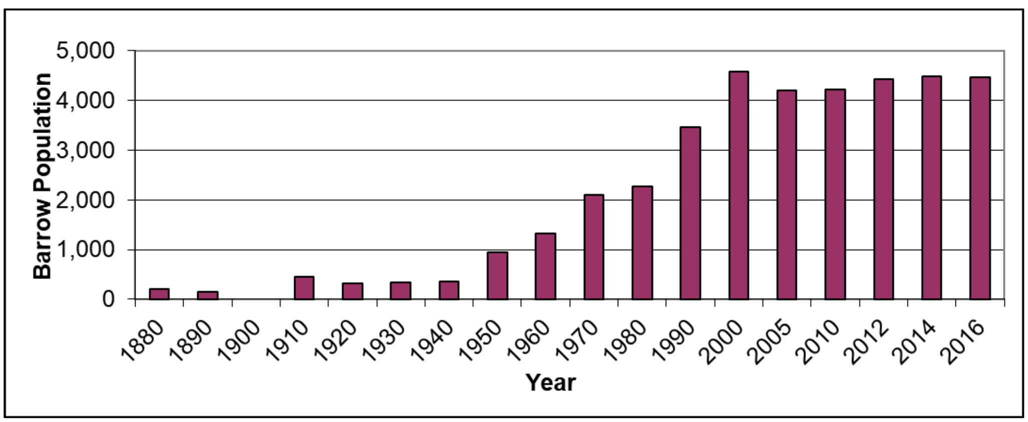

Figure 3 – Population Change in Barrow 1880-2016

Table 1 – Population by Race

Population in 2016: (Alaska State Demographer estimate)	4,469	
Population in 2016: (2016 American Community Survey)	4,316	
Racial Composition (2016 population):		
One Race Only:	3,995	93%
White:	511	12%
Alaska Native or Amer. Indian:	2,754	64%
Black:	10	1%
Asian:	513	12%
Hawaiian Native:	161	1%
Other Race:	46	1%
Two or More Races:	321	7%
All or Part Alaska Native/Indian:	3,043	71%
Hispanic Origin (Any Race):	213	5%
Not Hispanic (Any Race):	4,103	95%

The gender of Barrow's population in 2016 was approximately 52 percent male and 48 percent female. Approximately 39 percent of Barrow's population in 2016 was under the age of 20; with 45 percent between the ages of 20 and 54 and 16 percent over the age of 54. Barrow's median age was reported as 27. Table 2 provides a summary of Barrow's 2016 population statistics by gender and age.

Table 2 – Population by Gender and Age

Male:	2,260	52%
Female:	2,056	48%
TOTAL POPULATION (2016):	4,316	100%
Age 4 and under:	469	10.90%
Age 5 - 9:	466	10.80%
Age 10 - 14:	400	9.30%
Age 15 - 19:	350	8.10%
Age 20 - 24:	308	7.10%
Age 25 - 34:	661	15.30%
Age 35 - 44:	489	11.30%
Age 45 - 54:	502	11.60%
Age 55 - 59:	243	5.60%
Age 60 - 64:	194	4.50%
Age 65 - 74:	155	3.60%
Age 75 - 84:	74	1.70%
Age 85 and over:	5	0.10%
Median Age:	27.0	
Pop. Age 18 and over:	2,725	63%
Pop. Age 21 and over:	2,584	60%
Pop. Age 62 and over:	338	8%

Documented coastal flooding and erosion risk in the study area present a likelihood of numerous adverse consequences to the population of Barrow. These consequences are presented in subsequent sections of this appendix.

4.2 Housing

Barrow's 2016 population was grouped into 1,370 households and the City included 1,662 total housing units. The average household size was 3.11 persons. Table 3 summarizes the 2016 Census data related to housing and household characteristics in Barrow.

Table 3 – Housing/Household Characteristics

Total Housing Units:	1,662	
Owner-Occupied Housing:	603	44%
Renter-Occupied Housing:	676	56%
Vacant Housing:	292	18%
Total Households:	1,370	
Average Household Size:	3.11	
Family Households:	999	73%
Average Family Household Size:	3.63	
Non-Family Households:	371	27%

The 2016 Census data characterizing Barrow's housing stock is presented in Table 4.

Table 4 – Housing Structure Types

Single Family (Detached):	1,093	66%
Single Family (Attached):	53	3%
Duplex:	115	7%
3 or 4 Units:	134	8%
5 to 9 Units:	11	1%
10 to 19 Units:	129	8%
20 plus Units:	116	7%
Trailers/Mobile Homes:	11	1%
TOTAL STRUCTURES:	1,662	100%

Documented coastal flooding and erosion risk in the study area present a likelihood of adverse consequences to housing infrastructure in Barrow. These consequences are presented in subsequent sections of this appendix.

4.3 Employment and Income

Of the Census-estimated 4,316 people living in Barrow in 2016, approximately 67 percent were considered as being in the potential work force (age 16 years and over), with 2,053 in the labor force (employed or seeking work), and 857 not in the labor force (not seeking work). Of the labor force, 59 percent were reported as employed and 11 percent reported as unemployed. The largest employer was government, accounting for 864 of the 1,722 jobs in 2016 (50 percent). Table 5 summarizes the employment statistics for Barrow from the 2016 Census. Figure 4 presents a breakdown of employment in Barrow by category.

Table 5 – Employment

Total Potential Work Force (Age 16+):	2,910	
Unemployed (Seeking Work):	331	11.4%
Adults Not in Labor Force (Not Seeking Work):	857	29.5%
Total Employment:	1,722	59.2%
Breakdown of Employed Labor Force:		
Private Wage & Salary Workers:	818	48%
Self-Employed Workers (in own not incorporated business):	38	2%
Government Workers (City, Borough, State, Federal):	864	50%
Unpaid Family Workers:	2	0.10%

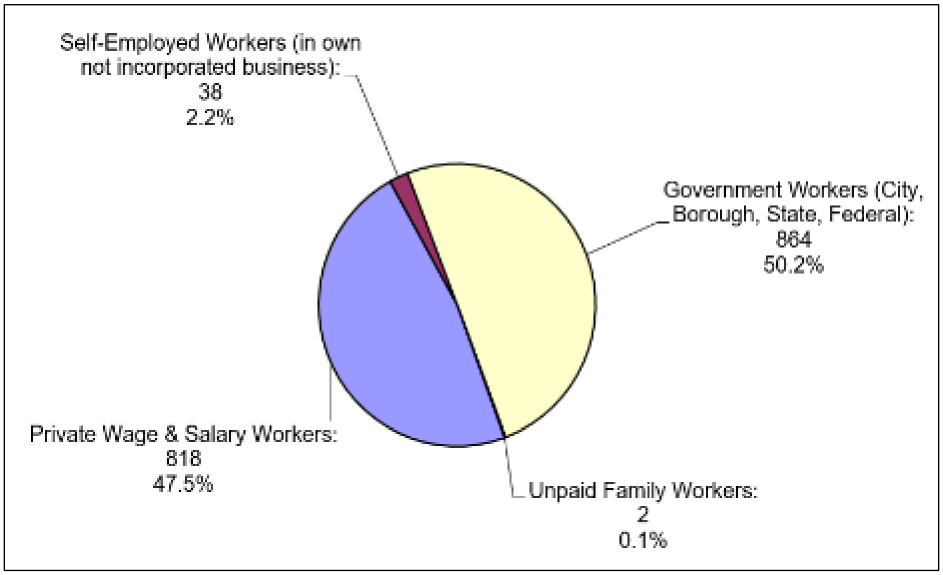

Figure 4 – Employment by Employment Category

Table 6 presents the breakdown of the 2016 Barrow employed workforce by industry. The industry category of Education, Health, and Social Services accounts for the most jobs, followed by Public Administration. Combined, these two industry categories account for approximately 43 percent of the jobs in Barrow.

Table 6 – Employment by Industry

Education, Health & Social Services:	426	24.7%
Public Administration:	321	18.6%
Transportation, Warehousing & Utilities:	194	11.3%
Other Services (Except Public Administration):	48	2.8%
Retail Trade:	169	9.8%
Construction:	193	11.2%
Professional, Scientific, Management, Administrative & Waste Mgmt.:	71	4.1%
Finance, Insurance, Real Estate, Rental & Leasing:	66	3.8%
Arts, Entertainment, Recreation, Accommodation & Food Services:	132	7.7%
Agriculture, Forestry, Fishing & Hunting, Mining:	74	4.3%
Information:	16	0.9%
Manufacturing:	0	0%
Wholesale Trade:	12	0.7%
TOTAL EMPLOYMENT:	1,722	100.0%

Barrow's Per Capita Income was reported at $28,137 in the 2016 Census data (18 percent lower than the state average of $34,191). Table 7 presents summary income data for Barrow.

Table 7 – Income

Per Capita Income: (Reported in 2016 Census)	$28,137
Median Household Income: (Reported in 2016 Census)	$78,804
Median Family Income: (Reported in 2016 Census)	$94,107
Persons in Poverty: (Reported in 2016 Census)	609
Percent Below Poverty: (Reported in 2016 Census)	14.1%

Documented coastal flooding and erosion risk in the study area present a likelihood of numerous adverse consequences to the employment and income opportunities in Barrow. These consequences are presented in subsequent sections of this appendix.

5.0 EXPECTED NATIONAL ECONOMIC DEVELOPMENT WITHOUT-PROJECT DAMAGES

NED benefits are effects that increase the economic value of the National output of goods and services. Evaluation of NED effects are required by USACE planning regulations and all economic development projects require identification of the NED plan as the alternative plan that maximizes net benefits (the difference in project costs and benefits). At Barrow, potential beneficial NED effects are possible by reduction of damages from flooding and erosion that would be expected to occur without a project.

To expedite the study in response to the time-critical nature of the flood and erosion hazard in Barrow, the NED assessment was made using the best available existing information (coastal modeling results and economic damage estimates from the 2010 studies), with specific refinements, as discussed in this section. It was the judgment of the PDT that the previous analysis was the best information available and reasonably representative of current conditions and appropriate for use in this study.

5.1 Discount Rate and Price Level Updates

The updated computation of without-project condition (WOPC) damages was based upon a 50-year period of analysis. All costs and benefits are presented in Q1 FY19 prices. Price level updates were performed using Engineering Manual 1110-2-1304, Civil Works Construction Cost Index System (Revision 30 Sep 2017), the Bureau of Labor Statistics Consumer Price Index, and the Marshall & Swift Valuation Service, as needed. Reference Attachment A for specific documentation of price level update calculations. Preliminary cost and benefit calculations were discounted using the FY19 Federal discount rate for water resources implementation studies of 2.875 percent, as published in USACE Economic Guidance Memorandum 19-01. The final iteration of the CE/ICA analysis which informs the decision for a recommended plan was conducted using the FY20 discount rate of 2.750% as published in USACE Economic Guidance Memorandum 20-01. There is negligible change in price level between FY19 and FY20, therefore prices included in this analysis are understood to be FY20 prices.

The general approach to efficiently converting WOPC damages to current price level and discount rate included:

- Identification of all relevant damage categories and verification that each category was still applicable
- Identification of the expected annual damages (EAD) value previously calculated for each applicable category
- Conversion of the old EAD to a Present Value (PV) using the 2010 study's discount rate
- Performance of a price level update to current prices
- Amortization of the PV at current prices using the current Federal discount rate, yielding the updated EAD value

5.2 NED Damage Analysis Refinements

Estimation of future without project NED damages were updated based on new coastal erosion emergency response costs information available from the NSB and the inclusion of an analysis of likely growth in open water (ice-free) season. However, as previously noted, no new risk-based hydraulic or economic (Beach-fx) modeling was performed. The NSB data and expected changes in open water season were applied to estimate expected future coastal erosion response costs in a method that was reviewed and approved by the USACE for one time use in this feasibility study.

5.2.1 Coastal Erosion Storm Response and Future Without Project Capital Costs

Two categories from the 2010 study (sacrificial beach berm erosion and frontage road erosion), were replaced by an updated analysis of coastal erosion emergency response costs and future expected capital costs for coastal erosion. This analysis was developed based upon new information provided by the NSB, which included a detailed accounting of relevant costs that was developed as a requirement of FEMA recovery program participation following the September 2017 storm.

The NSB provided a memorandum (NSB 2018) that related wind conditions to hourly rate of expenditures for coastal storm erosion (Table 8). Based upon review of National Oceanic and Atmospheric Administration (NOAA) wind data from the Barrow Airport monitoring station, an updated forecast of expected annual costs was developed. The NSB correlated the nature of their response efforts to five operational states. For each state, the NSB also developed physical weather parameters to define the occurrence of each state.

Table 8 – NSB Operational State Parameters and Cost

Operational State	Direction	Speed	Duration	$/hour	Description
Watch	210-360	10-20	24+	$7,260	forecasted weather event, in storm season
Prepare	210-360	20-30	12+	$14,740	imminent weather event, in storm season
Emergency	210-360	30+	6+	$22,000	weather event ongoing, in storm season
Repair	210-360	-	-	$14,740	follows emergency; 5 hours of repair per hour of emergency
Maintain	-	-	-	$3,520	in storm season, no active weather event

Next, 10 years of hourly weather data for the annual storm season was obtained for the Barrow Airport station from NOAA, from 2008 to 2018. Based on this history and the parameters specified by the NSB, the average annual number of hours in each state was tabulated to generate an estimate of average annual expenditures (Table 9). The resultant expected annual cost was $3,758,700. This value does not reflect the inclusion of expected open water season growth, as discussed in the next section.

Table 9 – NSB Annual Costs from Weather Events

State	Hours	$/Hour	Total Cost ($)
Watch	104.70	$7,260	$760,122
Prepare	38.80	$14,740	$571,912
Emergency	3.70	$22,000	$81,400
Repair	18.50	$14,740	$272,690
Maintain	588.80	$3,520	$2,072,576
TOTAL	165.70	-	**$3,758,700**

For capital expenditures, the NSB provided a detailed summary of historical capital expenditures for coastal storm erosion management to inform an estimate of future without project capital expenditures. The forecast of expected annual costs has a total value of $2,559,040. This value does not reflect the inclusion of expected open water season growth, as discussed in the next section.

Finally, in support of the planned sensitivity analyses to accompany the CE/ICA, the NSB was consulted to allocate the proportion of response costs and future capital costs that would accrue to each reach of the study area. Table 10 summarizes this assessment in terms of the proportion of expected annual costs to be allocated to each reach. The NSB noted that for response costs, the most critical infrastructure and concentration of homes are in reaches 2 through 5. For the capital costs, the NSB noted that the allocation of costs by reach reflects expected need and priority, but that the NSB does not have the resources to meet all needs.

Table 10 – NSB Annual Costs from Weather Events

Reach	% Response Costs	% Capital Costs
1 – Bluff	10%	15%
2 – Barrow	25%	25%
3 – Lagoon	20%	10%
4 – Browerville	20%	25%
5 – South and Middle Salt	20%	25%
6 – NARL	5%	0%

5.2.2 Growth in Open Water Season

This analysis considered the effects of an increasingly long open-water (ice free) season. This analysis was approved for one-time use through the USACE model certification process as part of the same review as the coastal erosion response costs.

The current open water season is approximately 92 days, from July 15 to October 15. Once the sea is frozen over in Fall, coastal storm risk is minimized until the ice recedes again in Spring. Given ongoing changes in long-term climate patterns in the Arctic, researchers forecast growth in the duration of the open water (ice-free) season. Such growth would expose the community to damage from wind events for a longer period of the year. In other words, if the trend of increase in the annual duration of the open-water season continues, the likelihood of storms occurring during open water also increases. Data for the ice-free durations was based upon research by the University of Alaska Fairbanks (Johnson and Eicken 2016, Figure 5).

Timing feature	Chukchi Sea			Beaufort Sea		
	Mean date or duration[a]	Trend (days per decade)[b]	r	Mean date or duration[a]	Trend (days per decade)[b]	r
Freeze-up start	October 21	14	0.6	October 16	7	0.6
Freeze-up end	November 10	11	0.3	October 30	9	0.4
Freeze-up duration	22 days	-5	–0.3	18 days	1	0.1
Break-up start	May 24	-9	–0.1	May 26	–5	–0.1
Break-up end	July 28	-12	–0.3	August 1	–10	–0.4
Break-up duration	58 days	-2	–0.1	68 days	–6	–0.2
Break-up end to freeze-up start	97 days (34)	22 (27)	0.6	79 days (25)	16 (25)	0.6
Break-up start to freeze-up end	174 days (38)	18 (33)	0.5	158 days (31)	14 (33)	0.5

[a]Standard deviation in parentheses.
[b]N values in parentheses.
doi: 10.12952/journal.elementa.000124.t004

Figure 5 –Open Water Season Research

Based upon this research, three growth scenarios were evaluated:

- Low growth: growth of 1.1 days per year, for 25 years
- Medium growth: growth of 2.2 days per year, for 25 years
- High growth: growth of 2.2 days per year, for 50 years

For the purpose of the analysis, the low-growth scenario was chosen as an appropriate scenario to incorporate the risk associated with additional open water season while remaining conservative regarding the representation of long-term changes in climate conditions.

This open water analysis was used to adjust the expected coastal erosion response and capital costs presented in the previous section. To do so, the annual costs were converted to daily costs and scaled according to the expected growth in the open water season duration throughout the period of analysis. The resultant estimate of total expected annual coastal erosion response cost and capital costs was $7,449,256.

5.2.3 Other NED Refinements

During development of the CE/ICA (see Section 11), several additional potential NED categories were identified. These categories were evaluated based upon available data. Damage estimates were annualized based either upon the annual exceedance probability of the associated damage initiating elevation or were assumed to occur half way through the period of analysis for annualization purposes. Table 11 presents these estimates.

Table 11 – Additional WOPC Costs

Category	Type	Annual Damage ($)	Description
Bluff, Historic Village, cultural resource emergency recovery	Erosion	$13,820	Annualized damage from $740,000 recovery cost assuming failure at year 25
South and Middle Salt Lagoon failure	Erosion	$106,715	Annualized damage from $5.7 million recovery cost assuming failure at year 25
Isatkoak Lagoon (water supply and utilities)	Flood	$123,704	Annualized damage from securing an emergency supply of drinking water following flooding of the Lagoon, based on 1.55% AEP of top of dam. Note that the value in Table 12 also includes $60,432 in annual damage that corresponds to the direct utility damage that was included in the 2010 Report.

5.3 Updated Expected NED Damages

NED categories in the 2010 study were divided between coastal storm damages and coastal erosion damages. Coastal storm damages included structures and contents, spillway and associated utilities, and utilidor damages. Coastal erosion damages included land loss, structure condemnation, beach berm emergency erosion maintenance (including storm-fighting), Stevenson Road repairs, South and Middle Salt Lagoon failure, and utilidor damages. Table 12 presents an updated accounting of without project NED damages by flooding and erosion. As shown in the table, the Berm/Emergency Maintenance category is the largest category. Additionally, it shows that flood damages are under 3 percent of the total without project damages. The fact that flood damages are a small proportion of total risk is important to determining the overall uncertainty in the estimate of potential benefits of the alternatives. If flood damages were a significant proportion of damages, there would be high uncertainty in the benefits achieved by a given alternative in the absence of updated risk-based flood modeling which estimates residual damages. However, since the main benefit driver is erosion, and residual risk of erosion is negligible with the project in place, there is much less uncertainty that an alternative would achieve estimated benefits. As such, it was determined that these updated values were suitable for use in the plan formulation process and for use in generating updated benefit-cost ratios for the alternatives and in sensitivity analyses (presented in Section 11.7).

Table 12 – Updated WOPC NED Damage Summary

Category	Type	Annual Damage ($)	%
Isatkoak Lagoon, (Water Supply and Utilities)	Flood	$184,136	2.2
Structures & Contents		$51,887	0.6
Utilidor (Critical Utilities)		$13,898	0.2
Subtotal		**$249,921**	**2.99**
Berm/Emergency Maintenance	Erosion	$7,449,256	89.2
Structures & Contents		$347,028	4.2
Utilidor (Critical Utilities)		$168,433	2.0
South and Middle Salt Lagoons (Sewage System & Old Navy Landfill)		$106,715	1.3
Land loss		$18,166	0.2
Bluff (Historic Native Village Site)		$13,820	0.2
Subtotal		**$8,103,419**	**97.0**
Total	**-**	**$8,353,339**	**100%**

6.0 ALTERNATIVE PLANS

The planning process for the current study established and screened a range of alternatives to reduce flood and erosion risks for the community of Barrow. The array of alternative plans was comprised of ten plans (including the No Action Alternative). Detailed descriptions of the alternatives are included in the main Feasibility Report. Each alternative and its primary features are summarized below for reference.

Alternative 1: No Action
The No Action Alternative would not take action to reduce the risk of erosion and flooding along the coastline of Barrow, Alaska. The study objective would not be met, and no opportunities would be realized. Erosion would continue to take place and flooding would occur during strong weather events. Public and private infrastructure, historical buildings, and cultural resources would continue to be lost as the ground beneath them erodes away.

Alternative 2: Rock Revetment, Revetted Berm and Raise Stevenson Street
A rock revetment would be constructed against the natural bluff in Barrow. The Lagoon area would have a revetted berm constructed to reduce the risk of saltwater inundation to the community's freshwater source. The areas of Browerville, South and Middle Salt, and NARL would have a raised and revetted Stevenson Street to reduce the risk of flooding and over topping of the road during strong weather events.

Alternative 5A: Protect Major Infrastructure
A rock revetment would be constructed against the natural bluff in Barrow. The Lagoon area would have a revetted berm constructed to reduce the risk of saltwater inundation to the community's freshwater source.

Alternative 5B: Barrow and Browerville Neighborhoods
Alternative 5B is Alternative 5A with the addition of a rock revetment constructed against the natural bluff in Barrow. In addition, Browerville would have a revetted berm constructed to reduce the risk of flooding to the Browerville neighborhood, which is a low-lying area.

Alternative 5C: Barrow and Browerville Neighborhoods plus NARL
Alternative 5C is Alternative 5B with the addition of raising and revetting Stevenson Street at NARL to reduce the risk of flooding and over topping of the road during strong weather events.

Alternative 5D: Barrow and Browerville Neighborhoods Plus NARL and Landfill
Alternative 5D is Alternative 5C with the addition of beach nourishment in the South and Middle Salt reach to reduce over topping of the road and flooding and erosion to the landfill and sewage lagoons.

Alternative 6A: Combination Rock Revetment, Raise Stevenson Street, and Revetted Berm with Limited Beach Nourishment
A rock revetment would be constructed against the natural bluff in Barrow. The Lagoon area would have a combination of revetted berm and beach nourishment constructed to reduce the risk of saltwater inundation to the community's freshwater source. The area of Browerville would have a revetted berm to reduce flooding in this low-lying area. The areas of South and Middle Salt and NARL would have a raised and revetted Stevenson Street to reduce the risk of flooding and over topping of the road during strong weather events.

Alternative 6B: Combination Rock Revetment, Raise Stevenson Street, Revetted Berm, and Beach Nourishment
A rock revetment would be constructed against the natural bluff in Barrow. The Lagoon area would have a combination of revetted berm and beach nourishment constructed to reduce the risk of saltwater

inundation to the community's freshwater source. The area of Browerville would have a revetted berm to reduce flooding in this low-lying area. The areas of South and Middle Salt and NARL would have a raised and revetted Stevenson Street to reduce the risk of flooding and over topping of the road during strong weather events.

Alternative 6C: Beach Nourishment Only
Beach nourishment would be placed along approximately 5 miles of coastline, from the bluff through NARL. The beach nourishment material would be dependent upon modelling results and could potentially be gravel or coarse sand, depending on the method of fill design. The interval of re-nourishment would depend on the size of material used for the initial nourishment.

7.0 COSTS OF ALTERNATIVES

Planning level cost estimates[2] were developed for the alternatives under consideration. Alternative costs are presented in current FY19 prices and use the FY19 discount rate. See the separate Cost Appendix for a detailed description of the costs, back-up information, which includes detailed spreadsheet cost estimates, unit prices, quantity calculations, and abbreviated risk analysis. Table 13 presents costs by alternative. Table 14 presents costs by reach, by treatment type, and for two additional design heights, as required for the sensitivity analyses presented in Section 11.

Table 13 – Alternative Costs

Alternative	First Costs	Contingency	Total Costs	OMRR&R ($ PV)
2	$204,140,000	46.2%	$298,030,000	$45,643,000
5A	$82,388,000	46.8%	$121,575,000	$11,587,000
5B	$144,822,000	46.5%	$213,850,000	$26,523,000
5C	$189,164,000	46.4%	$279,566,000	$35,858,000
5D	$263,975,000	46.7%	$390,716,000	$68,517,000
6A	$323,474,000	46.6%	$478,370,000	$48,726,000
6B	$462,715,000	47.0%	$684,466,000	$35,858,000
6C	$637,064,000	47.6%	$944,066,000	$605,000
Note: Present value of OMRR&R based on 50-years of maintenance and 2.875% discount rate. The separate Cost Appendix provides documentation of the development of the alternative costs.				

[2] Consistent with guidelines in ER 1110-2-1302 for Class 4 estimates for Feasibility Alternatives.

Table 14 – Reach-Based Costs for Selected Measures and Design Heights for Sensitivity Analyses

Reach	Construction Measure	Height (feet)	Total PV ($)	Annualized ($)
1	Revetment	19	$33,891,000	$1,286,000
		21	$36,261,000	$1,376,000
		23	$38,684,000	$1,468,000
2	Revetment	14.5	$25,827,000	$980,000
		15.5	$27,321,000	$1,037,000
		17	$29,291,000	$1,112,000
3	Berm	14.5	$50,185,000	$1,904,000
		15.5	$56,478,000	$2,143,000
		17	$64,387,000	$2,443,000
4	Raise Stevenson	14.5	$52,611,000	$1,996,000
		15.5	$55,855,000	$2,120,000
		17	$60,926,000	$2,312,000
4	Berm	14.5	$73,912,000	$2,805,000
		15.5	$81,103,000	$3,078,000
		17	$92,457,000	$3,509,000
5	Raise Stevenson	14.5	$106,139,000	$4,028,000
		15.5	$112,581,000	$4,272,000
		17	$126,773,000	$4,811,000
5	Berm	14.5	$149,611,000	$5,677,000
		15.5	$164,043,000	$6,225,000
		17	$187,204,000	$7,104,000
6	Raise Stevenson	14.5	$74,958,000	$2,845,000
		15.5	$79,635,000	$3,022,000
		17	$86,731,000	$3,291,000
6	Berm	14.5	$106,326,000	$4,035,000
		15.5	$117,067,000	$4,442,000
		17	$133,533,000	$5,067,000
Note: Present value based on 50-year period and 2.875% discount rate.				

8.0 NED EFFECTS OF ALTERNATIVES

The data in Table 15 provides a comparison of the annual costs for the initial array of alternatives to the estimated NED benefits for each alternative. These benefit estimates were informed by the 2010 Report and refined based upon the information presented in Section 5 as well as the implementation of the CE/ICA described in Section 11.

This benefit cost ratio (BCR) calculation includes the simplifying assumption that every alternative would eliminate all damages in the reaches that alternative includes. In short, the maximum benefits shown here are equivalent to the estimated future without project annual damages presented in Section 5. The adjustment of maximum benefits by alternative was based upon the extent of construction of each alternative. This was judged to be acceptable because 97 percent of expected damages are from erosion and the project would effectively eliminate the coastal erosion risk in included reaches.

Given the small proportion of damages that are from flooding (under 3 percent), the simplification to not quantify residual flood damage does not significantly affect the BCR. Available information regarding the with-project level of risk reduction and residual risk of the recommended plan is presented in the main body of the feasibility report.

Table 15 – Estimated Benefits with Updated NED Damages

Alternative	Annual Costs ($, 2.875%)	Annual Benefits ($, 2.875%)	Annual Net Benefits ($, 2.875%)	BC Ratio
2	$13,042,000	$8,353,000	-$4,689,000	0.64
5A	$5,053,000	$3,517,000	-$1,536,000	0.70
5B	$9,122,000	$6,334,000	-$2,788,000	0.69
5C	$11,970,000	$6,595,000	-$5,375,000	0.55
5D	$17,427,000	$8,353,000	-$9,074,000	0.48
6A	$20,002,000	$8,353,000	-$11,649,000	0.42
6B	$27,335,000	$8,353,000	-$18,982,000	0.31
6C	$35,848,000	$8,353,000	-$27,495,000	0.23

9.0 REGIONAL ECONOMIC EFFECTS OF ALTERNATIVES

The RED account displays changes in the distribution of regional economic activity as a result of each alternative plan. Regional income and employment are commonly applied measures of regional economic activity. The absolute level of effects is of less importance than the relative impact on the region.

The positive effects of a plan on a region's income are equal to the sum of the NED benefits that accrue to that region, plus transfers of income to the region from outside the region. The positive effects of a plan on regional employment are directly parallel to the positive effects on regional income. The primary types of positive regional impacts associated with the final alternatives involve short term employment and income gains associated with project construction. In the longer term, the final alternatives have the potential to positively affect income and employment stability in the community, economic growth, and tax revenues. The relative potential effects of each alternative on RED are summarized in the following paragraphs.

9.1 Alternative 1 (No Action)

With the No Action Alternative, expected coastal storm/flood damages would likely result in negative employment and income impacts in the study area. Based upon results of the modeling in the 2010 study, businesses and government agencies with facilities at risk of coastal storm damage employ approximately 210 people in the study area. The 210 employees account for approximately 12 percent of Barrow's total of 1,722 jobs as reported in the 2016 U.S. Census. Approximately 75 percent of the 210 at-risk jobs are in the public sector, and approximately 25 percent are in commercial establishments. Based upon mean annual earnings of $63,100 in the 2016 Census American Community Survey, the value of income of employees in at-risk facilities is estimated at approximately $51,000 per day (assuming a 5-day work week: ~$1.02M per month; ~$12.24M per year). A large potential risk to employment and income in the study area is loss of the utility services provided by the underground utilidor. As noted previously in the NED analysis, the utilidor is subject to flooding in extreme events and is estimated to be impacted by erosion within 25 years. The risk of coastal storm damage serves as a disincentive for businesses to invest in the community, further reducing the potential for future employment and income growth in Barrow.

9.2 Alternatives 2, 6A, 6B, and 6C

Because Alternatives 2, 6A, 6B, and 6C are designed to provide risk reduction throughout the study area, effects would be similar for each.

In the short term, the study area is expected to experience positive income and employment effects from construction of any of these alternatives. Construction is expected to occur from June to October for several seasons, which would employ a construction crew. Opportunities for direct local employment associated with project construction are possible, but expected to be limited. Secondary positive employment and income impacts are expected to result from the crew's demand for lodging, groceries, food, entertainment, automobile rental/service/supply, health care, and payment of taxes.

Over the longer term, these alternatives would reduce the risk of coastal flooding and erosion in Barrow and the associated negative employment and income effects described previously for the No Action Alternative. The alternatives would also reduce the existing disincentive for business investment in Barrow, due to the current risk of potential storm damages. Out of pocket expenses of businesses and residents associated with coastal storm damage repairs and rehabilitation would be reduced, resulting in more disposable income, increased earnings, increased demand for local goods and services, and an increased tax base. Collectively, these positive income and employment effects are expected to result in a more stable, growing economy in Barrow than with the No Action Alternative.

9.3 Alternatives 5A, 5B, 5C, and 5D

These alternatives offer incrementally increasing levels of risk reduction for the study area. In the short term, the study area is expected to experience positive income and employment effects from construction of any of these alternatives. However, implementation of successively larger alternatives would be expected to increase the magnitude of these positive effects as a result of increased construction cost, duration, and crew size, all of which could increase impacts.

Construction is expected to occur from June to October for several seasons, which would employ a construction crew. Opportunities for direct local employment associated with project construction are possible but expected to be limited. Opportunities for secondary positive employment and income impacts are expected to result from the crew's demand for lodging, groceries, food, entertainment, automobile rental/service/supply, health care, and payment of taxes.

Over the longer term, these alternatives would reduce the risk of coastal flooding and erosion in Barrow and the associated negative employment and income effects described above for the No Action Alternative. Alternative 5A, which reduces risk to critical infrastructures, would achieve the largest increment of beneficial regional effects. Successively larger plans would achieve additional benefits from risk reduction in Browerville, NARL, and the South and Middle Salt lagoons.

10.0 OTHER SOCIAL EFFECTS OF ALTERNATIVES

10.1 Life, Health and Safety

The final alternatives have the potential to affect personal health and safety, including risk of injury and mortality. They also have the potential to affect the safety of property and the risk of property damage. Such damages have profound effects on quality of life for local residents. Additionally, the alternatives have the potential to affect life, health, and safety of not only local residents, but also residents of outlying smaller communities throughout the North Slope Borough that depend on Barrow for emergency response and other support services. The relative effects expected with each final alternative are:

- **No Action Alternative:** The No Action Alternative poses risks to personal safety and mortality by not addressing the current risks of coastal storm damages and erosion in the study area. Frigid flood waters during storms in the study area result in unusually dangerous conditions. Additionally, the current practices of flood fighting during storms place equipment operators in extremely hazardous conditions to protect the community. The community faces risk of damage to personal property, including residential and non-residential structures and their contents. Flooding and the risk of flooding negatively impact the quality of life of local residents. While local medical facilities and emergency response resources are not expected to be physically impacted by coastal flooding and erosion, localized coastal storms may fully occupy local emergency response personnel and limit their ability to serve regional outlying communities within the North Slope Borough. Expected erosion damage to the beach frontage roadway could result in hazardous road conditions during storms.

- **Alternatives 2, 6A, 6B, and 6C:** These alternatives would reduce the identified risks to personal safety and mortality associated with coastal flooding, erosion, and flood fighting activities. The alternatives would also reduce coastal storm and erosion damages to property. Because these alternatives are designed to provide reduce risk throughout the study area, effects would be similar. Risk to human health and safety associated with coastal erosion creating unstable bluffs in Barrow and risks to the safety of property along the Barrow Bluff erosion zone would improve relative to those conditions with the No Action Alternative. The improved safety of the local community in eastern Barrow and in Browerville resulting from the revetted berm alternative would result in an increased quality of life for residents. These alternatives would reduce the safety risk associated with damage to the beach frontage roadway. Risk reduction for the utilidor from erosion damage would reduce the potential losses human health and safety risks that would be associated with an interruption in utility service. The decreased risk of local coastal flood emergencies would reduce the likelihood that Barrow would not be able to provide emergency response services to other NSB communities during periods of coastal storms in Barrow.
- **Alternatives 5A, 5B, 5C, and 5D:** These alternatives would reduce the identified risks to personal safety and mortality associated with coastal flooding, erosion, and flood fighting activities. The alternatives would also reduce coastal storm and erosion damages to property. The magnitude of these positive effects increases with each alternative as additional areas are included. All these alternatives offer risk reduction for the utilidor at Pump Station #4 from erosion damage would reduce the potential losses human health and safety risks that would be associated with an interruption in utility service. With alternatives 5A, 5C, and 5D, risk to human health and safety associated with coastal erosion creating unstable bluffs in Barrow and risks to the safety of property along the Barrow Bluff erosion zone would improve relative to those conditions with the No Action Alternative, as well as improved safety of the local community in eastern Barrow and in Browerville which would result in an increased quality of life for residents. Incrementally larger alternatives would reduce the safety risk associated with damage to the beach frontage roadway. The decreased risk of local coastal flood emergencies would reduce the likelihood that Barrow would not be able to provide emergency response services to other NSB communities during periods of coastal storms in Barrow.

10.2 Educational Opportunities

No flooding or erosion damages are expected to directly impact school facilities in Barrow. Interruption of utility service associated with flooding or erosion damage to the utilidor could impact ability to provide school services depending on the extent of damage to the utilidor and the resulting level and duration of service interruption. All the action alternatives would substantially reduce the risk of utility outages from flooding or erosion at Pump Station #4 or damages to utilities spanning Tasigrook and Isatkoak lagoons.

10.3 Recreational Opportunities

The primary traditional recreational opportunity affected by the final alternatives is recreational beach combing. The relative effects expected with each alternative are described below. With the No Action Alternative, future opportunities for recreational beach combing are expected to remain in the study area. For the action alternatives, opportunities may experience minor adverse changes depending upon the structure proposed for a given reach of the study area. At the bluff, the revetment may reduce opportunities due to the narrow beach that would be further occupied by the revetment. Similarly, areas behind a berm may see a reduction in beach area. A continuous structure could pose potential risks to human health and safety during beach combing where exit from the beach would be limited to the beach access locations or climbing over the structure.

10.4 Subsistence

Subsistence is extremely important to the community in Barrow. Sixty-four percent of the population is Alaskan Native (primarily Inupiat Eskimo) and practices a subsistence lifestyle. Traditional marine mammal hunts and other subsistence practices are an active part of the culture.

With the No Action Alternative, future opportunities for subsistence participation are expected to remain in the study area. Although past storm erosion damages to Stevenson Street have impeded eastward connectivity to Pt. Barrow, where fish camps used for subsistence harvesting are located at Elson lagoon, a new alternative connector road is planned for construction that would address the issue.

Opportunities to participate in subsistence activities are not expected to be limited or improved from without project conditions by any of the action alternatives evaluated. Beach access for fishing boats would be maintained.

10.5 Cultural Opportunities

Cultural opportunities affected by the alternatives include loss of/damages to portions of the Utqiagvik Village Archeological Site in Barrow and fishing/whaling activities.

With the No Action Alternative, cultural resources and opportunities would be negatively impacted by the expected damages to the Utqiagvik Village archeological site in Barrow. Cultural activities associated with fishing/whaling are expected to continue as present.

Alternative 5A is the only action alternative that would not reduce risk for the bluff at the Utqiagvik Village Site from continued erosion, and effects would be similar to the No Action. All other action alternatives would reduce risk at the archeological site in Barrow, the associated cultural resources, and cultural opportunities. It is assumed that the construction and any required maintenance of the project near the Utqiagvik Village Site would be from the water side of the site to ensure that no negative impacts to resources at the site occur.

10.6 Population

The final alternatives have the potential to affect the local population size in Barrow by influencing net migration. Additionally, conditions associated with the alternatives could result in the displacement of people and businesses.

Because the No Action Alternative would not reduce the risk or occurrence of coastal flooding and erosion in the study area, some local residents could be expected to migrate to safer communities following damaging and threatening coastal storms. Additionally, the local flood risk might preclude businesses from establishing in Barrow limiting employment opportunities that could attract new residents. Residences could be displaced by condemnation, especially in the Barrow bluff erosion zone.

The action alternatives would result in a reduction of the flooding and erosion damage risk in Barrow. All the alternatives would reduce the risk of critical infrastructure failure and utility loss. The magnitude of other positive effects increases as the length of the alignment increases. The alternatives would serve to reduce expected erosion damages and their effect as an incentive for outmigration from the community and a disincentive for establishment of business enterprises. The magnitude of these positive effects increases as the length of the alignment increases. Since a stable growing economy is more likely to provide an incentive for new residents to settle in Barrow, the population might be expected to increase as the level of risk reduction increases.

10.7 Aesthetics

The final alternatives have the potential to affect aesthetic resources in the study area.

Under the No Action Alternative, the project area is already occupied by beach berms for coastal storm risk reduction. These berms are gravel mounds generally anywhere from 6-8 feet in height and placed at the crest of the beach (top elevation of berm is approximately 12 feet – 15 feet above msl) as a risk reduction measure against rising water from storm surge and wave attack.

All the action alternatives that include a structure would be built to 19 feet at the bluff and 14.5 feet throughout the remainder of the study area. The increased height of the structure would adversely affect the viewshed from low-lying areas in the study area; particularly those closest to the shoreline. The visual effect from the beach side of the dike/revetment would be more pronounced because the structure would result in more isolated perspective with no view of the transitional zone to upland areas.

The aesthetic effects associated with beach nourishment are expected to be similar to those presented for the revetted berms. However, the smaller unit size of the nourishment materials relative to the revetment materials could result in a relatively more natural appearance than with the revetted berm.

11.0 COMMUNITY RESILIENCE ASSESSMENT

The Section 116 Authority is intended to support development of USACE projects in rural Alaska that improve communities' resilience to flooding and erosion hazards. In pursuit of a project implemented under this authority, it is the responsibility of the USACE to identify the recommended plan in a manner consistent with USACE planning principles and procedures. There are significant risks to the Barrow community that can be quantified in terms of local and regional economic impacts, risk to life and public health and safety, and risk of environmental contamination.

As directed by Section 116 Implementation Guidance, when there is no NED Plan and/or the selection of a plan other than the NED Plan is based in part or whole on non-monetary units, the selection must be supported by a CE/ICA consistent with established evaluation procedures in ER 1105-2-100, Appendix E. The implementation guidance further states that the alternatives evaluation should present the tradeoffs of impacts in the four accounts for the plans contained in the final array and describe in detail the compelling justification for any plan that is not the NED Plan. The guidance allows for consideration of non-monetary benefits. Examples provided in the guidance include public health and safety; local and regional economic opportunities; and, social and cultural value to the community.

A framework was developed for evaluating the effects of alternatives based upon the concept of community resilience and an evaluation of the extent to which the alternatives would support and contribute to the community's resilience goals. The proposed community resilience evaluation framework provides the data required for a CE/ICA to compare alternatives in terms of their contribution to improving community resilience at Barrow. Development of the framework was based upon the USACE approaches to consideration of resilience, applied to the project context at Barrow. In general, the purpose of the CE/ICA is not to directly estimate damages as would be performed in a NED analysis, rather it is to compare the relative performance of the alternatives in a systematic way to inform selection of a preferred plan and provide information which supports understanding of plan tradeoffs. To this end, the framework utilizes best available information about the occurrence of coastal storms and erosion, the initiation of related damages, and the impacts of those direct damages on the Barrow community; but it does not attempt to develop a damage model.

11.1 Defining Resilience

Increasingly frequent extreme events, such as natural disasters, amplified by increasing urbanization and impacts from climate change, result in severe and costly impacts wherever they occur. Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions (EO 13653). Resilience – of a person, project, system, and/or communities of any size – can help reduce the extent and duration of negative consequences from adverse events. Resilience represents a comprehensive, systems-based, lifecycle approach to both acute hazards and changes over time, and the concept of resilience is used to convey a broad-based, collaborative approach to finding creative solutions to such challenges (USACE 2017 and 2018).

Figure 6 conceptually illustrates resilience in terms of response to a hazard event, where the combination of event severity and resilience result in different possible responses to the event (Linkov et al. 2014). Under WOPC, Barrow best fits the category of High Risk & Low Resilience.

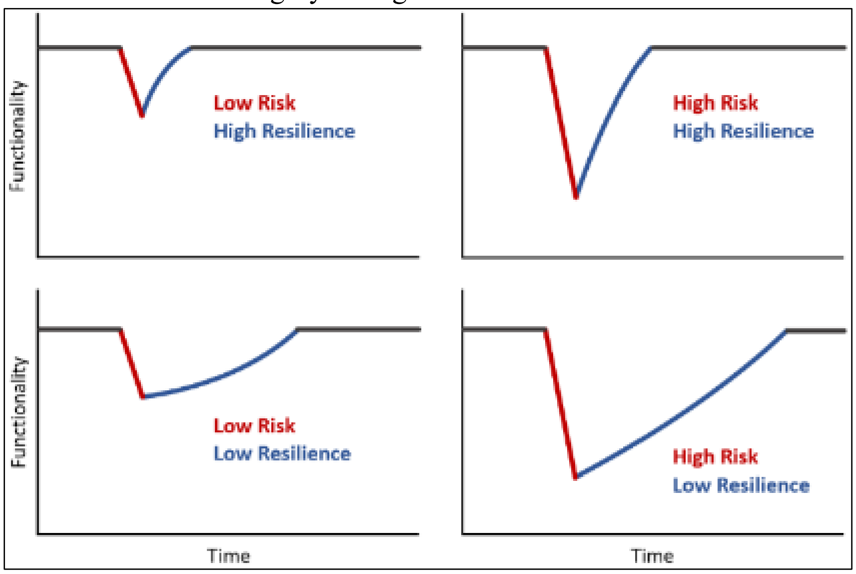

Figure 6 –Resilience Over Time (Linkov et al. 2014)

Resilience Goal: The USACE defines its role in fostering resilience in terms of projects. The goal for resilience in projects is to increase performance reliability in anticipated use, reduce the risk of failure during extreme events, maintain primary function during changing conditions, and/or help meet specific community resilience goals (USACE 2017).

At Barrow, the community resilience goal is well-aligned with the planning objectives, which both convey the need to address immediate risks associated with regularly occurring storms and long-term risks associated with lower-probability (higher magnitude) storm events and the effects of coastal erosion, especially in consideration of changing global weather patterns that have resulted in delayed freeze-up and longer open-water storm seasons.

Levels of Resilience: As shown in Figure 7, the USACE identifies three interdependent levels of applied resilience: (1) project, (2) system, and (3) community (USACE 2017).

- *Project Resilience* refers to USACE or other projects and their own resilience. For example, a measure of project resilience might be a levee, berm, or revetment's performance over the probable storm frequency curve.
- *System Resilience* refers to a set of integrated projects which have a system-wide resilience. This might include the combined ability of the levee and an upstream storage reservoir to reduce risk associated with probable storms. Some systems may be all USACE projects, or may have non-USACE projects, or may have no USACE projects.

- *Community Resilience* refers to the combined resilience of all the systems in a community (system of systems). Community resilience encompasses the entirety of all aspects that make up a community. It is complex and complicated, and each community is different (USACE 2018a).

Figure 7 – Three Levels of Resilience (USACE 2017)

The Community Resilience evaluation framework described in this section provides a methodology to assess and compare the relative contributions of each alternative to community resilience to erosion and flooding in Barrow. Given the scope of the project being proposed at Barrow, the alternatives may be considered in terms of project resilience (the resilience of the project itself) as well as system resilience (how a project would contribute to the resiliency of utility and transportation infrastructure in the community). To the extent that the proposed project improves system resilience, it would also thereby contribute to community resilience.

Four Resilience Actions: To help organize resilience activities and describe how resilience measures can be applied, the USACE has divided resilience into four key principles (or actions): prepare, absorb, recover, and adapt. These principles provide a lifecycle perspective for resilience-related actions in recognition of the fact that adverse events happen, and conditions change over time (USACE 2017). These four principles are illustrated graphically in Figure 8, which considers a system's resilience in terms of its reaction to a hazard event over time (Linkov et al. 2014). As shown in the figure, all four principles of resilience contribute to a system's response to a hazard event.

Figure 8 – Four Resilience Principles (Linkov et al. 2014)

NSB staff **plan** and prepare for storms through an ongoing maintenance program that involves shoring up the sacrificial berms in advance of each storm season and readying equipment and materials for emergency maintenance during storms. The community's ability to **absorb** the impacts of a storm rely heavily on this active flood and erosion fighting during the event, as well as the availability of resources to **recover** from (rebuild and restore) any damages following the event. The community's efforts to **adapt** have been limited by available resources and have focused on essential upgrades to specific utility components, such as elevating man holes and pump stations in flood and erosion hot spots. Despite the community's concerted and commendable efforts to plan for and adapt to the risks of coastal erosion and flooding, Barrow remains minimally resilient to the occurrence of coastal storm events and has limited capacity and resources to absorb and recover from them.

11.2 Measuring Resilience for this Study

In the discussion of a resilience framework, the USACE highlights the importance of resilience at the local level, contributing to greater community resilience. The way that the USACE can contribute to community resilience is through delivery of resilient projects. In Barrow, a resilient coastal storm project would not only be independently resilient, but would also improve the resilience of existing transportation and utility systems in the community, reduce risks to public health and safety, and reduce risk to cultural and environmental resources in the study area.

To facilitate characterization of community resilience across systems for this study, the Barrow community is described using a triple bottom line framework with economic, social/cultural, and environmental components (or "resilience areas") (USACE 2018 and 2018a). A triple bottom line community resilience evaluation framework allows for a holistic approach to assessing without project conditions and the effects of alternatives for application in a CE/ICA. Note that the framework evaluates how implementation of a project would contribute to community resilience, but it not intended as a means of exhaustively cataloging of all aspects community resilience.

The framework evaluated alternatives in terms of their reduction in the risk of occurrence of adverse effects compared to the without project condition (i.e. each alternative's positive contribution to community resilience). In coordination with the PDT, including the North Slope Borough, consequence categories were identified, followed by identification of a series of output variables which would be representative of the consequence categories and whose quantification would be practicable given the available information from the sponsor and previous study efforts. This set of consequence categories and related output variables were judged by the PDT to be representative of the risks associated with coastal storm flooding and erosion in Barrow, and as such a good representation of the benefits that could be achieved by implementation of a project. Figure 9 highlights the evaluation framework in terms of known risk areas at Barrow.

Table 16 provides a cross-walk between the nine identified adverse consequence categories and the three resilience areas. As shown in the table, consequence categories may have more than one relevant unit of measure and may apply to more than one resilience area. Figure 10 shows key geographic locations related to these consequences on a map.

Figure 9 – Barrow Community Resilience Framework

Table 16 – Resilience Consequence Categories and the Triple Bottom Line

<table>
<tr><th rowspan="2">Consequence Category</th><th rowspan="2">Figure 9 Consequence Map Item</th><th colspan="3">Community Resilience</th></tr>
<tr><th>Economic</th><th>Social / Cultural</th><th>Environmental</th></tr>
<tr><td>1) Flooding of Structures & Contents</td><td>▪ Structures in Barrow and Browerville Neighborhoods</td><td rowspan="5">▪ Direct Damages</td><td>-</td><td>-</td></tr>
<tr><td>2) Erosion Loss of Structures & Contents</td><td>▪ Structures in Barrow Neighborhood</td><td>-</td><td>-</td></tr>
<tr><td>3) Erosion Land Loss</td><td>▪ Land in Barrow</td><td>-</td><td>-</td></tr>
<tr><td>4) Erosion of Bluff (Historic Village Site)</td><td>▪ Utqiagvik Cultural Site in Barrow Neighborhood</td><td>▪ Cultural Resources Lost</td><td>-</td></tr>
<tr><td>5) Flood Damage to South and Middle Salt Lagoons (Sewage System & Old Navy Landfill)</td><td>▪ South Salt Lagoon Sewage Lagoons
▪ Old Navy Landfill
(Both just north of Browerville Neighborhood)</td><td>-</td><td>▪ Landfill Contaminants Released
▪ Sewage Lagoon Breached</td></tr>
<tr><td>6) Flooding of Isatkoak Lagoon (Water Supply and Utilities)</td><td>▪ Spillway and Utilities at Tasigrook Dam
▪ Water Supply Behind Isatkoak Dam
▪ Utilities on Isatkoak Dam</td><td rowspan="3">▪ Direct Damages
▪ Job Opportunities Lost</td><td rowspan="3">▪ Utility / Water Supply Service Lost</td><td>-</td></tr>
<tr><td>7) Flooding of Utilidor (Loss of Service for Critical Utilities)</td><td rowspan="2">▪ Pump Station 4 (PS#4) in Barrow Neighborhood
▪ Pump Station 3 (PS#3) in Browerville Neighborhood</td><td>-</td></tr>
<tr><td>8) Erosion Damage to Utilidor (Loss of Service for Critical Utilities)</td><td>-</td></tr>
<tr><td>9) Flooding/Erosion Damage to Stevenson Street and Beach Berm, Emergency Maintenance and Capital Expenditures</td><td>▪ Throughout study area along or near beach</td><td>▪ Direct Damages</td><td>▪ Days Flood Fighters at Risk</td><td>-</td></tr>
</table>

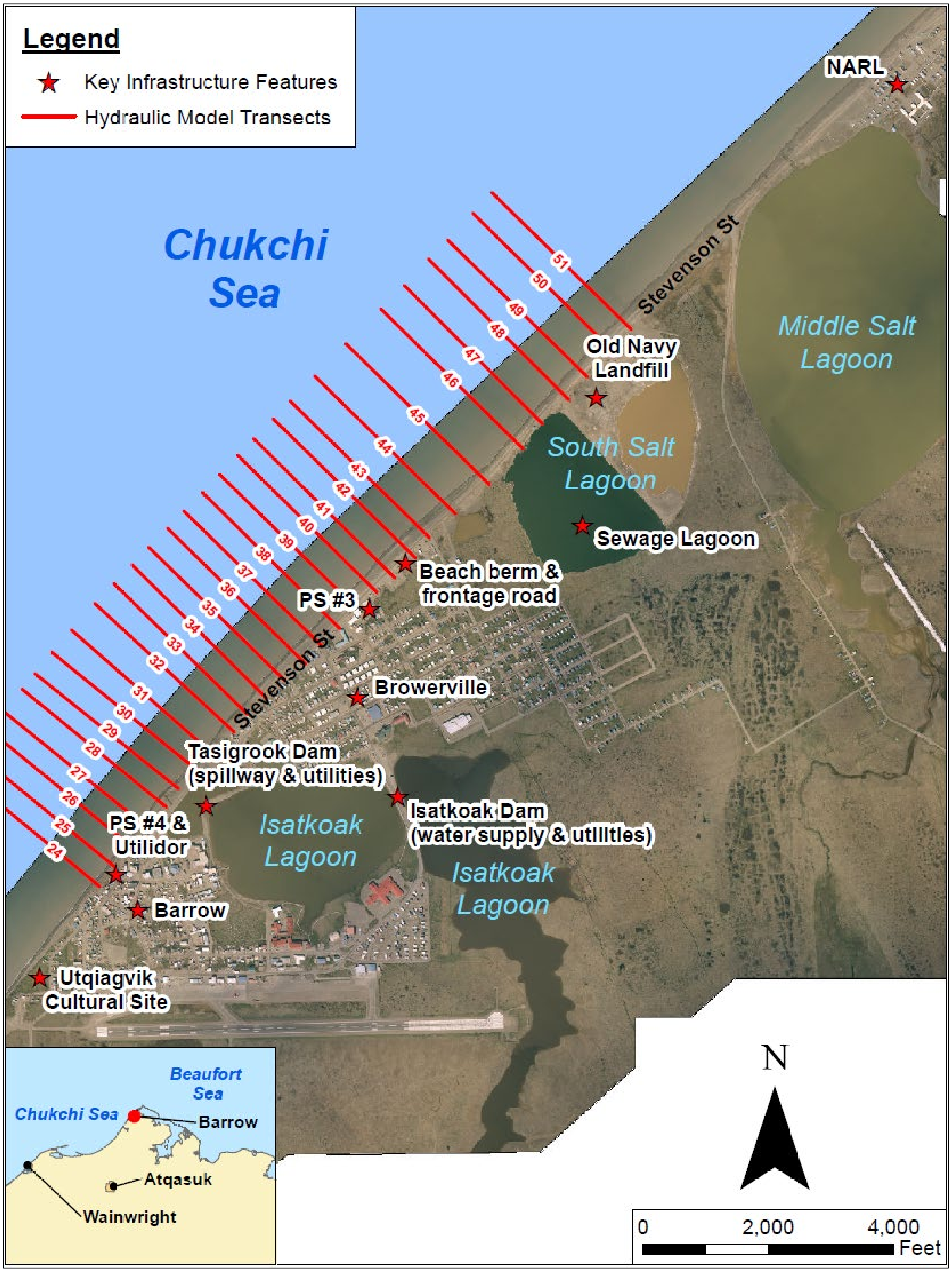

Figure 10 – Key Locations for Consequence Categories

The evaluation framework was applied to develop a quantified measure of community resilience under without project conditions and to quantify and compare the effects of alternatives. This quantified unit of measurement is called a Community Resilience Unit (CRU). In this application, CRUs are based upon a set of output variables which may serve as measurement tools for the types of consequences that were presented in Table 16. Six such variables were identified for this framework. The bullets below describe the variables, and a crosswalk of these variables, how they address the three resilience areas, and the identified consequence categories are shown in Figure 11. Subsequent sections document the process for derivation of the CRUs.

	Community Resilience					
	Economic		Social/Cultural			Environmental
Consequence Category	DDD	FTE	CRA	PDU	PDH	CYF
1) Structures & Contents, Flood	✓					
2) Structures & Contents, Erosion	✓					
3) Land loss, erosion	✓					
4) Bluff (historic village)	✓		✓			
5) Central Lagoons, Erosion (sewage system & landfill)	✓					✓
6) Tasigrook Dam & Lagoon (water supply and utilities)	✓	✓		✓		
7) Utilidor, Flood (critical utilities)	✓	✓		✓		
8) Utilidor, Erosion (critical utilities)	✓	✓		✓		
9) Berm/Emg. Maintenance and Capital Expenditures	✓				✓	

Figure 11 – Variable Cross-walk

Economic Resilience Variables

- *Direct Dollar Damage (DDD)*: This variable accounts for dollar damages and costs as a direct result of flood and/or erosion damage; such as structure and content losses, or storm response costs.
- *Full Time Equivalent Job Impacts (FTE)*: This variable accounts for the number of person days (full time equivalent) job opportunities lost due to estimated downtime of critical utility services due to coastal erosion and/or flooding.

Social/Cultural Resilience Variables

- *Cultural Resource Acres at Risk (CRA)*: This variable accounts for the known area of significant cultural resources associated with the old original Utqiagvik village site in the Barrow Neighborhood. Areas are quantified in terms of the total area at risk of loss to coastal erosion.
- *Person-days without Critical Utilities (PDU)*: This variable accounts for the threat to public health and safety associated with loss of critical life sustaining utility services in the harsh arctic environment of the study area. The variable is based upon the affected population and the expected duration of service interruption due to either breach or damage to the water supply and utility infrastructure at Isatkoak Lagoon, Tasigrook Dam, or the Utilidor.
- *Person-days in High-Risk Flood Fighting Activity (PDH)*: This variable accounts for risk to human health and safety and is quantified in person-days of high-risk emergency maintenance flood fighting activity. During coastal storms the NSB frequently must perform emergency berm repair and shore protection during the storm, necessitating that machinery operators work during dangerous conditions; including operation of heavy equipment in the surf, seaward of the protective berm.

Environmental Resilience Variables

- *Cubic Yards Contaminated Fill (CYF)*: This variable accounts for the damage to the environment surrounding the study area. It is based upon the estimated volume of potentially contaminated materials at risk of spill from flooding or erosion; including both the community sewage lagoons and known contaminated solid waste in the adjacent old Navy Landfill.

After estimating effects (risk reduction) in terms of each variable for each alternative, results can be presented at the triple bottom line level by combining the effectiveness scores across variables for each resilience area. For input into CE/ICA, a single derived variable termed Community Resilience Units (CRU's) was generated by combining effects across the 3 resilience areas (Economic, Social/Cultural, and Environmental) and their constituent output variables. Using estimated CRU's for each alternative, a CE/ICA model was run using the IWR Planning Suite software.

11.3 CE/ICA

Four main steps were conducted for the CE/ICA. This section describes each step and the CE/ICA outputs. The four steps include:

1) Quantify without project adverse effects by consequence category and output variable
2) Quantify each alternative's potential contribution to community resilience by estimating how much each alternative would reduce the adverse effects for each output variable
3) Compute CRU's for each alternative based on the percent reduction in adverse effects (increase in resilience) estimated for each alternative
4) Assemble CE/ICA Input Data
5) Perform CE/ICA in IWR Planning Suite

STEP 1 – Quantify without project adverse effects by consequence category and variable.

The quantification of resilience effects for the future without project condition (No Action Alternative - Alternative 1) are shown in Table 17, followed by a brief description of the derivation of these values. The evaluation of future without project conditions was based upon best available data obtained from the previous 2010 Technical Report and coordination with the PDT and Sponsor to obtain the latest datasets. Note that the PDT considered the inclusion of sea level rise in the forecast of future conditions but found that it would not be significant in the study area. Based upon the PDT's understanding of sea level rise near Barrow, it is not expected to play a significant role, as local sea level rise is mitigated by the effects of postglacial rebound.

DDD outputs are presented in annualized dollars. All other output variable consequence estimates are presented as estimate of effect for the event that induces the subject damages (single event loss). In all cases, monetary estimates are computed in FY19 price level and interest rate (2.875 percent).

Table 17 – WOPC Adverse Effects

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
1) Structures & Contents, Flood	$51,887					
2) Structures & Contents, Erosion	$347,028					
3) Land loss, erosion	$18,166					
4) Bluff (historic village)	$13,820		5			
5) South and Middle Salt Lagoons, Erosion (sewage system & old Navy landfill)	$106,715					2,608,760
6) Isatkoak Lagoon (water supply and utilities)	$184,136	397		258,960		
7) Utilidor, Flood (critical utilities)	$13,898	122		48,914		
8) Utilidor, Erosion (critical utilities)	$168,433	244		97,829		
9) Berm/Emergency Maintenance and Capital Expenditures	$7,449,256				72	
Total	**$8,353,339**	**763**	**5**	**405,703**	**72**	**2,608,760**
Note: DDD outputs are annualized (FY19 price level, FY19 (2.875%) discount rate). Other outputs are single-event values. See text preceding table.						

DDD: For the structures and contents (consequence categories 1 and 2), outputs for the DDD variable were generated by updating the price level and discount rate for the modeling results from the 2010 study. This same approach was taken for land loss from erosion (category 3). As discussed in Section 5, Emergency Maintenance and Capital Expenditures reflect a refined analysis which has been through the USACE model approval process. DDD outputs related to the bluff and historic village (category 4) were based upon a rough estimate of one-time cultural resource recovery/protection costs in the event of major erosion of the bluff. A similar approach was taken for discounting the estimated response costs associated with major impacts to the South Salt and Middle Salt lagoons (category 5). For consequences associated with the water supply lagoon and its dam/associated utility crossing (category 6), information was available to equate initiation of those consequences with an annual exceedance probability based upon the 2010 study. Erosion impacts associated with the utilidor (category 8) were estimated by performing a price level and discount rate update of the 2010 analysis, with adjustment to reflect loss of the facility earlier in the period of analysis, given the passage of time between the previous analysis' base year and the current one. Finally, consequences associated with flooding of the utilidor were also based upon the 2010 study but reduced to 50 percent of the price-updated value given that the NSB has elevated the entrance to Pump Station #4 since the 2010 analysis.

FTE: FTE's are estimated for consequence categories 6, 7, and 8, which equate to those categories dealing with risk of major disruption to utility service in the study area. Based upon previous studies of the utility system and confirmation of basic downtime and population affected assumptions with the NSB, potential FTE outputs were estimated for a major storm or erosion event that resulted in a prolonged period of utility outage which would preclude normal business operations. The ASCG Report estimated the number of establishments affected by such an event, which was factored according to the average employees per establishment in Barrow per the 2012 Economic Census.

CRA: Quantified cultural resource acres are limited to the historic village site atop the bluff at the southwest end of the study area at this stage. The potential acreage was measured in GIS.

PDU: Person-days without critical utilities quantifies human health and safety risk associated with outages of the electrical, gas, water, or sewer systems. Due to the extreme conditions in Barrow, the ability for residents to heat their homes and have power is critical for much of the year. Additionally, Barrow's major power-generation infrastructure is gas-powered, meaning that loss of natural gas service would quickly lead to loss of electrical generation. If unpowered for a significant duration, the community's constant circulation systems, which prevent freezing of water and sewer pipes would be at risk of failure. Any combination of these outages would result in substantial risk to human health and safety. Quantification of this variable is based upon the affected population and the expected duration of service interruption due to either breach or damage to the water supply and utility infrastructure at Isatkoak Lagoon, Tasigrook Dam, or the Utilidor. Affected populations for critical systems and duration of service interruptions were identified in coordination with the NSB and previous utility failure scenario investigations (USACE 2005).

PDH: Person-days of high-risk job activity was identified as a human health and safety risk borne by the NSB under their current flood/storm fighting regime, where equipment operators must work in dangerous conditions, including operating heavy machinery in the surf during storms, to maintain the sacrificial berms, which protect critical infrastructure. The person-day estimates used in the analysis were developed in coordination with the NSB and informed by their knowledge from the recent 2017 storm.

CYF: Cubic yards of fill provided a straightforward way to quantify the risk associated with release of contaminated materials into the ecosystem from the landfill and sewage lagoon. At this stage, the variable was estimated based upon simple GIS calculations of the surface area of the South Salt and Middle Salt lagoons and an assumed 1 yard of depth. Future study phases may refine this calculation.

STEP 2 – *Quantify each alternative's potential contribution to community resilience by estimating how much each alternative would reduce the adverse effects for each output variable.*

The effects for each action alternative were quantified by estimating the percent reduction in without project adverse effects that would be accomplished by each action alternative.

For erosion risk; The PDT concluded that only Alternative 5A did not completely address erosion risk because it excludes any structure in front of the bluff at the southwest end of the study area.

For flood risk, the PDT incorporated annual exceedance information from the 2010 study. As introduced in Section 5, the PDT chose to perform the CE/ICA based upon existing engineering inputs to assess the potential for positive net benefits. For each consequence category, the PDT identified a representative transect, stage-frequency curve, and damage initiation elevation from the 2010 Hydraulics Appendix. This data was the best available information to support the assessment and was judged by the PDT to be reasonably representative of current conditions to be used in the analysis. These curves were used to estimate the without project level of risk reduction (annual exceedance probability) at each relevant transect by fitting a natural log function to each transect based on the available data. Then, the design bank heights for each alternative were plotted on the curves to estimate the reduction in annual exceedance probability that would be provided at each transect. The PDT found that use of these best-fit curves allowed estimation of AEP for elevations which fell outside the range presented in the existing data, which was necessary given the design elevations for the alternatives. Based upon review of the calculations, use of these fit-function yielded only marginal variation as compared to linear interpolation from the source data since both the without project and with project elevations were affected, and was judged to be a suitable approach for comparing the relative change in AEP between the alternatives. Note that this approach is not intended as a substitute for modeling expected annual damage but was judged to be suitable for identifying relative differences across alternatives and applicable for the CE/ICA.

Note that the NARL reach was not included in the H&H analysis in the 2010 Technical Report. As such, the PDT identified Transect 51 as the best available proxy to represent flooding conditions at the NARL reach. Transect 51 is the closest to NARL and has the most similar shoreline conditions.

This approach allowed the PDT to quantify the reduction in the probability of coastal storm damage initiation for each consequence category and alternative. Figure 12 illustrates this approach at Pump Station 4 (Transect 25). Given a current elevation of 12.9 feet (the recently elevated height of the entrance), the pump station has a 2.6 percent probability of being exceeded every year. Under Alternative 2, which would place a structure to 14.5 feet, the probability of damages being initiated in each year drops to 1.1 percent, an approximate 58 percent reduction in annual exceedance probability. This reduction in AEP may be interpreted as an increase in the magnitude of event that would be required to initiate damages at this location, in this case corresponding to an increase in return period event that would be expected to overtop the bank from the 38-year to the 91-year event based on the stage-frequency curve shown in **Figure 12**. Provided at the end of this subsection, Figure 14 through Figure 19 provide maps showing the stage-frequency curves for the transects selected to represent each coastal flooding consequence category.

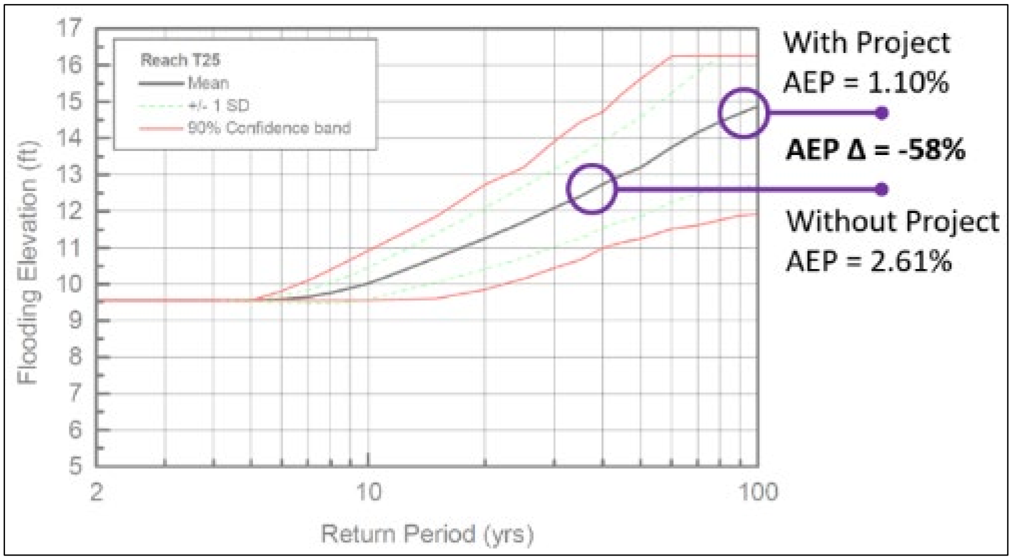

Figure 12 – Estimating Reduction in Flooding Effects

Continuing with the example of Alternative 2, this tabulation is repeated for all consequence categories and variables. Table 19 illustrates the resultant estimates of reduction in adverse effects by output variable for Alternative 2. As shown in the table, the 58 percent reduction is carried through in the Utilidor-Flood consequence category.

The next step is to compute a weighted average DDD output across all the variables. Weighting is necessary to include consideration of the relative magnitude risk exposure associated with each consequence category in the overall weighted DDD output. For example, the value of flood damages to the utilidor in the DDD variable are small compared to the loss from erosion of structures and contents. As such, while flood losses to the utilidor are only reduced by 58 percent, it would not be fair to perform a simple average of this value and the 100 percent reduction of erosion losses, because the actual damage potential between these two consequence categories is very different. Therefore, a weighted average was selected as a more appropriate approach.

Thus, to generate the weighted total for each variable, the WOPC output data from Table 17 is used as weights. Table 18 illustrates this process using the Alternative 2 DDD variable as an example. This same calculation would then be repeated for each variable using the corresponding WOPC output column from Table 17, and then repeated again for each alternative.

Table 20 to Table 26 present the estimates of reduction in adverse effects by output variable for remaining alternatives. Table 27 presents the summary of resultant weighted scores by alternative for each variable.

Table 18 – Example Weighting Calculation

Consequence Category	DDD, WOPC Effects (Table 17)	x	DDD ΔAEP (Table 19)	=	Weighted Contribution
Structures & Contents - Flood	$51,887	x	-86%	=	-$44,750
Structures & Contents - Erosion	$347,028	x	-100%	=	-$347,028
Land loss from erosion	$18,166	x	-100%	=	-$18,166
Bluff (historic village)	$13,820	x	-100%	=	-$13,820
Mid. & S. Salt Lagoons	$106,715	x	-99%	=	-$105,933
Dam (water supply) - Flood	$184,136	x	-97%	=	-$179,465
Utilidor - Flood	$13,898	x	**-58%**	=	-$8,054
Utilidor - Erosion	$168,433	x	-100%	=	-$168,433
Berm/Emg. Maint. & Cap. Expend.	$7,449,256	x	-100%	=	-$7,449,256
TOTAL	**$8,353,339**				**-$8,334,906**
Weighted Average = Sum of Weighted Contribution ÷ Sum of WOPC Effects = -$8,334,906 ÷ $8,353,339 = **99.78%**					

Table 19 – Resilience Outputs by Variable for Alt 2

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-86.25%					
Structures & Contents - Erosion	-100.00%					
Land loss from erosion	-100.00%					
Bluff (historic village)	-100.00%		-100.00%			
Mid. & S. Salt Lagoons	-99.27%					-99.27%
Dam (water supply) - Flood	-97.46%	-97.46%		-97.46%		
Utilidor - Flood	-57.95%	-57.95%		-57.95%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-100.00%				-100.00%	
WEIGHTED TOTAL	**-99.78%**	**-91.96%**	**-100.00%**	**-93.31%**	**-100.00%**	**-99.27%**

Table 20 – Resilience Outputs by Variable for Alt 5A

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-26.69%					
Structures & Contents - Erosion	-50.00%					
Land loss from erosion	-50.00%					
Bluff (historic village)	0.00%		0.00%			
Mid. & S. Salt Lagoons	0.00%					0.00%
Dam (water supply) - Flood	-99.42%	-99.42%		-99.42%		
Utilidor - Flood	-57.95%	-57.95%		-57.95%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-18.30%				-18.30%	
WEIGHTED TOTAL	**-22.98%**	**-92.97%**	**0.00%**	**-94.56%**	**-18.30%**	**0.00%**

Table 21 – Resilience Outputs by Variable for Alt 5B

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-52.98%					
Structures & Contents - Erosion	-100.00%					
Land loss from erosion	-100.00%					
Bluff (historic village)	-100.00%		-100.00%			
Mid. & S. Salt Lagoons	0.00%					0.00%
Dam (water supply) - Flood	-99.42%	-99.42%		-99.42%		
Utilidor - Flood	-57.95%	-57.95%		-57.95%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-45.40%				-45.40%	
WEIGHTED TOTAL	**-49.66%**	**-92.97%**	**-100.00%**	**-94.56%**	**-45.40%**	**0.00%**

Table 22 – Resilience Outputs by Variable for Alt 5C

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-86.25%					
Structures & Contents - Erosion	-100.00%					
Land loss from erosion	-100.00%					
Bluff (historic village)	-100.00%		-100.00%			
Mid. & S. Salt Lagoons	0.00%					0.00%
Dam (water supply) - Flood	-99.42%	-99.42%		-99.42%		
Utilidor - Flood	-57.95%	-57.95%		-57.95%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-67.10%				-67.10%	
WEIGHTED TOTAL	**-69.22%**	**-92.97%**	**-100.00%**	**-94.56%**	**-67.10%**	**0.00%**

Table 23 – Resilience Outputs by Variable for Alt 5D

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-86.25%					
Structures & Contents - Erosion	-100.00%					
Land loss from erosion	-100.00%					
Bluff (historic village)	-100.00%		-100.00%			
Mid. & S. Salt Lagoons	-92.15%					-92.15%
Dam (water supply) - Flood	-99.42%	-99.42%		-99.42%		
Utilidor - Flood	-57.95%	-57.95%		-57.95%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-100.00%				-100.00%	
WEIGHTED TOTAL	**-99.73%**	**-92.97%**	**-100.00%**	**-94.56%**	**-100.00%**	**-92.15%**

Table 24 – Resilience Outputs by Variable for Alt 6A

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-86.25%					
Structures & Contents - Erosion	-100.00%					
Land loss from erosion	-100.00%					
Bluff (historic village)	-100.00%		-100.00%			
Mid. & S. Salt Lagoons	-99.27%					-99.27%
Dam (water supply) - Flood	-99.42%	-99.42%		-99.42%		
Utilidor - Flood	-57.95%	-57.95%		-57.95%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-100.00%				-100.00%	
WEIGHTED TOTAL	**-99.82%**	**-92.97%**	**-100.00%**	**-94.56%**	**-100.00%**	**-99.27%**

Table 25 – Resilience Outputs by Variable for Alt 6B

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-86.25%					
Structures & Contents - Erosion	-100.00%					
Land loss from erosion	-100.00%					
Bluff (historic village)	-100.00%		-100.00%			
Mid. & S. Salt Lagoons	-92.15%					-92.15%
Dam (water supply) - Flood	-99.42%	-99.42%		-99.42%		
Utilidor - Flood	-57.95%	-57.95%		-57.95%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-100.00%				-100.00%	
WEIGHTED TOTAL	**-99.73%**	**-92.97%**	**-100.00%**	**-94.56%**	**-100.00%**	**-92.15%**

Table 26 – Resilience Outputs by Variable for Alt 6C

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-83.18%					
Structures & Contents - Erosion	-100.00%					
Land loss from erosion	-100.00%					
Bluff (historic village)	-100.00%		-100.00%			
Mid. & S. Salt Lagoons	-92.15%					-92.15%
Dam (water supply) - Flood	-98.78%	-98.78%		-98.78%		
Utilidor - Flood	-56.20%	-56.20%		-56.20%		
Utilidor - Erosion	-100.00%	-100.00%		-100.00%		
Berm/Emg. Maint. & Cap. Ex.	-100.00%				-100.00%	
WEIGHTED TOTAL	**-99.70%**	**-92.36%**	**-100.00%**	**-93.94%**	**-100.00%**	**-92.15%**

Table 27 – Resilience Outputs by Alternative

	DDD	FTE	CRA	PDU	PDH	CYF
Alt	**% Δ**	**% Δ**	**% Δ**	**% Δ**	**% Δ**	**% Δ**
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	99.78%	91.96%	100.00%	93.31%	100.00%	99.27%
5a	22.98%	92.97%	0.00%	94.56%	18.30%	0.00%
5b	49.66%	92.97%	100.00%	94.56%	45.40%	0.00%
5c	69.22%	92.97%	100.00%	94.56%	67.10%	0.00%
5d	99.73%	92.97%	100.00%	94.56%	100.00%	92.15%
6a	99.82%	92.97%	100.00%	94.56%	100.00%	99.27%
6b	99.73%	92.97%	100.00%	94.56%	100.00%	92.15%
6c	99.70%	92.36%	100.00%	93.94%	100.00%	92.15%
All values are percent reduction in adverse effect expected under without project conditions.						

The outputs shown in Table 27 are the total weighted outputs for each of the six variables. These outputs may also be summarized using the triple bottom line approach of economic, social/cultural, and environmental resilience areas. In deriving the total score for each area, all variables were assigned equal weight, and equal the average of the percent reductions in adverse effects shown in Table 27 for the variables applicable to the resilience area. Section 11.7 describes sensitivity analyses that were performed to consider weighting among the three components, which determined that equal weighting was an appropriate scheme for this study. The economic resilience area reflects the DDD and FTE variables. The social/cultural resilience area includes the CRA, PDU, and PDH variables. The environmental resilience area includes only the CYF variable. Table 28 shows the resulting estimate of resilience output by alternative for each resilience area. Figure 13 demonstrates the tradeoffs across the resilience areas and across the alternatives.

As discussed in Section 11.7, equal weighting was determined to be the most appropriate approach by the PDT. Per discussion with the PDT and Sponsor, reduction of risk across the social, economic, and environmental components are equally important. Thus, while each component of the triple bottom line may be composed of multiple variables, the intent was to maintain equal weighting across the three components. In other words, variables are equally weighted within their parent component, and components are equally weighted amongst each other.

Table 28 – Resilience Outputs for the Triple Bottom Line

	Community Resilience Scores		
Alt	**Economic**	**Social/Cultural**	**Environmental**
1	0.00%	0.00%	0.00%
2	95.87%	97.77%	99.27%
5a	57.97%	37.62%	0.00%
5b	71.32%	79.99%	0.00%
5c	81.09%	87.22%	0.00%
5d	96.35%	98.19%	92.15%
6a	96.40%	98.19%	99.27%
6b	96.35%	98.19%	92.15%
6c	96.03%	97.98%	92.15%
All values are percent reduction in adverse effect expected under without project conditions.			

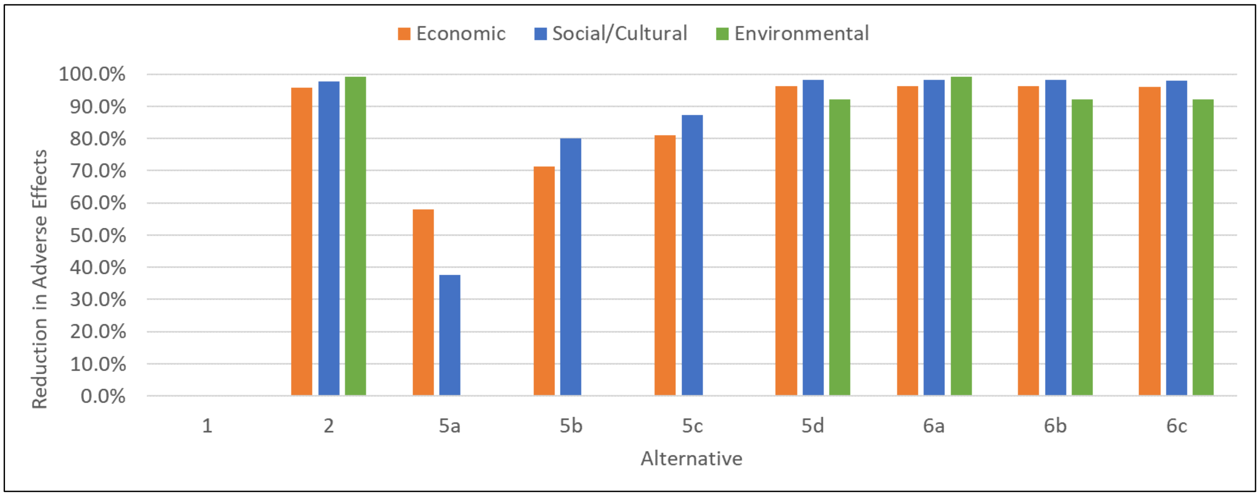

Figure 13 – Triple Bottom Line Alternative Performance

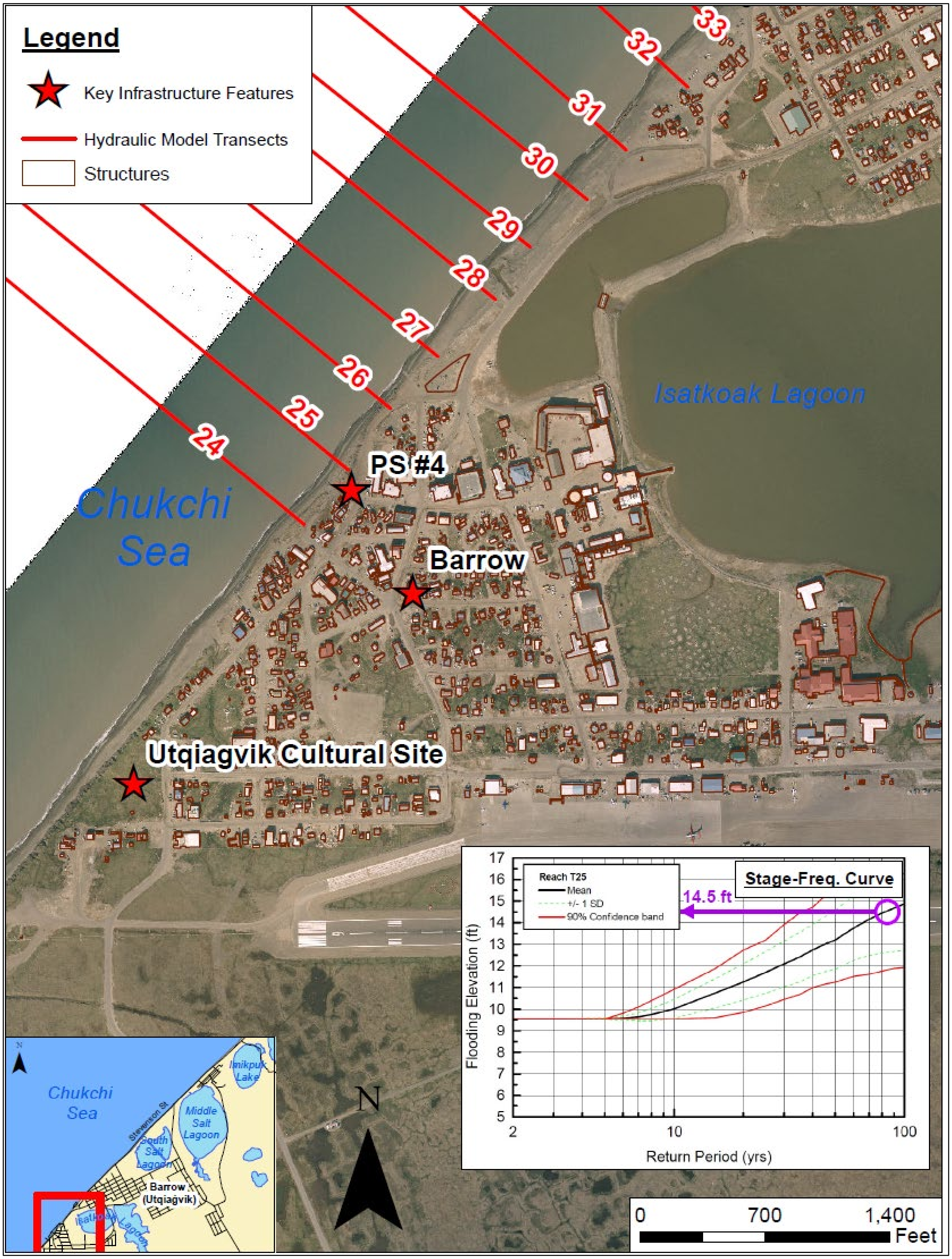

Figure 14 – Barrow Flood Analysis

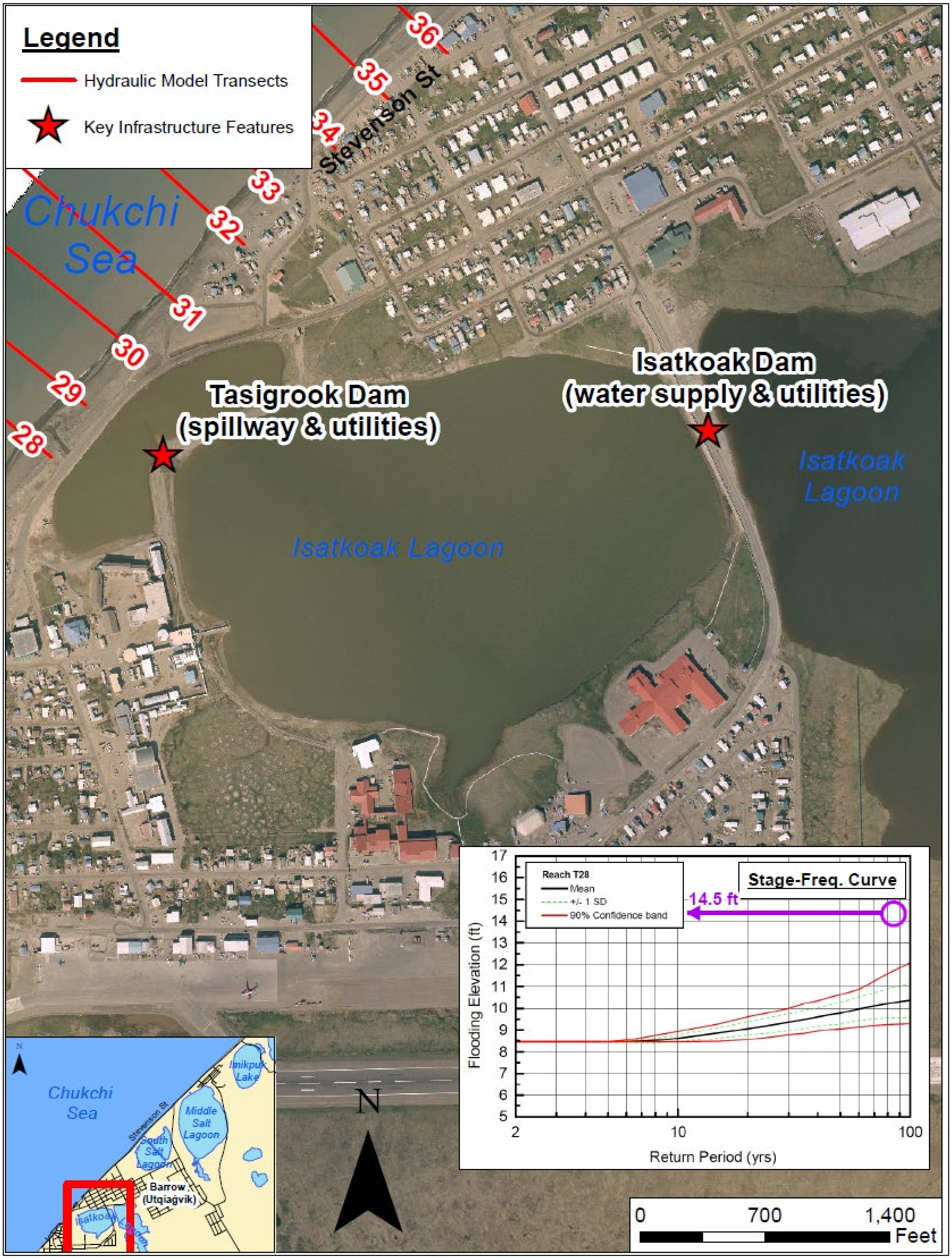

Figure 15 – Lagoon Flood Analysis

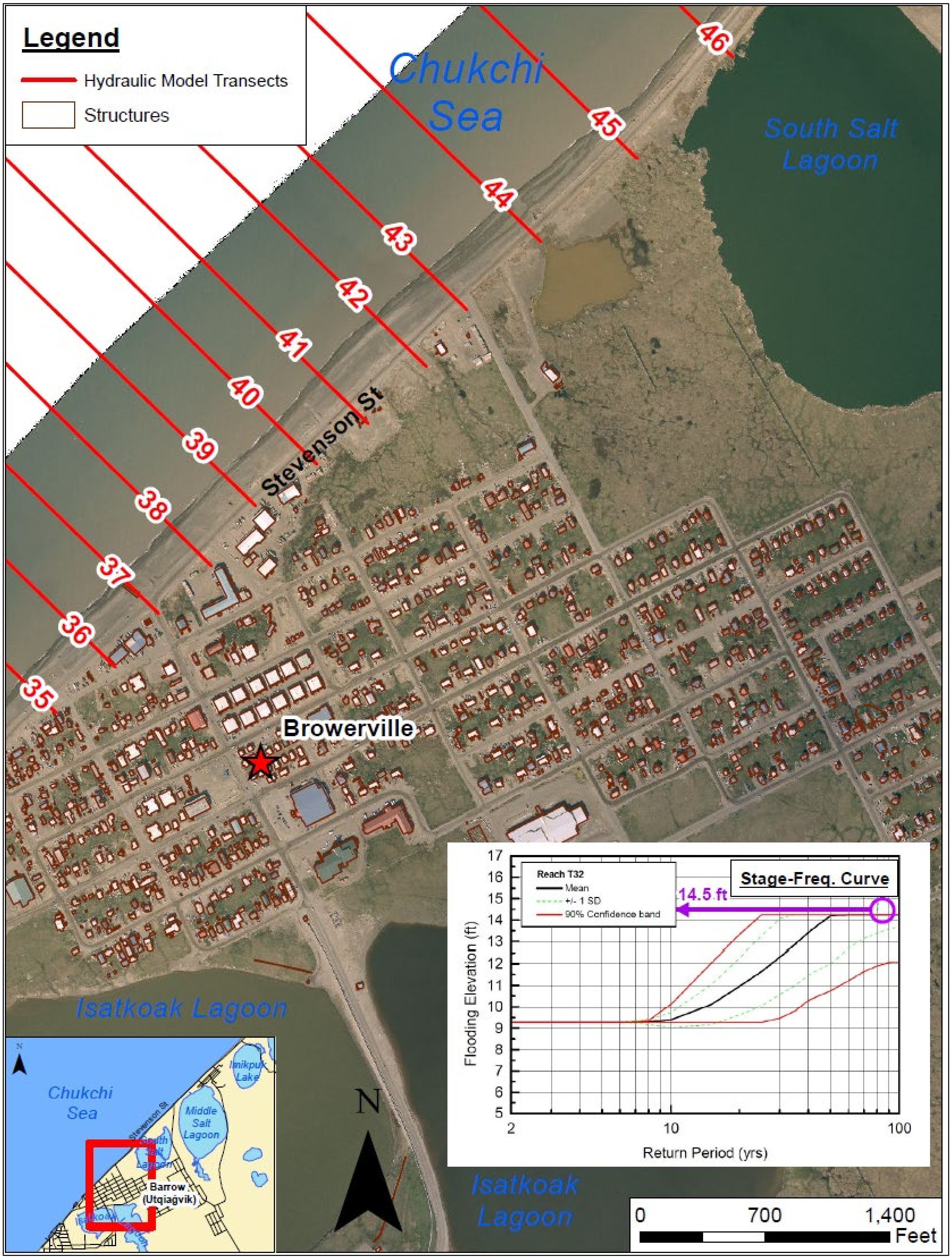

Figure 16 – Browerville Flood Analysis

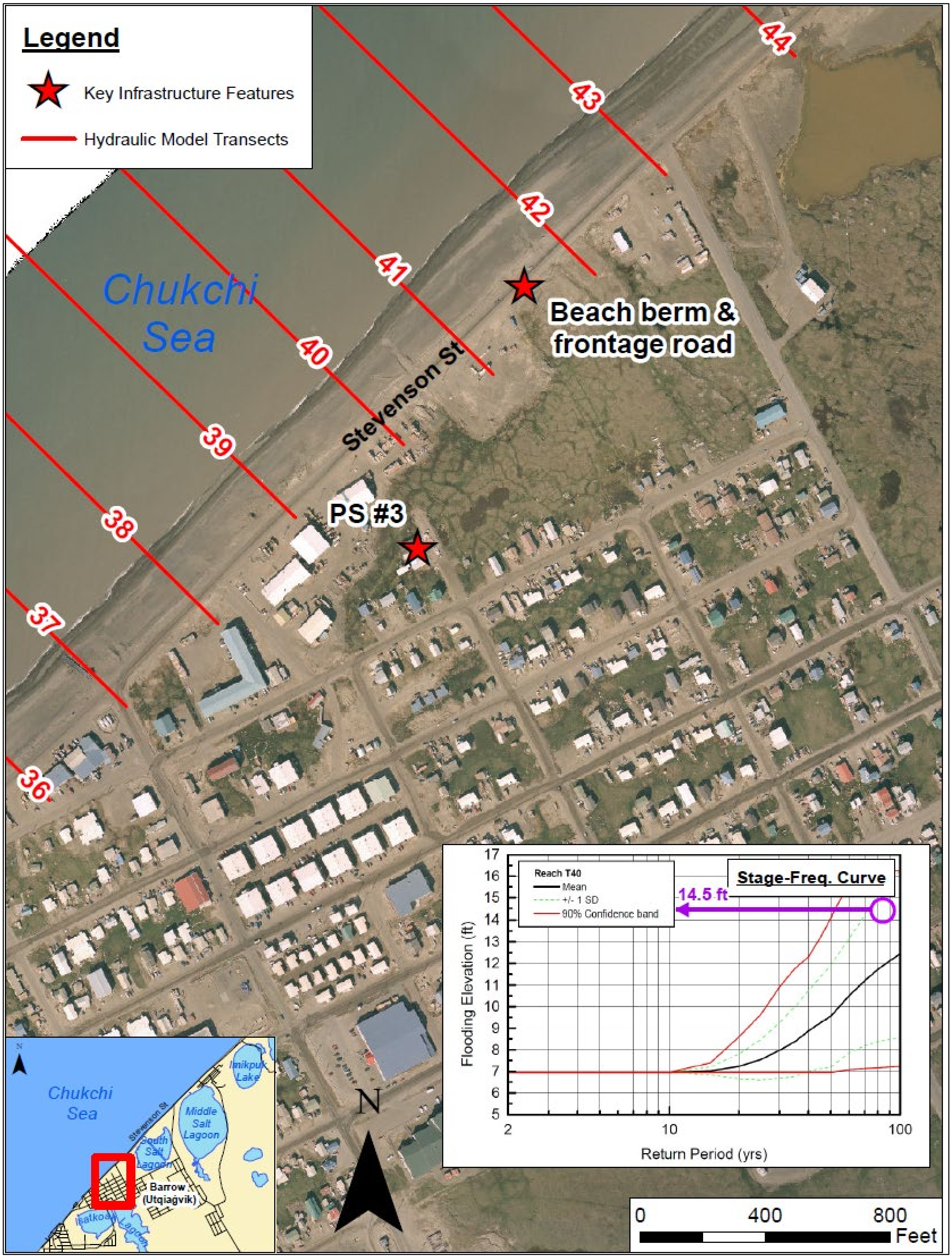

Figure 17 – PS #3 Flood Analysis

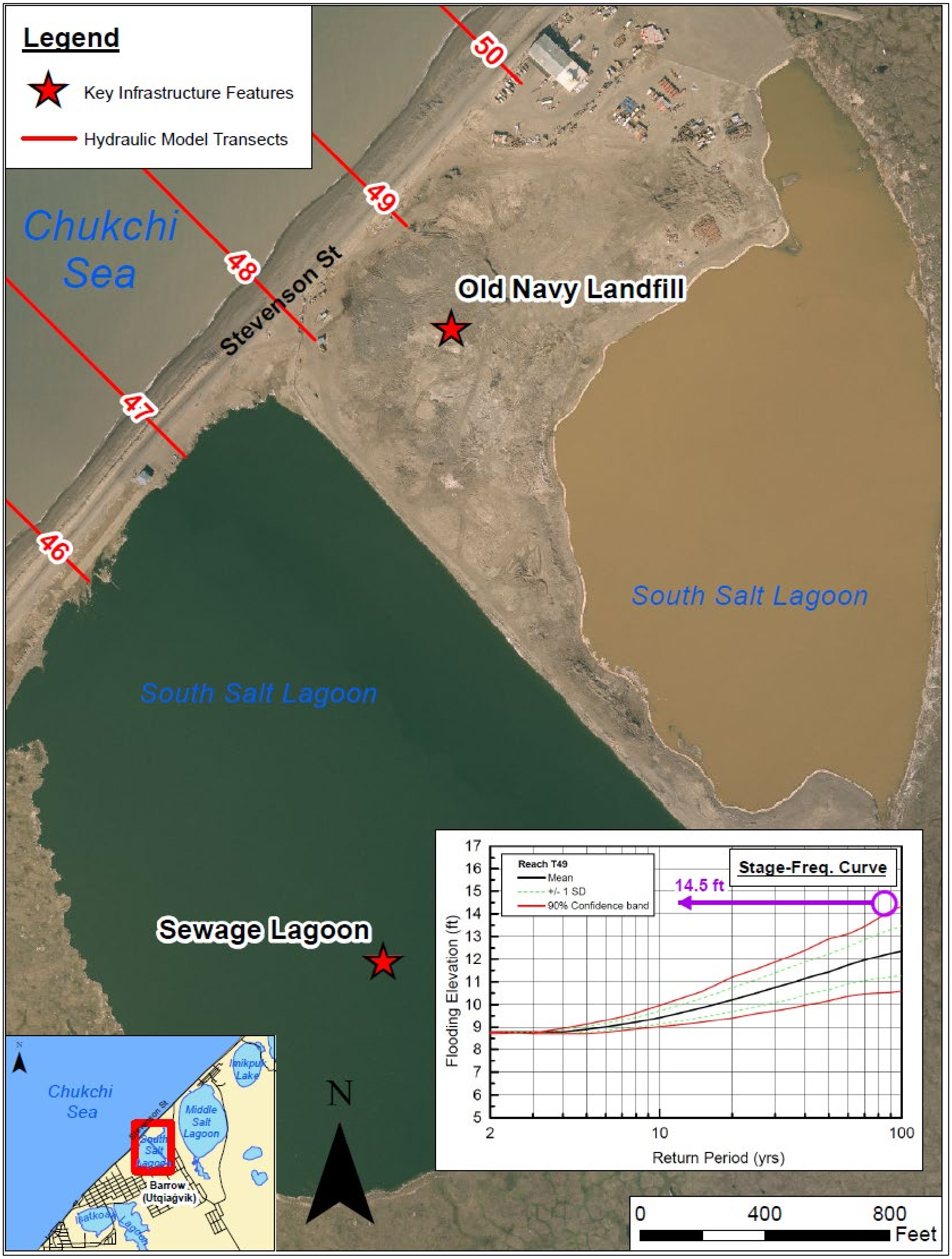

Figure 18 – South & Middle Salt Flood Analysis

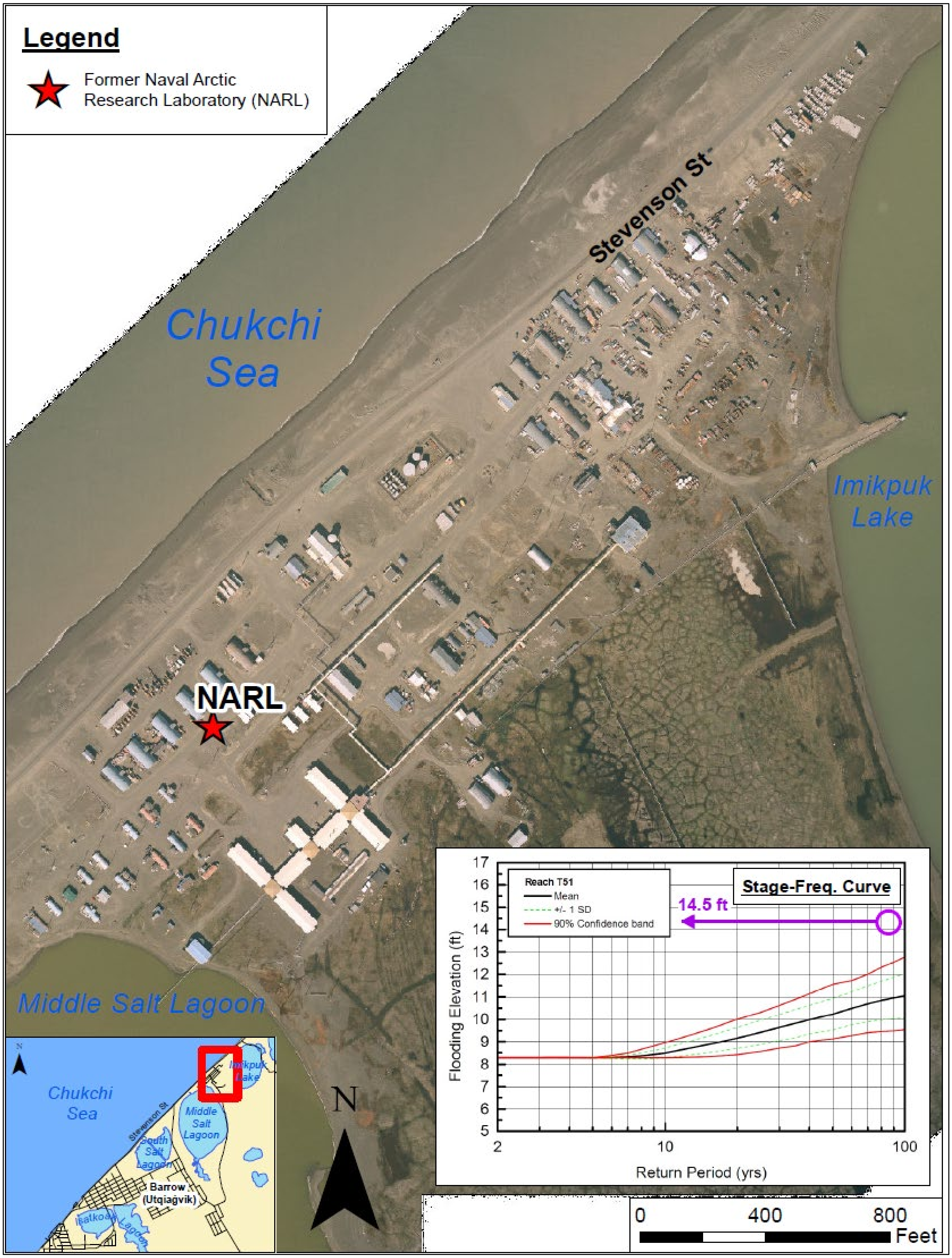

Figure 19 – NARL Flood Analysis

***STEP 3** – Compute CRU's for each alternative based on the percent reduction in adverse effects (increase in resilience) estimated for each alternative*

After equally weighting each of the three resilience areas, Community Resilience Units (CRU's) for each alternative were calculated by summing the percent reductions (in decimal form) across the three resilience areas (see Section 11.7 for sensitivity analysis of weighting). To improve readability, a scale factor of 1000 is used, which results in total CRU's having a maximum value of 3000, which would equate to an alternative that reduced 100 percent of risk in all three resilience areas [(1+1+1)*1000]. Because the percent reductions used in previous steps were relative to the No Action, the estimated total CRU's are inherently net of the No Action Alternative. The total CRU's may also be averaged over the period of analysis to show average annual CRU's. Table 29 shows the estimated total CRU's and average annual CRU's for each alternative.

Table 29 – CRU's by Alternative

Alt	CRU's	Average Annual CRU's
1	0	0.00
2	2929	58.58
5a	956	19.12
5b	1513	30.26
5c	1683	33.66
5d	2867	57.34
6a	2939	58.77
6b	2867	57.34
6c	2862	57.23

***STEP 4** – Assemble CE/ICA Input Data*

Table 30 presents the input data to the CE/ICA. Costs for each alternative may be viewed in detail in the Cost Appendix. All costs are presented in FY2019 price level and use the FY19 discount rate of 2.875 percent.

Table 30 – CE/ICA Input Data

Alt	Annualized Cost ($)	Average Annual CRU's
1	$0	0.00
2	$13,042,000	58.58
5a	$5,053,000	19.12
5b	$9,122,000	30.26
5c	$11,970,000	33.66
5d	$17,427,000	57.34
6a	$20,002,000	58.77
6b	$27,335,000	57.34
6c	$35,848,000	57.23

***STEP 5** – Perform CE/ICA in IWR Planning Suite*

The CE/ICA was performed using IWR Planning Suite for consistency with standard practices. Annualized cost and average annual CRU's (Table 30) were entered for each alternative and the CE/ICA was run. Based upon current costs and outputs, Alternatives 1, 2, and 6A were identified as Best Buy plans, Alternatives 5A, 5B, and 5C were identified as cost-effective plans, and Alternatives 5D, 6B, and 6C were not cost effective.

Figure 20 presents a scatter plot of all the alternatives, differentiated. Table 31 presents the incremental cost calculations for the best buy plans 1, 2, and 6A. Finally, Figure 21 presents the incremental cost box plot.

Section 116 implementation guidance requires a tradeoff analysis across the four plan evaluation accounts of NED, RED, OSE, and EQ. The alternatives in this study were formulated to address all the objectives that address reduction of adverse impacts across all accounts and therefore do not have give-and-take tradeoffs across alternatives. However, the alternatives do offer varying levels of reduction of adverse impacts across alternatives as described in this appendix. Splitting the economic resilience category into its two component variables (Direct Dollar Damages (DDD) to reflect NED effects; and Full Time Equivalent Employment and Income Effects (FTE) to reflect RED effects) allows comparison of effects across variables that reflect all four accounts. Figure 22 presents the same data as shown in Figure 13 organized in this manner to show the tradeoffs across alternatives in terms of reduction in adverse effects across each account.

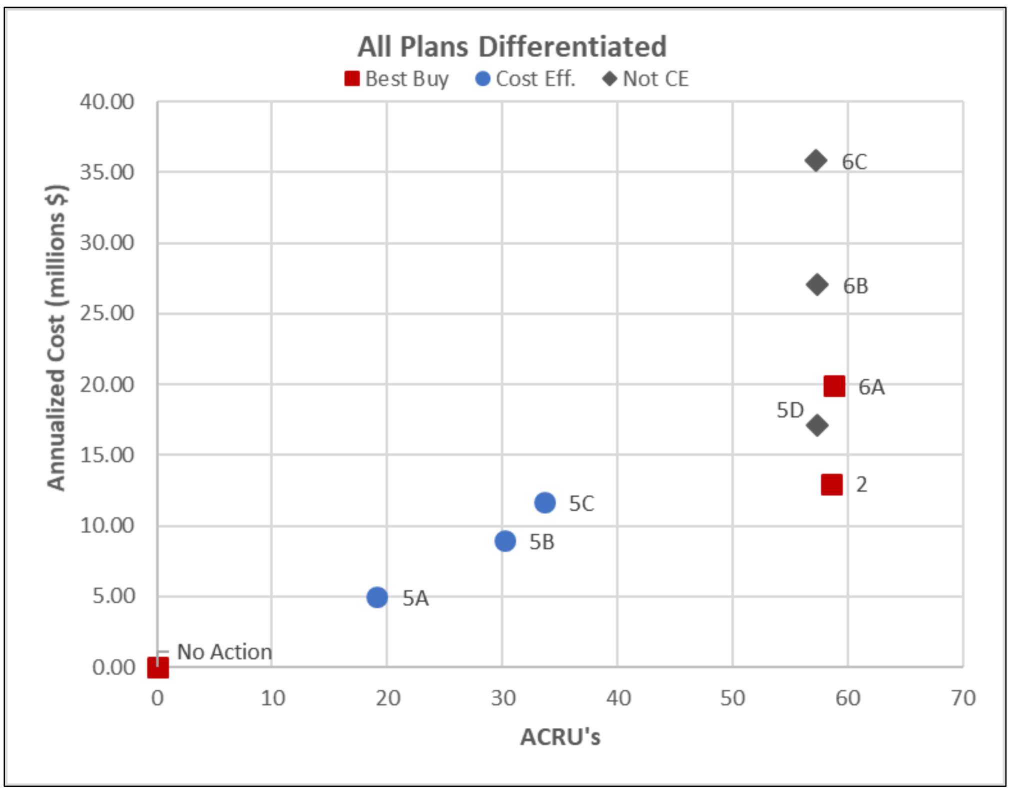

Figure 20 – Initial Alternatives, All Plans Differentiated

Table 31 – Initial Alternatives, Incremental Cost Summary

Best Buy #	Alternative	Average Annual Cost ($)	Annual CRU's	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
1	**1**	$0	0.00	$0	0.00	$0
2	**2**	$13,042,000	58.58	$13,042,000	58.58	$222,630
3	**6a**	$20,002,000	58.77	$6,960,000	0.19	$36,823,614

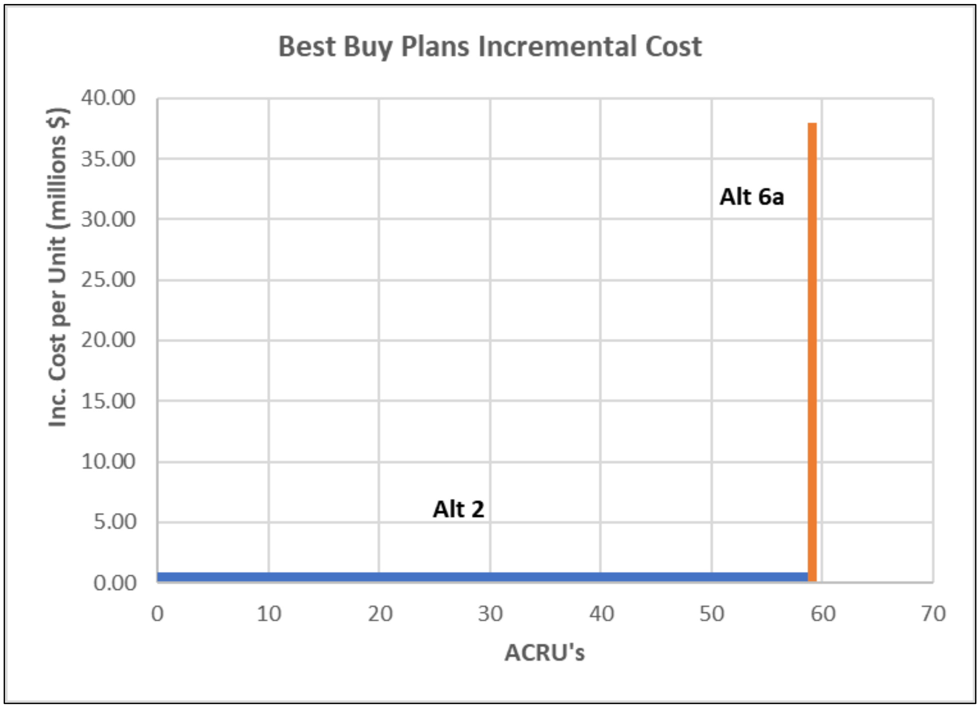

Figure 21 – Initial Alternatives, Incremental Cost Box Chart

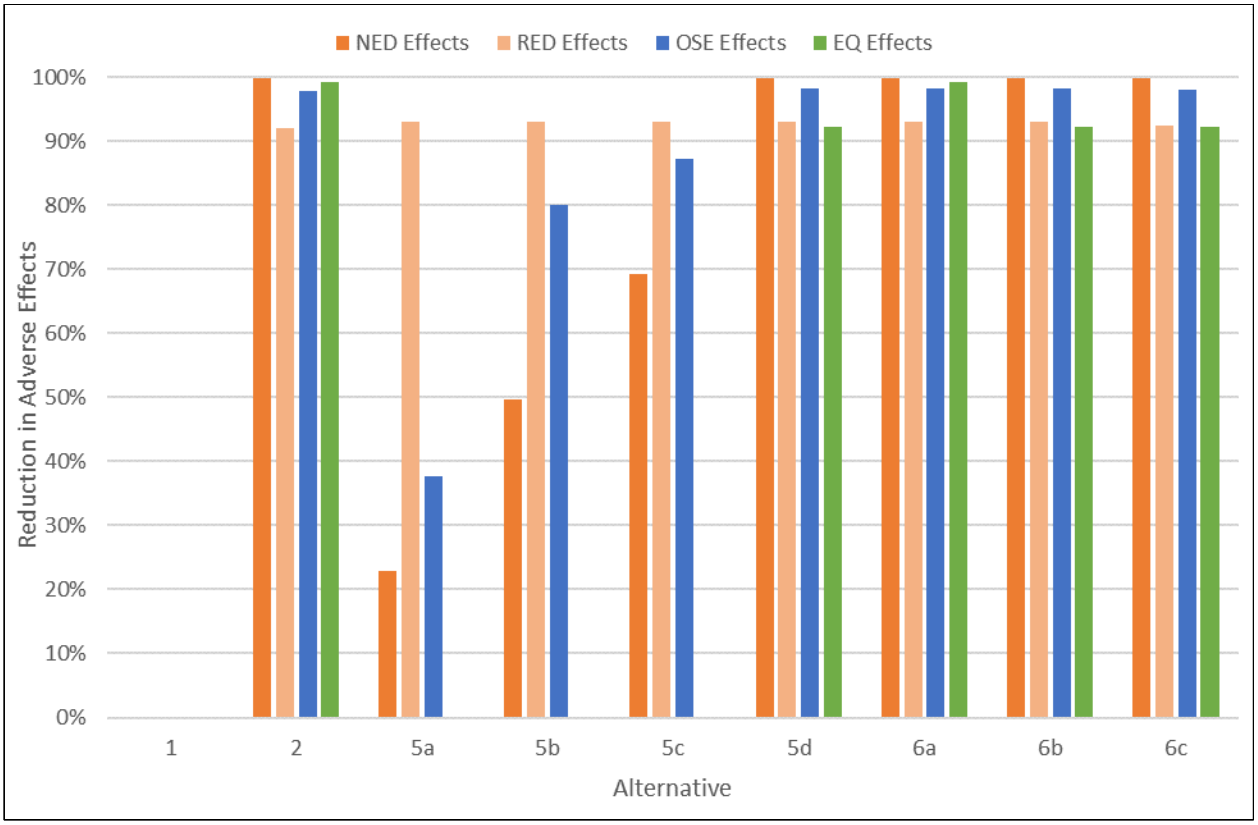

Figure 22 – Initial Alternatives, Tradeoffs of Effects by Plan Evaluation Account

11.4 CE/ICA Outcomes from Initial Iteration

Following performance of the initial CE/ICA detailed in Section 11.3, the PDT identified Alternative 2 as having potential for selection, but additional data was desired to better inform the selection process. Refinements to the plan formulation process based upon findings and conclusion from the CE/ICA included:

- Need for screening out ineffective measures from further analysis
- Need for identifying minimum included reach requirements to meet planning objectives
- Need for sensitivity analysis of CRU component weightings and design elevations

11.5 Screening of Ineffective Measures

The results of the CE/ICA helped to demonstrate that two measures considered in the initial array of alternatives were not effective and it was elected to screen these measures from further analyses. The two measures were Beach Nourishment and Filling of Tasigrook Lagoon.

- **Beach Nourishment** was a poorly performing treatment option across all the alternatives due to the high cost of obtaining and delivering appropriate material to Barrow.
- **Filling of Tasigrook Lagoon** was developed as a means of provided a secondary level of risk reduction for the water supply, but further consideration by the PDT engineering element found this measure to be unnecessary for project performance.

Removal of these two treatments left only the revetment option. In reaches 1 to 3, only one type of revetment was possible. In reaches 4 to 6, both a revetted berm seaward of the existing roadway, and the raising and revetting of the existing roadway were options.

11.6 Minimum Reaches to Address Planning Objectives

The PDT identified that for a selected plan to meet the minimum requirements of the planning objectives, the plan would need to include risk reduction for Reach 2 (Barrow) and Reach 3 (Lagoon).

11.7 Sensitivity Analyses

The PDT desired information regarding sensitivity of the CE/ICA outcomes to weighting of the three main CRU components (economic, social, and environmental), as well as sensitivity of the results to variations in the design elevation of the proposed berm and revetted roadway.

Sensitivity analyses were conducted to evaluate:

- Consideration of the weighting applied to the three components of the triple bottom line CRU evaluation framework
- Effect of the environmental component weighting
- Evaluation of the effect of different design heights

11.7.1 Weighting among the Three Components of the Triple Bottom Line

To consider the weights among the three components, alternative weighting scenarios were developed by the PDT using the Analytical Hierarchy Process (AHP) module within the IWR Planning Suite software. The AHP module provides a template for performing pairwise comparison of the input variables and generating the implied weighting scheme associated with the comparison. The computed weights were then used to weight in the CRU contribution from each component of the triple bottom line and run a new CE/ICA model. Because the environmental component is associated with only Reach 5, it was not necessary to include a scenario with environmental ranked the highest, as this would simply push Reach 5 further to the top. As such, two AHP weighting schemes were developed, one that prioritized the Economic component, and one that prioritized the Social/Cultural component. Figure 23 and Figure 24 provide the pairwise comparison and resultant weights for the components. In the first scenario, the economic component is weighted at 64 percent, the social/cultural component at 26 percent, and the environmental component at 10 percent. In the second scenario, the economic component is weighted at 28 percent, the social/cultural component at 65 percent, and the environmental component at 7 percent. Additionally, these two AHP-based scenarios were bookended by running two more scenario, one that only considered the economic component, and one that only considered the social/cultural component.

	ECON	SOCU	ENVR
ECON	N/A	(3) Slightly More Important	(5) Strongly More Important
ENVR	(-5) Strongly Less Important	(-3) Slightly Less Important	N/A
SOCU	(-3) Slightly Less Important	N/A	(3) Slightly More Important
Weight	63.699	25.828	10.473

Figure 23 – By Reach, Weighting Sensitivity Scenario 1

	ECON	SOCU	ENVR
ECON	N/A	(-3) Slightly Less Important	(5) Strongly More Important
SOCU	(3) Slightly More Important	N/A	(7) Demonstrably More Importa
ENVR	(-5) Strongly Less Important	(-7) Demonstrably Less Importar	N/A
Weight	27.895	64.912	7.193

Figure 24 – By Reach, Weighting Sensitivity Scenario 2

For each of these scenarios, the CRU calculations were revised, and a new CE/ICA run was performed. Table 32 summarizes the results of these sensitivity runs by presenting the ranking of the reaches, where a rank of "1st" indicates that the reach was the first reach to be included in the derived best buy plans (lowest incremental cost), and "2nd" indicates that the reach was the next to be included in the derived best buy plans (next lowest incremental cost). As shown in the table, a key takeaway from the analysis was that the economic and social/cultural components both point to a similar ranking of the reaches in terms of the order in which they appear in the best buy plans (see scenarios 2 and 4), and that the environmental component's weight drives the ranking of Reach 5 (see scenarios 1, 3, and 4). The effect of the environmental component is investigated further in the next section. Figures 25 through 29 present the best buy incremental cost box plots for scenarios 1 through 5 from the Table 32.

Table 32 – Component Weighting Sensitivity Results Summary

Reach	**Scenario and Best Buy Inclusion Rank** ***(Economic % / Social/Cultural % / Environmental %)***				
	1 Equal	**2 100 / 0 / 0**	**3 64 / 26 / 10**	**4 28 / 65 / 7**	**5 0 / 100 / 0**
R1 – Bluff	4th	3rd	3rd	3rd	3rd
R2 – Barrow	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd
R3 – Lagoon	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd
R4 – Brower.	5th	4th	4th	4th	4th
R5 – S&M Salt.	3rd	6th	5th	5th	6th
R6 – NARL	6th	5th	6th	6th	5th

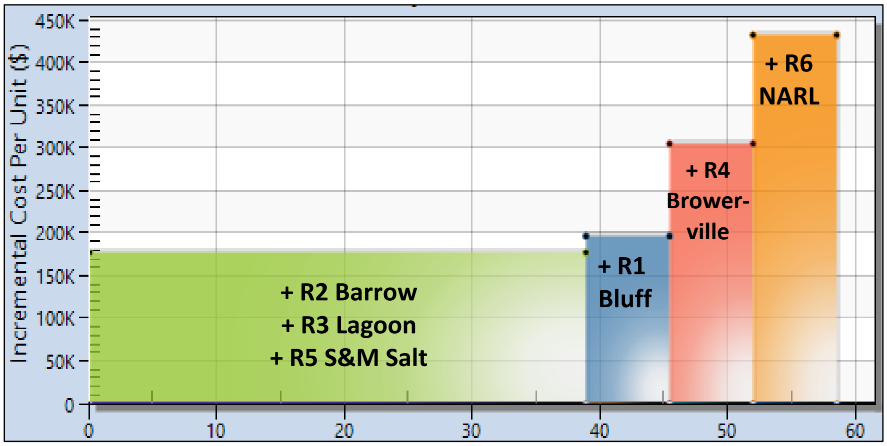

Figure 25 – Weighting Sensitivity, Best Buy Chart, Scenario 1

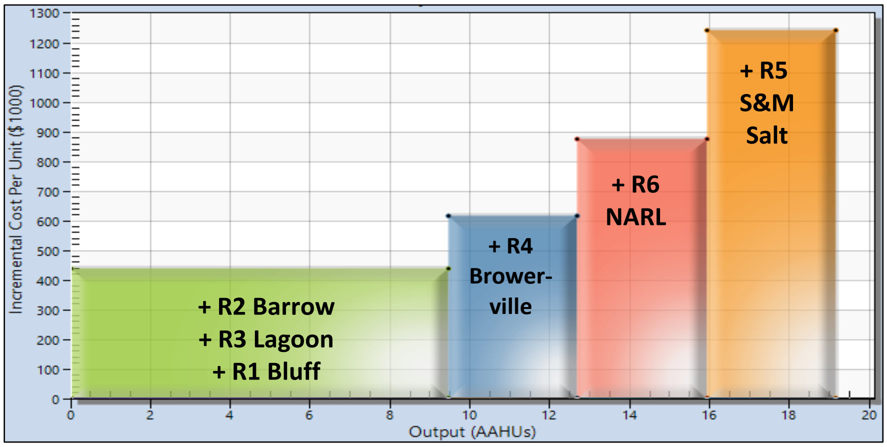

Figure 26 – Weighting Sensitivity, Best Buy Chart, Scenario 2

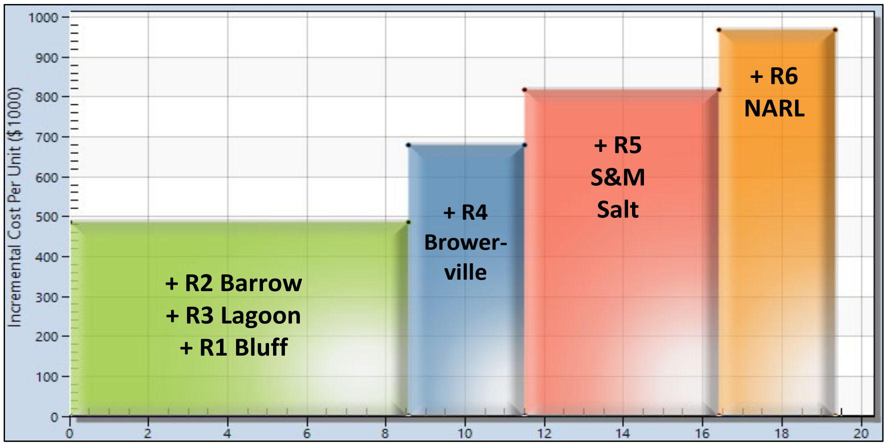

Figure 27 – Weighting Sensitivity, Best Buy Chart, Scenario 3

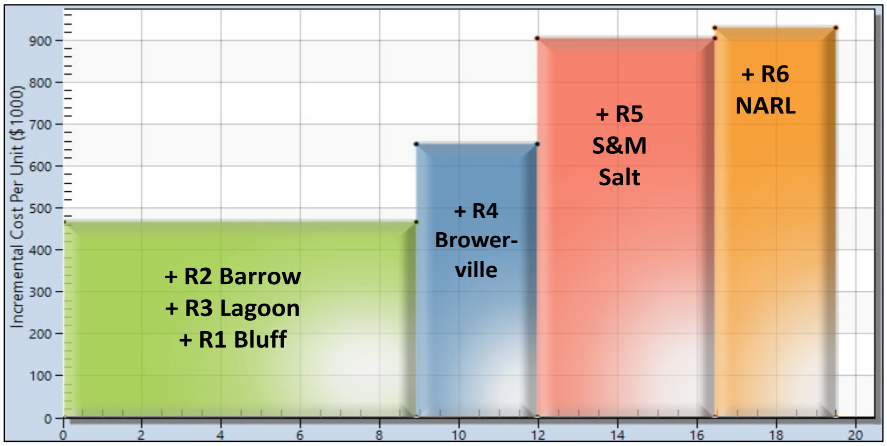

Figure 28 – Weighting Sensitivity, Best Buy Chart, Scenario 4

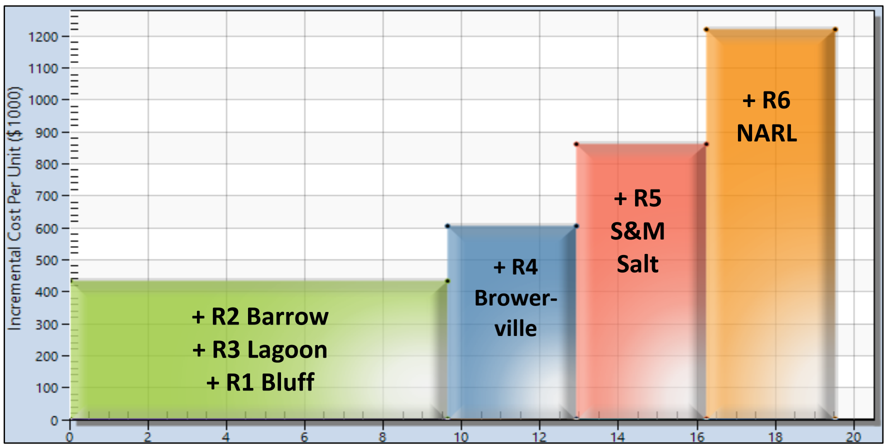

Figure 29 – Weighting Sensitivity, Best Buy Chart, Scenario 5

11.7.2 Effect of the Environmental Component Weighting

To consider the effects of weight given to the environment component of the triple bottom line, the PDT generated four different weighting scenarios, for a total of five, including the base analysis.

- Equal (base analysis): All three components receive equal weight
- 40/40/20: Economic and social/cultural components weighted 40 percent each, environmental 20 percent
- 47.5/47.5/5: Economic and social/cultural components weighted 47.5 percent each, environmental 5 percent
- 49/49/2: Economic and social/cultural components weighted 49 percent each, environmental 2 percent
- 50/50/0: Economic and social/cultural components weighted 50 percent each, environmental 0 percent

For each of these scenarios, the CRU calculations were revised, and a new CE/ICA run was performed. Table 33 summarizes the results of these sensitivity runs by presenting the ranking of the reaches, where a rank of "1st" indicates that the reach was the first reach to be included in the derived best buy plans (lowest incremental cost), and "2nd" indicates that the reach was the next to be included in the derived best buy plans (next lowest incremental cost).

Given the calculation approach for CRUs, and given that Reach 5 is the only reach with environmental output, Reach 5 represents at least one-third of potential CRUs output when the three components are equally weighted (scenario 1). Reducing the weight of the environmental component to 20 percent would result in Reach 1 being included in the best buy sets before Reach 5, but Reach 5 would still be included before Reach 4 and Reach 6 (scenario 2). The weight for the environmental component would need to be reduced to 5 percent or less before Reach 4 and Reach 6 would rank higher than Reach 5 in terms of the formation of the best buy plans (scenario 3). Figures 30 through 34 present the best buy incremental cost box plots for scenarios 1 through 5 from the Table 33. Note that the box plot for scenario 1 is the same as presented previously in Figure 25 because it relies on the same scenario assumptions.

Table 33 – Environmental Component Sensitivity, Results Summary

Reach	**Scenario and Best Buy Inclusion Rank** ***(Economic % / Social/Cultural % / Environmental %)***				
	1 Equal	**2 40 / 40 / 20**	**3 47.5 / 47.5 / 5**	**4 49 / 49 / 2**	**5 50 / 50 / 0**
R1 – Bluff	4th	3rd	3rd	3rd	3rd
R2 – Barrow	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd
R3 – Lagoon	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd	1st / 2nd
R4 – Brower.	5th	5th	4th	4th	4th
R5 – S&M Salt.	3rd	4th	6th	6th	6th
R6 – NARL	6th	6th	5th	5th	5th

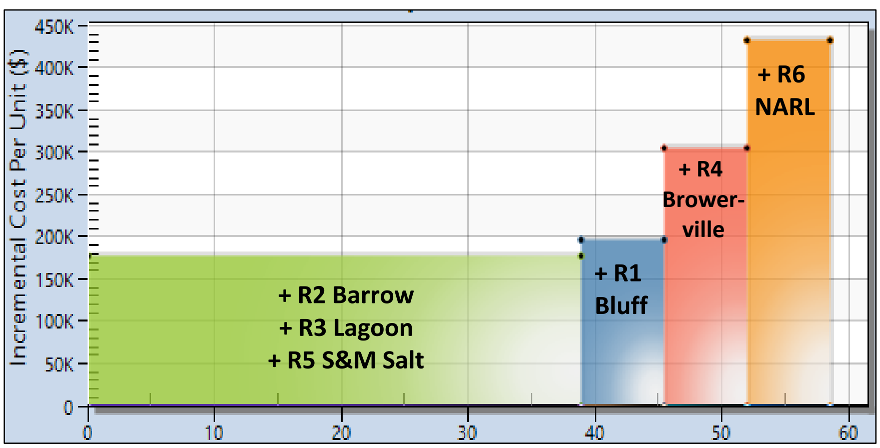

Figure 30 – Env. Component Sensitivity, Best Buy Chart, Scenario 1

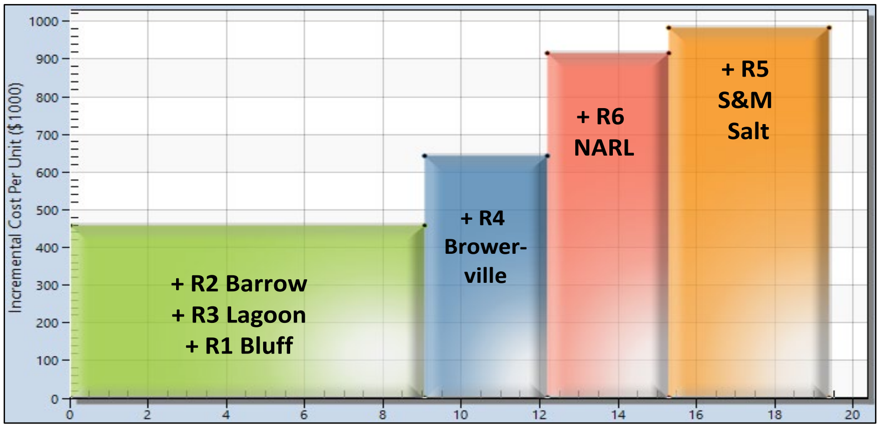

Figure 31 – Env. Component Sensitivity, Best Buy Chart, Scenario 2

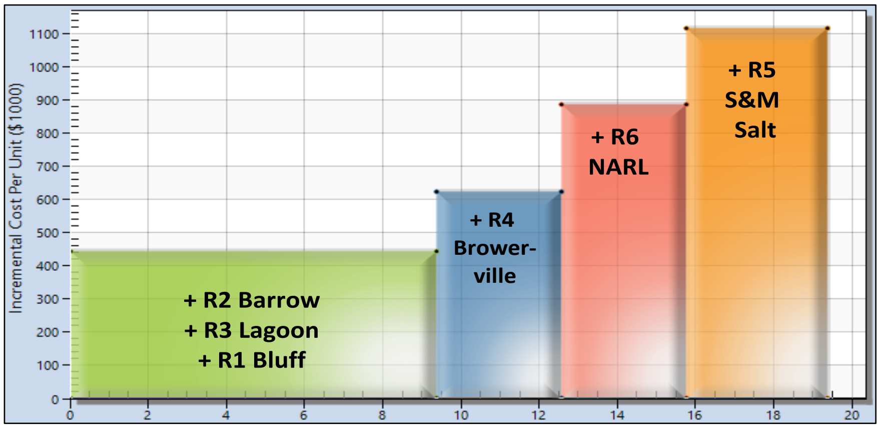

Figure 32 – Env. Component Sensitivity, Best Buy Chart, Scenario 3

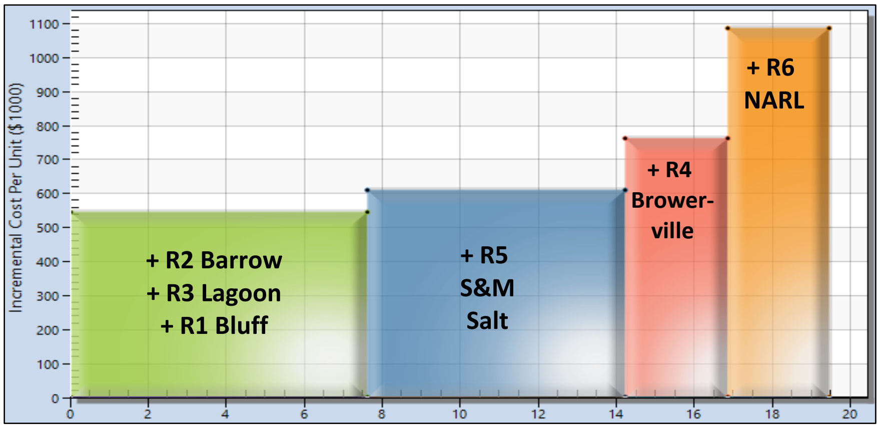

Figure 33 – Env. Component Sensitivity, Best Buy Chart, Scenario 4

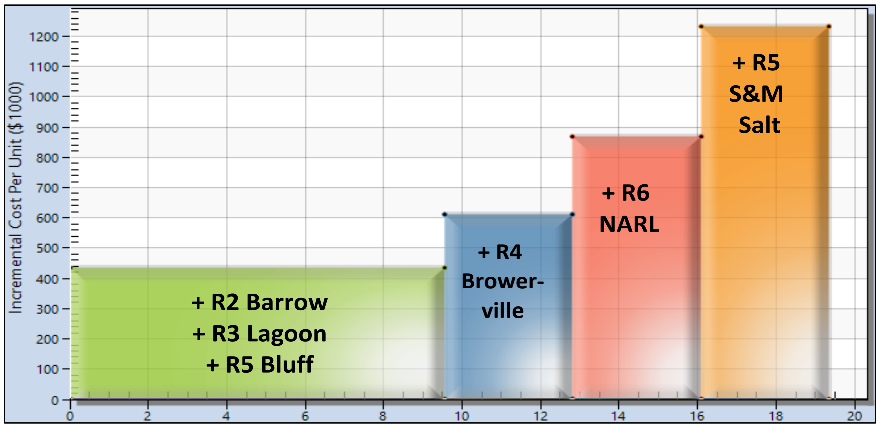

Figure 34 – Env. Component Sensitivity, Best Buy Chart, Scenario 5

11.7.3 Sensitivity for Design Height

The sensitivity analysis for design height considered two increased heights for the design. No lower heights were considered, based upon the judgment of the PDT engineering component that the minimum height was already specified in the base design. To evaluate the effects of height, the reach-by-reach analysis was repeated for the two additional height scenarios. The first scenario increased the height of the revetment by 1 foot, and the second scenario increased it by another 1.5 feet. In each scenario, the CRU output was recomputed based upon the CE/ICA framework. Table 34 summarizes the computed CRUs and NED benefits for each design height.

Table 34 – Sensitivity for Design Height

Scenario	Ann. Cost ($1000)	NED Benefits ($1000)	Net NED Benefits ($1000)	BCR	CRUs
Base	$13,039	$8,329	($4,710)	0.64	58.58
Base + 1 foot	$13,970	$8,339	($5,631)	0.60	59.28
Base + 2.5 feet	$15,437	$8,345	($7,092)	0.54	59.69

11.7.4 Summary of Sensitivity Analyses

As shown previously, the PDT thoroughly considered the effects of the weighting of the components of the triple bottom line in the calculation of CRUs and effects on the identification of plans. The sensitivity analysis shows that the economic and social components both point to a similar ranking of Reaches 1 through 4 and 6, and that the ranking of Reach 5 is a function of the weight placed upon the environmental component. Based upon the results of these sensitivity analyses and given the importance of environmental quality and reduction of risk to assets in Reach 5, the PDT determined that the equal weighting approach applied in the base analysis was appropriate and should be maintained.

As shown in Table 34, net NED benefits are maximized at the lowest design height, with net benefits decreasing as height increases. Additionally, it is noted that the ranking of reaches and the identified best buy plans did not change with design height and the increase in CRUs was marginal.

11.8 Second Iteration of CE/ICA by Reach

The changes resulting from the CE/ICA Iteration 1 conclusions required a secondary iteration of the CE/ICA framework to optimize the plans under consideration and evaluate the remaining options on a reach by reach basis. The conclusion of the sensitivity analyses also showed that it was appropriate to proceed to final analysis with the equal weighting scheme for CRU components and that the lowest design height would be carried forward. After screening out beach nourishment and filling of Tasigrook Lagoon from the original array of alternatives, the remaining options by reach are shown in Table 35. To consider all possible combinations of reaches and treatments, reaches were defined as measures, and treatment options as scales. Any subsequent combinations require that Reaches 2 and 3 be included.

Both outputs and costs were developed at the reach level to support the CE/ICA. For outputs, this required allocation of outputs from each variable in the CE/ICA framework to one or more reaches. For most variables, this allocation was straightforward, as the outputs corresponded directly to a specific geographic location (erosion at the Native Village, for example). For the coastal storm erosion response costs, however, input from the NSB was required to allocate both the response costs driven by weather events and the expected future capital cost stream (see Section 5.2 for more information).

Table 35 shows an example of the DDD variables without project effects distributed by reach.

Table 35 – DDD WOPC Consequences by Reach

Consequence Category	Economic – DDD ($1000)						
	Total	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
Structures & Contents, Flood	$50.6		$13.5	$0.59	$30.6	$0.59	$5.3
Structures & Contents, Erosion	$349	$48.9	$80.3	$3.5	$181	$3.5	$31.4
Land loss, Erosion	$18.2	$1.6	$1.37	$1.3	$3.83	$6.4	$3.6
Bluff (Nat Village Site), Erosion	$13.8	$13.8					
South / Middle Salt Lagoons, Flood	$106					$106	
Isatkoak Lagoon, Flood	$182			$182			
Utilidor, Flood	$13.5		$13.5				
Utilidor, Erosion	$167		$167				
Berm/Emergency Maintenance	$7,449	$896	$1,862	$1,188	$1,641	$1,641	$222
Total	**$8,350**	**$960**	**$2,138**	**$1,376**	**$1,857**	**$1,757**	**$262**

After performing a similar allocation for each of the six variables and reaches, the CE/ICA framework was applied again to compute CRUs by reach for remaining treatment options.

Table 36 presents the costs and outputs by reach. In the scale column, "revetment" is specified in Reaches 1 and 2, where the treatment would include revetment of the existing bluff. In Reach 3, only "berm" is specified because there is no frontage road in reach 3. In Reaches 4 to 6, "berm" refers to the option of placing a revetted berm seaward of the existing Stevenson Road, and "raise road" refers to the option of raising and revetting Stevenson Road itself.

Table 36 – Reach-based Measures and Scales

MEASURE	SCALE	ANNUALIZED COST ($)	ANNUAL CRUS
R1 Bluff	Revetment	$1,286,000	6.55
R2 Barrow	Revetment	$980,000	6.08
R3 Lagoon	Berm	$1,904,000	6.46
R4 Browerville	Raise Road	$1,996,000	6.54
	BERM	$2,805,000	6.54
R5 South & Middle Salt Lagoons	Raise Road	$4,028,000	26.4
	BERM	$5,677,000	26.4
R6 NARL	Raise Road	$2,845,000	6.55
	BERM	$4,035,000	6.55

This set of measures was then run in the CE/ICA model. As noted in Section 11.6, the PDT identified that the selected plan would need to include reaches 2 and 3 at a minimum to sufficiently address the planning objectives. As such, dependencies were specified in the CE/ICA model to require that reaches two and three be included in all combinations of plans. Figure 35 presents the resultant plot of all possible combinations and Figure 36 presents the incremental cost box plot for the best buy plans. Table 37 presents the incremental cost calculations for the best buys.

Because the results indicated that some plans which were cost effective but not best buy may have positive net NED benefits, both the cost effective and best buy plans were carried forward. These plans were assigned letter codes A through H. Figure 37 presents the cost effective and best buy plans on a map in order to relate them to the study area. Table 38 presents plans A-H and describes their costs, NED benefits, and CRU outputs.

As illustrated in the figures and tables, Reach 5 is the first best buy addition after the required reaches. This is attributable to the fact the in the CE/ICA framework for this project, only Reach 5 includes any environmental output, and as such, Reach 5 is the only reach where the Environmental component of the triple bottom line framework is represented. Since each of these components is equally weighted within the framework, Reach 5 effectively accounts for about one third of the total possible CRUs. The sensitivity of the results to this weighting is considered in Section 11.7. The findings of that sensitivity were that the equal weighting is appropriate.

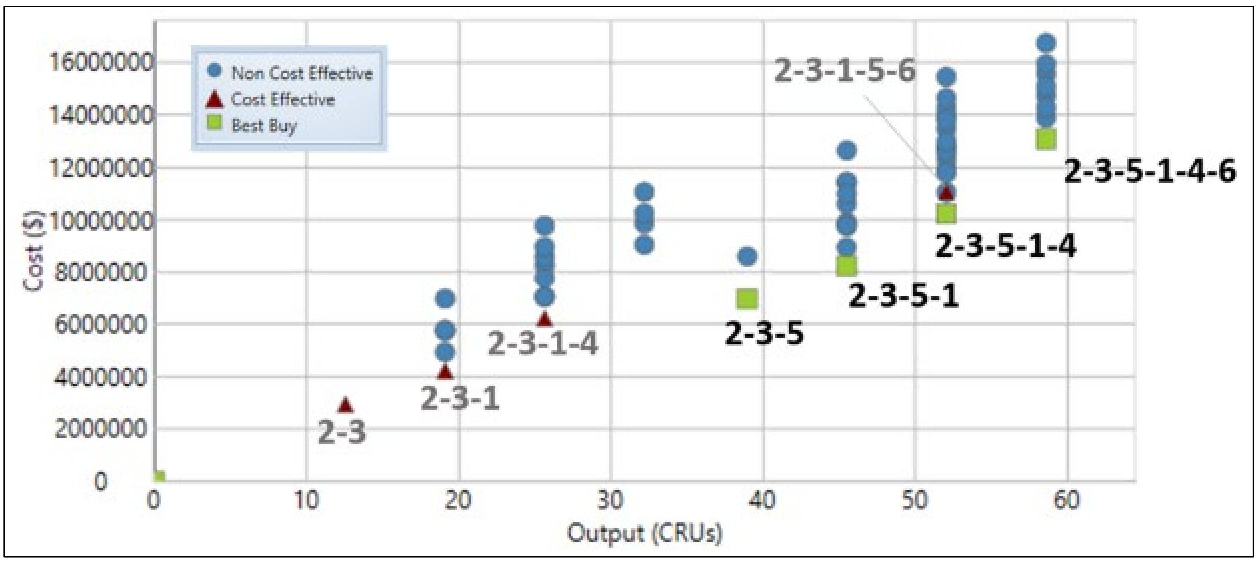

Figure 35 – By Reach, All Possible Plans

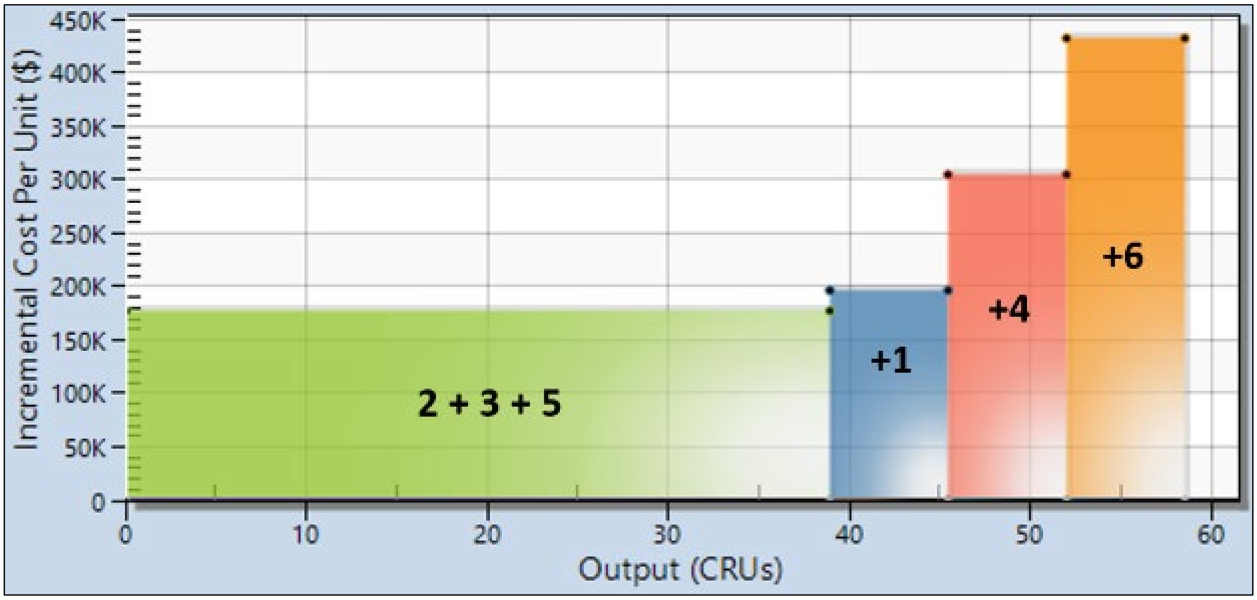

Figure 36 – By Reach, Best Buy Plans

Table 37 – By Reach, Incremental Cost for Best Buy Plans

Scenario	**Annualized Cost ($)**	**CRU**	**Inc. Cost per Unit ($)**
No Action	$0	0	$0
R2+R3+R5	$6,912,000	38.95	$177,000
R2+R3+R5+**R1**	$8,198,000	45.49	$196,000
R2+R3+R5+R1+**R4**	$10,194,000	52.03	$305,000
R2+R3+R5+R1+R4+**R6**	$13,039,000	58.58	$434,000

Figure 37 – By Reach, Cost Effective and Best Buy Plans Mapped

Table 38 – Incremental Cost, by Reach

ID	Scenario	Type	Ann. Cost ($1000)	Annual CRUs	NED Benefits ($1000)	Net NED Benefits ($1000)
NA	No Action	Best Buy	$0	0.00	$0	$0
A	R2+R3	Cost Effective	$2,884	12.54	$3,501	$617
B	R2+R3+R1	Cost Effective	$4,170	19.09	$4,461	$291
C	R2+R3+R1+R4	Cost Effective	$6,166	25.63	$6,311	$145
D	R2+R3+R5	**Best Buy**	$6,912	38.95	$5,257	($1,655)
E	R2+R3+R5+R1	**Best Buy**	$8,198	45.49	$6,217	($1,981)
F	R2+R3+R5+R1+R4	**Best Buy**	$10,194	52.03	$8,067	($2,127)
G	R2+R3+R5+R1+R6	Cost Effective	$11,043	52.04	$6,479	($4,564)
H	R2+R3+R5+R1+R4+R6	**Best Buy**	$13,039	58.58	$8,329	($4,710)

11.9 Final Iteration of the CE/ICA by Reach

In response to questions during vertical review, the use of H&H data from the 2010 Technical Report was revisited to ensure that its use was reasonable and consistent across reaches. During this review, it was noted that the computed AEP's for Reach 3 (Lagoon) varied substantially from the AEPs for other reaches in the study. Transect 28, located at the Lagoon and used in the analysis presented in Section 11.8, was an outlier in terms of the stage-frequency curves developed in each reach. Coordination with the H&H element of the PDT indicated that Transect 28 was unique because of its location on the Lagoon. The lack of berm at this location made the resulting stage-frequency less indicative of the risk of water entering the lagoons. As a result, the PDT determined that using Transect 31 as an indicator for AEP of damage initiation for Reach 3 would be more appropriate. Transect 31 is the next available transect to the northeast from the 2010 Technical Report, and the presence of a berm at this location results in a better representation of the risk of flood overtopping that would initiate damages. The computed AEP for Transect 31 is also more consistent with other reaches in the analysis. Figure 38 compares Transect 28 and 31 based and their stage-frequency curves from the 2010 Technical Report. Table 39 presents the final computed AEPs by reach.

Following this revision, a final iteration of the CE/ICA was completed. This final iteration was conducted with the FY20 discount rate of 2.750% and FY20 price level as discussed in **Section 5.1 Discount Rate and Price Level Updates**. As documented in Table 40 through Table 42 and Figure 39 and Figure 40, the final iteration had results very similar to the previous iteration, with a minor decrease in total possible CRUs and total NED benefits. However, all plans experienced the same changes, so there was no relative change in position or priority among the plans resulting from the CE/ICA.

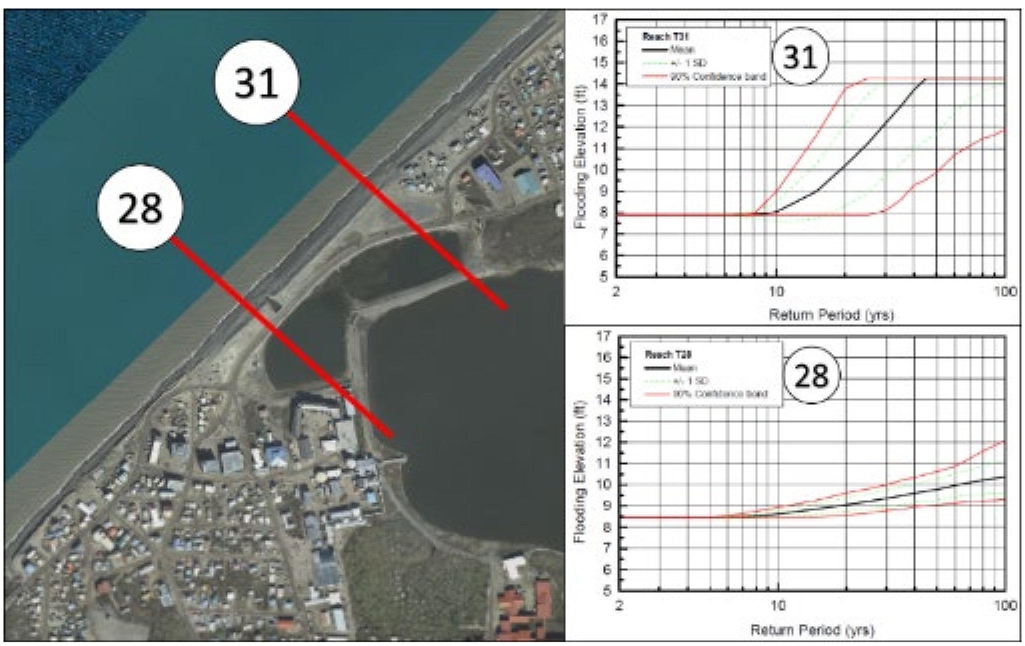

Figure 38 – Comparison of Transect 28 and 31

Table 39 – Computed AEP by Reach

Reach	Barrow (Structures)[1]	Barrow (Pump Station)	Lagoon	Browerville	South & Middle Salt	NARL
Transect	**25**	**25**	**31**	**32**	**49**	**51**
Without Project						
Dmg. initiation (ft)[2]	11.42	12.85	12.00	11.16	8.70	8.29
AEP (%)	5.520%	2.615%	3.1%	5.549%	21.029%	14.728%
RI (years)	18	38	32	18	5	7
With Project						
Project Height (ft)	14.50	14.50	14.50	14.50	14.50	14.50
AEP (%)	1.100%	1.100%	1.3%	1.173%	0.154%	0.029%
RI (years)	91	91	79	85	649	3,449

Notes:
AEP = annual exceedance probability from flood stage-frequency curves in 2010 Technical Report H&H appendix.
RI = Recurrence interval for each AEP (1 ÷ AEP).
1) Two calculations are included for Barrow reach to separately consider the trigger elevation for structures and for Pump Station #4.
2) Reflects adjustment of top of bank as follows.
Barrow (structures): berm/bank height plus 1.875 feet to adjust for typical foundation height above ground
Barrow (pump station): berm/bank height at transect plus 3.3 feet to reflect current elevation of pump station entrance
Lagoon: Previous studies identified 12 feet as trigger elevation for utility infrastructure at this location
Browerville (structures): berm/bank height plus 1.875 feet to adjust for typical foundation height above ground
South & Middle Salt: reflects berm/bank crest at transect corresponding to the landfill.
NARL: reflects top of bank/berm at transect 51, the closest available transect to NARL from 2010 Technical Report

Table 40 – Reach-based Measures and Scales, Final Iteration

MEASURE	SCALE	ANNUALIZED COST ($)	ANNUAL CRUS
R1 Bluff	Revetment	$1,259,000	6.13
R2 Barrow	Revetment	$960,000	5.70
R3 Lagoon	Berm	$1,865,000	4.80
R4 Browerville	Raise Road	$1,955,000	6.12
	BERM	$2,747,000	6.12
R5 South & Middle Salt Lagoons	Raise Road	$3,944,000	25.99
	BERM	$5,560,000	25.99
R6 NARL	Raise Road	$2,785,000	6.13
	BERM	$3,951,000	6.13

Annualized costs by reach presented here do not include Interest During Construction. Interest During Construction was manually added after generating plans in order to reflect the total construction duration that would result from each combination of reaches.

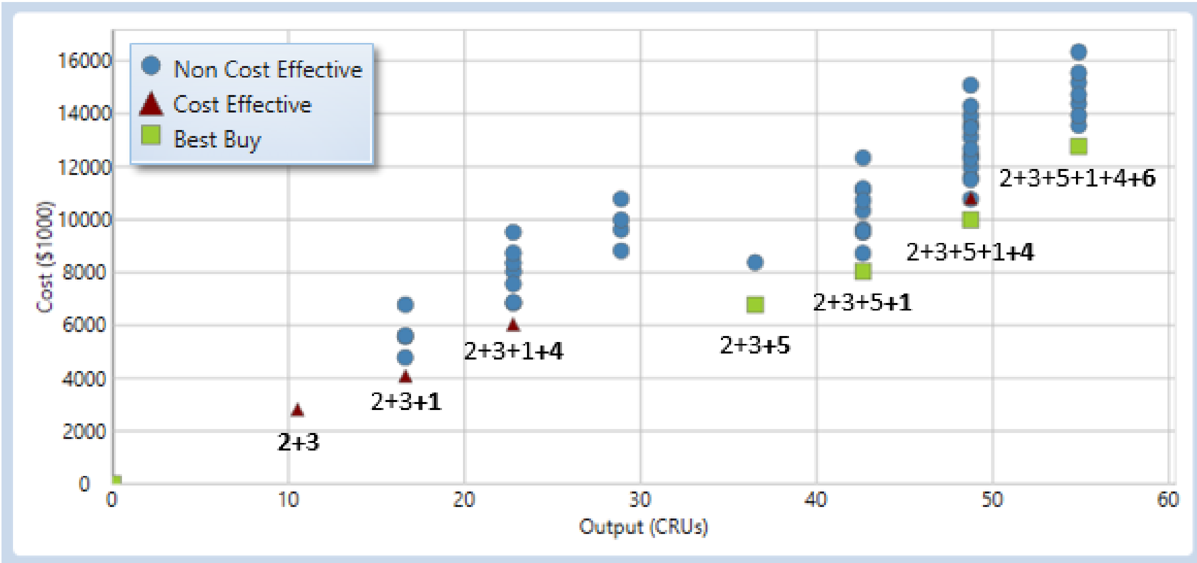

Figure 39 – By Reach, All Possible Plans, Final Iteration

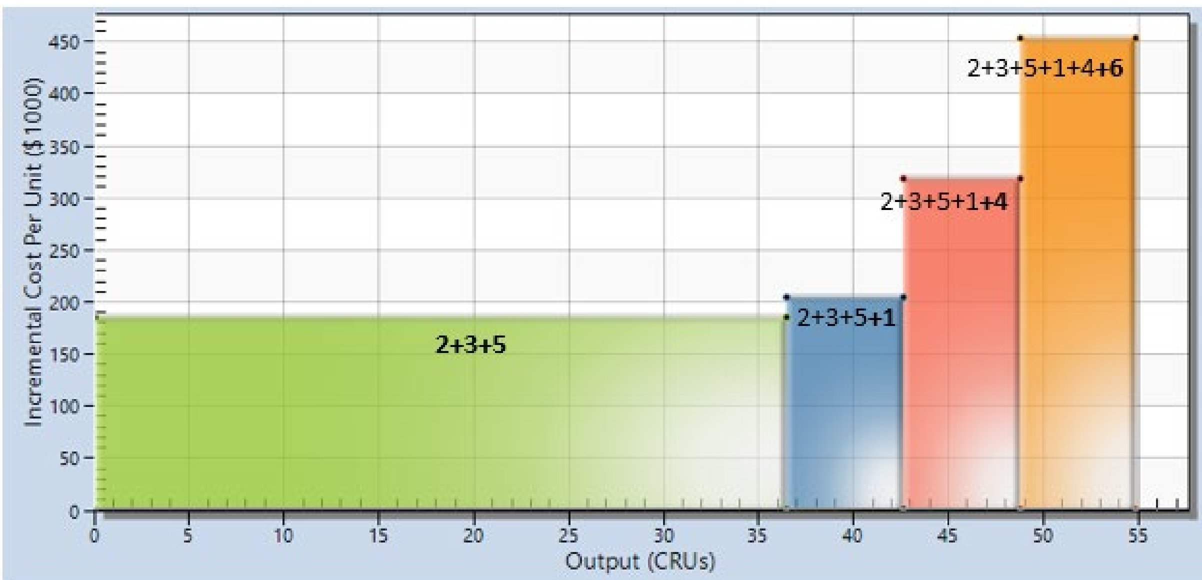

Figure 40 – By Reach, Best Buy Plans, Final Iteration

Table 41 – By Reach, Incremental Cost for Best Buy Plans, Final Iteration

Scenario	Annualized Cost ($)	CRU	Inc. Cost per Unit ($)
No Action	$0	0	$0
R2+R3+R5	$6,842,500	36.49	$188,000
R2+R3+R5+**R1**	$8,147,500	42.62	$213,000
R2+R3+R5+R1+**R4**	$10,171,600	48.74	$331,000
R2+R3+R5+R1+R4+**R6**	$13,061,200	54.87	$471,000

Interest During Construction was estimated at 4 months of construction duration per reach (FY20 rate of 2.750%) and was added manually after running the CE/ICA.

Table 42 – Incremental Cost, by Reach, Final Iteration

ID	Scenario	Type	Ann. Cost ($1000)	Annual CRUs	NED Benefits ($1000)	Net NED Benefits ($1000)
NA	No Action	Best Buy	$0	0.00	$0	$0
A	R2+R3	Cost Effective	$2,844	10.50	$3,431	$587
B	R2+R3+R1	Cost Effective	$4,129	16.63	$4,391	$263
C	R2+R3+R1+R4	Cost Effective	$6,129	22.75	$6,242	$113
D	R2+R3+R5	**Best Buy**	$6,843	36.49	$5,189	($1,653)
E	R2+R3+R5+R1	**Best Buy**	$8,148	42.62	$6,149	($1,998)
F	R2+R3+R5+R1+R4	**Best Buy**	$10,172	48.74	$7,999	($2,172)
G	R2+R3+R5+R1+R6	Cost Effective	$11,018	48.75	$6,411	($4,606)
H	R2+R3+R5+R1+R4+R6	**Best Buy**	$13,061	54.87	$8,261	($4,800)

Interest During Construction was estimated at 4 months of construction duration per reach (FY20 rate of 2.750%) and was added manually after running the CE/ICA.

12.0 IDENTIFYING THE RECOMMENDED PLAN

As shown in Section 11.8, Second Iteration of the CE/ICA, the final array of plans included plans A through H. Plans A, B, and C all had positive net benefits. Plan A maximizes net benefits, and as such was identified as the NED plan.

The Section 116 authority affords the USACE an opportunity to develop and implement a project that both embraces the community resilience paradigm and is consistent with the planning principles and procedures which govern Civil Works investigations. In the discussion of a resilience framework, the USACE highlights the importance of resilience at the local level, contributing to greater community resilience. The way that the USACE can contribute to community resilience in Barrow is through delivery of a resilient coastal storm risk reduction project. In consideration of the opportunity to select a project which best contributes to community resilience and potential benefits across all four accounts, Alternative H has been identified by the PDT as the recommended plan.

This recommended plan presents a robust Corps coastal risk reduction project would be resilient at the project level to flooding and erosion forces, in turn improving resilience of economic, social/cultural, and environmental systems at the community level. Alternative H is the same in design, costs, benefits, and other effects as Alternative 2 from the first iteration of the CE/ICA, would provide risk reduction for the lineal extent of the study area, and address all three components of the community resilience triple bottom line by addressing short- and long-term coastal erosion and coastal storm flood risk.

Alternative H would include erosion risk reduction for the bluffs in front of Barrow starting in front of Wiley-Post Will Rogers airport and heading north until the bluffs start to decrease in height from +19 feet to +15 feet. A +14.5 feet berm would tie into the rock revetment and follow the shoreline north to where Tahak Street intersects Stevenson Street. Stevenson Street would be raised to a height of +14.5 feet with the seaward side revetted starting at this intersection and heading north to Dewline Road, just past NARL. Beach access points within the project area would be established during the PED phase and would account for spring break-up, drainage, and public access. Design of the beach access points would be based on community feedback and modeling. Reaches within this alternative would be further refined during PED.

Recurring recent federal disaster declarations in 2015 and 2017 highlight the need for improved resilience for the Barrow community. In the October 2015 storm, Barrow suffered damage during a relatively moderate fall storm. FEMA declared a disaster for the Borough and committed to provide disaster assistance "for emergency work and the repair or replacement of disaster-damaged facilities" in Barrow. Total costs associated with the 2015 storm reached over $7.2 million. Another 1-2 feet of storm surge would have flooded Barrow's Utilidor, disrupting water and sewer service for the entire city of Barrow. With an additional 18 inches of storm surge, sea water would have breached Barrow's fresh water lagoon, and the entire community would have been left without potable water. The September 2017 storm resulted in over $10 million in damages. This included flooding to approximately elevation +10 feet, MLLW, and Borough man-power and equipment were mobilized to reduce risk to the community and critical infrastructure such as Pump Station 4 and sections of the utilidor. Large sections of the bluff were eroded and collapsed from wave erosion, threatening the adjacent buildings. Many sections of the near-shoreline road system required immediate maintenance to provide emergency vehicle egress and access for the community. Large sections of Stevenson Street were closed. The recommended plan identified in this current study would have precluded these previous damages.

Regarding the assessment of resilience over time as presented in Figure 6, the recommended plan would move Barrow from a state of High Risk with Low Resilience to one of much Lower Risk with much Greater Resilience. Regarding the four resilience principles presented in Figure 8, implementation of the plan would drastically improve the community's capacity to absorb expected coastal storms and greatly decrease the community's and nation's recovery time and costs after storms hit. The PDT and the NSB judge the reductions in risk and associated increase in community resilience and the significance of effects of the recommended plan to be worth the plan's implementation, operation, and maintenance costs.

The recommended plan would provide benefits across all four accounts. The plan would achieve NED benefits by the reduced risk of direct dollar damages to private and public property and infrastructure in the study area. RED benefits would be achieved by the reduced risk of business disruption and adverse employment and income effects that would occur following a major coastal storm and erosion damaging event. The plan would achieve OSE benefits by the reduction in risk to human health and safety, both within Barrow and within other borough communities reliant upon Barrow's regional services. The plan would also support reduction of risk to cultural resources and improve the long-term viability of the Barrow community in its historical location, supporting the preservation of Barrow's unique sense of place. EQ benefits would include reduction of risk to the community and the local marine food web from contamination if the sewage lagoon and landfill were breached. Taken together, the recommended plan would provide benefits across the four accounts, and would achieve a significant increase in community resilience at Barrow by adapting to a changing coastal storm regime and better positioning the community to absorb the impacts of minor to moderate storms and recover and rebuild following severe events. Table 45 provides a summary of the significance of the contributions of the recommended plan towards community resilience to erosion and flooding risk for Barrow and the surrounding communities in the region which are dependent on Barrow.

12.1 Cost and Benefit Summary for the Recommended Plan

Following identification of Plan H as the recommended plan, a refined cost estimate was developed in MCACES, including the development of a Cost and Schedule Risk Analysis. Table 43 summarizes the resulting Total Project Cost Summary. Estimated Costs from this table were used to compute the project benefit to cost ratio, presented in Table 44.

Table 43 – Recommended Plan Total Project Cost Summary

Item	Estimated Cost ($1000, FY20)	Project First Cost ($1000, FY20)	Fully Funded Cost ($1000, *)
Construction	$290,404	$297,410	$333,041
Lands and Damages	$4,349	$4,454	$4,701
Planning, Engineering & Design	$8,460	$8,748	$9,331
Construction Management	$17,424	$18,018	$20,748
Total	**$320,637**	**$328,630**	**$367,820**
** Fully Funded Cost reflects escalation of each activity to its estimated midpoint of construction, which varies between FY21 and FY23 depending on activity.*			

Table 44 – Recommended Plan Benefit-Cost Analysis Summary

Item Description	Recommended Plan ($FY20)
Construction Costs	$205,960,000
Preconstruction Engineering/Design	$6,000,000
Construction Management	$12,358,000
Contingency	$92,720,000
Real Estate (LERRDs)	$3,600,000
Estimated Project Cost	**$320,637,000**
Interest During Construction	$8,486,000
Total Investment Cost	**$329,123,000**
Annualized Investment Cost	$12,505,000
Annual O&M	$1,729,000
Total Annualized Investment Cost	**$14,234,000**
Present Value Investment Cost	**$384,278,000**
Annual Benefits	$8,261,000
Present Value Benefits	$223,024,000
Annual Net Benefits	-$5,973,0000
Benefit-Cost Ratio	**0.58**
Notes: Values may not add due to rounding. Estimated Project Cost corresponds to the TPCS for the recommended plan. Interest During Construction was included based upon the FY20 rate of 2.750% and 24 months of construction duration, as documented in the Cost Engineering Appendix.	

12.2 Key Risks and Uncertainties

With regard to uncertainty in the achievement of the benefits documented in this report, the key identified risk was the use and price level update of the 2010 Technical Report information as input to this current analysis, including:

- Use of the 2010 flood hydraulics information to support the CE/ICA (Section 11.3), and
- Use of the previously estimated expected annual flood damages in Beach-fx (Section 5).

This data was used because new coastal hydraulic analysis required for a new coastal flood damage analysis was not available at the time of this study. However, the risk of using this information was found to be minor because flood risk is not a driver of project benefits. Rather, it is the reduction of damages in the Berm/Emergency Maintenance and Capital Expenditures consequence category; both associated with coastal erosion, which drive the benefits. Because erosion damages identified in this analysis are expected to be eliminated by construction of a berm/revetment, 97 percent of the without project damages would be expected to be achieved, even if the flood risk benefits were not included in the study entirely. As such, the PDT determined that such use of the 2010 Technical Report (updated to current price levels) was a tolerable risk given the need for timely delivery of a project at Barrow.

Table 45 – Significance of Recommended Plan Effects

Technical Significance	Coastal Storm Flood and Erosion Damage Reduction Existing technical studies and resulting information have demonstrated that under without project conditions, coastal storm driven flood and coastal erosion risk is expected to result in adverse consequences for the community of Barrow. Such consequences can be categorized as Economic, Social/Cultural, and Environmental risks. Without Project Economic Coastal Storm and Erosion Risks include: Direct Damages [NED] *(estimated annual damage based upon DDD output variable from CE/ICA)* ▪ $51K from flooding of structures and contents ▪ $349K from erosion of structures ▪ $18K for land expected to be lost (7.5 acres) to erosion in Barrow neighborhood ▪ $14K for cultural resources recovery actions expected to be required due to loss of original village site parcels ▪ $107K for recovery costs associated with landfill and sewage lagoon breaches ▪ $183K for utility and water supply impacts for Isatkoak Lagoon ▪ $14K in flood damages to Utilidor and related critical utilities based on current Pump Station #4 elevation ▪ $167K in erosion damages to Utilidor Pump Station #4 and related critical utilities ▪ $7.5M for annual sacrificial berm maintenance and emergency response costs, and future capital costs Adverse Employment and Income Effects (RED) ▪ Loss of up to ~400 FTEs if community gas line were lost from flooding ▪ Loss of up to ~120 FTEs if utility service in Utilidor were flooded ▪ Loss of up to ~240 FTEs if utility service in Utilidor was lost due to erosion of Pump Station #4 <u>Potential NSB Facility Relocations</u> ▪ NSB has identified the likely future need for relocation of Publics Works facilities on Stevenson Street at an estimated cost of up to ~$90M (NSB estimate). Without Project Social/Cultural Coastal Storm Risks include: (OSE) ▪ Barrow population (~4,320) without water supply estimated at ~60 days until new system online if fresh water supply is breached by flooding. ▪ Significant erosion expected to original village site and associated cultural resources (5-acre site that was original village and contains priceless cultural resources). ▪ Affected Barrow population (~1,270) without utilities estimated at ~40 days until normal service restoration if Utilidor is flooded. ▪ Affected population (~1,270) without utilities after erosion damage to Utilidor estimated at duration of ~80 days until normal service restoration. ▪ Emergency crews at health and safety risk when actively building protective berms in the surf under storm conditions. Without Project Environmental Coastal Storm Risks include: (EQ) ▪ Contaminated site (old U.S. Navy Landfill) and active sewage lagoons at risk of release of materials into environment under flooding conditions and/or following unabated erosion. With Project Effects of the recommended plan significantly reduce all identified adverse economic, social/cultural, and environmental consequences of flooding: ▪ Project effectively eliminates erosion advancement over the period of analysis. ▪ Reduces initiation of flooding of structures/contents changes from current (~10-yr event) to over ~80-yr event ▪ Effectively eliminates risk of flooding and breach of Sewage Lagoon and Old Navy Landfill ▪ Increases exceedance probability for flooding damage to Utilidor from current (~40-yr event) to over the ~90-yr event ▪ Effectively eliminates risk of loss of Stevenson Street under with project conditions ▪ Effectively precludes the need for active flood fighting and emergency berm maintenance Based on these technical findings, the recommended plan is expected to result in a significant increase in the resilience of economic, social, and environmental systems of Barrow to coastal storms.

Public Significance	The community of Barrow and the government of the North Slope Borough have expressed their public support for implementation of a project to provide relief from the continued risk of flooding and erosion damages to their community. Local government representatives have participated in the planning process and development of flood risk reduction measures included in the recommended plan. Further, the NSB has stressed the unique dependence of other, even more remote, North Slope communities that depend on fully functioning services in Barrow for providing lifeline services and supplies to their communities. Implementation of the recommended plan would not only improve the community resilience of Barrow to coastal storms but also those other remote communities which depend on Barrow for their livelihood, public health, and safety.

Institutional Significance	Institutional recognition of an effect means its importance is recognized and acknowledged in the laws, plans and policies of government, public agencies and private groups. The recommended plan-produced project outputs are consistent with codified USACE mission areas of coastal storm risk management including erosion risk management. Evaluation methods are consistent with procedures as identified in USACE Engineering Regulation ER 1105-2-100 Planning Guidance. Additional plan evaluation procedures have been applied as authorized in Section 116 of the Energy and Water Development and Related Agencies Appropriations Act of 2010 (Public Law 111-85) and associated USACE implementation guidance. Resilience principles incorporated into evaluation methodology are consistent with current USACE publications on resilience in civil works projects.

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13.0 SOURCES

(BLS) United States Department of Labor Bureau of Labor Statistics. 2018. CPI Inflation Calculator. BLS Data Tools website: https://www.bls.gov/data/inflation_calculator.htm

(USACE) *Engineer Regulation 1105-2-100, Planning Guidance Notebook*; U.S. Army Corps of Engineers; April 2000.

(USACE) U.S. Army Corps of Engineers. July 2010. Appendix D - Economic Analysis, Barrow Alaska Coastal Storm Damage Technical Report. Alaska District. Provided electronically.

(USACE) *Engineer Manual 1110-2-1304; Civil Works Construction Cost Index System (CWCCIS);* U.S. Army Corps of Engineers; Dated 30 September 2017.

(USACE) US Army Corps of Engineers. 30 Sept 2017. Amendment #1, EM 1110-2-1304 Civil Works Construction Cost Index System (CWCCIS). https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1304.pdf

(USACE) US Army Corps of Engineers. Oct 2017. EMG 18-01 Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2018. https://planning.erdc.dren.mil/toolbox/library/EGMs/EGM18-01.pdf

(USACE) U.S. Army Corps of Engineers. September 2005. Draft – Barrow Alternative Utility Cost Estimates in the Event of Major Storm Damage. Prepared by ASCG Inc. for the Alaska District U.S. Army Corps of Engineers.

(USACE) U.S. Army Corps of Engineers. 2018. Headquarters > Media > Fact Sheets > Building Resilience. Web. http://www.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/609942/building-resilience/

(USACE) U.S. Army Corps of Engineers. 2018a. Headquarters > Missions > Sustainability > Building Resilience. https://www.usace.army.mil/Missions/Sustainability/Building-Resilience/

(USACE) U.S. Army Corps of Engineers. October 2017. Engineering Publication 1100-1-2 Resilience Initiative Roadmap 2016. Available online: http://www.publications.usace.army.mil/Portals/76/Publications/EngineerPamphlets/EP_1100-1-2.pdf?ver=2017-11-02-082317-943

Exec. Order No. 13653. November 2013. Preparing the United States for the Impacts of Climate Change. https://obamawhitehouse.archives.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change

Johnson M and Eicken H. September 2016. Estimating Arctic sea-ice freeze-up and break-up from the satellite record: A comparison of different approaches in the Chukchi and Beaufort Seas. Published, journal. Elementa: Science of Anthropocene 4:00.124. https://www.elementascience.org/articles/10.12952/journal.elementa.000124/

Linkov I., Bridges T., Creutzig F., Decker J., Fox-Lent C., Kröger W., Lambert J.H., Levermann A., Montreuil B., Nathwani J., Nyer R., Renn O., Scharte B., Scheffler A., Schreurs M., Thiel-Clemen T. June 2014. Changing the resilience paradigm. Nature Climate Change, Volume 4, June 2014. Journal. http://www.pik-potsdam.de/~anders/publications/linkov_bridges14.pdf

(NSB) North Slope Borough. December 5 2018. Subject: Modeling North Slope Borough Operating Costs of Barrow Coastal Erosion. Letter provided by Bernadette Adams, Director, Department of Capital Improvement Program Management, North Slope Borough.

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Attachment A

Price Level Update Calculations for 2010 Technical Report Data

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Update of 2010 Technical Report Information

NED categories in the 2010 study were divided between coastal storm flood damages and coastal erosion damages. Coastal storm flood damages included structures and contents, spillway and associated utilities, and utilidor damages. Coastal erosion damages included land loss, structure condemnation, beach berm emergency erosion maintenance (including storm-fighting), Stevenson Road repairs, South and Middle Salt Lagoon failure, and utilidor damages.

Prior to further refinement, these values from the 2010 Technical Report were price level updated for use in this current study. The update relied upon establishes indices, including Engineering Manual 1110-2-1304, Civil Works Construction Cost Index System (Revision 30 Sep 2017), the Bureau of Labor Statistics Consumer Price Index, and the Marshall & Swift Valuation Service, as needed. The general approach was to calculate the present value of the expected annual damages (EAD) cited in the 2010 Technical Report, then apply an update factor to that present value, and the re-amortize the updated present value at the FY20 discount rate, yielding an updated estimate of EAD.

Table 1 presents the update factor and source for each category from the 2010 Technical Report. Note that some categories subsequently underwent further refinement, as already documented in Section 5 of the Economic Appendix. This table is provided only to detail the price update of the 2010 Technical Report information.

Table 1 – Price Update Details

Category	Type	2010 PV	Factor	Adjusted PV	Adjusted EAD	Notes
Isatkoak Lagoon, (Water Supply and Utilities)	Flood	$1,254,600	1.27	$1,592,489	$58,987	A, B
Structures & Contents		$1,096,300	1.25	$1,367,304	$50,646	C
Utilidor (Critical Utilities)		$577,041	1.27	$732,450	$27,131	A, B
Berm/Emg. Maintenance	Erosion	$10,554,280	1.39	$14,687,649	$544,044	D, E
Frontage Road		$2,047,568	1.35	$2,769,396	$102,581	D, F
Structures & Contents		$4,735,538	1.99	$9,420,205	$348,933	G
Utilidor (Critical Utilities)		$1,400,000	2.12	$2,963,351	$109,765	B, I
Land loss		$283,131	1.73	$490,238	$18,159	H
PV = Present Value; EAD = Expected Annual Damage						

A. Category was subject to additional refinement, and numbers may not match Main Report. See Section 5 of Economics Appendix.
B. CWCCIS factor: Feature Code 19 Buildings Grounds & Utilities; Q1 2007 (658.14) to Q1 2019 (835.39)
C. The update factor for value of lost property was 1.25 based on the Marshall & Swift Annual Cost Index for Wood Frame buildings in the Western District between 2007 and 2019.
D. Category was replaced by the Coastal Erosion Storm Response and Future Without Project Capital Costs analysis which was approved for one-time use.
E. CWCCIS factor: Feature Code 16 Bank Stabilization; Q1 2007 (654.93) to Q1 2019 (911.42)
F. CWCCIS factor: Feature Code 17 Beach Replenishment; Q1 2007 (676.88) to Q1 2019 (915.5)
G. Consistent with approach in 2010 Report, loss occurs at interval (years 5, 15, 25, 35, and 45) for present value purposes. The value lost at each interval was updated to current prices and then the updated EAD and PV were calculated. The update factor for value of lost property was 1.25 based on the Marshall & Swift Annual Cost Index for Wood Frame buildings in the Western District between 2007 and 2019. After the interval calculation the present value of erosion damages changed by a factor of 1.99.
H. Like erosion of structures, erosion of land was performed using an interval analysis. For lack of specific real-estate data, the update factor for value of lost land was 1.20 based an accounting of inflation using the Consumer Price Index between 2007 (2507) and 2019 (3128). After the interval calculation the present value of erosion damages changed by a factor of 1.73.
I. Category subject to subsequent refinement to move the assumed year of failure forward in the analysis period to account for the passage of time since the previous study. See Section 5 of the Economic Appendix.

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Attachment B

Ability to Pay Analysis for Barrow Alaska Coastal Erosion Feasibility Study

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Ability to Pay Analysis

An ability to pay analysis for the Barrow Alaska Coastal Erosion Feasibility Study assesses the ability of the North Slope Borough (NSB) to cost share construction expenditures as required (generally it does not include operations, maintenance, and rehabilitation). This analysis is required by the Section 116 Guidance authorizing this project; therefore, while the regulations (33 CFR 241) only discuss that ability to pay tests are required for flood control projects, in this instance, it is also required for this erosion project.

The ability to pay "test" described in 33 CFR 241 depends not only on the economic circumstances within the project area but also on the economic circumstances of the state in which the project is located. Additionally, it is governed in part by project benefits.

The test is also referred to as the "alternative level of cost-sharing determined under the ability to pay principle" (33 CFR 241.4(f)(3)) and the procedures for determining ability to pay are also referred to as "procedures for estimating the alterative cost-share" (33 CFR 241.5). The procedures thus aim to reduce non-Federal cost share to the extent possible, and involve several steps.

The first step in the ability to pay analysis is the Benefits Test divides the project's benefit-to-cost ratio (BCR) by four.[3] If this amount (expressed as a percentage) is greater than the standard Non-Federal level of cost sharing, which is 35 percent Non-Federal and 65 percent Federal, then project is not eligible for reduction. For the Barrow project, a BCR of 0.58 divided by 4 is 0.145, which is less than 0.35, so the next step is applicable. The BCR value will be updated when it becomes available.

The second step is the Income Test, determines eligibility using an eligibility factor (EF), where EF = a – b_1*(state factor) – b_2*(area factor). If the EF is zero or less, "the project is not eligible for a reduction" (33 CFR 241.5(b)(5)). Coefficients a, b_1, and b_2 are given by USACE Headquarters and are: 19.59, 0.082, and 0.164, respectively.[4] The state factor is calculated by comparing Alaska's adjusted per capita income to the U.S.'s given income and cost of living differences. The area factor is then an adjustment to the state factor based on area income and cost of living differences.

For the Barrow Alaska Coastal Erosion Feasibility Study, EF is negative (-7.394) and therefore not eligible for reduction in cost sharing.[5]

[3] For this step, including O&M costs is acceptable per 33 CFR 241.5(a)(1).
[4] Economic Guidance Memorandum 14-04. 19 November 2013.
[5] EF = 19.59 – .082(84.54) – 0.164(100.55) = -3.832