US Army Corps of Engineers®
Alaska District

Integrated Feasibility Report and Environmental Assessment

Lowell Creek Flood Diversion Seward, Alaska

April 2021

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Prepared By:

U.S. Army Corps of Engineers

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (USACE), Alaska District, conducted this General Investigation study under the authority granted by Section 5032 of the Water Resources Development Act (WRDA) of 2007, as amended (Public Law (PL) 110-114). This study evaluates Federal interest and the feasibility of constructing a project for an alternative method of diversion at Lowell Creek in Seward, Alaska in accordance with Section 5032. USACE completed the current flood diversion system along Lowell Creek within Lowell Canyon in 1940. This system in Lowell Canyon does not adequately manage flood events, presenting risks to life, property, and critical infrastructure with little to no warning.

The concerns at the Lowell Creek Flood Diversion project are threefold: flooding and life safety risk associated with the performance of the existing diversion/spillway, the likelihood of landslides which exacerbate the risk, and hazardous recurring sediment management requirements at the outfall. The project consists of a diversion dam, emergency spillway, and tunnel. The spillway is located approximately 800 feet west of the closest buildings, which include critical infrastructure such as the hospital and senior living center. The diversion dam and tunnel divert stream flow away from the natural channel, through a tunnel in Bear Mountain and into Resurrection Bay. The system was designed to pass the largest flood experienced at that time, about 2,000 cubic feet per second (cfs) which is now considered to have greater than a 2% annual chance of exceedance. The capacity of the tunnel is currently estimated to divert 2,800 cfs of flow under Bear Mountain. The diversion dam has little storage capability. Any flow greater than 2,800 cfs would flow over than diversion dam and into downtown Seward. This lack of warning time and a largely developed floodplain lead to there being life safety risks unacceptable to the community.

Landslides are commonplace within the basin, sometimes blocking flow and resulting in surges of water and debris. Although the system can handle small events, a significant landslide could contribute to an outburst surge of 2.5 times larger than the existing stream flow. In addition, if a landslide or other debris were to block the tunnel, there is no relief for the flow other than overtopping the diversion and flowing directly into the town.

The basin above the diversion is situated in steep, rugged, mountainous terrain with a near endless supply of sediment. This sediment is transported through the tunnel as well and, especially during high water events, accumulates at the outlet whereupon it must be removed or the road and bridge providing the only access to the adjacent community of Lowell Point will be blocked. Currently, Seward actively combats the debris accumulation with heavy machinery at the outfall, which presents great hazards.

Blockage and damage to the bridge has occurred several times in the past. The accumulation of debris can also damage critical infrastructure, including the City's sewage treatment facility, the shellfish hatchery, and the Alaska SeaLife Center.

This study identifies a feasible solution that provides safe, reliable, and efficient flood diversion of the waters from Lowell Creek during precipitation and surge events. This project would reduce risk to life safety, economic damages, flood fighting activities, and reactionary debris management costs. The project would also address landslide issues, which can compound the flooding effects and damages by initiating surge releases.

The team conducted a hybrid risk assessment to analyze the risk to life safety and formulated and evaluated six alternatives. Some of these alternatives contain multiple designs with similar features, thus leading to twelve options total. These alternatives include No Action, improving or enlarging the existing tunnel, constructing a new tunnel, constructing an upstream retention basin, and relocation of structures on the floodplain. The options the team evaluated included two tunnel sizes for existing tunnel enlargement, four tunnel sizes for constructing a new tunnel, and four combinations of structure relocation in the floodplain.

- Alternative 1: No Action
- Alternative 2: Improve Existing Flood Diversion System
- Alternative 3: Enlarge Current Flood Diversion System to Convey Larger Flow Considering Two Tunnel Diameter Options:
    - (3A) 18-foot (ft) Tunnel
    - (3B) 24-ft Tunnel
- Alternative 4: Construct New Flood Diversion System
    - (4A) 18-ft Tunnel
    - (4B) 24-ft Tunnel
    - (4C) 14-ft Tunnel
    - (4D) 16-ft Tunnel
- Alternative 5: Construct Debris Retention Basin.
- Alternative 6: Floodplain Relocation
    - (6A) Floodway Through Town
    - (6B) Relocation of All Lowell Canyon Structures
    - (6C) Relocation of All Lowell Canyon Structures, Except the Hospital
    - (6D) Relocation of Residential Structures in Lowell Canyon

Alternatives 2, 3A, 3B, 4A, 4B, 4C, and 4D include a new outfall design as a structural measure because these alternatives involve modification of the existing outfall and/or creation of a new tunnel. The team evaluated the outfall for the optimal length to accrue benefits at the outlet. The basic design remains relatively consistent, primarily differing in length of the outfall. The team analyzed five differing design lengths: limited (base of mountain), 100 feet (ft), 150 ft, 500 ft, and 750 ft. The team qualitatively compared the designs based on effectiveness, benefits, and the Rough Order of Magnitude (ROM) cost. The 150-ft outfall with an estimated construction cost of $14 million (M) provides optimal benefits to the community with adequate sedimentation control for the project.

There is no NED plan because no plan produces positive net benefits. The Alaska District obtained a NED policy exception from the Assistant Secretary of the Army for Civil Works (ASA(CW)). The team evaluated Alternatives using total life safety residual risk as exemplified by Average Annual Life Loss (AALL) as a metric for Cost-Effectiveness/Incremental Cost Analysis (CE/ICA) in combination with the NED benefit analysis.

The CE/ICA analysis identified eight cost effective plans, of which six were Best Buy alternatives (No Action, Alternatives 4A, 4B, 4C, and 6D). The three plans that were only cost effective but not Best Buys included Alternatives 2, 4D, and 6C. Alternatives 3A, 3B, 6A and 6B were not cost effective. [redacted] The CE/ICA showed that Alternative 4B would provide more benefits than Alternative 4A, but at a much higher cost. Alternative 4C would provide similar benefits to Alternative 4A with a similar cost, but Alternative 4C has a higher level of uncertainty in its risk reduction. [redacted] Alternative 5 would have no effect on risk to life safety; therefore, it was eliminated and excluded from the CE/ICA analysis.

The Recommended Plan is Alternative 4A: Construct New Flood Diversion System. Structural components of this alternative include a new diversion dam and 18-ft-diameter tunnel upstream from the existing tunnel, refurbishing the existing tunnel, extending the outfall 150 ft to take flow and debris over the road, protecting the tunnel inlet from landslide with a canopy, and improving the low flow diversion system. Non-structural components include tree removal. Alternative 4A has a project first cost of $185,225,000. The total National Economic Development (NED) cost, including the cost of LERRDs and interest during construction, is $193,007,000. The average annual OMRR&R cost for Alternative 4A is $699,000. The average annual equivalent cost is $7,504,000, with annual National Economic Development benefits of $1,869,000. The project's Benefit-Cost Ratio (BCR) is 0.25, with net annual benefits of -$5,635,000. With the approval of the NED exception waiver, the team utilized CE/ICA in combination with

NED benefits analysis to determine the Recommended Plan. [redacted]

PERTINENT DATA

Table ES 1. Project Data.

Existing Lowell Creek Diversion Features (Retained in the Future Without Project or With Project for Recommended Plan)	
Existing Diversion Dam	
Design crest elevation	Varies approx. 225.7 – 203.2 ft (NAVD88)
Crest width	5 ft
Length	450 ft
Structural height (maximum height above streambed)	25 ft
Existing Uncontrolled Dam weir/spillway	
Crest Elevation	199.0 ft NAVD88
Width	~70 ft
Maximum discharge capacity	1,700 cfs
Existing Tunnel	
Diameter & Shape	10-ft-diameter semi-elliptical horseshoe
Length	2,089 ft
Average Grade	-4.2 %
Maximum discharge capacity	Approx. 2,800 cfs
Existing Outfall	
Type	Inverted Flume
Elevation	70.5 ft (NAVD88)
Width	10 ft
Length	109 ft
New Lowell Creek Diversion Features	
New Diversion Dam	
Design crest elevation	Varies approx. 225-260 ft (NAVD88)
Crest width	5 ft
Length	500 ft
Structural height	30 ft (maximum height above streambed)
New Tunnel	
Diameter & Shape	18-ft-diameter horseshoe
Length	2,272 ft
Average Grade	-4.2 %
Maximum discharge capacity	Approximately 8,500 cfs
New Outfall	
Type	Elevated open-channel flume
Elevation at outlet	57.9 ft MLLW
Width	18 ft base and 25.5 ft top

Grade	-7.0 %
Length	150 ft

Notes: 1) All elevations given in this table are based on the 1945 design drawing elevations rounded to the nearest 10th of a ft, comparing these values with the 2006 LiDAR topographic data, which is in NAVD88, and subtracting 3.5 ft to make the 1945 elevations roughly match the 2006 LiDAR elevations. This is an approximate adjustment.
2) The hydraulic height value given is based on the 2006 LiDAR data.
3) The Source of data is the 2012 inundation report and original contract drawings (USACE 2012).

Table ES 2. Economics Summary Table

Summary of Total Project Costs and Benefits	
Item	Total ($)
Total Average Annual Equivalent Cost	$7504,000
Total Average Annual Equivalent Benefit	$1,869,000
Net Annual NED Benefits	($5,635,000)
Benefit-Cost Ratio	0.25

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Note: “*” indicates a NEPA required Section

TABLES

FIGURES

APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

AALL	Average Annual Life Loss
AAD	Average Annual Damage
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
AEP	Annual Exceedance Probability
AHRS	Alaska Heritage Resources Survey
APE	Area of Potential Effect
APF	Annual Probability of Failure
ASA(CW)	Assistant Secretary of the Army (Civil Works)
BCR	Benefit-Cost Ratio
BCERE	Baseline Cost Estimates for Real Estate
BF	Bulking Factor
C	Celsius
CAA	Clean Air Act
CARSWG	Coastal Assessment Regional Scenario Working Group
CDP	Census Designated Place
CE/ICA	Cost-Effectiveness and Incremental Cost Analysis
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
CSVR	Content-to-Structure Value Ratio
CWA	Clean Water Act
cy	Cubic Yards
DSAC	Dam Safety Action Classification
DLWD	Department of Labor and Workforce Development
E	Exponent
ECB	Engineering and Construction Bulletin
EFH	Essential Fish Habitat
EA	Environmental Assessment
EAD	Expected Annual Damage
EGM	Economic Guidance Memorandum
EM	Engineer Manual
EPA	Environmental Protection Agency
EQ	Environmental Quality
ER	Engineer Regulation
EJ	Environmental Justice
EO	Executive Order
ERDC	USACE Engineer Research and Development Center
ESA	Endangered Species Act
Etc.	Et Cetera
F	Fahrenheit
FEMA	Federal Emergency Management Agency
FONSI	Finding of No Significant Impact
FWCA	Fish and Wildlife Coordination Act
FWOP	Future Without Project
FWP	Future With Project

ft	Foot/Feet
FY	Fiscal Year
GMSL	Global Mean Sea Level
H	Horizontal
HEC-RAS	Hydraulic Engineering Center's River Analysis System
HQUSACE	Headquarters, United States Army Corps of Engineers
HTRW	Hazardous, Toxic, and Radioactive Waste
IDC	Interest During Construction
IDF	Inflow Design Flood
IFR/EA	Integrated Feasibility Report and Environmental Assessment
IPCC	Intergovernmental Panel on Climate Change
KFNP	Kenai Fjords National Park
LERRD	Lands, Easements, Rights of Way, Relocations, and Disposal Area
LiDAR	Light Detection and Ranging
LMSL	Local Mean Sea Level
MBTA	Migratory Bird Treaty Act
$\mu g/m^3$	Micrograms per cubic meter
M	Million
MAP	Mean Annual Precipitation
MCE	Maximum Credible Earthquake
MDE	Maximum Design Earthquake
MLLW	Mean Lower Low Water
MMPA	Marine Mammal Protection Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level
M_w	Moment Magnitude
N/A	Not Applicable
NAVD88	North American Vertical Datum of 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NFS	Non-Federal Sponsor
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRCS	Natural Resource Conservation Service
NRHP	National Register of Historic Places
O&M	Operation and Maintenance
OBE	Operating Basis Earthquake
OHA	Office of History and Archaeology
OMRR&R	Operation, Maintenance, Repair, Replacement, and Rehabilitation
OSE	Other Social Effects
PAR	Population at Risk
PDT	Project Delivery Team
PED	Pre-Construction Engineering and Design
PFM	Potential Failure Mode
PGA	Peak Horizontal Ground Acceleration
PL	Public Law

PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
POA	U.S. Army Corps of Engineers, Alaska District
POD	U.S. Army Corps of Engineers, Pacific Ocean Division
pH	Power of Hydrogen
PPA	Project Partnership Agreement
PSHA	Probabilistic Seismic Hazard Analysis
RED	Regional Economic Development
R	Republican
RECONS	Regional Economic System (software)
REP	Real Estate Plan
ROM	Rough Order of Magnitude
RSLC	Relative Sea Level Change
SD	Standard Deviation
SHPO	State Historic Preservation Officer
SLC	Sea Level Change
SLR	Sea Level Rise
SQRA	Semi Quantitative Risk Assessment
SNOTEL	NRCS Snow Telemetry system
TSP	Tentatively Selected Plan
U.S.	United States
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
V	Vertical
VLM	Vertical Land Movement
WRDA	Water Resources Development Act

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1. INTRODUCTION

1.1 Project and Study Authority

Congress authorized this current General Investigations Study under Section 5032 of the Water Resources Development Act (WRDA) of 2007 (Public Law (PL) 110-114). Section 352 of WRDA 2020 (PL 116-260) amended the length of time United States Army Corps of Engineers (USACE) would assume long-term maintenance from 15 to 20 years. Section 5032, as amended, directs the USACE to assume long-term maintenance responsibilities for the Lowell Creek Flood Diversion tunnel until 2027, or until an alternative method of flood diversion is constructed and operational, whichever is earlier. The legislation also directs the USACE to study whether an alternative method of flood diversion at Lowell Canyon is feasible. The amended legislative language follows.

SEC. 5032. LOWELL CREEK TUNNEL, SEWARD, ALASKA

(a) LONG-TERM MAINTENANCE AND REPAIR. —

(1) MAINTENANCE AND REPAIR. — The Secretary shall assume responsibility for the long-term maintenance and repair of the Lowell Creek tunnel, Seward, Alaska.

(2) DURATION OF RESPONSIBILITIES. — The responsibility of the Secretary for long-term maintenance and repair of the tunnel shall continue until an alternative method of flood diversion is constructed and operational under this section or 20 years after the date of enactment of this Act, whichever is earlier.

(b) STUDY. — The Secretary shall conduct a study to determine whether an alternative method of flood diversion in Lowell Canyon is feasible.

(c) CONSTRUCTION. —

(1) ALTERNATIVE METHODS. — If the Secretary determines under the study conducted under subsection (b) that an alternative method of flood diversion in Lowell Canyon is feasible, the Secretary shall carry out the alternative method.

(2) FEDERAL SHARE. — The Federal share of the cost of carrying out an alternative method under paragraph (1) shall be the same as the Federal share of the cost of the construction of the Lowell Creek tunnel.

USACE implementation guidance for the authority specific to the study portion states:

At such time as funds are appropriated for such work, the District should conduct a reconnaissance study to determine whether an alternative method of flood diversion in Lowell Canyon is feasible in accordance with procedural guidance contained in ER 1105-2-100. If the reconnaissance study determines that there is at least one feasible solution, once funds are appropriated for such work, the District should conduct a feasibility study in accordance with current budgetary policy and procedural guidance contained in ER 1105-2-100 for projects authorized without a report. The costs of the feasibility study will be shared 50 percent Federal and 50 percent non-Federal pursuant to a Feasibility Cost Sharing Agreement. The feasibility report will be submitted to the POD RIT for policy compliance review by HQUSACE and approval by the Secretary.

Upon approval of a report that documents a feasible alternative to flood diversion in Lowell Canyon and receipt of Federal funding for construction of such alternative, a project partnership agreement (PPA) addressing design and construction of the approved plan may be executed in accordance with the current guidance on the preparation of, approval, and execution of PPAs. The design and construction of the approved plan shall be accomplished at Federal expense, and the non-Federal sponsor shall provide, at no cost to the Government, all lands, easements, and rights-of-way.

Paragraph (b) of Section 5032, as amended, states "The Secretary shall conduct a study to determine whether an alternative method of flood diversion in Lowell Canyon is feasible." This language could be interpreted as restricting the recommendation to diversion-only alternatives without seeking new authorization. While the study did consider a full suite of flood risk management measures in accordance with policy, it found diversion options most effective based on reduction of life loss.

1.2 Scope of the Study

This study evaluates the feasibility and environmental effects of implementing an alternative method of flood diversion at Lowell Creek in Seward, Alaska. The USACE Engineer Regulation (ER) 1105-2-100, "Planning Guidance Notebook," defines the contents of feasibility reports for flood risk management (USACE 2000). ER 200-2-2, "Procedures for Implementing NEPA," directs the contents of environmental assessments. This document presents the information required by both regulations as an Integrated Feasibility Report and Environmental Assessment (IFR/EA). It also complies with the Council on Environmental Quality regulations for implementing the National Environmental Policy Act (NEPA, 42 U.S.C. 4321 et seq.).

The Alaska District bears primary responsibility for conducting studies for flood risk management improvements at Lowell Creek in Seward, Alaska. The analyses conducted for this study were made possible with assistance from many individuals and agencies, including the City of Seward, Kenai Peninsula Borough, the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Alaska Department of Fish and Game (ADFG), Alaska Department of Environmental Conservation (ADEC), Alaska Department of Natural Resources, Alaska Office of History and Archeology (OHA), and many members of the interested public who contributed information and constructive criticism to improve the quality of this IFR/EA.

1.3 Non-Federal Sponsor (NFS)

The NFS for this project is the City of Seward.

1.4 Congressional District

The study area is in the Alaska Congressional District, which has the following Congressional delegation:

Senator Lisa Murkowski, Republican (R);

Senator Dan Sullivan, (R); and

Representative Don Young, (R).

1.5 Related Reports and Studies

1.5.1 USACE Reports

Letter from the Secretary of War Transmitted to Congress (1937) – This letter provides the basis of design and historical information about Lowell Creek and the previous flood control project.

Operation and Maintenance Manual (1946) – The District completed the Operation and Maintenance Manual with these responsibilities turned over to the city in 1946.

Historical Data: *Flood Control Project on Lowell Creek at Seward, Alaska (1949)* – This provides a brief overview of the early history of Lowell Creek and the Flood Control Project.

Lowell Creek Dam, Phase I Inspection Report, National Dam Safety Program (1978) – This report was part of a nationwide effort to ensure implementation of the National Dam Safety Program. No critical deficiencies were discovered.

Flood Damage Reduction Revised Reconnaissance Report, Seward, Alaska (1992) – This report presents a reconnaissance level study of the possibility of modifying or replacing the Lowell Creek Flood Project at Seward. Based on the findings in this report, a feasibility study is recommended.

Seward Area Rivers: Flood Damage Prevention Interim Reconnaissance Report (1994) – This report presents a reconnaissance level study of the rivers surrounding the Seward area.

Position Paper: Scoping the Initial Project Management Plan for Lowell Creek at Seward, Alaska (1995) – This paper argues that only alternatives that provide an emergency spillway for flows that exceed the tunnel capacity be considered in the feasibility report.

Reconnaissance Report Modifications to Completed Project Lowell Creek, Seward, Alaska (2007) – This report presents a reconnaissance level study of the Lowell Creek tunnel and diversion dam at Seward, Alaska, including deficiencies inherent in the original project, ramifications of the deficiencies, and proposed solutions.

Lowell Creek Dam, Seward, Alaska, Interim Risk Reduction Measures Plan (2011) – This assessment classified the Lowell Creek Dam as a Dam Safety Action Classification (DSAC) III dam. This classification places the Lowell Creek Dam in a category of “high priority,” which is considered conditionally unsafe, requiring immediate attention to reduce risk from potential failure modes. Implementation of seven interim risk reduction measures were recommended to reduce the probability of potential uncontrolled debris flows through Seward.

Seward, Alaska, Planning Assistance to States Flood Risk Management (2011) – This report provides flood mitigation information including risk assessment and hydrologic, economic, and environmental elements that will assist in the long-term management of water resources development in the vicinity of Seward, Alaska. Although Lowell Creek was not included in the analysis, the report provides an overview of flooding threats persistent throughout Seward.

Lowell Creek Inundation Study, Seward, Alaska (2012) – This report was prepared to assist with an emergency action plan for the City of Seward during extreme flooding scenarios in the Lowell Creek Watershed. Four downstream flooding scenarios were modeled: 100-Year Flood with the complete failure of the Lowell Creek Tunnel, Probable Maximum Flood (PMF) with the tunnel operational, PMF with debris dam surge release, and PMF with an uncertain alluvial fan flow path.

Lowell Creek Flood Damage Reduction, Trip Report; Lowell Creek Tunnel Inspection (2013) – This report documents the 2013 inspection done on the Lowell Creek tunnel by USACE.

Lowell Creek Tunnel, Seward, Alaska, Operations, and Maintenance Letter Report (2015) – This report presents a summary of the repair and maintenance that has been done on the Lowell Creek Tunnel in Seward, Alaska, and the associated costs of these activities. This report also outlines the estimated extent of the long-term maintenance and repair that will be required at the Lowell Creek Tunnel for the 15 years after the enactment of WRDA.

In addition to the above reports, there are project inspection reports and letter reports documenting project maintenance and repairs.

1.5.2 Reports by Others

CH2M HILL. 1979. Reconnaissance Feasibility Study: Hydroelectric Potential on Lowell Creek.

Jones, Stanley H., and Chester Zenone. 1988. Flood of October 1986 at Seward, Alaska. Water-Resources Investigations Report 87-4278, U.S. Geological Survey.

Kenai Peninsula Borough. 2013. Seward/Bear Creek Flood Service Area: Flood Hazard Mitigation Plan. June.

1.6 Study Location

The Lowell Creek Flood Diversion System is located in Seward, Alaska, 125 miles south of Anchorage by the highway. The City of Seward, with a 2019 population of 2,545, lies immediately below the flood diversion system at the head of Resurrection Bay, a deep fjord about 25 miles long on the north shore of the Gulf of Alaska, on the Kenai Peninsula. The bay in the vicinity of Seward is 2–3 miles wide and about 500 ft deep. The water is deep immediately offshore except at the head of the bay and at the toe of alluvial fan-deltas that have formed at the mouths of steep-gradient streams tributary to the bay. The glaciated Kenai Mountains rise steeply above Resurrection Bay and the valley of the Resurrection River, with the highest peaks on the west side of the bay and river reaching elevations of 4,000 to 5,000 ft above sea level. Seward has one of the two ice-free ports in Alaska with road and rail connections to the state’s interior.

The existing Lowell Creek Flood Diversion System project was authorized by the Flood Control Act of 1936 (PL 74-738) with an authorized project purpose of flood risk management. The flood diversion system reroutes Lowell Creek through Bear Mountain and diverts flows to Resurrection Bay prior to those flows entering Seward (Figure 1).

Lowell Creek passes through Lowell Canyon, a rocky, rugged canyon near Seward. The canyon is bordered by steep hillsides and talus-covered slopes. The stream, approximately 3 miles long above the tunnel, drains an area of about 4.02 square miles. Ground cover in the canyon is sparse (30%), consisting of low-growing shrubs and patches of isolated spruce and cottonwood trees in the lower portion of the basin. Small glaciers in the upper extent of the basin provide an impervious area of about 10% of the watershed. Lowell Creek has a gradient of 1,000 ft per mile and transports large amounts of debris, often including boulders, to a one-half cubic yard in volume. On average and using all available data, the team estimated that stream flow carries over 25,000 cubic yards (cy) of rock and other debris through the tunnel each year. Neither the original creek flow path nor the current flow path of the stream have levees downstream, and there are no dams upstream or downstream of the Lowell Creek constructed features.

Figure 1. Location of Seward, Alaska

1.6.1 Specific Location Considerations

1.6.1.1 Alluvial Fan Flooding

A majority of Seward is located upon the broad alluvial fan formed at the mouth of Lowell Canyon. Alluvial fans are depositional landforms located at the base of mountain ranges where a steep mountain stream emerges onto lesser valley slopes. Alluvial fans are usually conical or fan-shaped in plan view. Prior to construction of the diversion dam, the most recent flow path of Lowell Creek was down Jefferson Street through the middle of town (Figure 2). Hydrologically, flooding on alluvial fans is characterized within two generally defined areas. The upper area of the alluvial fan contains a section where the flow path can generally be determined with some degree of certainty. This area is subject to erosion and deposition, but a relatively stable flow path remains during floods. Downstream from this area, alluvial fan flooding is characterized by flow path uncertainty so considerable that this uncertainty cannot be set aside in a realistic assessment of flood risk or the reliable mitigation of the hazard. Flood flows will contain floating debris, suspended sediment, and a portion of the Lowell Creek bedload in addition to debris and sediment that is entrained downstream from the diversion dam. Debris could include material from damaged houses and other materials swept away from people's yards and driveways.

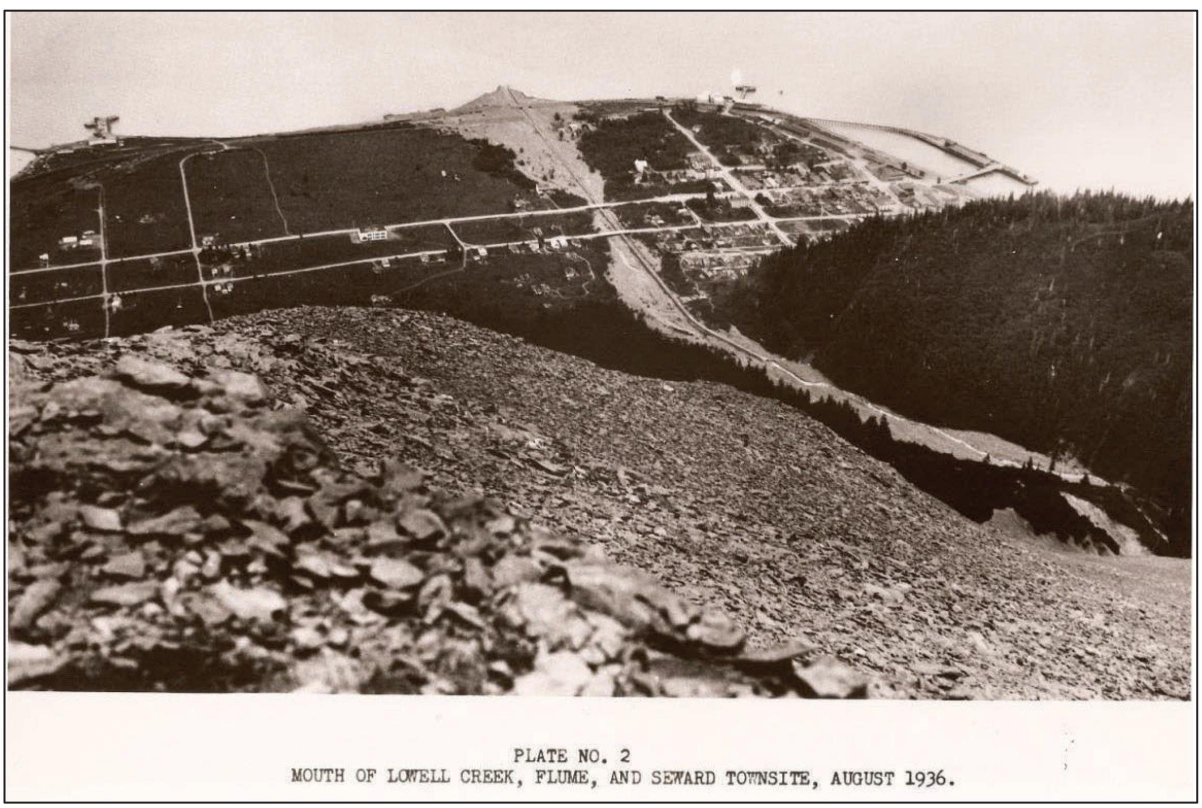

Figure 2. Oblique Aerial View of Seward (1936), Looking Downstream from Mt. Marathon.

1.6.1.2 Landslide Potential and Surge Release Flooding

The topography around Seward, described in Section 3.1.2, provides an area prone to both landslides and debris-laden flows within the streams of the area (Figure 3). In the figure, the Large "A"s indicate a very high potential for landslides (Jones and Zenone 1988). The Circle is Lowell Creek and Lowell Canyon is crosshatched upon magnification.

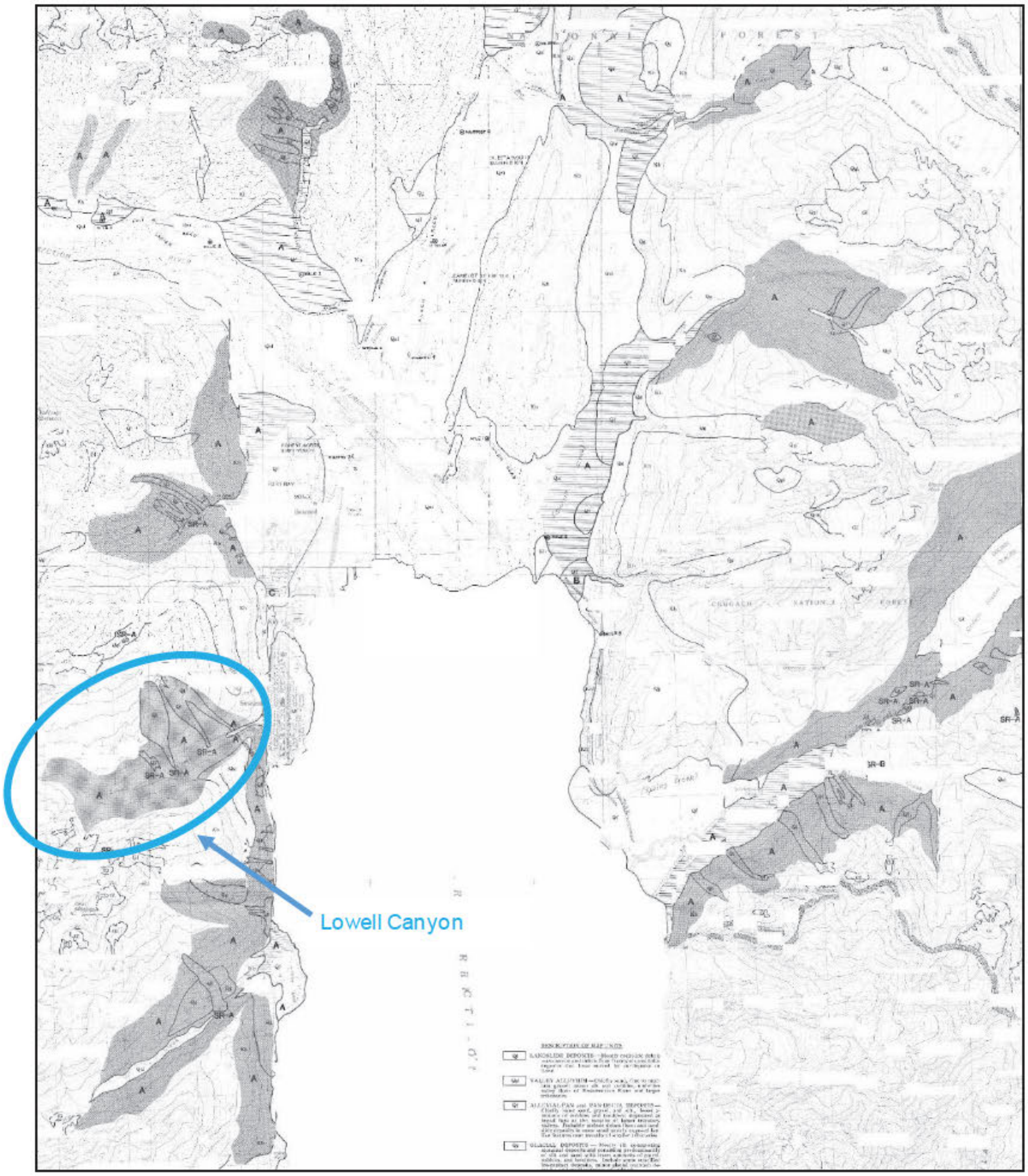

Figure 3. USGS Map Showing the Areas of Landslides Potential (Gray Shaded Areas) and Debris-Laden Flows (Crosshatched Areas).

The team has identified the potential for landslides which can form temporary dams as a key consideration for the study. These dams can subsequently be breached and release a surge of water and debris toward the tunnel and diversion dam. [redacted] Lowell Creek's old drainage paths deposited these sediments as an alluvial fan delta, upon which the City of Seward was built. There is geological evidence of historical landslides in Lowell Creek Canyon (Figure 4), and multiple modern instances of landslide or avalanche activity. There is also evidence of similar landslide-driven surge events on surrounding streams.

During the October 1986 flood, five other Seward-area streams had landslide debris blockages resulting in surge releases when the blockages were breached. Such surge releases may be an order of magnitude above non-surge effected flood flows in terms of water and debris volume and associated consequences. For this study, a surge factor was elicited based on the surges produced by the other streams during the 1986 event. USGS investigations following the 1986 flood concluded, based on the geomorphology of Lowell Creek, there was a high potential for similar landslide-induced surge release flooding on Lowell Creek (Jones and Zenone 1988). Such a surge release would subject the flood diversion structure to elevated stream flows and debris loads, increasing the chance of an overflow with or without a tunnel blockage. A Probable Maximum Flood (PMF) compounded with a surge release event is estimated to produce stream flow of up to 19,000 cfs, far exceeding the capacity of the existing system. [redacted]

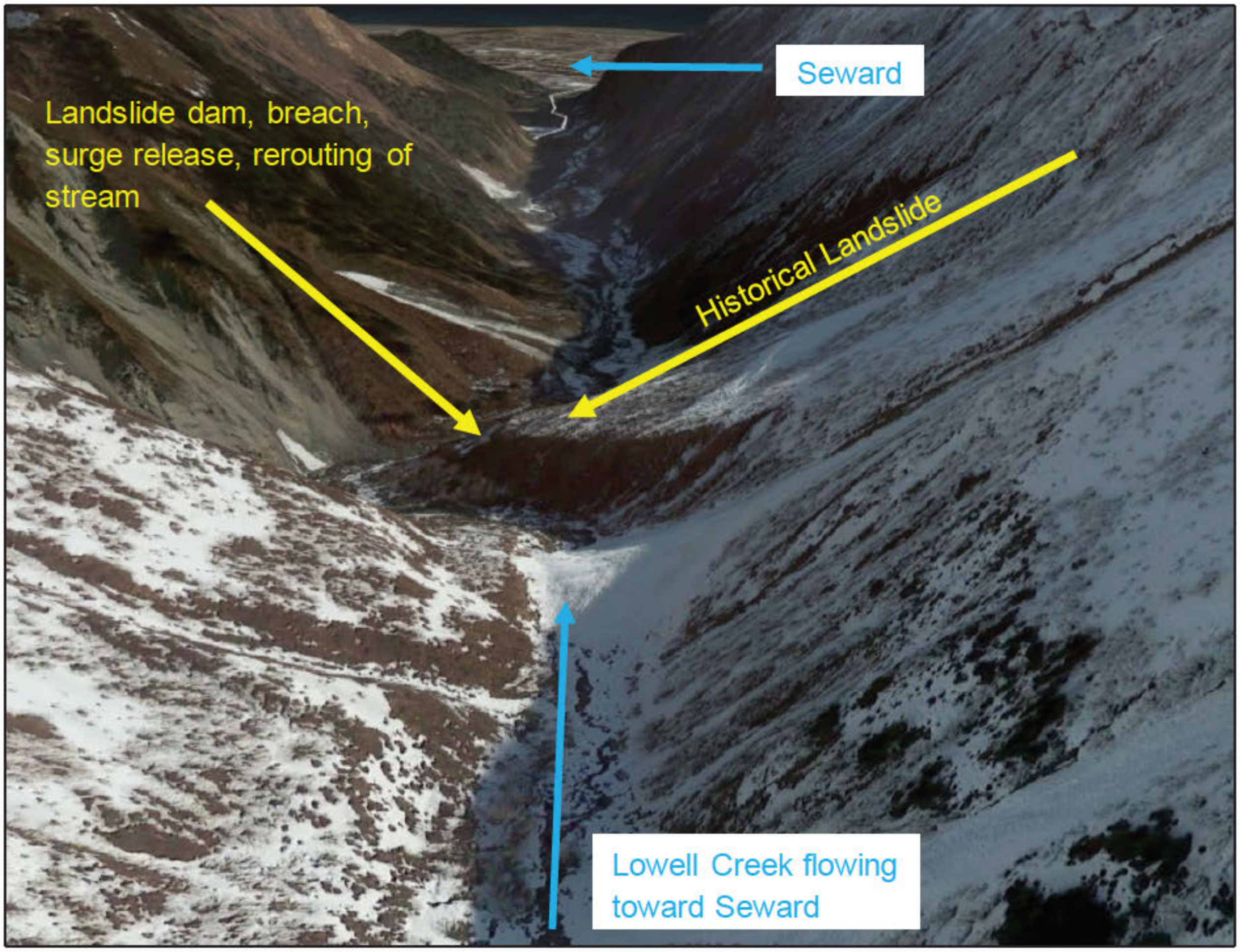

Figure 4. Historical Landslide in the Lowell Creek Watershed

1.6.2 Historical Background

Historically, Lowell Creek flowed out of its canyon and down its natural channel through present-day downtown Seward along Jefferson Street. 1917 produced the most damaging flood before the current system was constructed. The 1917 flood brought down enough debris to bury some buildings in Seward past the second floor (Figure 5). In 1928 the city built an 8-ft-high rock and timber dam at the mouth of Lowell Canyon with a 12-ft by 7-ft timber flume measuring 3,300-ft-long running down Jefferson Street. Flooding in 1932 almost destroyed the flume. The 1935 flood filled the entire flume with debris and sent debris-laden waters into Seward, damaging the railroad, the power plant, and bridges among other structures. The flume also partially filled and flooded the town in 1934 and 1936 though not as severely. USACE built the current system on assumptions of a maximum flow of 2,000 cfs and an estimate of only 27,000 cy deposited annually. The 1986 flood proved both assumptions incorrect.

Figure 5. Flood of 1917 with Building Buried to Second Story in Debris.

USACE completed the current Lowell Creek Diversion System and turned the system over to the City of Seward in 1946 for operations and maintenance. Per Executive Order (EO) 8330, the land is encumbered by the Federal government for the purposes of flood control. According to the 1937 Letter from the Secretary of War to Congress, a large part of the justification for the project lay in the damages and potential damages to government interests in Seward, particularly the railroad and power plant. The current system includes the diversion channel, diversion dam (no storage), emergency spillway, a 10-ft-diameter 2,070-ft-long tunnel, and an outfall. Due to the significant scouring effect of the sediment load through the tunnel, USACE has periodically performed repairs.

1.6.3 Existing Infrastructure and Facilities

The main components of the existing Lowell Creek Flood Diversion System include a diversion dam (no storage), emergency spillway, a 10-ft-diameter 2,070-ft-long tunnel, and an outfall (Figure 6). Appendix C: Hydraulic and Structural Design includes more detailed drawings depicting the key features of the existing system and the proposed project. Table 1 presents the pertinent data for these existing components.

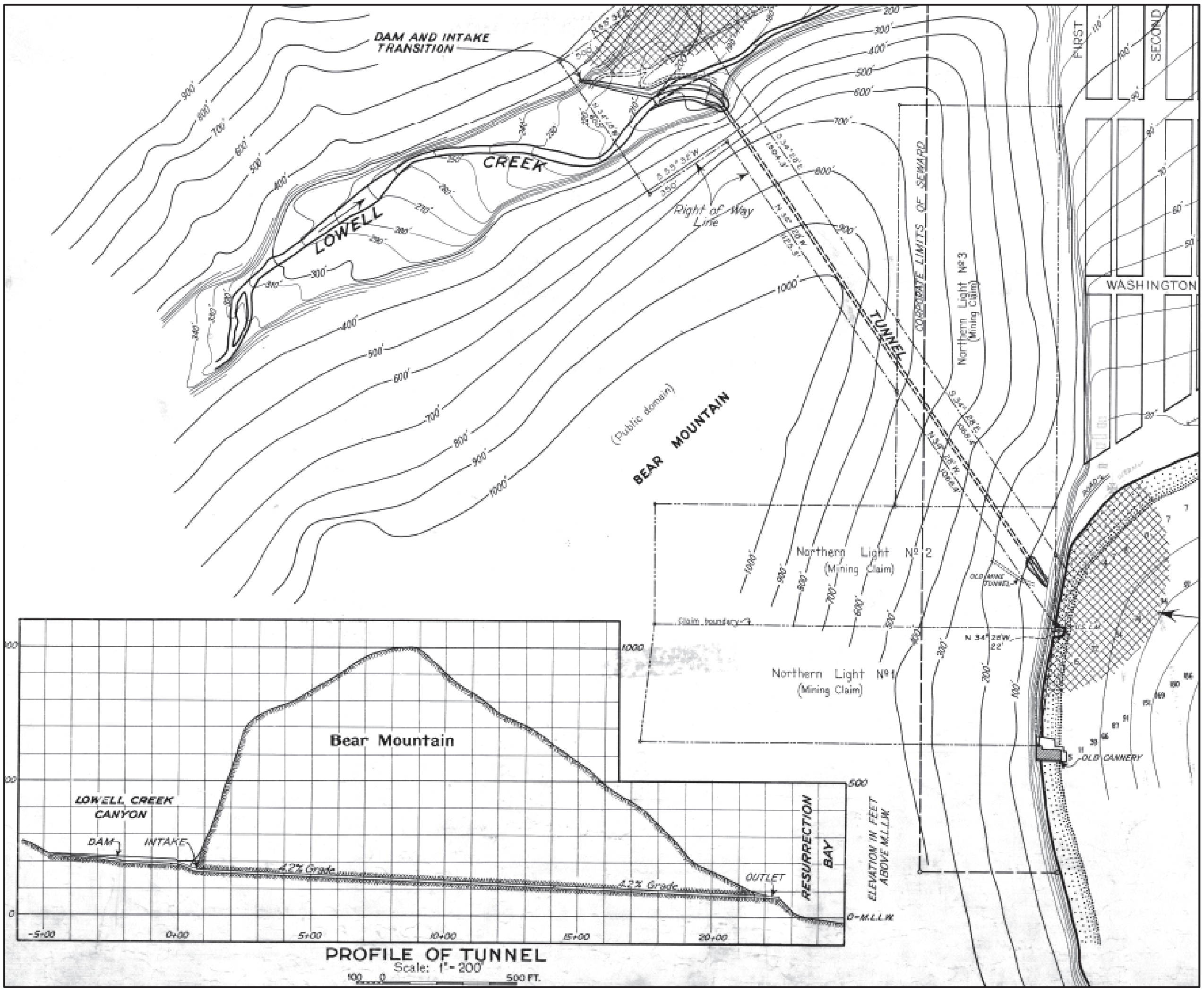

Figure 6. Existing System Overview

Table 1. Existing Lowell Creek Flood Diversion System Components.

Lowell Creek Diversion Dam	
Type	Diversion Dam
Design crest elevation	Varies approx. 225.7 – 203.2 ft (NAVD88)
Crest width	5 ft
Length	450 ft
Structural height (maximum height above streambed)	25 ft
Lowell Creek Dam Emergency Spillway	
Type	Uncontrolled weir
Crest Elevation	199.0 ft NAVD88
Width	~70 ft
Maximum discharge capacity	1,700 cfs
Lowell Creek Tunnel	
Type	Tunnel
Size	10-ft-diameter, semi-elliptical/horseshoe-shaped
Length	2,089 ft
Average Grade	-4.2 %
Maximum discharge capacity	Approx. 2,800 cfs
Lowell Creek Tunnel Outfall	
Type	Inverted Flume
Elevation	70.5 ft (NAVD88)
Width	10 ft
Length	109 ft

Notes:
1) All elevations given in Table 1 are based on the 1945 design drawing elevations rounded to the nearest 10th of a ft, comparing these values with the 2006 Light Detection and Ranging (LiDAR) topographic data, which is in NAVD88, and subtracting 3.5 ft to make the 1945 elevations roughly match the 2006 LiDAR elevations. The adjustment is approximate.
2) The hydraulic height value given is based on the 2006 LiDAR data.
3) The Source of data is the 2012 inundation report and 1945 design drawings.

1.6.3.1 Reservoir Data

No reservoir data is available for the system as it does not retain a pool, and no flow gage is present at the inlet to obtain flow data. Reports from the 1986 event indicate that the storage area has been near full (within 0.7 ft of spillway) in the past.

1.6.3.2 Dam

The diversion dam consists of a 450-ft-long rock-filled embankment with a crest elevation that varies from 203.2 to 225.7 ft, the North American Vertical Datum of 1988 (NAVD88), and a maximum height of 25 ft. The dam design diverts water into the tunnel but does not impound water for long periods. The upstream face has a one horizontal to one vertical (1H:1V) slope and is lined with a reinforced concrete slab. The downstream face has a two horizontal to one vertical (2H:1V) slope and is lined with grouted rock fill. Specifications for the embankment rock fill indicate a range in size from 0.5 cubic ft to 1 cubic yard, of which not less than 25% are pieces of 5 cubic ft or more in volume. Rock chips and spalls are included only to the extent necessary to fill the voids between the larger stones. The dam contains no rock slabs having an average thickness of less than

25% the average width. The left abutment of the dam is against the canyon wall, with the rock cut to a four horizontal to one vertical (4H:1V) slope and a concrete slab attached with dowels against the rock face. The dam's right abutment dam ties into the tunnel entrance, which is cast into the rock of Bear Mountain. The dam also features a 12-inch drainpipe intended for use during maintenance operations. However, debris has plugged this pipe and it is not usable. A typical cross-section of the dam is given in Figure 7.

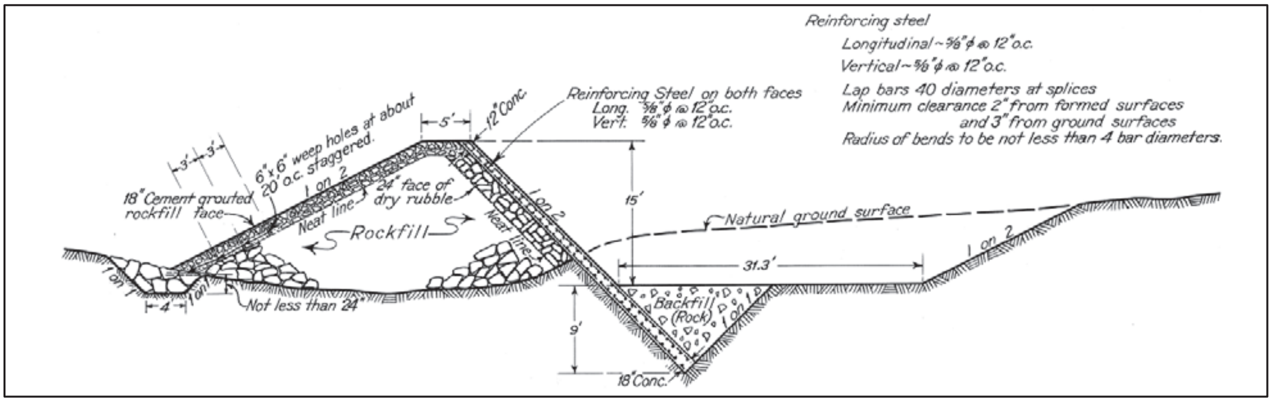

Figure 7. Typical Embankment Cross-Section.

The City of Seward placed a water line under the left abutment in 1985. During the installation of this water line, a section of the dam was removed to facilitate construction. During the rebuilding of this dam section, the City used fill soil as core material for the dam. The compaction requirements required for the backfill material are unknown, however, due to the sloping crest profile, the elevation of this location is higher than the dam crest in other locations, and therefore unlikely to be loaded.

1.6.3.3 Spillway

The spillway is a 70-ft-wide notched section of the dam lowered to a crest elevation of 199.0 ft NAVD88. The emergency spillway is an uncontrolled weir with a discharge capacity of 1,700 cfs. The downstream side of the dam has a slope of three horizontal to one vertical (3H:1V) at the spillway and is protected by grouted rock fill. No channel exists for water flowing over the spillway to enter and the water would flow directly into downtown Seward within a few minutes of overtopping the dam. Such flow would immediately impact a retirement center and the Seward Hospital as they are among the first structures downstream. A PMF event would have catastrophic damages. Appendix B: Geotechnical provides additional details.

1.6.3.4 Floodway

The Lowell Creek Flood Diversion System functions only to divert water into the Lowell Creek Tunnel and provides essentially no floodwater storage. The project also does not include a channel downstream from the spillway to convey water in the case of a tunnel blockage or flow events exceeding the tunnel flow conveyance capacity. Once passing over the spillway, flood water would flow unimpeded down gradient through a highly developed area of Seward with as many as 298 structures at risk (Figure 8). Prior to the current system, the original channel flowed down what is now Jefferson Street. Flood flows would begin on Jefferson Street, but flows would spread over the populated alluvial fan. Peak water levels would reach populated areas of Seward with essentially no warning time. In high flow events or tunnel blockage, the diversion dam is expected to be overwhelmed resulting in all flow and debris reaching the town in just a few minutes. Effective evacuation would be very difficult due to this limited warning time and uncertain flow paths on the alluvial fan.

[redacted]

1.6.3.5 Tunnel

The tunnel consists of a 10-ft-high horseshoe-shaped tunnel through Bear Mountain that is 2,089-ft-long, with an average grade of -4.2% with a sharp drop at the intake transition; accelerating water to approximately 35 cfs and facilitating debris movement through the tunnel. USACE constructed the tunnel with drill and blast techniques. Timbers and lagging supported the bedrock until the placement of the tunnel liner. It is likely crews left the timber supports in place during liner construction and performed no contact grouting after the liner was installed. The tunnel is lined with concrete throughout and 40-pound railroad rails are welded to the channel cross ties embedded in the invert from the original tunnel armoring. Appendix B: Geotechnical includes Sheet 2 of the 1945 original drawings which shows design details. At the intake, the lining of the outside curve side of the tunnel also includes rails. Subsequent tunnel repairs filled the spaces between rails with concrete. The tunnel capacity has been computed to 2,800 cfs based on the assumption that the spillway crest is wholly filled.

1.6.3.5.1 Tunnel Maintenance and Repair Needs

Since completion of the original project in 1940, USACE and the City of Seward have conducted repairs to the tunnel because of damage from regular wear or high flow events. The first major repair of the tunnel took place in 1945. Tunnel repairs were made in 1968, 1980, 1984, 1988, 1991, 2003, and 2017. The tunnel continues to deteriorate due to continual wear and periodic high flow events. Repair and maintenance can only be done during the winter low-flow periods. Although winter construction makes the work more complicated, it is the difficulty of dealing with occasional higher than normal flows and the short duration of the low-flow season that limits what can be accomplished in any given construction season. Repairs in 2017 included repairs to a large scour hole in the tunnel floor that reached bedrock and was approximately 30 ft long (Figure 9); however, all the recommended repairs to the tunnel could not be completed during the 2017 construction season. Table 2 provides a summary of repair activities and costs since the original construction was completed.

Figure 9. Large Scour Hole in Floor of Tunnel Repaired During 2017 Repairs.

Table 2. Lowell Creek Flood Diversion System Repair Activities and Costs.

Date	Respon-sibility	Repair	Cost	Costs in 2020 Dollars (a)
Annual	USACE/City	Annual Tunnel Inspection Trip and Report	$10,000 each year	$10,000 each year
1945	USACE/City	Rails welded to steel channel crossties and finished with concrete to complete project.	Unknown	
Up to 1978	USACE	PL 84-99 authorized repairs performed to replace loose rails in the floor and tunnel walls. Rails welded to sole plates and concrete lining between the floor rails was replaced.	$447,000 (b)	$1,800,000
1980	City	All loose rails removed from tunnel by the City of Seward.	Unknown	
1984	City	Loose rails removed and replaced, concrete placed between invert rails, cover of Anvil Top placed over concrete between invert rails, sidewall rails repaired at tunnel entrance. All protective rails in the middle third of the tunnel and the outfall plume section were removed due to degraded conditions. New concrete was not placed in this area due to lack of funding and the end of the low flow period.	$1,700,000 (c)	$4,452,000
1988	USACE	Alaska District performs emergency repairs under PL 84-99. Funding was spent filling one large hole in the tunnel floor and a few other adjacent holes. Lack of funding and the end of the low flow period prevented any other work from being done.	$512,000	$1,239,000
1991	USACE	Alaska District performs repairs under PL 84-99. Repairs included filling invert holes with concrete and installing silica fume concrete over the invert.	$421,000	$915,000
2003	USACE	The Alaska District performs one-time emergency repairs as authorized by Section 510 of WRDA 2000. Repairs included replacement of ten rails in the ogee section and the entire invert was brought up to the original finish grade with 10,000 psi silica fume concrete.	$1,935,000	$3,176,000
2017	USACE	The Alaska District performs repairs under WRDA 2007. Repairs included removal of loose concrete and placement of new 10,000 psi silica fume concrete between rails at the tunnel intake transition and intake portal crown and the placement of mass concrete, new rails and 10,000 psi silica fume concrete at a sidewall and floor cavity.	$3,821,000	$4,078,000
2018	USACE	The Alaska District continues repairs under WRDA 2007. Repairs included bringing 2,000 ft of tunnel invert that was significantly eroded back to the original invert profile with 10,000 psi silica fume concrete.	$4,371,000	$4,578,000
Total	**USACE/City**	**Total Without Annual Inspection Expense**	**$13,207,000**	**$20,238,000**

Notes:
(a) Costs adjusted to 2020 dollars using Engineer Manual (EM) 1110-2-1304 (30 Sep 19), using the Yearly Cost Indexes by Cost-Work Breakdown Structure Feature Code. The Feature Code used was 09, Channels and Canals.
(b) Detailed annual project cost information is not available before 1978. The costs shown for this repair are all the funds expended by the USACE prior to 1978.
(c) Includes $1,500,000 for construction, $226,600 for design, and $20,000 for engineering during construction

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1.6.3.6 Outfall

The tunnel discharges to an outfall which consists of a trapezoidal concrete flume 10 ft wide at the bottom and 109 ft long. The flume invert is 70.5 ft NAVD88, allowing for the accumulation of debris that is carried through the tunnel. The flume exits over a near-vertical rock cliff. At the toe of the cliff, the debris forms a creek channel, which continues about 500 ft to tidewater. A two-lane bridge crosses the channel about 100 ft from the toe of the mountain.

1.6.3.6.1 Debris Management

The outfall conditions at the end of the tunnel cause flooding and major maintenance costs for the Department of Public Works of the City of Seward. Each year stream flow carries approximately 25,000 cy of rock and other debris through the tunnel. One flood event in the fall of 2012 generated an estimated 60,000 cy of debris. During major flooding, the deposition of large quantities of debris effectively forms an alluvial fan at the outfall, bringing debris and floodwaters into contact with adjacent buildings and infrastructure. Infilling from the sediment has resulted in increased need for facilty owners to dredge the adjacent fisheries dock and Alaska SeaLife Center dock. The City of Seward, using heavy equipment, pushes the material into the bay or removes it from the site during the actual flooding event. Such activities put equipment operators and other personnel at extreme risk (Figure 10 and Figure 11). Removal of this material is not desirable as the State of Alaska charges a royalty on the material if it is removed from the outfall area. Sediment discharged from the tunnel has buried the Lowell Point Road Bridge, leading to both repair and replacement as a direct result of the debris-laden floodwaters. Damage associated with debris has happened even without the flood volumes that are of greatest concern for property damage and loss of life. The city spends an estimated $758,000 annually managing debris during flood events.

Figure 10. Heavy Equipment Removing Sediment from Tunnel Outfall During 2012 Flood.

In October 2006, a typhoon remnant brought 9–15 inches of rain to Seward over the course of 48 hours. The resultant outflow from the tunnel placed 15 ft of debris atop the Lowell Creek Bridge. Lowell Point residents had to rely on water transportation to get into town for three days while city workers cleared the bridge. Water flows from the outfall joined with tidal water to flood the adjacent shellfish hatchery with water and bury it in gravel. The City of Seward's sewage treatment facility was flooded, and the freshwater pump house belonging to the Alaska SeaLife Center was destroyed. City utility lines were also damaged (Kenai Peninsula Borough 2013).

In July 2009, storm-driven tides and heavy rain wreaked havoc on the city waterfront. Lowell Point Road was closed due to gravel overwhelming the Lowell Creek Bridge and water running across the approaches (Figure 11). Lowell Point Road is the only road in and out of Lowell Point community; such closures completely isolate the community until such time that debris can be cleared from the road. One event in September 2012 caused over 8 inches of precipitation which also caused high flows, again impacting the Lowell Creek Bridge and adjacent facilities with debris and high water (Figure 12).

Figure 11. Lowell Creek Bridge during 2009 Flood.

Figure 12. Tunnel Outlet Area during 2012 Flood.

2. PLANNING CRITERIA, PURPOSE & NEED FOR THE PROPOSED ACTION*

2.1 Problem Statement

The existing flood diversion system in Lowell Canyon does not adequately manage flood events and presents a risk to life, property, and critical infrastructure with little to no warning. Structures, including the hospital and senior living center, are located approximately 800 ft from the existing spillway. Overtopping or failure of the system would result in immediate inundation, risk to life and safety, and major structural damages. Additionally, during a catastrophic flood the hospital would be out of service. The road out of Seward would also likely be compromised in an extreme event with no secondary hospitals available. The tunnel has capacity to transport only relatively low flows (up to 2800 cfs) through the system and is prone to blockages from upstream debris. A higher flow event, tunnel blockage, or surge release would lead to flows going immediately into downtown Seward. A surge release, as described in Section 1.6.1.2, can discharge immense flows. In addition, debris and sediments accumulate at the area of the tunnel outfall near Resurrection Bay and threaten the bridge on the only road to the Lowell Point community. On multiple occasions, as much as 20 ft of debris has damaged, destroyed, and/or buried the bridge resulting in the isolation of the Lowell Point community. Debris and sediment also have resulted in damage to other critical infrastructure in the vicinity, including the Alaska SeaLife Center.

2.2 Purpose and Need

The purpose of the project is to determine the feasibility of an alternative method of diversion to improve the management of flows associated with Lowell Creek at Seward, Alaska and, if feasible, to implement an alternative method of diversion. The need for the project is to reduce risk and uncertainty for life loss and damages due to uncontrolled flows from Lowell Creek, which are associated with large precipitation events.

2.3 Opportunities

The project would help provide the following opportunities at Seward through flood risk management:

- Reduce outfall operations and maintenance
- Enhance advanced warning and evacuation time and capabilities
- Reduce impacts of landslide events in Lowell Canyon
- Reduce impacts on docks and businesses near the outlet
- Maintain access to roads and evacuation routes
- Reduce impacts from seismic or other events
- Allow beneficial use of removed material
- Provide ecological benefits

2.4 National Objectives

The Federal objective for water and related land resources project planning is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Water resource planning must be consistent with NED objectives and must consider engineering, economic, environmental, and social factors. The following sections describe study objectives, constraints, and opportunities which were guidelines for developing alternative plans and were used to evaluate those plans.

2.5 Study Objectives

The overarching objective of this study is to improve flood risk management at Lowell Creek in Seward and to realize any associated opportunities that may arise from doing so to improve the quality of life for the residents of Seward, Alaska.

Planning objectives for the study include the following:

- Reduce risk to public health, life, and safety from flooding of Lowell Creek to the City of Seward
- Reduce flood damages to property and critical infrastructure in the City of Seward
- Reduce the cost of emergency response and management of post-flood event cleanup

2.6 Study Constraints

Constraints are restrictions that limit the planning process related to laws, policies, and resource availability. There are no known legal constraints at this time. Additional constraints for this study include:

- Modifications must comply with Federal and state dam safety regulations, if applicable
- Tolerable Risk Guidelines are only applicable to the incremental risk and cannot be used for plan determination for this study (Planning Bulletin 2019-04 and Engineering and Construction Bulletin (ECB) 2019-15 detail the use for tolerable risk guidelines and define the risk to be considered with them as incremental risk)
- Impacts to historic properties and/or sites of cultural importance should be avoided or minimized
- Impacts to environmental resources and environmental quality should be avoided or minimized

2.7 National Evaluation Criteria

The Water Resources Council's Federal Principles and Guidelines document establishes four criteria for the evaluation of water resources projects. These criteria and their definitions are explained below.

2.7.1 Acceptability

Acceptability is defined as the viability and appropriateness of an alternative from the perspective of the Nation's general public and consistency with existing Federal laws, authorities, and public policies. It does not include local or regional preferences for particular solutions or political expediency.

2.7.2 Completeness

Completeness is defined as the extent to which an alternative provides and accounts for all features, investments, and/or other actions necessary to realize the planned effects, including any necessary actions by others. It does not necessarily mean that alternative actions need to be large in scope or scale.

2.7.3 Effectiveness

Effectiveness is defined as the extent to which an alternative alleviates the specified problems and achieves the specified opportunities.

2.7.4 Efficiency

Efficiency is defined as the extent to which an alternative alleviates the specified problems and realizes the specified opportunities at the least cost.

2.8 Study Specific Evaluation Criteria

The Assistant Secretary of the Army for Civil Works (ASA(CW)) granted approval via a memorandum dated 02 September 2020 for the team to utilize a justification based on life safety criteria under the Other Social Effects (OSE) account. A Cost-Effectiveness and Incremental Cost Analysis (CE/ICA) was conducted to support the recommendation. The CE/ICA metric for this study is reduction of risk to life safety as exemplified by the reduction in Average Annual Life Loss (AALL). [redacted]

3. BASELINE CONDITIONS/AFFECTED ENVIRONMENT*

3.1 Physical Environment

Lowell Creek passes through Lowell Canyon, a rocky, rugged canyon near Seward. The canyon is bordered by steep hillsides and talus-covered slopes. The stream, approximately 3 miles long above the tunnel, drains an area of about 4.02 square miles. Ground cover in the canyon is sparse (30%), consisting of low-growing shrubs and patches of isolated spruce and cottonwood trees in the lower portion of the basin. Small glaciers in the upper extent of the basin provide an impervious area of about 10% of the watershed. Lowell Creek has a gradient of 1,000 ft per mile and transports large amounts of debris, often including boulders up to 0.5 cy in volume. Based on available data, the team estimated that stream flow carries over 25,000 cy of rock and other debris through the tunnel each year. Neither the original creek flow path nor the current flow path of the stream have levees downstream, and there are no dams upstream or downstream of the Lowell Creek constructed features.

Seward lies at the head of Resurrection Bay, a deep fjord about 25 miles long on the north shore of the Gulf of Alaska. The bay in the vicinity of Seward is 2–3 miles wide and about 500 ft deep. The water is deep immediately offshore except at the head of the bay and at the toe of alluvial fan-deltas that have formed at the mouths of steep-gradient streams tributary to the bay. The glaciated Kenai Mountains rise steeply above Resurrection Bay and the valley of Resurrection River, with the highest peaks on the west side of the bay and river reaching elevations of 4,000 to 5,000 ft above sea level.

3.1.1 Climate

The Gulf of Alaska coast of the Kenai Peninsula has relatively mild winters and cool summers; mean winter lows range from 0 to 20 °F, while mean highs in the summer are below 60 °F. The extreme mountain relief and its effect on the coastal maritime climate cause great local variations in weather in the Resurrection Bay-Seward area. The lifting and cooling of moist air masses at the mountain fronts cause a rapid increase in precipitation with increasing elevations along the windward side of the mountains. Mean annual precipitation ranges from 67 inches at Seward to more than 100 inches in the high-elevation glaciated areas. About 40% of the total annual precipitation falls as rain from September through November. Beginning in early October, the precipitation above an altitude of 2,100 ft is usually in the form of snow. Mountain and glacier snowpack store most of this snow. Severe flooding on Lowell Creek normally mirrors the October through November rainfall period, though one known major flood occurred as late as early December. Seward averages 172 days with precipitation a year.

3.1.2 Topography

Lowell Creek drains a 4.02 square mile basin between Mount Marathon and Bear Mountain to the west of Seward (Figure 13). The mountainous terrain in the basin consists of steep slopes of loose rock. Rain falling in Lowell Canyon has a high runoff percentage and a low time of concentration due to the steep slopes of the basin and the rocky nature of the material.

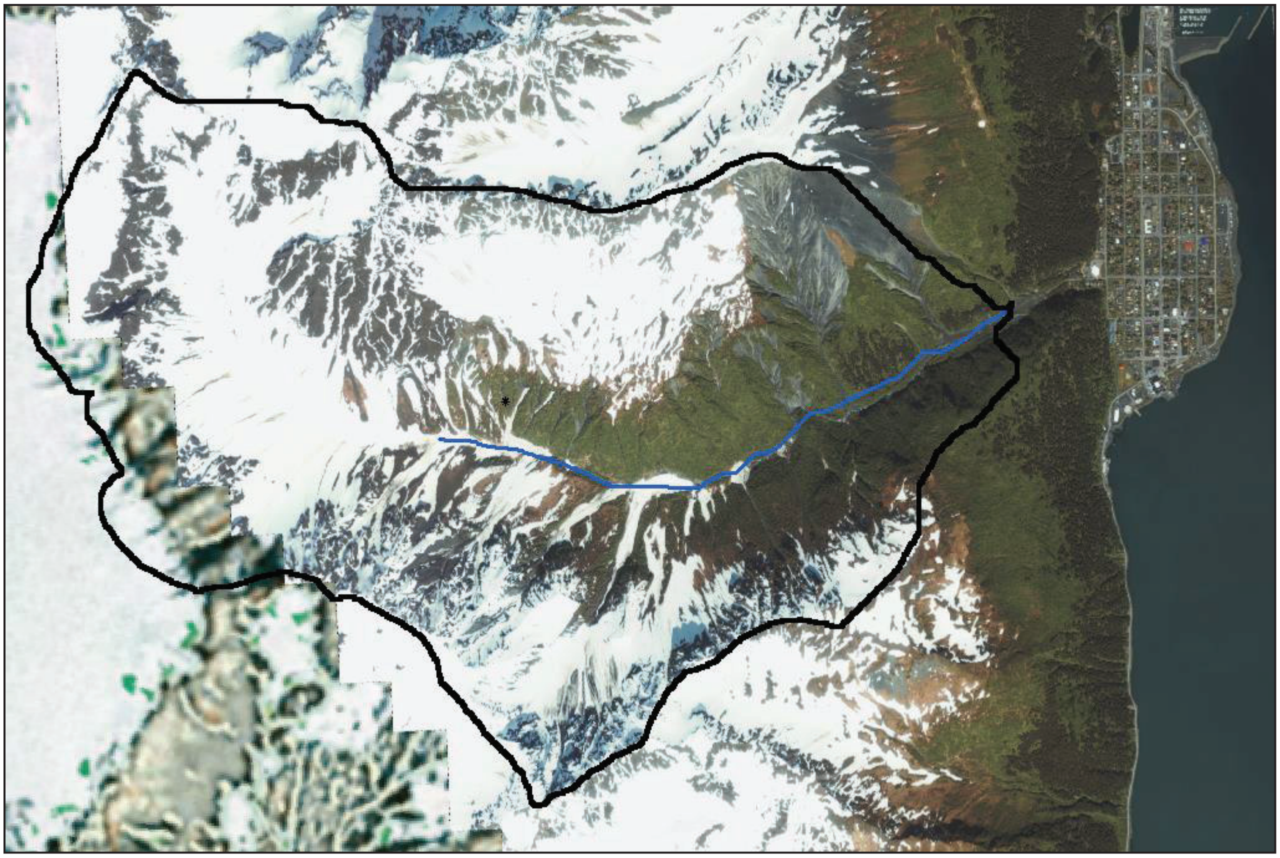

Figure 13. Lowell Creek Drainage Area.

Several creeks in the vicinity of Seward drain into Resurrection Bay (Figure 14); most notable for this study is Spruce Creek. Spruce Creek provided data which the team translated as a proxy for the Lowell Creek hydrologic analysis. Additional detail on this analysis is discussed in Appendix C: Hydraulic and Structural Design.

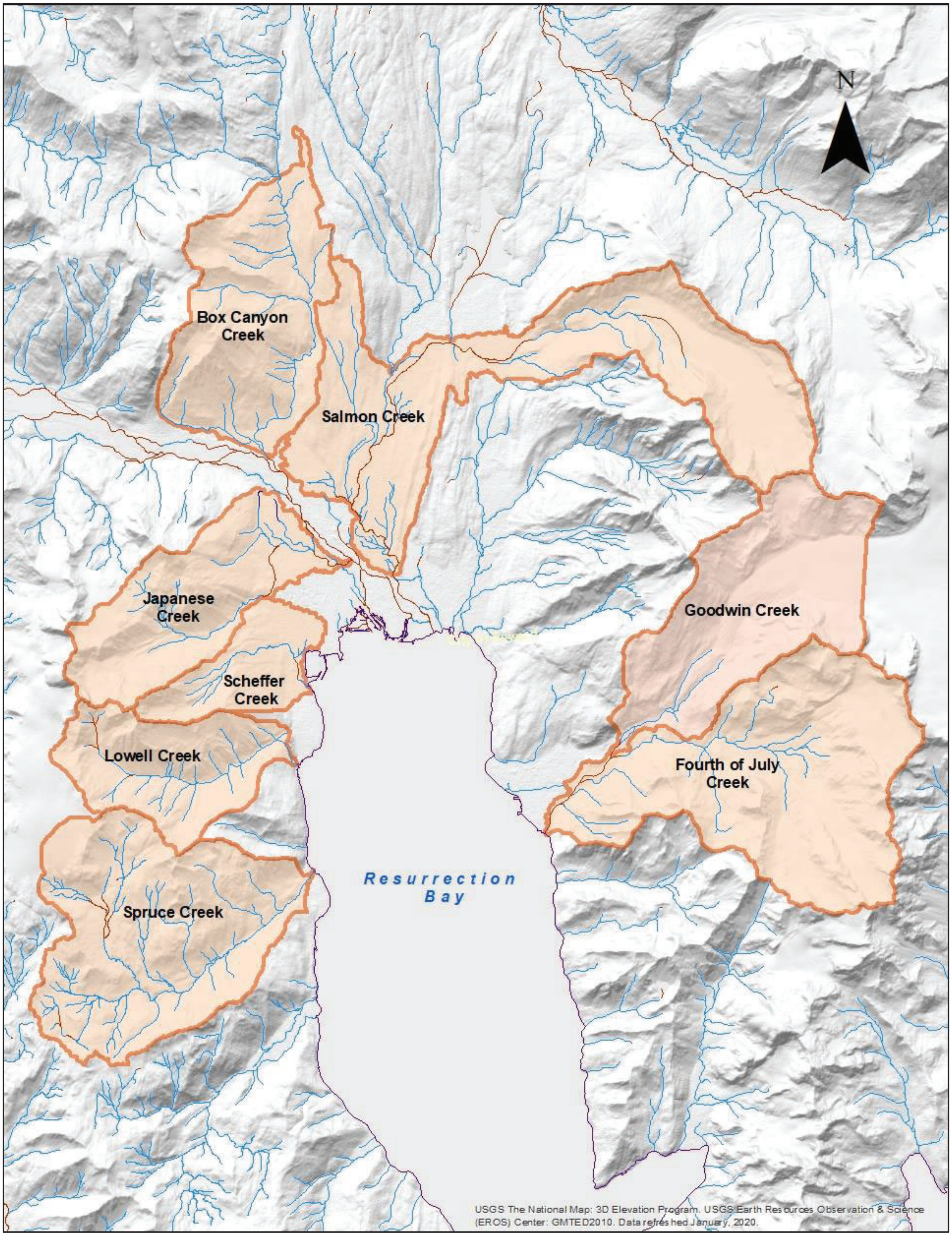

Figure 14. Watersheds in the Seward Area and their Spatial Relation to Lowell Creek.

3.1.3 Geology

Seward is located on the Kenai Peninsula at the north end of Resurrection Bay. The Kenai Mountains are composed primarily of sedimentary rocks that show a wide range of character and varying degrees of metamorphism. The material was deposited as impure sand and mud. Time and pressure cemented the sediments into shale and impure sandstone. Plate tectonics further altered the sediments during the folding of the mountains. The common geologic structure now appears as hard shale, or argillite, and greywacke, or impure quartzite, although local metamorphism has proceeded far enough to convert them to slate or schist. Temperature fluctuation (freeze/thaw cycle) and high rain quantities have resulted in significant surface weathering in this area. These factors contribute to the rock structure within this drainage basin producing great quantities of trap rock or shingle, which have a very flat angle of repose and are readily transported by water action. Recent satellite imagery indicates that there is still significant landslide activity within this drainage basin.

Alternating units of greywacke and phyllite constitute virtually all the bedrock near Seward. The rocks in the site area are of the greywacke complex of which the shale member is at the site. The existing Lowell Creek Tunnel passes through the shale member. The bedding of the shale is steeply dipping at about 65 degrees to the west and strikes north-to-south. The rock cleaves parallel to the bedding planes. The shale appears quite competent for the tunnel. The main structural trend of the rocks in the Seward area is from near north to approximately north 20 degrees east. Beds and cleavage commonly dip 70 degrees west or northwest to near vertical.

Small faults, shear zones, and joints are common. The rocks are commonly offset from a few inches to several feet vertically along these faults. The shear zones, mostly less than 5 ft wide, commonly are made up of angular pieces of greywacke or phyllite a few inches to a few feet long, though some are composed of finely ground rock fragments or a bluish-gray clayey gouge. A major and a secondary joint system characterizes the more massive greywacke in many places. North of Lowell Point, where the joints are well exposed, the major set strikes north 60-70 degrees west and dips approximately 85 degrees northeast, and the secondary set trends northeastward. Most of the joints are filled with quartz, but some are filled with calcite.

The rocks in the Kenai Peninsula bordering Resurrection Bay are of the greywacke complex, which forms a crescent from the southern tip of the Kenai Peninsula northeast to Valdez thence eastward towards Yakutat. The greywacke series is composed of conglomerate beds and thick beds of shale with some thin limestone members.

Unconsolidated glacial and fluvial deposits overlie the bedrock except on the steep, higher slopes. Remnants of the lateral moraines flank the main valley of Resurrection

River and extend up the sides of tributary valleys to a maximum altitude of about 1,500 ft. The moraines are heavily vegetated in most places, but where exposed, consist of smaller amounts of clay-sized particles, cobbles, and large boulders. Glaciers in the Seward area have been retreating and thinning in recent years. Continuation of this trend would create and leave additional areas of unconsolidated moraine material subject to accelerated erosion and deposition by streams. Terminal or recessional moraines in mountain glaciated areas may be sufficiently well-preserved so that they dam the stream that replaces the melting glacier.

3.1.4 Seismicity

Alaska is the most seismically active state in the United States (U.S.). An average of one magnitude (M) 8 or greater earthquake occurs in Alaska every 13 years, one M7–8 earthquake occurs every two years, and six M6–7 earthquakes occur every year. Subduction of the Pacific Plate and the Yakutat microplate beneath the North American plate dominates crustal deformation in Alaska. Figure 15 shows Earthquakes with a Moment Magnitude (M_W) greater than 5.5 that have occurred between 1900 and 2004 in Alaska.

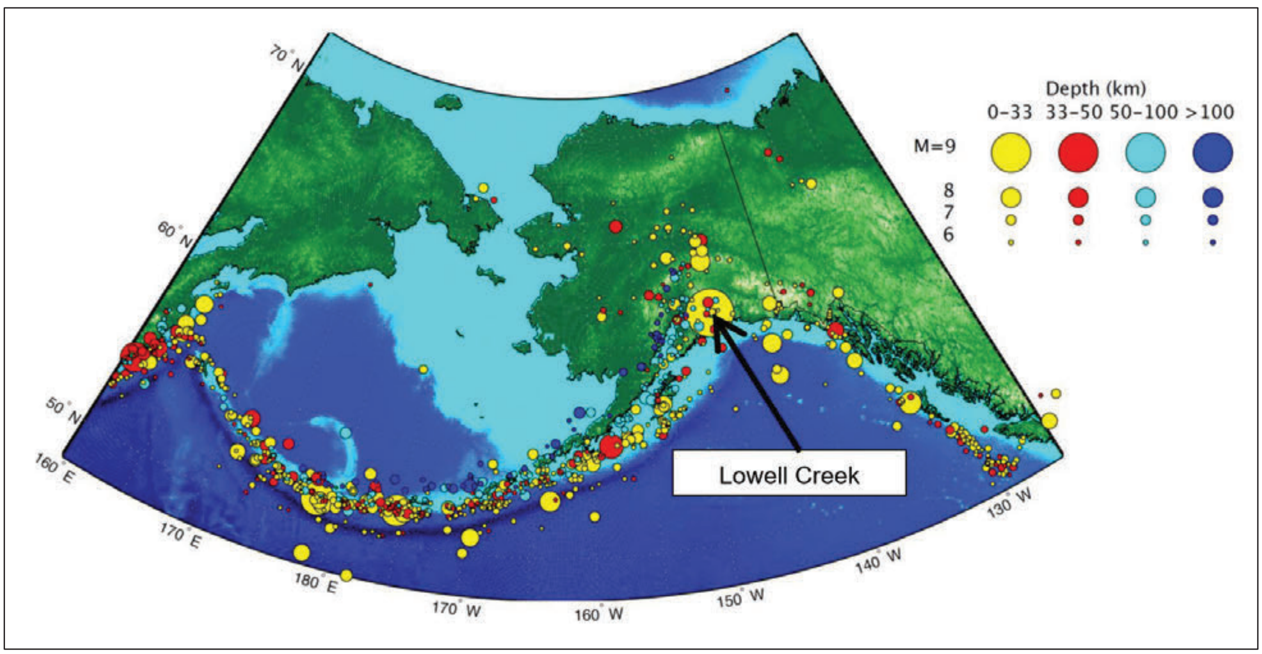

Figure 15. Alaska Earthquakes with Mw ≥ 5.5 from 1900 to 2004 (*from* Wesson et al. 2007).

Most of the seismicity in Alaska is associated with the Alaska-Aleutian megathrust fault, which runs along the Aleutian arc. The fault is where the northwestward-moving Pacific plate is subducting beneath the North American plate (Wesson et al. 2007). The Alaska-Aleutian subduction zone is the source for the 1938 M8.3 Alaska Peninsula earthquake, the 1946 M7.8 Unimak earthquake, the 1957 M8.6 Fox Islands earthquake, the 1964

M9.2 Prince William Sound earthquake, and the 1965 M8.7 Rat Islands earthquake (Koehler et al. 2012). The 1964 M_W 9.2 Prince William Sound earthquake is the second-largest earthquake ever recorded. Other significant sources of seismicity include the Denali fault in south-central Alaska and a series of northwest-striking right-lateral strike-slip faults that run along the panhandle of southeast Alaska. These faults form the northeast boundary of the Pacific Plate. The 2002 M_W 7.9 Denali fault earthquake is the largest earthquake to occur on land in the U.S. since the 1906 San Francisco earthquake. The Denali fault ruptured over a distance of 340 kilometers, with up to 8 meters of offset during the event (Wesson et al. 2007).

Lemke (1967) describes the effects of the Prince William Sound earthquake on the City of Seward. The effects are summarized as follows. Strong ground motion lasted three to four minutes in Seward. Large-scale submarine landsliding during the earthquake resulted in a 50–400-ft-wide strip of land along the Seward waterfront sliding into Resurrection Bay. The slide created a tsunami which generated waves that inundated the shore. Wave run-up was as much as 30 ft above Mean Lower Low Water (MLLW) and caused significant damage to the city. The strong ground motions caused comparatively minor damage. Tectonic subsidence of about 3.5 ft resulted in low areas being inundated at high tide. The earthquake reactivated old slides and triggered new ones in the mountains. Snow avalanches were triggered in Lowell Canyon. Two snow avalanches in the lowermost mile of the canyon reached the creek bed and piled up snow, rock fragments, and broken trees as high as 30 ft.

No seismic instruments are present at the project. According to a Lowell Creek Tunnel Repair Report dated August 2001, the 1964 Alaska earthquake did not affect the project.

3.1.5 Climate Change

Climate in the project area is projected to change over this century. Temperatures are expected to increase for the Alaska Region, with winters becoming milder, and summers becoming hotter. These effects are projected to be more prevalent in the latter part of the century as opposed to the early part.

A trend of increasing temperatures starting in the 1970s has been identified and is projected to continue throughout the state of Alaska, especially in the winter and spring seasons. The largest temperature increases have been found in winter months with average minimum temperature increases of around 2 degrees Fahrenheit (°F) statewide. The region is experiencing warmer average winter temperatures, warmer average annual temperatures, earlier spring onset, and longer growing seasons. Extreme cold temperatures have become less frequent while extreme warm temperatures have become more frequent.

The primary potential climate change impacts to the hydrology of Lowell Creek would be changes in precipitation volumes. Annual maximum one-day precipitation is projected to increase by 5%–10% in southeastern Alaska and by more than 15% in the rest of the state, although the longest dry and wet spells are not expected to change over most of the state. An increase in 24-hour precipitation would generally increase the frequency of flow values for the basin.

3.1.6 Aesthetics

Almost the entirety of the existing project is located within Lowell Canyon and inside Bear Mountain and is not visible to the general public or would take significant effort to observe. Also, several safety features such as exclusionary fencing and signage on the crest of the diversion dam have been erected specifically to prevent accidents associated with people getting too close to the tunnel entrance invert. However, the point of outfall is readily observable in south Seward and forms a somewhat scenic waterfall feature that naturally attracts attention from tourists and residents alike.

3.1.7 Soils/Sediments

In the Lowell Creek watershed, sediments are comprised almost uniformly of greywacke shale that has been mechanically weathered from the surrounding exposed mountain faces. Generally, cobbles and boulders comprise the in-channel sediments above the diversion dam and tunnel structures. Sediments in the vicinity of the outfall are the same greywacke shale. Hydrodynamic forces have pulverized the greywacke shale as it traveled the Lowell Creek channel and tunnel system, and it emerges as coarse sands, gravels, and cobbles. Nearshore intertidal and subtidal benthic sediments near the Lowell Creek outfall are identical to those at the outfall.

3.1.8 Water Quality

The surface waters of Lowell Creek are not categorized as being impaired according to the ADEC water quality mapping tool, accessed April 2020 (ADEC 2020a). The anthropogenic footprint in the Lowell Creek watershed above the existing project is limited to the remnants of a decommissioned hydroelectric plant; its slowly disintegrating concrete constituent components do not affect surface flows or sediment transport. Precipitation events heavily influence the variable surface flows.

Similarly, the water quality of Resurrection Bay meets ADEC water quality standards and is not impaired. However, regular precipitation events can elevate ambient turbidity levels in Resurrection Bay for hours to days due to glacial activity in the upper watersheds surrounding the Bay.

3.1.9 Air Quality

Seward is not in or near a "non-attainment," "maintenance," or Class I area (as defined by the Clean Air Act of 1963 (CAA; PL 88-206) for any criteria pollutants.

The readily observed rigorous atmospheric convection presumably contributes to Seward's good air quality. The terrain surrounding Seward is steep and facilitates orographic forcing on low-pressure systems generated in the Gulf of Alaska and the North Pacific Ocean, resulting in precipitation and varying air pressure gradients.

3.1.10 Hazardous, Toxic, and Radioactive Waste (HTRW)

No known HTRW sites, active or otherwise, are present in the community of Seward or the Lowell Creek watershed according to the ADEC's contaminated sites database, accessed April 2020 (ADEC 2020b).

3.1.11 Noise

Wind, rain, and the sounds of Lowell Creek's surface waters flowing through the existing diversion, tunnel, and outfall are the most prominent sources of ambient noise in the vicinity of the proposed project. The portion of the watershed above the diversion dam is acoustically isolated by Lowell Creek's steep canyon walls, hillside vegetation, and whipping winds. The outfall area, located south of Seward's population center, experiences ambient noise generated by ocean waves, nearby vehicle and vessel traffic, wind, rain, and the sounds generated by surface flows from the exit of the tunnel to where they empty into Resurrection Bay.

3.1.12 Surface Water Stream Flow

Only a minimal history of surface water flow measurements exists for the Lowell Creek system. In-stream gaging of the surface waters of Lowell Creek has been problematic to implement due to the system's bedload during high flow events.

3.1.13 Floodplain Management

The hydrogeomorphologic characteristics of the Lowell Creek watershed consist primarily of the watershed's steep, talus-strewn slopes, confined primary channel, and alluvial cone. The traditional definition of a floodplain does not apply to Lowell Creek because the elevation gradient from the mouth of Lowell Canyon to the surface waters of Resurrection Bay is relatively steep, thereby precluding the predictable lateral distribution of flood waters from what might be considered the creek's center channel. USACE's proposed project would be located in the confined primary channel above Lowell Creek's alluvial cone identified as Zone A by the National Flood Insurance

Program (NFIP), immediately upstream of USACE's existing flood control project, where no base flood elevations have been determined.

3.2 Biological Resources

3.2.1 Terrestrial Habitat

Vegetation characteristics for the Lowell Creek watershed are similar to those previously described in 1978: "approximately 30% of the upland drainage exhibits vegetative cover, and is comprised of low growing alders, small shrubs, and isolated patches of scrub conifers" (USACE 1978). Vegetation does not occur upon the steeper portions of the surrounding slopes and is limited to an area of transitional slope between creek bankfull and the boundary of the bare rock/scree zone that constitutes the majority of the watershed. The area beneath the tunnel discharge flume to the point where Lowell Creek's surface waters meet Resurrection Bay is completely devoid of vegetation. Discharge velocities and debris deposition in this section are sufficient to preclude vegetation establishment.

3.2.2 Birds

The scope of analysis for birds is an area of approximately 100 acres of terrestrial and nearshore marine habitat between the diversion structure and the outlet of the creek from the tunnel into Resurrection Bay. This area encompasses the land and water, where both direct and indirect impacts could potentially occur. There are a variety of birds that may occur in this area; the most common birds in the forested areas include the black-billed magpie and Steller's jay. Along the coast, the most common species are pigeon guillemot, red-breasted merganser, common and thick-billed murres, black oystercatcher, black-legged kittiwakes, and a variety of gull species.

Bald eagles are frequently observed in the vicinity of Resurrection Bay, and along with golden eagles, receive special conservation status under the Bald and Golden Eagle Protection Act of 1940 (PL 86-70), as amended. Bald eagles in Alaska initiate courtship and nest-building behaviors in January and February. September through January is generally considered the non-nesting period (USFWS 2020). No site-specific bald or golden eagle nest surveys have been conducted in Lowell Creek's upper watershed or along the coastal portion of the proposed project area.

3.2.3 Terrestrial Mammals

A list of terrestrial mammals potentially occurring within the Lowell Creek watershed is derived from the adjacent Kenai Fjords National Park (KFNP)'s species account list and includes black bear, brown bear, beaver, coyote, mountain goat, snowshoe hare, little brown bat, lynx, hoary marmot, marten, mink, moose, meadow jumping mouse, northern bog lemming, porcupine, shrew (five species), red squirrel, vole (four species), short-tailed weasel, gray wolf, and wolverine (KFNP 2020a).

Lowell Canyon's sparsely vegetated hillsides, steep, talus covered slopes, and unpredictable hydrologic characteristics likely do not provide suitable habitat for the entirety of the KFNP species list mentioned above. However, terrestrial mammals may utilize portions of the Lowell Creek watershed as a transit corridor between areas of higher habitat quality. Terrestrial mammals would not be expected to utilize the existing project features as a form of preferred habitat and would likely choose to avoid it.

3.2.4 Freshwater Fish

There are no freshwater fish in Lowell Creek. Furthermore, the existing outfall structure acts as a complete barrier to anadromy.

3.2.5 Marine Habitat

Since the inception of the existing diversion dam, tunnel, and outfall, sediment deposition at the outfall point actively builds an alluvial fan in the same fashion that the alluvium which the City of Seward sits on is also derived from the deposition of Lowell Creek sediments. As such, these depositional sediments encroach into the waters of Resurrection Bay and become intertidal and subtidal components of the marine habitat. This encroachment interface, where Lowell Creek sediments are deposited, is naturally highly disturbed, both through continual deformation of the loose sediments and through covering of the exposed sediments by new sediments as the alluvium grows. This condition generally precludes the establishment of marine algae and subsequent invertebrate communities. Based upon available aerial imagery comparisons and multiple site visits, USACE biologists have determined that because of the substrate homogeneity and existing disturbance regime, intertidal and nearshore subtidal marine habitat quality in the vicinity of the Lowell Creek outfall alluvium is relatively poor when considered against the proximal marine habitats of the greater Resurrection Bay.

3.2.6 Marine Mammals

Although Resurrection Bay exhibits a great diversity of marine mammals, they would not be expected to occur within the footprint of the project, as proposed, because all aspects of the project occur entirely on land and well above the Mean Higher High Water line.

3.2.7 Federal and State Threatened and Endangered Species

No Federal or State threatened or endangered species are known to occur within the project's footprint, as proposed. Appendix G: Correspondence details the USACE coordination efforts with the USFWS under the precepts of the Fish and Wildlife Coordination Act (FWCA; PL 85-624).

3.2.8 Essential Fish Habitat

Lowell Creek is not designated as Essential Fish Habitat (EFH). The waters of Resurrection Bay are designated as EFH. The continual deposition of Lowell Creek's bedload sediments to the outfall alluvium that encroach into Resurrection Bay constitutes a naturally occurring process. The in-water area of the alluvium is highly disturbed by the deposition of Lowell Creek's sediment load.

3.2.9 Invasive Species

Generally, the establishment of invasive species, both floral and faunal, in Alaska is curtailed due to the state's climate and relative geographic isolation. KFNP maintains a list of established invasive plant species that are observed within the National Park (KFNP 2020b). Due to the proximity of KFNP to the project area, it is expected that some of these species may be established in the Lowell Creek watershed. Similarly, the ADFG provides invasive species information on their website along with preventative methods for reducing the risk of invasive species introduction. Currently the status of invasive species, particularly to the Lowell Creek watershed, is unknown.

3.3 Cultural Resources

Although no prehistoric sites have been recorded in the vicinity of the proposed project footprint, the Lowell Creek Diversion Tunnel is itself considered to be a significant historic property. It is identified in the Alaska Heritage Resources Survey (AHRS) database as SEW-00011 (OHA 2018). USACE visited the structure during a pedestrian survey in 2018. The survey reaffirmed that there are no other cultural resources located in the vicinity upriver of the dam or in the spillway area. The Lowell Creek Diversion Tunnel (SEW-00011) was nominated to the National Register of Historic Places (NRHP) by the USACE in 1975, and was listed on the NRHP in 1977 by the Keeper of the National Register under Criterion C "for its embodiment of pioneering engineering characteristics" (USACE 1977). Approximately 100 historical structures or cultural features have been identified within the downtown Seward area. Most of these cultural resources have not been evaluated for eligibility for listing in the NRHP.

The Seward area has a long history going back at least 4,000–3,500 years, based off of archaeological sites identified as semi-permanent settlements inhabited seasonally depending on food resources. In 1793, Russian explorers established a fort and harbor at the head of Resurrection Bay. The City of Seward was founded in 1902 and is an important fixture of the growth and history of Alaska (AKDCCED 2019). Appendix G: Correspondence contains a more thorough history of the City of Seward in the Letter to the SHPO.

3.3.1 Area of Potential Effect

The Area of Potential Effect (APE) is a term specific to the National Historic Preservation Act (NHPA; PL 89-665), as amended. The APE includes any areas that would be used for the proposed project. The area generally includes construction sites, access routes, staging areas, worker camp locations, monitoring wells, etc. The APE is defined in the Code of Federal Regulations (36 CFR § 800.16(d)) as the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist, for the foreseeable future. The APE is influenced by the scale and nature of an undertaking and may be different for different kinds of effects caused by the undertaking.

3.3.2 Historical Context

Since the City's founding in 1902, water and sediment transported by Lowell Creek has inflicted damages on Seward. Efforts to alleviate these threats predate the current flood diversion system. In 1918, a pile and timber-lined channel 100 ft wide by 15 ft deep was excavated across town along Jefferson Street. A single autumn flood later that year overtopped this channel with detritus as documented in a letter from the Secretary of War transmitted to Congress in 1937. In 1929, the Alaska Railroad constructed a 12 ft-wide, 7 ft-deep, 3,300 ft-long, pile-supported, rectangular timber flume. Although initially effective for several years, beginning in 1934 the flume became prone to clogging with debris and overtopping from each flood (also documented in the 1937 letter). The current flood diversion system was identified as an alternative for construction when it was evident that the flume was no longer viable.

Lowell Creek is currently ungaged and there are no known, validated, historical stream gage data available. Severe flooding on Lowell Creek normally mirrors the October through November rainfall period. Generally, floods are of short duration, lasting 3 or 4 days. Lowell Creek rises very rapidly, with flooding occurring soon after heavy rainfall begins. The existing diversion dam has not been overtopped during any previous flood events. In October 1986, water came to within 1 ft of the spillway crest of the diversion dam. USGS estimated peak flow on Lowell Creek during the 1966 storm of 1,200 cfs. Peak flow on Lowell Creek was estimated to be approximately 2,300 cfs for the 1986 flood and 1,810 cfs for a September 1995 storm. For comparison, the PMF of Lowell Creek is estimated to be 8,400 cfs. During all three storms, the tunnel suffered damage requiring repairs. No damages were reported to the diversion dam. Due to the lack of stream gage data, there may be additional high flow events not captured above. High flow events with flooding and significant debris in the outfall area also occurred in 2006, 2009, 2012, 2015, and 2016, with the first three years noted as requiring significant debris removal as discussed in Section 1.6.3.6.1.

3.3.3 Environmental Justice and Protection of Children

EO 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," directs Federal agencies to identify and address any disproportionately high and adverse human health or environmental effects of their actions on low-income, minority, and tribal populations, to the greatest extent practicable and permitted by law. An Environmental Justice (EJ) analysis typically includes the following elements:

- Identification of any minority and/or low-income status communities in the project area;
- Identification of any adverse environmental or human health impacts anticipated from the project; and
- Determination of whether those impacts would disproportionately affect minority and/or low-income communities.

EO 13045, “Protection of Children from Environmental Health Risks and Safety Risks,” directs Federal agencies to identify and address environmental health and safety risks that may disproportionately affect children, to the greatest extent practicable and permitted by law. This analysis typically builds off of the EJ analysis. It includes a determination of whether the identified adverse environmental or human health impacts anticipated from the project would disproportionately affect children.

3.3.4 Protected Tribal Resources

The Executive Memorandum on Government-to-Government Relations with Native American Tribal Governments of 1994, the Department of Defense American Indian and Alaska Native Policy of 1998, and the Department of the Army Memorandum on American Indian and Alaska Native Policy of 2012 require that the USACE assess the impact that Federal projects may have on protected Tribal resources and assure that the rights and concerns of Federally-recognized Tribes are considered during the development of such projects. Protected Tribal Resources are defined by the Department of the Army as those natural resources and properties of traditional or customary religious or cultural importance, either on or off Tribal lands, retained by, or reserved by or for Federally-recognized Tribes through treaties, statutes, judicial decisions, or executive orders. The Federal government's trust responsibility, deriving from the Federal Trust Doctrine and other sources, for these Protected Tribal Resources is independent of their association with Tribal lands.

3.4 Environmental Resources Not Considered in Detail

Implementation of USACE's proposed project is not expected to affect the environmental resources identified in Table 3; therefore, these resources are dismissed and not carried forward for further analysis.

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Table 3. Environmental Resources Not Considered in Detail.

Resource	Authority	Technically Important	Reason for Dismissal
Climate	NEPA; USACE Engineer Circular 1165-2-211	Promotes enhancement of the environment by evaluating the effects of government actions on a full suite of resource categories. Incorporates the physical effects of projected sea-level rise in planning, engineering, designing, constructing, operating, and maintaining USACE projects.	Short- and long-term greenhouse gas emissions resulting from the implementation of this project would be negligible. Appendix C: Hydraulic and Structural Design contains sea level rise planning and design analysis regarding this project.
Geology/ Topography	NEPA	Promotes enhancement of the environment by evaluating the effects of government actions on a full suite of resource categories.	Implementation of USACE's project would not affect the geology or topography of the immediate region.
Seismicity	NEPA	Promotes enhancement of the environment by evaluating the effects of government actions on a full suite of resource categories.	Implementation of USACE's project would not affect the seismicity of the region.
Air Quality	CAA, as amended; NEPA	Designed to control air pollution from listed criteria pollutants on a national level; promotes the enhancement of the environment by evaluating the effects of government actions on a full suite of resource categories.	CAA conformity determination requirements do not apply to USACE's project at this time.
Hazardous, Toxic, and Radioactive Waste	USACE Engineer Regulation 1165-2-132; 18 AAC75 (ADEC)	USACE defines the roles and responsibilities of HTRW sites. ADEC provides regulations for the management of such sites.	According to the ADEC Contaminated Sites database, no HTRW sites occur within or adjacent to all portions of USACE's project footprint.
Currents/ Tides/ Circulation/ Surface Water Stream Flow	NEPA	Promotes enhancement of the environment by evaluating the effects of government actions on a full suite of resource categories.	Implementation of USACE's project would not impact tidal regimes or nearshore currents. Also, the surface flows of Lowell Creek would still be directed through Bear Mountain and would discharge to Resurrection Bay.
Floodplain Management	EO 11988	Promotes human health and safety by requiring Federal agencies to determine whether the proposed action will occur in a floodplain	According to the NFIP mapping tool, USACE's project, as proposed, would not occur within the base floodplain.
Biological Resources			

Resource	Authority	Technically Important	Reason for Dismissal
Fish and Essential Fish Habitat	Magnuson Stevens Fishery Management and Conservation Act of 1976, as amended.	Resurrection Bay and the majority of its constituent freshwater streams are designated as EFH. Section 305(b)(2) of the Magnuson Stevens Act requires Federal action agencies to consult with National Oceanic and Atmospheric Administration's (NOAA) NMFS on all actions, or proposed actions, authorized, funded, or undertaken by the agency that may adversely affect Essential Fish Habitat.	Lowell Creek does not support populations of freshwater fish, and its outfall flume and subsequent waterfall are barriers to anadromy. No portion of the proposed project's footprint would extend into the waters of Resurrection Bay. The continual deposition of Lowell Creek's bedload sediments to the Lowell alluvium that encroach into Resurrection Bay, who's waters are designated as EFH, is consistent with regional phenomena and is considered a natural process. USACE's project, as proposed, would not impact EFH.
Marine Mammals	Marine Mammal Protection Act (MMPA) of 1972; Endangered Species Act (ESA) of 1973, as amended.	The waters of Resurrection Bay provide a habitat to various marine mammals. The harassment of marine mammals is not permitted by law.	Law and policy support the conservation and protection of marine mammals. Federal actions are required to comply with Federal laws regarding the conservation of such resources. There are no elements of USACE's project that might impact marine mammals.
Threatened and Endangered Species	ESA, as amended; MMPA of 1972.	All marine mammals are protected under the MMPA. Of these marine mammals, select populations may be designated as threatened or endangered under the ESA.	Law and policy support the conservation and protection of threatened or endangered species. Federal actions are required to comply with Federal laws regarding the conservation of such resources. There are no threatened or endangered species that would be affected by the implementation of USACE's project, as proposed.
Invasive Species	NEPA; EO 13751: Safeguarding the Nation from the impacts of invasive species; EO 13112: Invasive Species	The inadvertent introduction of novel species can be ecologically damaging.	Because of USACE's project type and specific location, the inadvertent release of novel species capable of becoming invasive is so low as to be discounted.

3.5 Relevant Resources

Relevant resources that could be impacted by USACE's proposed project are identified in **Table 4**. Effects analyses to resource categories identified in **Table 4** are presented in Section 8, Environmental Consequences.

Table 4. Relevant Resources.

Resource	Authority	Technically Important	Publicly Important
Non-Biological Resources			
Aesthetics	NHPA	Alterations to the project's existing state may deter from its historical significance.	Conservation of historically relevant viewshed is important to the public.
Water Quality	Section 401 of the Clean Water Act (CWA) of 1972, as amended.	Local and regional water quality is important to the community of Seward as well as for the greater Gulf of Alaska ecotone	Law and policy require that Federal actions adhere to water quality protection laws.
Sediments	CWA of 1972 as amended, Section 404(b)(1)	In-water placement of sediments or "fill" must comply with Section 404(b)(1) guidelines.	Law and policy require that Federal actions adhere to water quality protection laws. USACE's proposed project does not affect the final fate of bedload sediments, and any "fill" associated with the project would be those materials utilized in the construction and/or maintenance of the diversion dam structure and are evaluated in Appendix A: 404(b)(1) Evaluation.
Noise	Noise Pollution and Abatement Act of 1972	Designed to protect human health by minimizing annoyance of noise to the general public.	Ambient natural sounds in Lowell Canyon and Resurrection Bay are an effective attenuator of most noise; however, anthropogenic noise levels will increase during the construction period of this project.
Existing Infrastructure and Facilities	NEPA	Promotes enhancement of the environment by evaluating the effects of government actions on a full suite of resource categories.	Lowell Creek, at flood stage, has affected public infrastructure in Seward on multiple occasions.

Resource	Authority	Technically Important	Publicly Important
Cultural Resources	NHPA; NEPA	Alterations to the existing tunnel and dam may impact the historical significance of the structure.	Law and policy require that Federal actions are considerate of the protection and enhancement of cultural resources.
Environmental Justice	EO 12898: Federal actions to address environmental justice in minority populations and low-income populations.	Identifies impacts to minority or low-income populations	EOs and policy support that no group of people, because of their socioeconomic or racial or ethnic composition, should be disproportionately negatively affected by the execution and/or operation of Federal, state, local, or tribal programs or policies.
Biological Resources			
Terrestrial Habitat	NEPA	Promotes enhancement of the environment by evaluating the effects of government actions on a full suite of resource categories.	Law and policy require that Federal actions adhere to land and water quality protection laws.
Birds, including Bald and Golden Eagles	FWCA of 1934, as amended; Migratory Bird Treaty Act of 1918. The Bald and Golden Eagle Protection Act of 1940, as amended	Resurrection Bay and its surrounding upland habitats are important foraging nesting areas for marine and terrestrial birds as well as Bald and Golden Eagles.	Law and policy recognize that migratory birds, Bald Eagles and Golden Eagles transcend geopolitical borders and that the protection of their nesting, foraging, and resting habitats are important for the long-term conservation of avian resources.

3.6 Socio-Economic Conditions

3.6.1 Population

In 2019, the State of Alaska Department of Labor and Workforce Development (DLWD) estimated Seward's population to be 2,545. However, multiple Census Designated Places (CDPs) outside Seward's city limits are also located within the greater Seward area (**Table 5**).

Table 5. Area Population.

Area	2019 Estimated Population	Distance from Downtown Seward (miles)
City of Seward	2,545	0
Lowell Point CDP	94	2
Bear Creek CDP	2,093	5
Crown Point CDP	80	25
Moose Pass CDP	233	28
Primrose CDP	65	18
Total:	5,110	
CDP=Census Designated Place		

The Seward population is approximately 69% White, 17% American Indian or Alaska Native, 3% African American, 2% Asian, and 8% two or more races in combination. Other small groups (less than 1%) include Pacific Islanders. The population is 58% male and 42% female. The median age of the population is 38 years.

Seward experiences an increase in the daytime population during the tourism season which ranges from May to September. Seward is a tourist destination for its deep-sea fishing, wildlife- and glacier-viewing boat tours, hiking trails, Alaska SeaLife Center, and summer festivals. The Seward 4th of July celebration can draw close to 30,000 people according to the Seward Chamber of Commerce. Other large attractions include halibut and salmon tournaments, music festivals, and craft fairs. Tourists arrive in Seward on various forms of transportation, including cruise ships, ferries, tour buses, passenger vehicles, and trains. Generally, tourists are not familiar with the area and are susceptible to natural disasters, which would include a flood event with little warning time along Lowell Creek.

The Alaska Visitor Statistics Program, which is a statewide visitor study funded by the Alaska Department of Commerce, published tourism visitation data and statistics for the 2016 tourist season. The report estimated that Seward hosted 441,000 tourists during the 2016 calendar year (ATIA 2017).

3.6.2 Employment & Income

According to the Alaska DLWD, 59% of resident workers were employed during 2016 (the last year for which statistics are available). Seward's largest industry is Trade, Transportation, and Utilities, though significant employment occurs in Education and Health Services, Leisure and Hospitality, and State and Local Government as well. Commercial fishing and businesses employ a substantial number of workers that support Trade, Transportation, and Utilities. The median household income in Seward is approximately $76,400, compared to the median annual income of approximately $61,900 across the entire U.S. Approximately 11.9% of residents have incomes lower than the Federal poverty threshold.

3.7 Risk to Life Safety

Any flood management project inherently contains a risk to human life. USACE is committed to the safety of its dams. USACE dams can be classified through a risk assessment process into five Dam Safety Action Classifications (DSACs) which represent varying levels of urgency of action and incremental flood risk. Lowell Creek Diversion Dam and Tunnel is currently categorized as DSAC 3 based on a USACE Screening Portfolio Risk Assessment. A DSAC 3 classification applies where the incremental risk is moderate. Incremental risk is the combination of life, economic, or environmental consequences with likelihood of failure. USACE considers this level of risk to be unacceptable except in unusual circumstances. The primary reasons for that classification are potential overtopping of the structure from a PMF event or an event with the tunnel blocked with debris.

It is imperative to appropriately assess this risk, ensure any actions would not detrimentally increase such risk, and assess the extent to which any actions taken would alleviate existing risk. To accomplish this, the team conducted a hybrid risk assessment and completed a consistency review of the risk assessment in accordance with ER 1110-2-1156. The team used the assessment to determine if there were any potential causes for failure, Potential Failure Modes (PFMs), which would affect the function of the existing diversion dam and tunnel during normal operation.

The assessment identified four PFMs as having a potential effect on risk to life safety:

- PFM 3 (Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area);
- PFM 5A (Landslide blocks tunnel entrance leading to flow into consequences impact area);

- PFM 6A (Upstream landslide forms dam that overtops and breaches, sending surge release flow into consequences impact area); and
- PFM 21 (Scour of tunnel liner which leads to liner/rock failure and tunnel blockage).

PFM 6A was determined to be the primary driver for risks to life safety. The team considered partial tunnel blockages; however, it was concluded that due to the gradients, the head pressure was sufficient to readily flush a partial blockage through the tunnel. Thus, partial tunnel blockages were not analyzed as a probable scenario. It is important to note that these four PFMs can occur at any size event and therefore are not correlated to specific flows, including the PMF.

The team compiled this information to develop probable solutions for mitigating the risks from the failure modes. The current structure does not adhere to the USACE definition of a dam due to lack of water impoundment. Additionally, failure of the diversion dam itself presented little, if any, incremental risk. As such, the feasibility study team focused on the residual risk experienced by the downstream population. This includes the incremental risk defined as tunnel blockage (due to one of the PFMs), as well as the non-breach risk that exists even if the system operates as intended. The terms used to describe the risk to life safety are defined as follows:

Incremental Risk = The risk (likelihood and consequences) to the downstream floodplain occupants that can be attributed to the presence of the tunnel and diversion dam should these structures fail to operate as intended. Because failure of the diversion dam contributes a negligible amount of risk, the incremental risk is essentially the risk due to tunnel blockage.

Non-breach Risk = The risk (likelihood and consequences) to the downstream floodplain occupants due to 'normal' operation of the tunnel and diversion dam, including flow that exceeds tunnel capacity and flows over the spillway/dam due to upstream rainfall (with or without an associated surge event).

Residual Risk = Incremental Risk + Non-breach Risk

For incremental risk, the chance of tunnel blockage was estimated given various hydrologic events. [redacted]

[redacted]

Combining these system response probabilities with the annual chance of the hydrologic events (and summing for the full range of potential events) gives the Annual Probability of Failure (APF). This is essentially the annual chance that the tunnel will be blocked. [redacted]

[redacted]

[redacted]

[redacted]

Lowell Creek Flood Diversion
Integrated Feasibility Report and Environmental Assessment

[redacted]

[redacted]

[redacted]

The risk assessment team carefully considered surge flow events, which contribute more risk than non-surge events. The team estimated the likelihood for a landslide to form a dam in the stream channel that later breaches and releases a surge of water and debris is around 10% (0.1) for all flood events. The USGS identified Lowell Creek as an area of High Potential for landslides, debris flows, and debris avalanches, which can lead to surge release floods. All flood events considered involve significant precipitation that will saturate the slopes. Based on the estimated size of the moraine that was observed upstream, there is a sufficient volume of material that could form a dam of the size needed to release on the order of two and a half times the peak inflow from the rain event. In addition, during the 1986 flood event, surge release floods occurred on five nearby creeks, including adjacent Spruce Creek. Once a landslide dam has formed, it will very likely overtop soon after and quickly scour and breach the easily erodible landslide dam materials. While flood events in recent history have carried significant quantities of debris down Lowell Creek, no landslides of this size have occurred on Lowell Creek in recent history, which was a key factor in determining the likelihood of a landslide forming a dam that fails and causes a large surge release.

4. FUTURE WITHOUT PROJECT (FWOP) CONDITIONS

This section provides an analysis of conditions that are expected to persist in Seward, Alaska, in the absence of flood risk management improvements at Lowell Creek. The purpose of this section is to estimate the economic costs of those conditions. The expected without project conditions form the basis of evaluation against which with project conditions are compared. For this analysis, the Federal Fiscal Year 2021 (FY21) discount rate of 2.5% was used.

4.1 Physical Environment (Future Projection, Climate Change)

Bear Mountain, on which the project area is located, borders the City of Seward with the local hospital and low-income housing about 800 ft from the dam and spillway. It is unlikely that the fundamental nature of the area will change over the 50-year planning period of analysis.

The analysis of climate change was conducted in accordance with Engineering and Construction Bulletin (ECB) 2018-14, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects. The publication “Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Water Resources Region 19, Alaska, 2015”, was used in this analysis. Temperature increases have been observed throughout the state and are projected to continue into the future. Within the observed record, a trend of increasing temperatures starting in the 1970s has been identified and is projected to continue. Increasing temperatures will cause winters to become milder, and summers to become hotter. These effects are projected to be more prevalent in the latter part of the next century as opposed to the early part. Shifts in temperature will have the most significant impact on snowmelt driven flows. However, snowmelt does not produce peak stream flow in Lowell Creek and changes to snowmelt should have minimal impact on the effectiveness of the project.

The potential climate change impacts most relevant to the Lowell Creek Flood Diversion Study are changes to precipitation volumes. An increase in 24 hour precipitation would likely increase the frequency of occurrence of high flows in the basin. Annual maximum one-day precipitation is projected to increase by 5%–10% in southeastern Alaska. This will likely result in a projected increase in runoff. However, it is unlikely that changes in projected precipitation and runoff will undermine project performance. The project is designed to safely pass a Probable Maximum Flood (PMF) event, which is highly infrequent. There is currently no guidance supporting climate-related changes to the definition of the PMF. It is expected that increased runoff due to changes in temperature and precipitation will not undermine project performance.

In accordance with, ER 1100-2-8162: *Incorporating Sea Level Changes in Civil Works Programs,* and ETL 1100-2-1: *Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation (June 2014),* USACE requires that planning studies and engineering designs consider alternatives that are formulated and evaluated for the entire range of possible future rates of relative sea level change (RSLC). Designs must be evaluated over the project life cycle. An analysis of the potential sea level rise was performed in the project area. The gage at Seward, Alaska (NOAA ID:9455090) was used for the analysis. This gage was established in 1925 and has been in its present location since 1989. It is located on the Alaska Railroad Pier, inside the Cruise Ship Terminal building. The result of the calculation indicates a relative sea level change of 3.71 feet was determined in the year 2100 at the high condition. For the intermediate condition, the change is 0.42 feet, and the low condition shows a decrease in sea level of 0.62 feet. These values are relative to Local Mean Sea Level (LMSL). The resulting sea level rise curve is shown below (Figure 18). Based upon the sea level rise calculator and existing ground elevations, it is unlikely that sea level rise will have any effect on this project. Detailed analysis for climate change and RSLC can be found in Appendix C: Hydraulic and Structural Design.

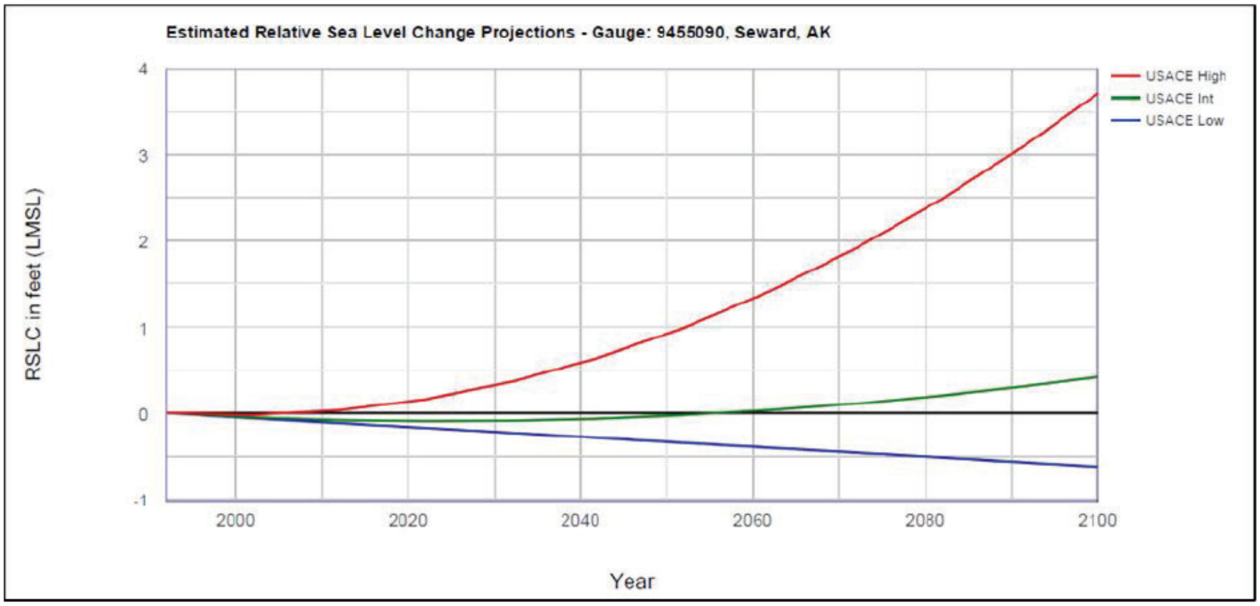

Figure 18. Sea Level Change in Feet

4.2 Biological Resources

Under the FWOP, recurring flood damage to the residential and commercial properties of Seward presents an inherent risk to the biological environment through the inadvertent release of environmentally persistent contaminants. Many of the commercial and private buildings in the estimated flood failure path of Lowell Creek (see Figure 19 below) incorporate an above-ground heating oil storage system. These systems would be destroyed and their contents released to the environment if floods similar to those of the historical record occurred. Underground storage tanks in the flood failure path would also be susceptible to damage and inadvertent discharge. Water could displace fuels or oils in the tanks or dislodge, puncture, and transport the tanks themselves. Similarly, industrial and household solvents, fuels, detergents, lubricants, heavy metals, pesticides, and various other anthropogenic compounds could be released to the environment during or following catastrophic flood events.

Some anthropogenic compounds are capable of disrupting endocrine function in other mammals, fishes, and birds leading to reproductive failure, disfigurement, anticoagulation, etc. Household anthropogenic compounds may bioaccumulate as they move through the food chain, often resulting in adverse health effects to higher-order species. Humans are not exempt from the effects of persistent environmental compounds; a whole suite of household chemicals are known to be carcinogenic in humans. The inadvertent release of such compounds represents a risk to both the biological and human environments of Seward and the greater Resurrection Bay biome.

4.3 Cultural Resources

Under FWOP conditions, the Lowell Creek Diversion Tunnel (SEW-00011) would likely continue to incur damage and repair from flood events. These events may lead to repair modifications, which would eventually result in the historic property losing its physical integrity and significance to the community and state. If a surge event occurs and the diversion dam is breached, flood damage could also impact historic properties downstream of the existing flood control project.

4.4 Environmental Justice and Protection of Children

An assisted living home that cares for elderly individuals, as well as the Providence Seward Medical Center, which is the primary care facility for the City of Seward, are located directly downstream of the current diversion dam. Under FWOP conditions, the USACE determined that an overtopping of the diversion dam would have adverse impacts on these vulnerable groups and any disabled persons who may be residing within the immediate floodplain. Normal operations are not expected to have any impact on these populations.

4.5 Protected Tribal Resources

The USACE did not identify any Protected Tribal Resources within the project area, and as such, no Protected Tribal Resources will be impacted under FWOP conditions, under normal operations, or from a surge event.

4.6 Economic Conditions

The State of Alaska DLWD projects the Kenai Peninsula Borough will gain several thousand residents over the next 30 years (Table 8). The city's relative proximity to Anchorage, access to marine recreation, and rural lifestyle while maintaining common services and conveniences make it an attractive location for future development. However, a significantly large increase in development and population is not expected. Because of this relatively stable environment, the prevailing economic and political conditions are not expected to change significantly throughout the period of analysis.

Table 8. State of Alaska Population Projections for the Kenai Peninsula Borough.

Year	Population	Increase
2017	58,024	N/A
2020	58,696	672
2025	60,412	1,716
2030	61,702	1,290
2035	62,586	884
2040	63,147	561
2045	63,472	325

4.7 Planned Development

The area downgradient of the diversion dam is well developed already, but significant additional development is not expected.

4.8 Risk to Life Safety

FWOP conditions would continue to present a very high risk to life safety. The system would still have the capacity of only 2,800 cfs and climate change trends discussed in Section 3.1.1 could increase the risk to life safety, flood damages, and debris management over the levels described for current conditions.

4.9 FWOP Scenarios

Under FWOP Conditions, flows that can exceed the capacity of the existing flood diversion system will continue to threaten to overtop the diversion dam, cause structural damages, and result in loss of life risk in Seward. Surge release floods from the failure of temporary landslide debris blockages will continue to compound this threat.

Flood water arrival with little to no warning will continue to make an effective evacuation of the population at risk very difficult. Attempts to mobilize threatened residents could result in greater life loss due to the short time window increasing the chance of getting caught in the flood. Given that the assisted living center and community hospital are directly downstream and close to the current structure, a large proportion of the threatened population are either over 65 or under medical care, and thus vertical evacuation would also remain difficult.

Due to the nature of alluvial fan flooding upon exit from Lowell Canyon, flood water flow paths will be uncertain, further complicating any potential mitigation and evacuation efforts. Floodwaters would include floating debris, suspended sediment, and a portion of the Lowell Creek bedload in addition to debris and sediment that is entrained downstream from the diversion dam. Flood flows would be expected to breach Seward from west to east isolating portions of town.

Frequent repairs will continue to be required to keep the existing flood diversion system operational. The City of Seward will continue to expend effort and funds to manage the excessive amounts of sediment deposited at the tunnel outlet, and nearby facilities will continue to experience elevated operational costs due to the sediment deposition and induced localized flooding. Summer tourism is anticipated to remain strong in Seward, putting additional people at risk if a flood occurred then. Also, many tourism services would be interrupted and local businesses would suffer losses if a flood occurred during the summer.

A scenario model of a PMF event exemplifies the FWOP conditions. USACE Lowell Creek Inundation Study, Seward, Alaska (2012) estimated PMF flow paths and depths utilizing Hydrologic Engineering Center's River Analysis System (HEC-RAS) (1D & 2D) and Adaptive Hydraulics hydraulic models. Modeling results for the PMF flood (8,400 cfs) and PMF flood with a surge release event (19,000 cfs) follow. Note that these predictions do not account for debris-laden flows, which will occur from Lowell Creek. [redacted]

[redacted]

[redacted]

The historical pre-project natural condition of Lowell Creek during peak flow transported and deposited large volumes of sediment and the Creek would meander about these depositions in route to Resurrection Bay. This condition precluded large-scale development within the lower watershed due to the possibility of flood damage. The existing Lowell Creek Flood Diversion System modified Lowell Creek so that surface flows and loose sediments are intercepted and diverted through the tunnel for concentrated placement in Resurrection Bay, away from existing downstream infrastructure.

With increasing infrastructure situated in the historical lower watershed, FWOP conditions continue to maintain an enhanced likelihood of environmental impact through the inadvertent release of environmental contaminants from catastrophic flooding. Petroleum products such as fuels and lubricants, and common household and industrial chemicals are now ubiquitous within Lowell Creek’s historical channel zone. The absolute failure of Lowell Creek's current condition would result in a return to its historical and natural condition, which would destroy infrastructure and expose potential contaminants to the environment. Typically, petroleum, its byproducts, and other industrial compounds persist in the environment longer than the effects witnessed at initial exposure. Despite differing levels of innate toxicity, some compounds impair surface water quality, migrate throughout the groundwater table, bioaccumulate in living organisms, and interrupt and affect a whole suite of human and animal endocrine functions.

4.10 Summary of Without Project Condition

Under the FWOP conditions, Lowell Creek would continue to threaten Seward with periodic flooding. The debris would continue to aggregate at the outfall area requiring flood-fighting efforts and bringing potential damages to the City of Seward, the Lowell Point community, the Alaska SeaLife Center, and the surrounding area. The bridge downstream of the outfall would likely incur future damage, and the city's sewage treatment facility would remain threatened. The threat of tunnel blockage would persist, potentially leading to an inflow of water and debris into downtown Seward resulting in structural damages and risk of loss of life. [redacted]

5. FORMULATION AND EVALUATION OF ALTERNATIVE PLANS*

5.1 Plan Formulation Rationale

Plan formulation is the process of building alternative plans that meet planning objectives and avoid planning constraints. Alternatives are a set of one or more management measures functioning together to address one or more study objectives. A management measure (measures) can be an activity or structural feature or element that can be implemented at a specific geographic location to address one or more planning objectives. A non-structural action, such as "structures relocation," is defined as an activity that reduces human exposure or vulnerability to a flood hazard without altering the nature or extent of that hazard. A structural activity typically impacts the hazard and requires construction or assembly, usually within the project area or site.

During the planning charrette meeting conducted in Seward on 25–26 October 2016, participants developed preliminary descriptions of existing and FWOP conditions. Then measures were identified, screened, and used to develop alternative plans. A combination of small and large group interactive exercises facilitated participation. These alternative plans were further refined during the study process.

The team noted early in the study that risk to life safety is inherent in any flood diversion system and incorporated a hybrid risk assessment methodology into the study to address the existing risk to life safety and to quantify reductions in risk attributable to potential alternatives.

The complexity of the project and environment resulted in several planning iterations throughout the study. Numerous subtle facets of the project led to reconsideration of measures such as tunnel diameter, outfall designs, debris basins, and non-structural alternatives. The process is described below.

5.2 Criteria and Metrics

The team screened measures and formulated alternative plans to address study objectives, adhere to study constraints, and consider the four national criteria of completeness, effectiveness, efficiency and acceptability (Section 2.7), and the study specific criteria of reduction of risk to life safety (Section 2.8). In the risk assessment, the PFMs were analyzed as pathways with various events leading to completion of the pathway. Completion of the pathway was determined as uncontrolled release of flow over the dam. These events were portrayed as risk nodes along the pathway with interruption at any node reducing the chance that the pathway would move forward to completion. All measures were also evaluated to determine what risk nodes each addressed, if any, within the PFMs identified by the risk assessment. The node descriptions are listed in Table 9. The team also ensured that measures would address study objectives. The team did consider natural and nature-based measures and alternatives, however, the energy regime and soils in the area were determined to not be conducive to natural or nature-based alternatives.

Table 9. General Description of PFM Risk Nodes.

Potential Failure Mode	Node Description
PFM 3: Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area	Node 1 – Debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the tunnel Node 2 – Head fails to flush the debris plug Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release
PFM 5A: Landslide blocks tunnel entrance leading to flow into consequences impact area	Node 1 – Soil and rock on steep slopes above tunnel become saturated, slide into the tunnel entrance, and block it Node 2 – Head fails to flush the landslide debris out of the tunnel Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release
PFM 6A: Upstream landslide forms dam that overtops, breaches, sending surge release flow into consequences impact area	Node 1 – Soil and rock on steep slopes become saturated, and a large landslide forms a dam in the canyon upstream of the project Node 2 – The landslide dam breaches, releasing a surge of water and debris down the canyon Node 3 – Debris blocks flow through the tunnel Node 4 – Water pressure fails to flush the landslide debris out of the tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Uncontrolled release
PFM 21: Scour of tunnel liner which leads to liner/rock failure and tunnel blockage	Node 1 – Un-remediated void in the tunnel liner Node 2 – The scour action continues undermining the concrete liner and invert into the rock Node 3 – Scour action continues to remove tunnel liner Node 4 – Tunnel liner collapses with rock mass blocking tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Blockage occurs, and uncontrolled release

5.2.1 Natural and Nature-based Measures

The physical environment of the basin that generates the flood risk to the community consists of a four square mile mountain canyon basin with a steep bed gradient and canyon walls formed from loose material resting at the angle of repose. Risk driving events cause movement of large material. Given these constraints of space, gradient and dynamic environment, the team did not find any natural or nature based features (NNBF) that would be effective at reducing flow frequency or flood risk to the community. Features such as detention basins, stream meanders, setback levees or introduction of vegetation into the basin would require space and stable ground conditions to function. The lack of space and the rate of debris movement within the basin prevent these types of features from being constructed in the basin.

5.3 Measures Considered

The charrette meeting initially identified a total of 26 structural measures and 10 non-structural measures (**Table 10**). Although some of the non-structural measures could be considered as stand-alone alternatives, none were carried forward from the charrette to the initial array of alternatives. Rationale for their elimination is provided in **Table 13** below.

Table 10. Initial Measures Considered.

MEASURES – STRUCTURAL	MEASURES – NON-STRUCTURAL
Add additional tunnel	Relocate properties and infrastructure from floodplain
Construct new replacement tunnel (decommission existing)	Upstream flow monitoring
Refurbish existing tunnel (extend its lifetime)	Monitor soil movement upstream
Make tunnel bigger - (increase tunnel diameter)	Early warning system and evacuation plan – public education on flood risk and evac routes
Upstream dam (detention (with or without hydropower))	Raise structures on Jefferson street and add levee (floodproof along road)
Jefferson Street Channel ("flume") (construct channel through town to convey water) (removal of existing structure)	Relocate Seward
Depress Jefferson Street (to make it into a channel?)	Debris repurposing (roads, house pads, civil works projects, build uplands)
Construct additional diversion dam	Dredge the outfall (pre-flood to increase debris storage)
Construct Sabo dam (sediment management)	Tree removal from slopes (so trees do not become debris)
Raise existing dam	Emergency pumping
Hopper and conveyance structure near outfall	
Upstream sediment mining/removal	
Extend existing outfall over road further into bay	
Upstream debris basin	
Re-align Lowell Point road	
Above ground pipe	
Underground channel (pipe) at Jefferson Street	
"Portal protection" - Modify existing tunnel entrance to minimize blockage potential	
Lower outfall to grade	
Protect Lowell point road from debris/landslide (slope stability)	
Jefferson Street restore natural channel (with removal of existing structure)	
Upstream river training	
Cable netting on watershed hillsides	
Shotcrete slopes	
Flood control wall near Alaska SeaLife Center	
Improve low flow diversion	

5.3.1 Measures Screenings

Some measures were screened during the charrette, taking into account the experience of the charrette attendees. After the charrette, the Project Delivery Team (PDT) evaluated the measures further with input from all disciplines to determine what each measure would or would not contribute to potential solutions.

The team screened initial measures based on their effectiveness, constructability, and affordability; and by considering the reduction of damages by either preventing the flow of water through Seward from the structure and/or reducing the build-up of debris at the tunnel outlet. Evaluation of these factors considered varying flows and recurrence intervals. In addition, the team evaluated the situation with and without the occurrence of the tunnel being blocked by landslide or debris and resulting surge. Diverting the flow away from Seward is essential in preventing economic damages and critical to reducing the risk to life safety. Inhibiting the build-up of debris at the outlet would reduce economic damages related to sediment management.

5.3.1.1 Nodal Risk Screening

The nodal risk analysis of measures indicated that several of the measures would not address any of the risk nodes of the various PFMs. Some were reasonably eliminated based on this alone, while others were still carried forward because they addressed study objectives or made an alternative complete (for example, outfall extension or removing structures from the floodplain). The summary of the risk analysis of initial measures is presented in Table 11.

Risk to life safety weighed heavily in the analysis of measures, and many of the measures initially carried forward show that they would not address any of the risk nodes. Table 12 displays all the measures which address at least one risk node.

Table 11. Summary of Initial Measures Analysis by Risk Node.

PFM Node	Measures to Address
PFM 3	
Node 1	Make tunnel bigger - (increase tunnel diameter), Upstream dam (detention/with or without hydropower), Tree removal from slopes (so trees don't become debris), Upstream sediment mining/removal, Upstream debris basin, Cable netting on watershed hillsides, Shotcrete slopes
Node 2	Add additional tunnel, Construct new replacement tunnel (decommission existing), Make tunnel bigger - (increase tunnel diameter), Upstream dam (detention/with or without hydropower), Construct additional diversion dam, Construct Sabo dam (sediment management), Raise existing dam
Node 3	Upstream flow monitoring, Monitor soil movement upstream, Early warning system and evacuation plan
Node 4	Add additional tunnel, Construct additional diversion dam, Raise existing dam
PFM 5A	
Node 1	Make tunnel bigger - (increase tunnel diameter), Add additional tunnel, Construct new replacement tunnel (decommission existing), "Portal protection" - Modify existing tunnel entrance to minimize blockage potential
Node 2	Make tunnel bigger - (increase tunnel diameter), Add additional tunnel, Construct new replacement tunnel (decommission existing), Construct additional diversion dam, Raise existing dam
Node 3	Early warning system and evacuation plan
Node 4	Add additional tunnel, Construct additional diversion dam, Raise existing dam
PFM 6A (Main Risk Driver)	
Node 1	Monitor soil movement upstream, Upstream sediment mining/removal, Shotcrete slopes
Node 2	Monitor soil movement upstream, Upstream dam (detention/with or without hydropower), Construct Sabo dam (sediment management), Upstream sediment mining/removal, Upstream debris basin
Node 3	Add additional tunnel, Construct new replacement tunnel (decommission existing), Make tunnel bigger - (increase tunnel diameter), Tree removal from slopes (so trees do not become debris)
Node 4	Add additional tunnel, Make tunnel bigger - (increase tunnel diameter), Construct additional diversion dam, Raise existing dam
Node 5	Early warning system and evacuation plan
Node 6	Add additional tunnel, Construct additional diversion dam, Raise existing dam
PFM 21	
Node 1	Add additional tunnel, Construct new replacement tunnel (decommission existing), Refurbish existing tunnel (extend its lifetime)
Node 2	Upstream dam (detention/with or without hydropower), Construct Sabo dam (sediment management), Upstream sediment mining/removal, Upstream debris basin, Cable netting on watershed hillsides
Node 3	Upstream dam (detention/with or without hydropower), Construct Sabo dam (sediment management), Upstream sediment mining/removal, Upstream debris basin, Cable netting on watershed hillsides
Node 4	None
Node 5	Early warning system and evacuation plan
Node 6	Construct additional diversion dam, Raise existing dam

Table 12. Summary of Initial Measures that Address at Least One Risk Node.

PFM Node	Measures to Address
PFM 3	
Node 1	Make tunnel bigger - (increase tunnel diameter), Tree removal from slopes, Upstream sediment mining/removal, Upstream debris basin
Node 2	Add additional tunnel, Construct new replacement tunnel (decommission existing), Make tunnel bigger - (increase tunnel diameter), Construct additional diversion dam, Construct Sabo dam (sediment management), Raise existing dam
Node 3	Early warning system and evacuation plan
Node 4	Add additional tunnel, Construct additional diversion dam, Raise existing dam
PFM 5A	
Node 1	Make tunnel bigger - (increase tunnel diameter), Add additional tunnel, Construct new replacement tunnel (decommission existing), "Portal protection"
Node 2	Make tunnel bigger - (increase tunnel diameter), Add additional tunnel, Construct new replacement tunnel (decommission existing), Construct additional diversion dam, Raise existing dam
Node 3	Early warning system and evacuation plan
Node 4	Add additional tunnel, Construct additional diversion dam, Raise existing dam
PFM 6A (Main Risk Driver)	
Node 1	None
Node 2	Construct Sabo dam (sediment management), Upstream sediment mining/removal, Upstream debris basin
Node 3	Add additional tunnel, Construct new replacement tunnel (decommission existing), Make tunnel bigger - (increase tunnel diameter), Tree removal from slopes
Node 4	Add additional tunnel, Make tunnel bigger - (increase tunnel diameter), Construct additional diversion dam, Raise existing dam
Node 5	Early warning system and evacuation plan
Node 6	Add additional tunnel, Construct additional diversion dam, Raise existing dam
PFM 21	
Node 1	Add additional tunnel, Construct new replacement tunnel (decommission existing), Refurbish existing tunnel (extend its lifetime)
Node 2	Construct Sabo dam (sediment management), Upstream sediment mining/removal, Upstream debris basin
Node 3	Construct Sabo dam (sediment management), Upstream sediment mining/removal, Upstream debris basin
Node 4	None
Node 5	Early warning system and evacuation plan
Node 6	Construct additional diversion dam, Raise existing dam

5.3.2 Measures Eliminated

Due to the complex nature of the study and the iterative process of planning, measures were eliminated and sometimes even reconsidered based on the collection of additional data or comments from public and agency reviewers. For example, an upstream debris basin was initially screened, but later reintroduced in a modified fashion. Floodplain relocation measures were also initially screened, but later reconsidered by incrementally removing alternative groups of select structures to evaluate risk reduction.

Eighteen structural and six non-structural measures were ultimately eliminated and not carried forward for further consideration in alternative plans. Table 13 provides a summary of the eliminated measures with rationale. Similar measures were grouped together which resulted in nine structural and four non-structural measures.

5.3.3 Measures Carried Forward

Of the measures the team initially identified, eight structural and two non-structural measures were considered to be viable in addressing problems identified at the site. Table 14 provides the summary of measures caried forward. It can be noted that there are two measures (refurbishing the existing tunnel and debris basin) in Table 14 which, while scoring low in the national criteria, were carried forward based on the fact they do address at least one risk node. Refurbishing the existing tunnel, combined with other measures, could provide more complete and effective alternatives. The debris basin was carried forward in an attempt to discover an alternative with positive NED benefits.

Table 13. Measures Eliminated and Rationale.

Measures	Addresses	Elimination Rationale
Structural		
Alter Jefferson Street/Structures (4 similar measures combined)	Lowell Creek Flooding	Effectiveness low. Altering Jefferson Street has been attempted in the past, and before the current system, a channel down Jefferson Street was the primary means of flood control. However, as happened with the previous channel, one large event could fill the channel and cause massive flooding (Section 3.4.2). Ineffective because the flow slows down and drops its sediment load, thus clogging the channel or pipe. These measures would not address any risk.
Pipe to covey flow (2 similar measures combined)	Lowell Creek Flooding	Effectiveness low. A pipe to convey flow would be ineffective in conveying the amount of flow that can occur during larger events. The existing storm sewer has shown that such a measure would not resolve the issue. These measures would not address any risk.
Upstream alterations, retention, or rack/slit dam (8 similar measures combined)	Lowell Creek Surge/ Outlet Debris Flooding	Effectiveness and constructability low. Although the team did carry forward an upstream retention dam for NED analysis (Alternative 5), the measures involving upstream alterations, in general, would only transfer the risks further up the drainage to a more difficult area to access and perform maintenance and debris removal. These alterations would also be more difficult to construct and would not provide a permanent, effective solution.
Lowell Point Road (3 similar measures combined)	Outlet Debris Flooding	Effectiveness low. Measures that alter Lowell Point Road would not be effective as they do not address the primary risk driver of surge flow and the associated debris with such flows that could overtop the dam. These measures also do nothing to address flows, not associated with a surge. These measures would not address any risk.
Hopper/conveyance at the tunnel outlet	Outlet Debris Flooding	Effectiveness low. The team considered placing a hopper with a conveyance system to move debris from the outfall. The flows and debris from any but the smallest events would likely destroy such a structure and/or require significant maintenance; thus, it would not be effective in addressing any risk.
Lower tunnel outlet to grade	Outlet Debris Flooding	Effectiveness low. Lowering the tunnel outlet to grade would do nothing to prevent flows or debris from filling the area and damaging or destroying the bridge. Such a measure would still leave Lowell Point cut off during flood events, flood the area and threaten critical infrastructure. This measure would not address any risk.
Raise existing dam	Lowell Creek Flooding	Effectiveness and affordability low. Raising the existing dam would not increase the flow in the tunnel as the tunnel only has a limited capacity. It may provide a small amount of extra time before the dam overtopped but would not prevent it or reduce flows into Seward.
Upstream river training	Lowell Creek Surge	Effectiveness low. Dependent on location, very difficult to maintain due to debris.

Measures	Addresses	Elimination Rationale
Flood control wall near Alaska SeaLife Center	Outlet Debris Flooding	Effectiveness low. Remnants of an old flood control wall can be seen near the Alaska SeaLife Center as the flow enters Resurrection Bay, and this shows that a sea wall would only provide a temporary solution for small events. Such a measure would not address larger flow events, debris, or surge. This measure would not address any risk.
Non-Structural		
Dredging outfall	Outlet Debris Flooding	Effectiveness low. The outfall can be dredged to remove debris; however, the event of record in 1986 deposited an estimated 60,000 cy of debris. This indicates that such measures would be ineffective at larger flow events and, if attempted during any event, would be dangerous and impossible for most events. This measure would not address any risk.
Monitoring/Technology (Early Warning System, 3 similar measures combined)	Outlet Debris Flooding/ Lowell Creek Flooding	Effectiveness low. Events occur with such suddenness that any efforts at monitoring would be of limited benefit. The terrain lends itself to flashy flows, and if debris blocks the tunnel, only a very short time would elapse before flow went over the spillway and into downtown Seward. Specifically concerning an early warning system. This was initially considered, but later analysis showed that a warning time of at least 8 hours would be needed to provide benefits from such a measure. Less time could actually lead to increased risk to life safety due to people being caught in vehicles in an attempt to evacuate the area. Landslides producing debris dams in Lowell Creek are quickly overwhelmed and breeched. The risk assessment estimated that such an event would only provide, at most, about 15 minutes of warning time. Thus, the early warning system measure cannot provide benefits to the project or the population and was subsequently eliminated from all alternatives, though the stream gage inside the tunnel would be beneficial to operations of the system and was retained within the tunnel measures.
Relocate Seward	Lowell Creek Flooding	Affordability and acceptability low. Relocating Seward would only transfer the risk. The area is on an alluvial fan, and no location in the vicinity is out of the floodplain.
Raise Structure	Lowell Creek Flooding	Effectiveness and acceptability low. With historical records showing flooding that left 20 feet of debris in the city, this measure would not be effective in preventing damages.
Emergency pumping	Lowell Creek Flooding	Effectiveness and constructability low. Emergency pumping would be completely overwhelmed in almost any appreciable event. In addition to the volume of flow, debris is deposited of such size and volumes that it could easily cause damage or destruction of the pumps. The sudden large flows and carried debris would challenge the pump system design and capacity with no backup if it failed.
Debris repurposing	Outlet Debris Flooding	Effectiveness low. Debris repurposing could only occur after an event, and this would do nothing to address the issues of flow, debris, and surge in the area. This measure would not address any risk.

Table 14. Summary of Final Measures Carried Forward.

Measure	PFM/Node Addressed	Study Objective Addressed	Completeness	Effectiveness	Efficiency	Acceptability
Enlarge existing tunnel	PFM3, Nodes 1,2 PFM5A, Nodes 1,2 PFM6A, Nodes 3,4	Reduce risk and flood damages	Incomplete	High	Medium	High
Refurbish existing tunnel	PFM21, Node 1	Slightly reduces risk and damages	Incomplete	Low	Low	Low
Additional tunnel	PFM3, Nodes 2,4 PFM5A, Nodes 1,2,4 PFM6A, Nodes 3,4,6 FFM21, Node 1	Reduce risk and flood damages	Incomplete	High	High	High
Additional diversion dam	PFM3, Nodes 2,4 PF5A, Nodes 2,4 PFM6A, Nodes 4,6 FFM21, Node 6	Reduce risk and flood damages	Incomplete	High	High	High
Extended Outfall	None	Reduce the cost of emergency response and management	Incomplete	Medium	Medium	High
Upstream debris basin	PFM3, Node 1 PFM6A, Node 2 FFM21, Nodes 2,3	Reduce the cost of emergency response and management	Incomplete	Low	Low	Low
Selective tree removal	PFM3, Node 1	Reduce risk and flood damages	Incomplete	Medium	Medium	High
Protect tunnel inlet from landslide	PF5A, Node 1	Reduce risk and flood damages	Incomplete	Medium	Medium	High
Relocation of select structures	None	Reduce risk and flood damages	Incomplete	Medium	Low	Low

Intentionally left blank.

5.4 Alternatives Considered

The planning process for this study led to a complex iterative formulation of alternatives. The team developed preliminary alternatives at the charrette, many of which would be revised, expanded, or discarded during the formation process. This section outlines the process of alternative formulation.

5.4.1 Preliminary Alternatives

The PDT combined measures to develop the preliminary array of alternative plan concepts at the charrette. The array of alternative plans was then assigned for evaluation by multi-disciplinary groups at the charrette. Each group then reported out refinements to these plans and received feedback from the other groups on ways to incrementally improve the various plans. This process at the charrette resulted in a preliminary array of 12 alternatives (**Table 15**).

Table 15. Preliminary Alternatives.

Alternative	Measures
1	"Improve status quo" - early warning and notification, improve outfall structure, minimize potential for landslide blockage
2	Alt 1 + heighten dam, add slit in dam
3	Alt 2 + enlarge existing tunnel
4	Alt 3 + modify existing dam
5	New system – new features, keep existing as overflow, extend existing outfall, 2nd tunnel with outfall south of fisheries docks, early warning system
6	Alt 5 + depression of Jefferson St. for utilization of road as spillway, flat-top on dams (for debris cleanout during event)
7	Refurbishment of existing system – increase capacity, increase dam height, extension of outfall, access for heavy equipment, enlarge pipe to & down Jefferson St. (Emer. maintenance diversion), non-structural (same as 5)
8	Extend outfall, portal protection to existing tunnel, non-structural (same as 5)
9	Enlarge current tunnel to handle PMF, reconstruct diversion dam to handle PMF, extend existing flume out to the bay, realigning Lowell Point Rd., add debris basin upstream, incorporate gages and cameras upstream, early warning system
10	Construct new dam upstream of current (to allow for controlled release), debris basin upstream, gages and cameras, early warning system, use existing system for controlled release
11	Flood control channel down Jefferson St. to handle PMF, decommission existing system or use as backup (maintenance), gages and cameras upstream, early warning system
12	Depress Jefferson St., use existing system as is, gages and cameras upstream, early warning system

5.4.2 Initial Alternatives

After the charrette, and as new data were collected, the PDT further evaluated the preliminary list of alternative plans, screening many of the preliminary alternatives due to impracticality and/or no reduction in risk to life safety before the Alternatives Milestone Meeting. This resulted in an array of 5 alternative plans, including the No Action plan, referred to in this report as the array of Initial Alternatives (**Table 16**).

Table 16. Initial Alternatives.

Alternative	Description
1	No Action
2	Improve Existing Flood Diversion System
3	Enlarge Current Flood Diversion System to Convey Larger Flow, with two tunnel diameter options
4	Construct New Flood Diversion System, with two tunnel diameter options
5	Construct Debris Retention Basin

Some may interpret the term "improve" used for Alternative 2 to include enlarging the tunnel, however, here the term is used to describe actions taken on the current system to improve its condition and provide elements to protect the current system in order to reduce possible blockages.

5.4.3 Tunnel Diameter Screening

As noted in Section 5.3, during plan formulation the need to determine effective tunnel diameter became apparent. The team analyzed several tunnel diameters for

Alternatives 3 and 4 with regards to flow capacity, reduction in residual risk to life safety, needed dam height, and cost to construct (Table 17. Initial Tunnel/Dam Height Screening.

Tunnel Diameter (ft)	Capacity based on matching existing tunnel-inlet invert to spillway crest height (cfs)	Approx. depth of flow and percent of diameter away from the tunnel entrance (ft / %)	Capacity based on raising spillway crest higher than existing condition (cfs)	Approx. depth of flow and percent of diameter away from the tunnel entrance (ft / %)	Amount spillway crest must be raised to achieve stated capacity (ft)	ROM Tunnel & Dam Cost ($M)
10	2,800	7.8 / 78	2,800	7.8 / 78	0.0	$45
12	4,100	8.6 / 72	4,500	9.3 / 78	6.0	$47
14	5,500	9.2 / 66	5,800	9.6 / 68	3.5	$49
16	7,000	9.7 / 61	7,600	10.3 / 64	5.5	$52
18	8,500	10.1 / 56	14,000	14.7 / 82	42.5	$54
20	10,000	10.4 / 52	19,000	16.8 / 84	58.0	$230
22	11,500	10.7 / 49	19,000	14.8 / 67	34.0	$140
24	14,000	11.4 / 48	19,000	13.8 / 58	19.5	$112

Note: The recommended tunnel diameter is highlighted in yellow.

). As can be seen in the table, only tunnel diameters of 18 ft and above would have the capacity to convey flows from a PMF event even with raising the dam height. Also, tunnel diameters above 18 ft would have the capacity to convey a PMF event with surge. Tunnel diameters above 18 ft with a raised dam height would be able to convey PMF with surge flows.

Tunnel diameters over 18 ft were considered at 20 ft, 22 ft, and 24 ft. The additional dam height necessary for the 20-ft and 22-ft tunnel diameters to produce sufficient head pressure compared to the 24-ft tunnel resulted in a much higher cost. Although preliminary screening indicates the 18-ft tunnel would provide sufficient benefits to the project, to determine the most cost effective design in relation to benefits in reduced risk to life safety, the 14-ft, 16-ft, 18-ft, and 24-ft diameters were included in the CE/ICA analysis (see Section 6.7).

Table 17. Initial Tunnel/Dam Height Screening.

Tunnel Diameter (ft)	Capacity based on matching existing tunnel-inlet invert to spillway crest height (cfs)	Approx. depth of flow and percent of diameter away from the tunnel entrance (ft / %)	Capacity based on raising spillway crest higher than existing condition (cfs)	Approx. depth of flow and percent of diameter away from the tunnel entrance (ft / %)	Amount spillway crest must be raised to achieve stated capacity (ft)	ROM Tunnel & Dam Cost ($M)
10	2,800	7.8 / 78	2,800	7.8 / 78	0.0	$45
12	4,100	8.6 / 72	4,500	9.3 / 78	6.0	$47
14	5,500	9.2 / 66	5,800	9.6 / 68	3.5	$49
16	7,000	9.7 / 61	7,600	10.3 / 64	5.5	$52
18	8,500	10.1 / 56	14,000	14.7 / 82	42.5	$54
20	10,000	10.4 / 52	19,000	16.8 / 84	58.0	$230
22	11,500	10.7 / 49	19,000	14.8 / 67	34.0	$140
24	14,000	11.4 / 48	19,000	13.8 / 58	19.5	$112

Note: The recommended tunnel diameter is highlighted in yellow.

5.4.4 Tunnel Outfall Design Screening

A new outfall design is a structural measure applicable to all structural alternatives, except Alternative 5. The tunnel and upstream features directly benefit the structures in downtown Seward by protecting from inundation resulting from an overtopping of the dam due to tunnel failure or the system being overwhelmed. The outfall feature allows the City of Seward to better manage the sediment and debris, only having a minor effect on the inundation of structures in the vicinity of the SeaLife Center.

The existing project functions without an extended outfall; however, an extended outfall would provide operational efficiencies that need to be justified based on the standalone benefits to the project from that measure. The outfall is a measure with a relatively consistent design and provides benefits that can be applied to each alternative for plan selection purposes. **Figure 21** shows the existing project in relation to nearby facilities.

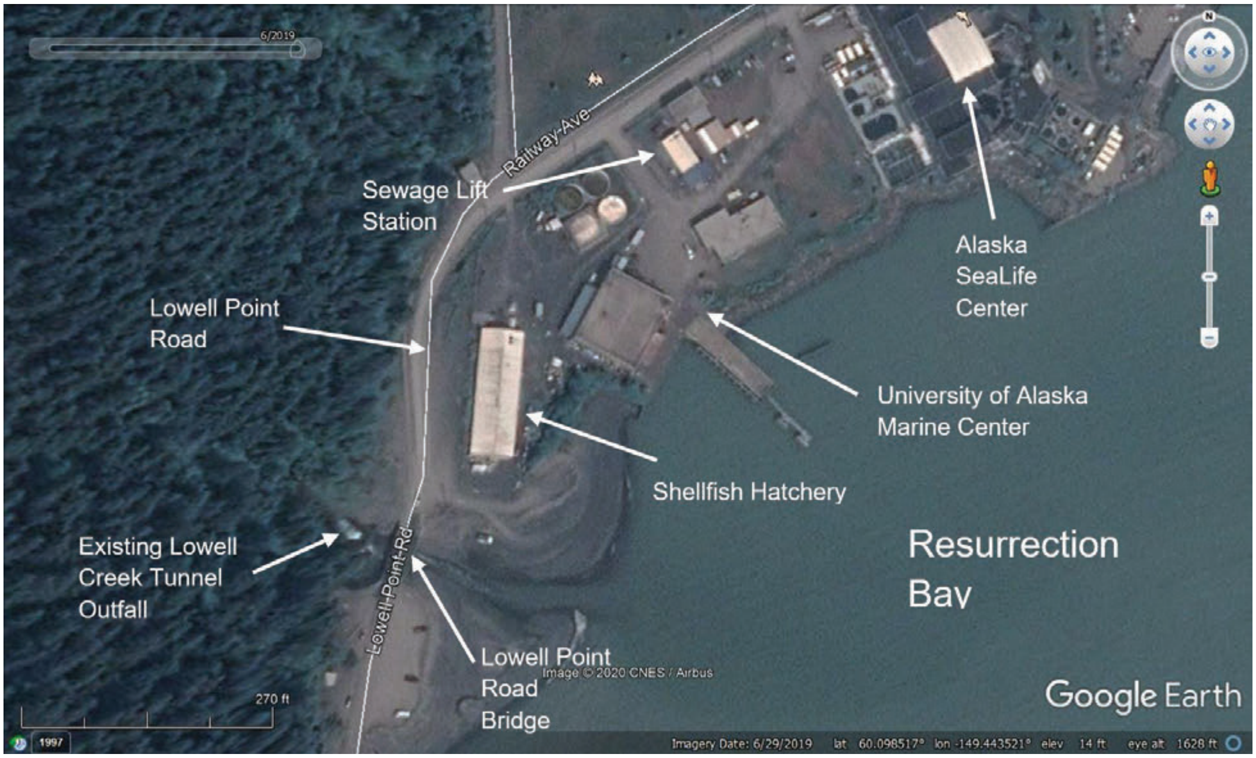

Figure 21. Existing Lowell Creek Tunnel Outfall and Vicinity (GoogleEarth Image 29 June 2019).

The existing tunnel discharge point is west of Lowell Point Road and requires the City of Seward to remove sediment that rapidly accumulates during storm events. The city must take such emergency actions to maintain road access to the Lowell Point community located south of the tunnel outfall, to reduce damage to the bridge and road, and to reduce the risk of flooding and associated damages to nearby infrastructure. The City of Seward spends an annual average of $758,000 on routine and emergency actions associated with the discharge from the Lowell Creek tunnel.

The team considered various outfall design lengths during the study and qualitatively compared effectiveness, benefits, and the ROM cost. The outfall effectiveness is based on the ability to convey the anticipated flow to a discharge point. All the lengths evaluated would have a similar basic design consisting of pre-cast concrete, open-channel flumes placed on drilled piers as described in Appendix C: Hydraulic and Structural Design, and Section 7.2.4 below. The construction costs increase as the outfall structure gets longer. Given the consistent design, the discharge point is the main consideration for the effectiveness evaluation for each outfall option.

The PDT did not analyze intermediate lengths between the 150-ft and 500-ft extensions. Preliminary consideration of intermediate lengths showed a high cost of construction with little or no change in management of debris until the outfall reached the deeper water at the 500-ft length with probable increases in operation and maintenance (O&M) costs due to the frequent offshore dredging required in shallow water.

The outfall evaluation consisted of five general outfall options with varying discharge points, associated benefits, ROM construction, and maintenance costs as listed below:

- Limited outfall length similar to the current outfall that discharges east of Lowell Point Road between the mountain and the road
- 100-ft-long extended outfall that discharges west of the current Lowell Point Road alignment between the mountain and the road. This option includes a cost to realign the road and bridge to a higher elevation on the mountain side to get above the discharge point
- 150-ft-long extended outfall that extends over Lowell Point Road that discharges on the existing fluvial fan in relatively shallow water
- 500-ft-long extended outfall that extends over Lowell Point Road that discharges into deeper water
- 750-ft-long extended outfall that extends over Lowell Point Road that discharges into even deeper water

Each outfall option was compared for benefits or negative impacts to:

- Threat of Lowell Point Road closure and maintenance of access to Lowell Point community to the south, especially during storm events
- Threat of flooding over the road caused by sediments and debris accumulating and blocking flow under the Lowell Point Road bridge
- Emergency action costs and safety concerns during storm events to maintain the road access and flooding associated with accumulating sediment east and west of the road
- Dredge maintenance costs to manage accumulated sediment

Of the five different lengths examined for a project outfall, the PDT determined that the 150-ft outfall would provide adequate sedimentation control for the project (Table 18). With the 100-ft outfall, the road would need to be realigned as the outfall discharge would otherwise remain on the west side of the road and bridge. This was expected to result in a higher cost for a 100-ft outfall than for a 150-ft outfall. Without the realignment of the road, this option would leave the Lowell Point community vulnerable to being cut off during flood events and fail to protect the road and bridge during storm events. In addition, City personnel would continue to be put in harm’s way during flood-fighting activities (see Figure 10 and Figure 11 above). With the road realignment, City personnel could perform maintenance activities when site conditions were safer. A drawback to realigning the road is that it would do nothing to reduce the risk to life safety and may increase this risk by bringing drivers closer to falling debris in the event of earthquake or tsunami. However, flood fighting would still be needed to reduce flooding impacts to nearby structures as the sediment would be deposited on land or very shallow water at higher tides.

The volume of material hauled off site during current operations is not known; however, it is assumed to be a very small portion of the estimated 25,000 cy of debris discharged through the tunnel annually. Operation of the existing project requires the City of Seward to push the majority of the material to the edge of the alluvial fan and into deeper water with bulldozers.

Construction of an outfall extension would reduce risk to damaging the road or utilities that cross the discharge path and minimize road closures for people living to the south of the project. The 100-ft and 150-ft extensions would still require handling of material at the discharge point with bulldozers to move it away from the outfalls and into Resurrection Bay. These designs still give the City the opportunity to load and haul away material from the outfalls to be used or stored elsewhere and it is assumed that the difference in quantities for these purposes will be minimal.

Data are insufficient to justify changes in the cost to operate equipment to manage debris between outfall extension alternatives. Intuitively, with a shorter push distance to deep water, there would be a shorter time required to clear debris, but without more detailed data from the sponsor, this could not be analyzed. The PDT made the conservative assumption that it would cost as much as the without project condition.

Maintenance of the 500-ft outfall extension was assumed to be accomplished by floating plant. This alternative was screened based the construction cost, but if it were employed, a dredged material disposal site would have been designated and this would reduce impacts to the docks adjacent to the alluvial fan by removing material from the system into deeper water where navigation would not be impacted.

Table 18. Outfall Evaluation Summary.

Outfall Length	Discharge Point	ROM Construction Cost	Maintenance Costs	Benefit Comments
Limited	Base of mountain west of road	$4,000,000	$758,000/year	Sediment would continue to be deposited in the current location damaging or destroying the bridge during events and threatening community infrastructure
100-ft	West of road	$14,200,000	$204,000/year	Would require realignment of the road to prevent damage to the bridge
150-ft	Fluvial fan east of road	$13,900,000	$204,000/year	Would eliminate flood-fighting during events and damage to the bridge. No dredging required, similar effort compared to current conditions, though damage to road and bridge would be avoided.
500-ft	Deep water east of road	$36,900,000	$744,000/year	Sediment would be deposited into the Bay, but periodic dredging would be required approximately every 5 years
750-ft	Deep Water in Resurrection Bay	$56,000,000	No dredging	Sediment deposited directly into deep water. No dredging would be required.

A 150-ft outfall would reach over Lowell Point Road, eliminating the need to realign the road while still protecting it from sediment deposition. This option discharges the sediment on the alluvial fan at approximately +22 ft MLLW. The quantity and cost would be similar to or same as the current maintenance cost and that of a 100-ft outfall; however, this activity would be safer for City personnel because this maintenance activity can be scheduled when site conditions (e.g., wave height) are safe, with limited, if any, need to conduct maintenance activities during flood events to reduce debris and flooding impacts to nearby structures.

A 500-ft outfall option would discharge sediments into the waters of Resurrection Bay at an approximate depth of -36.5 ft MLLW. These sediments would accumulate and require periodic dredging approximately every five years—the cost of offshore dredging results in a higher average annual cost. However, as with the 150-ft outfall, this dredging activity should be safer since it can be scheduled when conditions are favorable.

A 750-ft outfall discharges sediments into deeper water on a relatively steep slope (1.5H:1V) at approximately -179 ft MLLW and would require no periodic dredging. However, the cost of construction and the depth of construction led the PDT to determine an outfall of this length would not be feasible.

In addition to length of the outfall, the team looked at relocating the outfall to the south of the current location. This would increase the length of the tunnel. The team found that the elevation of the outfall was too low and there would be a high risk of debris accumulation blocking the tunnel at the exit. For the outfall to function, there needs to be a significant 'drop' from the end of the tunnel and outfall extension to allow for debris buildup without blocking the tunnel or flume. This was the failure mode of the original flume project and the height of the outfall is an important design feature for the system. Similarly, if the tunnel were moved up Lowell Canyon, any gains in terms of a higher intake elevation are lost due to the tunnel length increasing as Bear Mountain essentially gets wider farther upstream. As the tunnel length increases, the slope would also need to increase to offset friction losses, resulting in a low outfall. Due to these factors, relocation of the outfall was eliminated from further consideration.

The PDT concluded that the 150-ft outfall with an estimated construction cost of $14M provides optimal benefits to the community, including an added benefit of safer maintenance activities. Due to the conceptual nature of this outfall analysis, an environmental analysis was not carried out on all the options; however, an environmental analysis was carried out on the optimal (150-ft) option as it is included in all structural alternatives except for Alternative 5.

5.4.5 Alternatives Carried Forward to the Tentatively Selected Plan Milestone

Based on the additional screening for tunnel diameter, the team developed options within Alternatives 3 and 4 for 18-ft and 24-ft tunnels resulting in the following list of alternatives (**Table 19**).

Table 19. Alternatives Carried Forward to the TSP Milestone.

Alternative	Description
1	No Action
2	Improve Existing Flood Diversion System
3	Enlarge Current Diversion System to Convey Larger Flow 18-ft Tunnel 24-ft Tunnel
4	Construct New Flood Diversion System 18-ft Tunnel 24-ft Tunnel
5	Construct Debris Retention Basin

5.4.5.1 Alternative 1: No Action

If no action is taken to improve the Lowell Creek Flood Diversion System, flows threatening to exceed the capacity of the existing flood diversion system will continue to threaten to overtop the diversion dam and cause structural damages and risk life loss in Seward. Surge release floods from the failure of temporary landslide debris blockages will continue to compound this threat. Flood water arrival with little to no warning will continue to make an effective evacuation of the at-risk population very difficult. Once exiting Lowell Canyon, flood water flow paths will be uncertain, further complicating any potential mitigation and evacuation efforts. Flood flows will breach the only road providing access to the Lowell Point community. Frequent repairs will continue to be required to keep the existing flood diversion system operational. The City of Seward will continue to expend effort and funds to manage the excessive amounts of sediment deposited at the tunnel, often under hazardous conditions, and nearby facilities will continue to experience elevated operational costs due to the sediment deposition and induced localized flooding. Due to summer tourism in Seward, additional people will be at risk if a flood were to occur during the tourist season.

5.4.5.2 Alternative 2: Improve Existing Flood Diversion System

Structural components of this alternative (Figure 22) would include refurbishing the existing tunnel, extending the outfall 150 ft to go over the road, protecting the tunnel inlet from landslide with a canopy, and improving the low flow diversion system. Non-structural components would include tree removal and a stream gage within the tunnel.

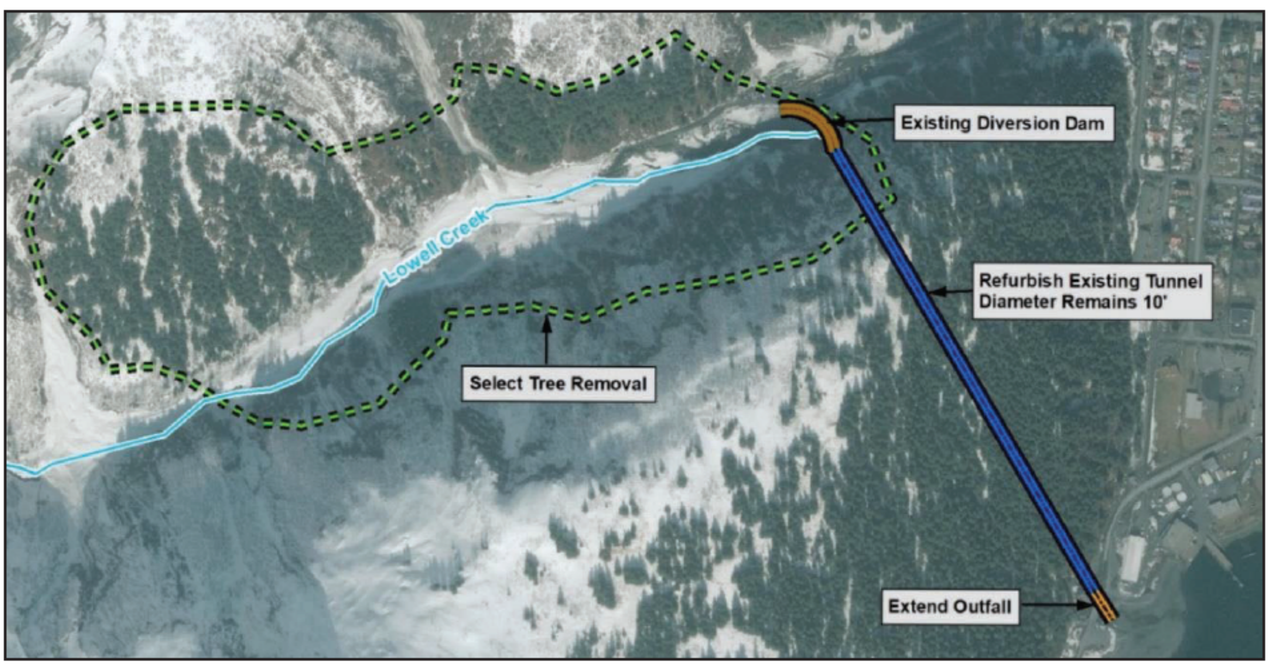

Figure 22. Alternative 2: Improve Existing Diversion System.

5.4.5.3 Alternative 3A and 3B: Enlarge Current Flood Diversion System to Convey Larger Flow

Alternative 3 includes enlarging the current flood diversion system to convey larger flows. Two options, “A” and “B,” were developed with the only difference being that the existing tunnel diameter would be enlarged to either 18 ft (Alternative 3A; Figure 23) or 24 ft (Alternative 3B). The flow capacities for these smaller and larger tunnel diameters would range from 8,500 cfs to 19,000 cfs, as discussed Section 4.9and in Appendix C: Hydraulics and Structural Design. The other components are consistent for each option and are listed below:

Structural components:

- Extending the outfall 150 ft to go over the road
- Protecting the tunnel inlet from landslide with a canopy
- Improving the low flow diversion system

Non-Structural Components:

- Tree removal
- Stream Gage within the tunnel

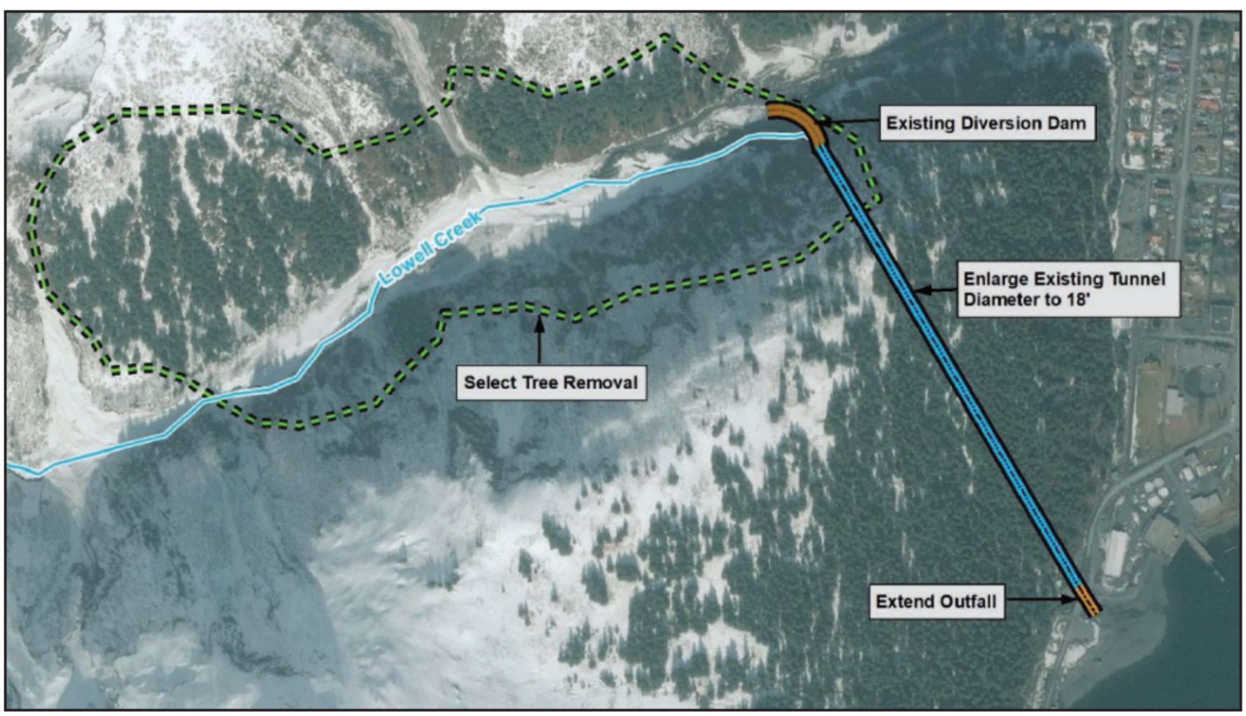

Figure 23. Alternative 3A: Enlarge Current System to Convey Larger Flow with 18-ft-Diameter Tunnel.

5.4.5.4 Alternative 4A and 4B: Construct New Flood Diversion System.

Alternative 4 includes a new tunnel and diversion dam upstream from the existing tunnel and refurbishing the existing tunnel. Two options, “A” and “B,” were developed with the only difference being that the new tunnel diameter would be either 18 ft (Alternative 4A; Figure 24) or 24 ft (Alternative 4B). The existing tunnel refurbishment would maintain the tunnel diameter at 10 ft. The flow capacities for these larger tunnel diameters would range from 8,500 cfs up to 19,000 cfs, and the existing tunnel capacity is estimated at 2,800 cfs, as discussed in Section 4.9 and in Appendix C: Hydraulics and Structural Design. The combined flow capacity of the system could approach 21,500 cfs. The other components are consistent with each option and are listed below:

Structural components:

- Extending the outfall 150 ft to go over the road
- Protecting the tunnel inlet of both tunnels from landslide with a canopy

Non-Structural Components:

- Tree removal
- Stream Gage within the tunnel

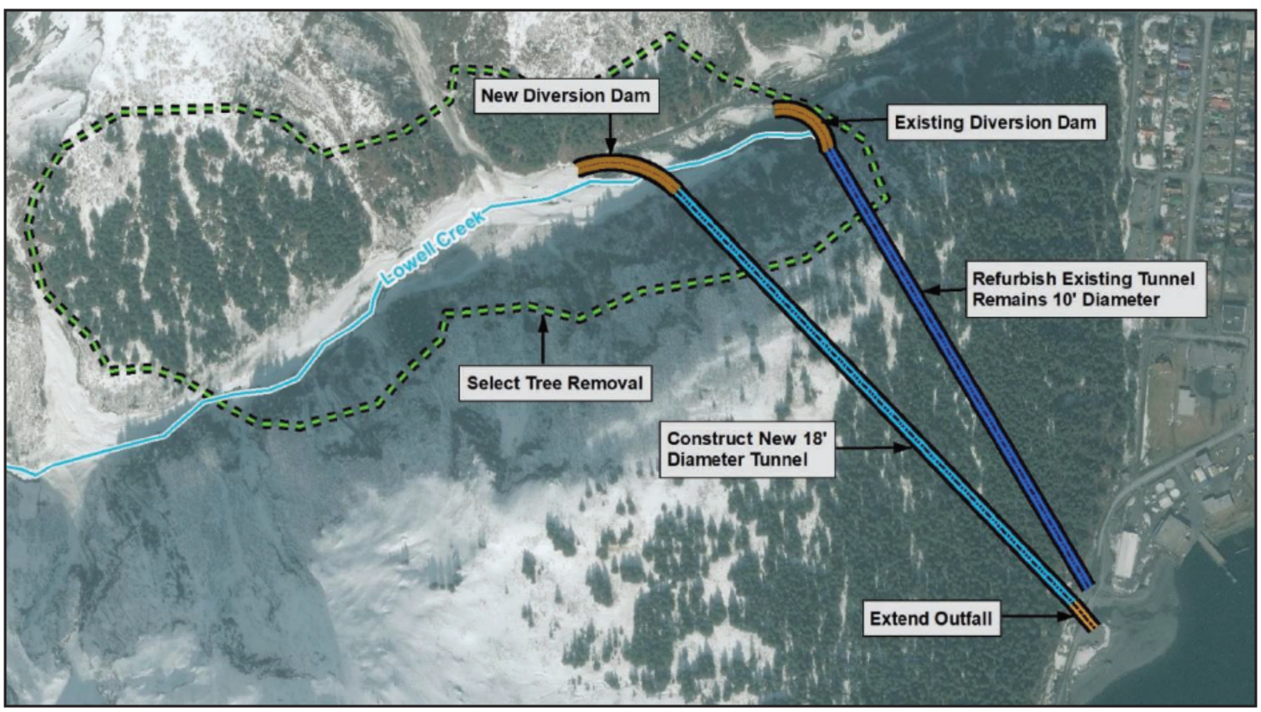

Figure 24. Alternative 4A: Construct New Flood Diversion System with 18-ft-Diameter Tunnel.

5.4.5.5 Alternative 5: Construct Debris Retention Basin.

Alternative 5 includes a roller-compacted concrete structure constructed approximately 700 ft upstream of the existing tunnel entrance to intercept debris before it passes through the tunnel (Figure 25). The structure is designed to create a 25,000 cubic yard detention volume where debris, mostly sand and gravel with cobbles and some boulders, could accumulate and be hauled out after rain events. The structure is approximately 200 ft in length, with a crest approximately 15 ft above the canyon floor. The upstream embankment face would be constructed at a 1H:1V slope, and the downstream face would be constructed at a 2H:1V slope, similar to the existing diversion dam. In an effort to identify a cost-effective plan to manage debris, Alternative 5 was developed with minimum features, thus many elements included in other alternatives are not included in Alternative 5.

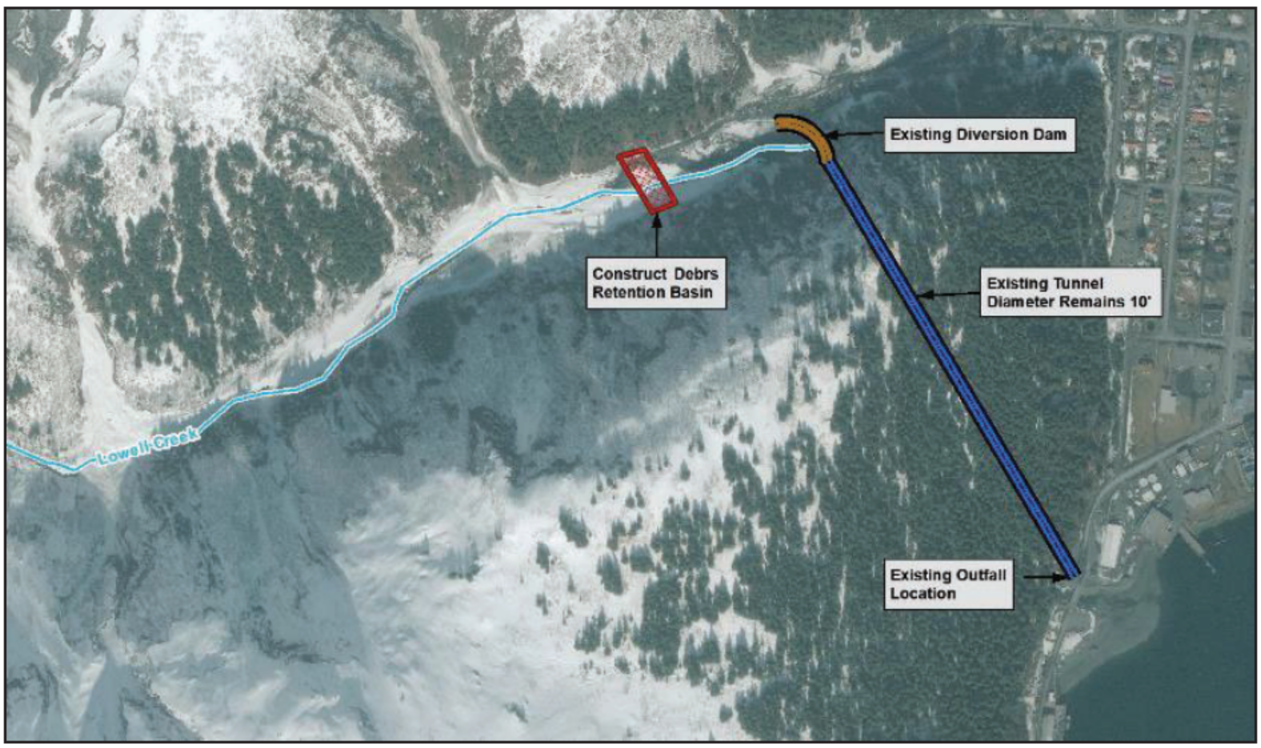

Figure 25. Alternative 5: Construct Debris Retention Basin.

5.4.6 Additional Alternatives

Concerns regarding the selection of tunnel diameter and the inclusion of non-structural alternatives in the study led to the late addition of several alternatives to the suite of alternatives: two further tunnel diameter options for Alternative 4 (4C and 4D); and the development of Alternative 6 options (6A, 6B, 6C and 6D). While the addition of tunnel diameters had no impact on alternative and resource analyses, Alternative 6 was added near completion of the study. Alternative 6 was developed for a comparative purpose, to reconsider non-structural measures and clarify their effectiveness at reduction of life loss. Therefore Alternative 6 options were minimally developed and analyzed, including cost and CE/ICA. After CE/ICA evaluation and subsequent non-selection of any of the Alternative 6 options, additional consideration in the resource impact analysis was not conducted.

5.4.6.1 Alternatives 4C and 4D: Construct New Flood Diversion System.

Consultation with the USACE Vertical Team (including Alaska District (POA), Pacific of Ocean Division (POD), and Headquarters, U.S. Army Corps of Engineers (HQUSACE)) raised concerns that a smaller tunnel may produce nearly as much reduction in risk to life safety and be more cost effective. The team, therefore, developed preliminary options for the 14-ft and 16-ft tunnels in Alternative 4 to address this concern. These alternatives are the same as Alternative 4 with the only difference being smaller tunnel diameters of 16 ft (Alternative 4C) and 14 ft (Alternative 4D). Alternatives 4C and 4D were developed to explore options to reduce uncertainty associated with project performance and with cost effectiveness at reducing life safety risk. Alternatives 4C and 4D include a new tunnel and diversion dam upstream from the existing tunnel and refurbishing the existing tunnel (similar to Figure 24 above). The existing tunnel refurbishment would maintain the tunnel diameter at 10 ft.

The other components are consistent with each option and are listed below:

Structural components:

- Extending the outfall 150 ft to go over the road
- Protecting the tunnel inlet from landslide with a canopy

Non-Structural Components:

- Tree removal
- Stream Gage within the tunnel

5.4.6.2 Alternatives 6A, 6B, 6C and 6D: Floodplain Relocation

Four plans for evacuating a floodway through Seward were studied; construction of a contained floodway through the City of Seward to prevent overflow and debris from damaging remaining structures on the Lowell Creek alluvial fan (Alternative 6A), relocation of all the structures in Lowell Canyon west of 1st Street (Alternative 6B), relocation of all the structures in Lowell Canyon except for the hospital (Alternative 6C), and relocation of only residential structures in Lowell Canyon (Alternative 6D).

Alternative 6A: Floodway Through Town

Alternative 6A designates a floodway across the Lowell Creek alluvial fan to be contained by dikes to prevent damage and risk to life safety to the remainder of the developed area. The plan includes relocating all structures south of Madison Street and north of Adams Street (Figure 26). The area to be relocated is approximately 82 acres. The area is composed of a mix of residential, commercial, and public structures including the hospital, City Hall, the public library and Resurrection Bay Historical Society, the City's Public Works Department, and the KFNP Visitors Center. The floodway was designed to be 750-ft-wide which is estimated to flow 2–3 ft deep during a design level event. Containment of the floodway would require the construction of 4,200 ft of new dikes armored on the floodway side to protect the remaining developed areas. A highway bridge would be constructed across the floodway with sufficient overhead clearance in the floodway for equipment to manage debris loads.

Approximately 9 acres of land outside the floodway would need to be acquired for construction of the bridge. The red lines shown on Figure 26 are floodway containment dikes to prevent overflow to the remaining developed areas on the alluvial fan. The yellow line is a highway bridge to allow traffic to cross the floodway. Yellow zones show areas that need to be acquired for bridge construction.

For all Alternative 6 plans, an approximately 5-acre area has been identified for relocation adjacent to the Seward Highway and outside of the tsunami zone (Figure 27). The area was previously a U.S. Army recreation area with utilities readily available and in an area protected by the Japanese Creek levee.

Figure 26. Floodway between Adams Street and Madison Street.

Figure 27. Relocation Area for Structures relocated under Alternative 6.

Alternative 6B: Relocation of All Lowell Canyon Structures

Alternative 6B would relocate the structures within Lowell Canyon, including the hospital, a 3-story, 30-unit apartment complex and 17 residential structures (Figure 28). Tearing down these structures to the bare ground and replacing them is assumed with demolition and cleanup of one known leaking Underground Storage Tank containing diesel.

Figure 28. Lowell Canyon Relocation.

Alternative 6C: Relocation of All Lowell Canyon Structures Except the Hospital

Alternative 6C would be the same as Alternative 6B, except it would not relocate the hospital (see Figure 28).

Alternative 6D: Relocation of Residential Structures in Lowell Canyon

This alternative would only relocate the residential structures in Lowell Canyon, leaving the hospital and apartment complex in their current locations (see Figure 28).

5.4.7 Final Array of Alternatives

With the addition of the alternatives described above, the final array of alternatives for analysis is presented in **Table 20**.

Table 20. Final Array of Alternatives.

Alternative	Description	Options	Description
1	No Action		
2	Improve Existing Flood Diversion System		
3	Enlarge Current Diversion System to Convey Larger Flow	A	18-ft Tunnel
		B	24-ft Tunnel
4	Construct New Flood Diversion System	A	18-ft Tunnel
		B	24-ft Tunnel
		C	16-ft Tunnel
		D	14-ft Tunnel
5	Construct Debris Retention Basin		
6	Floodplain Relocation	A	Floodway through the City
		B	Relocation of All Structures in Lowell Canyon
		C	Relocation of All Structures in Lowell Canyon except the Hospital
		D	Relocation of Residential Structures in Lowell Canyon

6. COMPARISON AND SELECTION OF PLANS*

6.1 With Project Conditions

The present section describes anticipated conditions at Lowell Creek and Seward, assuming a project has been constructed. The anticipated changes in the tunnel diameter and the extension of the outfall are the basis for the economic analysis. A larger tunnel would conduct more flow, therefore reducing the probability of flooding in the town. Extending the outfall would eliminate debris aggregation at the outfall and associated flooding. Reduced flood damages and reduced need for flood fighting at the outfall produce the expected NED benefits of a flood diversion project at Lowell Creek.

The damages and costs were calculated using FY21 price levels. Costs were annualized using the FY21 Federal discount rate of 2.5% and a period of analysis of 50 years with the year 2025 as the base year. The expected annual damage and benefit estimates were compared to the annual construction costs and the associated Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) costs for each of the project measures. Climate change and RSLC, as discussed in Section 4.1, are not expected to impact the project performance.

6.2 National Criteria Comparison

The alternatives were assessed against the National Criteria described in Section 2.7. The assessment is shown in **Table 21**.

Table 21. National Criteria Evaluation Summary.

	Alt 1	Alt 2	Alt 3A	Alt 3B	Alt 4A	Alt 4B	Alt 4C	Alt 4D	Alt 5	Alt 6A	Alt 6B	Alt 6C	Alt 6D
Acceptability	L	L	H	H	H	H	H	H	L	L	L	L	L
Completeness	C	C	C	C	C	C	C	C	C	C	C	C	C
Effectiveness	L	L	H	H	H	H	H	M	L	M	L	L	L
Efficiency	L	L	L	L	H	M	M	M	L	L	L	L	L
L = Low; M = Medium; H = High For completeness, C = Complete; I = Incomplete													

As can be seen from Table 22, Alternatives 1 and 2 have low acceptability, completeness, effectiveness, and efficiency because they do not provide benefits needed for the project and do not address the intent of Section 5032, as amended. This is because they do not provide an alternative method of diversion, but essentially maintain the existing conditions, although Alternative 2 does provide some improvements to the current system.

Alternative 5, similarly, does not provide an alternative method of diversion and does not address the risk to life safety associated with the system. It could provide minimal benefits in terms of debris management.

The Alternative 6 options also score low in most of the National Criteria because they do not actually divert flows from Lowell Creek, have a high cost (Alternatives 6A and 6B), and provide fewer benefits compared to the options of Alternatives 3 and 4. The medium rankings for completeness and effectiveness in Alternative 6A reflect the fact that it does provide a higher reduction in risk to life safety than other Alternative 6 options; however, these benefits are still far below the tunnel alternatives and at a much higher cost. Although Alternatives 6C and 6D have a lower cost than Alternatives 3 and 4, they are not effective, reducing the risk by about half to current risk, and do not meet the specifications within Section 5032 of WRDA 2007 that require an alternative method of flood diversion.

Alternative 4A ranks high in all National Criteria. It reduces the risk to life safety to minimal levels, provides additional protection from blockage and overflow by incorporating the existing tunnel into the new system, and provides similar benefits to Alternative 4B at a lower cost.

Alternatives 3A and 3B rank low in efficiency because the benefits are similar to Alternatives 4A and 4B, respectively, however their associated need to mobilize and demobilize over several more years results in a much higher cost. Alternatives 4C and 4D have lower rankings than Alternatives 4A and 4B because the benefits they provide are slightly lower and the analysis did not take into account the fact that due to the smaller diameter, these alternatives would be overwhelmed during events smaller than the PMF but larger than tunnel conveyance capacity.

6.3 Alternative Plan Costs

The team developed ROM costs for the alternatives, including those to construct and maintain facilities. Appendix E: Cost Engineering details the procedures and assumptions used to calculate these estimates. Cost risk contingencies were included to account for uncertain items such as sediment characterization. Project costs were developed without escalation and are in 2021 dollars. The ROM costs for each alternative are displayed in Table 22 for structural alternatives and Table 23 for non-structural alternatives. As shown in Table 22, the cost of the outfalls varies amongst alternatives. The variation is due to the sizes of the tunnel in the alternatives: 10 ft for Alternative 2, 18 ft for Alternatives 3A and 4A, and 24 ft for Alternatives 3B and 4B. Estimates for Alternative 6 options were developed using the software PACES (Parametric Cost Estimating Software).

Table 22. Summary of Structural Alternative Costs.

Item	Alt 2	Alt 3A	Alt 3B	Alt 4A	Alt 4B	Alt 4C	Alt 4D	Alt 5
Construct Additional Tunnel and Diversion Dam				$68,878,000	$91,728,000	$66,878,000	$63,878,000	
Enlarge Existing Tunnel to 18 ft		$97,839,000						
Enlarge Existing Tunnel to 24 ft			$211,155, 000					
Refurbish Existing Tunnel	$12,455,000			$12,455,000	$12,455,000	$12,455,000	$12,455,000	
Extend Tunnel Outfall 150 ft Over the Road	$12,350,000	$14,489,000	$33,495,000	$14,489,000	$33,495,000	$14,489,000	$14,489,000	
Tree Removal	$1,657,000	$1,657,000	$1,657,000	$1,657,000	$1,657,000	$1,657,000	$1,657,000	
Protect Tunnel Inlet from Landslide Blockage (canopy)	$5,919,000	$5,919,000	$5,919,000	$5,919,000	$5,919,000	$5,919,000	$5,919,000	
Stream Gage within the tunnel		$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	
Improve Low Flow Diversion System	$11,785,000	$11,786,000	$11,786,000					
Debris Basin								$15,800,000
Total (rounded):	**$53,100,000**	**$157,350,000**	**$314,850,000**	**$122,950,000**	**$172,650,000**	**$122,650,000**	**$121,650,000**	**$15,800,000**

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Table 23. Summary of Non-Structural Alternative Costs.

Item	Alternative 6A	Alternative 6B	Alternative 6C	Alternative 6D
Demolition	$13,345,000			
Dike Construction	$123,136,000			
Construct 2-lane Highway	$40,548,000			
Demo and Construct Hospital		$71,296,000		
Construct Supporting Facilities (Hospital)		$13,573,000		
Demo and Construct Apartments	$16,010,000	$12,459,000	$16,010,000	
Construct Supporting Facilities (Apartments)	$2,984,000	$2,322,000	$2,984,000	
Demo and Construct 17 Houses		$27,509,000	$35,351,000	$40,735,000
Construct Supporting Facilities (Houses)		$5,358,000	$6,885,000	$7,934,000
Real Estate Acquisition	$191,675,000	$3,447,000	$3,101,000	$3,062,000
Total (rounded):	**$368,705,000**	**$114,710,000**	**$54,462,000**	**$43,797,000**

6.3.1 OMRR&R Costs

OMRR&R costs associated with the project fall into two main categories: maintaining the system and debris removal. The maintenance of the system would include maintaining the low diversion system (Alternatives 2, 3A, and 3B only), concrete repairs, maintaining the stream gage, and project inspections. Debris removal consists of removing debris periodically from the outfall area. The outfalls of the project must be maintained to prevent material buildup that would jeopardize adjacent facilities or block the system. It is expected that the system will deposit approximately 25,000 cy of material annually at the outfall. Over time, this material would accumulate and create a new alluvial fan at the location of the new outfall in the same manner that an alluvial fan is accreting at the location of the current outfall. Sediment handling is expected to be similar to what has taken place under current conditions. Alternatives 2, 3 and 4 do not change the volume of sediment deposited on the alluvial fan, but the outfall extensions alter the material placement allowing for more efficient handling procedures. Alternative 5 intercepts some of the debris before it passes through the tunnel and it is assumed the 50% of the sediment handling will occur upstream from the tunnel(s) at the debris basin, and the remainder will be at the outfall(s). The estimated average annual cost of maintaining the current system, including maintenance to the system and debris removal, is approximately $1,183,000. The estimated cost of OMRR&R for each alternative is detailed below (Table 24). More details on the OMRR&R and their estimations are provided in Appendix C: Hydraulic and Structural Design. Rehabilitation and Replacement are not anticipated for the project features as they are designed to endure for the life of the project.

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Table 24. Estimate OMRR&R Cost by Alternative.

Activity	No Action Alt 6A*, 6B, 6C, 6D	Alt 2	Alt 3A	Alt 3B	Alt 4A	Alt 4B	Alt 4C	Alt 4D	Alt 5
Tunnel OMRR&R									
Existing Tunnel	$400,000	$200,000			$50,000	$50,000	$50,000	$50,000	$150,000
Enlarge Tunnel			$360,000	$480,000	$390,000	$519,000	$320,000	$280,000	
Extended Outlet		$15,000	$26,000	$35,000	$26,000	$35,000	$35,000	$35,000	0
Debris Basin									$255,000
Protect Tunnel Inlet		$15,000	$15,000	$15,000	$30,000	$30,000	$30,000	$30,000	0
Low Flow Diversion		$30,000	$30,000	$30,000					
Stream Gage in Tunnel	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000
Sediment Management at Outfall									
Sediment Handling	$758,000	$178,000	$178,000	$178,000	$178,000	$178,000	$178,000	$178,000	$379,000
Total Annual Costs	**$1,183,000**	**$463,000**	**$634,000**	**$763,000**	**$699,000**	**$837,000**	**$638,000**	**$598,000**	**$809,000**

Notes:
* Costs for Alternatives 6A, B, C, and D are primarily maintenance of the existing tunnel system. Alternative 6A would also include maintenance costs associated with keeping the floodway clear of vegetation. The floodway would lkely have been designed as a vacant grass field between the containment dikes. The field would need annual mowing from the dam to Resurrection Bay to prevent the establishment of willows or other woody vegetation. The additional costs for these OMRR&R items for 6A have not been developed, however, this is likely to be a small cost in comparison with maintenance of the tunnel.
The existing tunnel cost for no action and Alternative 5 would include repairs to the existing, non-refurbished tunnel. Alternative 4 options would provide minimal OMRR&R to the existing tunnel.
Enlarged tunnel costs were estimated using the length and diameter of the tunnel and based on historic costs of the existing tunnel
Extended outlet costs are based on 10-ft, 18-ft, and 24-ft costs
Protect tunnel inlet for Alternative 4 options would be for both tunnels
Sediment handling costs for Alternative 5 consider the debris basin capacity

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6.3.2 Construction and Investment Costs

As with benefit cash flows, costs are compounded to a base year and amortized for comparison against average annual benefits. As such, the project first costs shown above and detailed in Appendix D: Economics differ slightly from those used in the benefit-cost analysis. Costs used in the benefit-cost analysis include the project's initial cost compounded to the base year using the FY21 discount rate, interest during construction, and operations and maintenance costs greater than the without project condition. The construction of the project alternatives is expected to begin in the year 2022, during which time interest during construction (IDC) will be accrued. It will continue for three years for every alternative except for enlarging the existing flood diversion system (Alternatives 3A and 3B). For these alternatives, seasonal peak flows cannot be diverted. Therefore, construction activities are limited to the winter months and construction must be prolonged over seven years.

The costs used in the benefit-cost analysis are displayed in Table 25. Average annual costs were developed by combining the initial construction costs with the annual Operations and Maintenance costs for each potential alternative using the FY21 Federal Discount Rate of 2.5% along with a period of analysis of 50 years (Table 25). OMRR&R for Alternative 6 includes expected future maintenance costs associated with the existing tunnel.

Table 25. Project Costs for Benefit-Cost Analysis.

Item	Alternative 2	Alternative 3A	Alternative 3B	Alterative 4A
	Improve Existing Flood Diversion System	Enlarge Existing Flood Diversion System (18-ft Tunnel)	Enlarge Existing Flood Diversion System (24-ft Tunnel)	Construct New Flood Diversion System (18-ft Tunnel)
Construction First Cost	$53,061,000	$157,283,000	$314,846,000	$122,928,000
LERRD (Utility relocations)	$350,000	$350,000	$350,000	$350,000
Interest During Construction	$730,000	$13,587,000	$27,199,000	$5,164,000
Total Cost	**$54,141,000**	**$171,220,000**	**$342,395,000**	**$128,442,000**
Average Annual Construction	$1,909,000	$6,037,000	$12,072,000	$4,529,000
Average Annual OMRR&R	**$463,000**	**$634,000**	**$763,000**	**$699,000**
Total Average Annual Cost	**$2,372,000**	**$6,671,000**	**$12,835,000**	**$5,228,000**
Item	**Alterative 4B**	**Alterative 4C**	**Alterative 4D**	**Alterative 5**
	Construct New Flood Diversion System (24-ft Tunnel)	Construct New Flood Diversion System (16-ft Tunnel)	Construct New Flood Diversion System (14-ft Tunnel)	Debris Retention Basin
Construction First Cost	$172,607,000	$122,600,000	$121,600,000	$15,800,000
LERRD (Utility Relocations)	$350,000	$350,000	$$350,000	-
Interest During Construction	$7,251,000	$5,151,000	$5,109,000	$436,000
Total Cost	**$180,208,000**	**$128,101,000**	**$127,059,000**	**$16,236,000**
Average Annual Construction	$6,354,000	$4,517,000	$4,480,000	$572,000
Average Annual OMRR&R	**$837,000**	**$638,000**	**$598,000**	**$809,000**
Total Average Annual Cost	**$7,191,000**	**$5,155,000**	**$5,078,000**	**$1,381,000**
Item	**Alternative 6A**	**Alternative 6B**	**Alternative 6C**	**Alternative 6D**
	Non-structural Relocations (Entire Floodway)	Non-structural Relocations (Entire Valley)	Non-structural Relocations (Entire Valley, No Hospital)	Non-structural Relocations (Entire Valley, No Hospital/Apt)
Construction First Cost	$405,600,000	$126,200,000	$59,000,000	$48,000,000
LERRD (Utility Relocations)	-	-	-	-
Interest During Construction	$1,254,000	$390,000	$182,000	$148,000
Total Cost	**$406,854,000**	**$126,590,000**	**$59,182,000**	**$48,148,000**
Average Annual Construction	$14,345,000	$4,463,000	$2,087,000	$1,698,000
Average Annual OMRR&R	**$1,183,000**	**$1,183,000**	**$1,183,000**	**$1,183,000**
Total Average Annual Cost	**$15,528,000**	**$5,646,000**	**$3,270,000**	**$2,881,000**

6.4 Project NED Benefits

Each alternative provides a certain amount of relief from existing and expected future inefficiencies. Differences between the FWOP conditions and those that will occur under the various With Project Conditions are benefits that accrue to the project and form the basis of the Recommended Plan. As mentioned at the outset, the NED policy exception waiver utilizing life safety approved 05 October 2020 for this study allows for plan justification under a Non-NED framework: OSE.

Economic benefits are associated with reduced flood damages. The primary flood damages avoided would be structural damages and damages to the associated contents of the structures, though there are some benefits from reduced vehicular damages. Average annual flood reduction damages would be about $1,289,000 (**Table 26**).

Table 26. Expected Annual Damages Reduced by Measure ($1,000's).

Alt.	Plan	Vehicle	Commer-cial	Public	Residen-tial	Total
1	Without Project	231	407	346	305	1,289
2	Improve Existing FDS	231	407	346	305	1,289
3A	Enlarge Existing FDS: 18-ft Tunnel	0	3	5	2	10
3B	Enlarge Existing FDS: 24-ft Tunnel	0	3	5	2	10
4A	Construct New FDS: 18-ft Tunnel	0	3	5	2	10
4B	Construct New FDS: 24-ft Tunnel	0	3	5	2	10
4C	Construct New FDS: 16-ft Tunnel	0	3	5	2	10
4D	Construct New FDS: 14-ft Tunnel	0	3	5	2	10
5	Debris Retention Basin	231	407	346	305	1,289
6A	Non-structural Relocations (Entire Floodway)	223	337	285	247	1,092
6B	Non-structural Relocations (Entire Valley)	226	407	290	243	1,166
6C	Non-structural Relocations (Entire Valley, No Hospital)	226	407	341	200	1,174
6D	Non-structural Relocations (Entire Valley, No Hospital/Apt)	226	407	341	204	1,178
FDS=Flood Diversion System						

6.5 NED Analysis

Net benefits and the Benefit-Cost Ratio (BCR) are determined using the average annual benefits and average annual costs for each alternative. Net benefits are determined by subtracting the average annual equivalent costs from the average annual benefits for each alternative; the BCR is determined by dividing average annual benefits by average annual costs. Benefits by category, project costs, and the BCR were calculated for each alternative (**Table 27**,**Table 28**, and**Table 29**). Tables 28-30 do not reflect certified costs; final BCR may be different than what is reported in Tables.

Table 27. NED Analysis Results (1 of 3).

Damage Category	Alternative 2	Alternative 3A	Alternative 3B	Alterative 4A
	Improve Existing Flood Diversion System	Enlarge Existing Flood Diversion System (18-ft Tunnel)	Enlarge Existing Flood Diversion System (24-ft Tunnel)	Construct New Flood Diversion System (18-ft Tunnel)
Structural	-	$571,653	$571,653	$571,653
Contents	-	$625,167	$625,167	$625,167
Vehicle	-	$52,777	$52,777	$52,777
Debris Removal	-	$39,404	$39,404	$39,404
Flood Fight Costs Avoided	$580,000	$580,000	$580,000	$580,000
Total Average Annual Benefits	$580,000	$1,869,000	$1,869,000	$1,869,000
Total Average Annual Cost	**$2,372,000**	**$6,671,000**	**$12,835,000**	**$5,228,000**
Net Benefits	($1,792,000)	($4,802,000)	($10,966,000)	($3,359,000)
BCR	**0.24**	**0.28**	**0.15**	**0.36**

Table 28. NED Analysis Results (2 of 3).

Damage Category	Alterative 4B	Alterative 4C	Alterative 4D	Alterative 5
	Construct New Flood Diversion System (24-ft Tunnel)	Construct New Flood Diversion System (16-ft Tunnel)	Construct New Flood Diversion System (14-ft Tunnel)	Debris Retention Basin
Structural	$571,653	$571,653	$571,653	-
Contents	$625,167	$625,167	$625,167	-
Vehicle	$52,777	$52,777	$52,777	-
Debris Removal	$39,404	$39,404	$39,404	-
Flood Fight Costs Avoided	$580,000	$580,000	$580,000	$580,000
Total Average Annual Benefits	$1,869,000	$1,869,000	$1,869,000	$580,000
Total Average Annual Cost	**$7,191,000**	**$5,155,000**	**$5,078,000**	**$1,381,000**
Net Benefits	($5,322,000)	($3,286,000)	($3,209,000)	($801,000)
BCR	**0.26**	**0.36**	**0.37**	**0.42**

Table 29. NED Analysis Results (3 of 3).

Damage Category	Alternative 6A	Alternative 6B	Alternative 6C	Alternative 6D
	Non-structural Relocations (Entire Floodway)	Non-structural Relocations (Entire Valley)	Non-structural Relocations (Entire Valley, No Hospital)	Non-structural Relocations (Entire Valley, No Hospital/Apt)
Structural	$87,234	$54,411	$50,863	$49,120
Contents	$95,400	$59,505	$55,624	$53,719
Vehicle	$8,054	$5,023	$4,696	$4,535
Debris Removal	$6,013	$3,751	$3,506	$3,386
Flood Fight Costs Avoided	-	-	-	-
Total Average Annual Benefits	$196,700	$122,690	$114,689	$110,760
Total Average Annual Cost	**$15,528,300**	**$5,646,310**	**$3,270,311**	**$2,881,240**
Net Benefits	($15,331,300)	($5,323,310)	($2, 155,311)	($2,770,240)
BCR	**0.01**	**0.02**	**0.04**	**0.04**

No NED plan was identified. The team developed Alternative 5 in an effort to identify a plan with positive NED benefits, however even this alternative presented a BCR of only 0.49. In addition, Alternative 5 does not address the objectives of the study. While Alternative 5 does provide limited benefits to flood fighting and sediment accumulation at the outfall, one large event could fill and overwhelm the debris basin leading to continued accumulation and damages at the outfall. While these values represent NED benefits resulting from flood diversion at Lowell Creek, they do not represent the full scale of benefits that could be realized with the implementation of a project. Alternative 5 also does nothing to address the residual risk posed by high flows and/or tunnel blockage, thus providing no reduction in life loss or flood damages within Seward.

Because no alternative has positive net NED benefits, plan selection utilized CE/ICA. Section 6.7 discusses the CE/ICA metric and summarizes the results.

6.6 Risk and Sensitivity

There is a high likelihood that the net benefits associated with the alternatives presented will remain negative. This was considered to be conservative given that the alternatives with the highest reduction in damages assumed that nearly all damage in rare frequency events will be fully mitigated.

The exception is that the costs associated with the sedimentation issue in the study area are currently underrepresented in the economic analysis. The remaining risks are that proper quantification of the sedimentation issue could lead to additional NED benefits, though such benefits are unlikely to produce a positive BCR.

6.7 CE/ICA

A plan justified solely by NED benefits could not be identified. Therefore, the team submitted a policy exception request to the ASA(CW) to use CE/ICA for project justification. The policy exception was approved on 05 October 2020. A CE/ICA was conducted on all alternatives after the policy exception was approved, except for Alternative 5, which was eliminated earlier.

A CE/ICA is conducted to evaluate the effects of the proposed alternatives beyond what can be quantified in the NED category by analyzing non-monetary outputs. The CE/ICA is utilized to inform decisions on sound investments by identifying options that yield the maximum desired outputs for the least acceptable cost. The cost-effectiveness analysis evaluates a plan's level of output against its cost for a variety of alternatives of different scales. The subsequent incremental cost analysis evaluates the identified array of cost effective plans to arrive at a subset of "best buy" plans. Best buy plans are considered the most efficient plans because they provide the greatest increase in output for the least increase in cost. For this study, the team measured these outputs as reduced residual risk to life safety, as exemplified by AALL. This metric accounts for both the hazard, which includes the frequency of the hydraulic scenario, as well as performance, which includes how well the diversion dam will perform during the hydraulic scenario.

Evaluation of this metric through CE/ICA allows for the assessment of how alternatives perform with regard to achieving one of the primary planning objectives developed to address the flood risk problem at Seward:

> *Reduce risk to public health, life, and safety from flooding of Lowell Creek to the City of Seward.*

This critical objective was not directly addressed in the NED Damages analysis. AALL directly affects the public health, life, and safety of Seward residents and a transient population (tourists) that can be especially vulnerable camped along the waterfront downgradient of the Lowell Creek Drainage. With reduced AALL, residents will experience increased safety and public health while seeing a decrease in life loss during flood events. The CE/ICA compares the AALL between proposed alternatives and the No Action plan. The Alaska District Hydraulics & Hydrology and Geotechnical PDT Members collaborated with Economics staff on the model development of the metric.

The outputs of the CE/ICA, reduced risk to life safety, are also significant for non-monetary benefits in terms of the outputs' institutional, public, and technical significance, as defined in ER 1105-2-100 (Table 30).

Table 30. Significance for Future With Project (FWP) Condition.

Significance	FWP Condition
Institutional	• Addresses the requirements of Section 5032 of WRDA 2007, as amended
Public	• Promotes life, health, and safety • Decreases structural and non-structural damages
Technical	• Addresses negative impacts in association with flooding in Seward that have been documented in government reports and academic research

By analyzing alternatives to the current flood diversion system, the metric brings institutional significance to this study—specifically, the requirement of Section 5032 of WRDA 2007, as amended, to determine feasibility of alternative methods of flood diversion.

Reducing AALL is publicly significant in that it quantifies the reduction in lives threatened to the Seward populace.

Last, the metric is technically significant in that negative impacts to flooding in Seward have been well documented and the metric utilizes human ingenuity to analyze a complex and unique watershed to provide reduction in life, health, and safety risks associated with flooding.

6.7.1 CE/ICA Inputs

The inputs for the CE/ICA consist of the alternatives' costs and the AALL associated with each alternative. The alternatives reduce the overall annual chance of a flood event with tunnel blockage (or "APF"). [redacted]

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[redacted]

The AALL of the residual risk is the Total AALL and is referred to as simply “AALL” in the report, unless otherwise noted. [redacted]

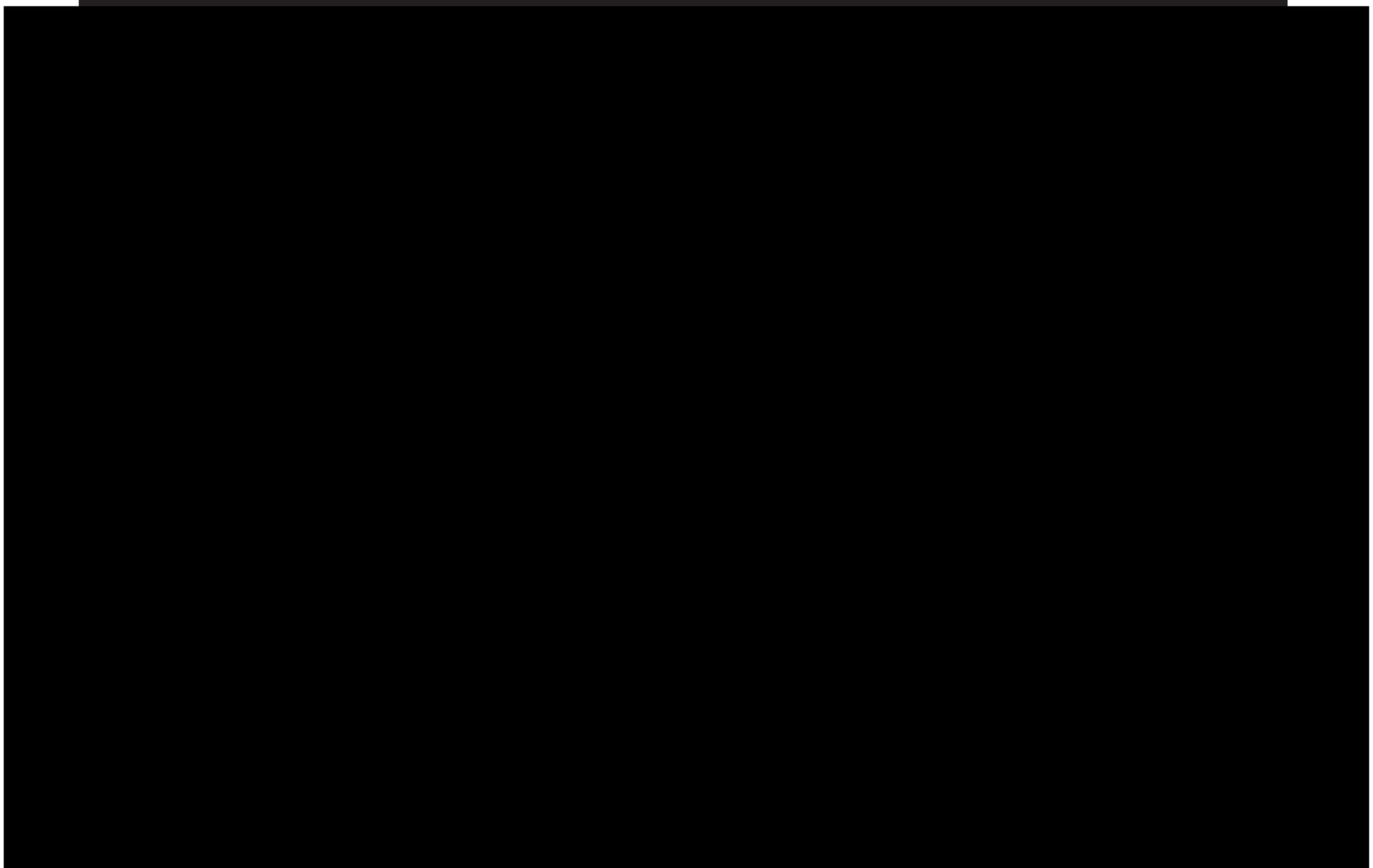

Table 37. CE/ICA Results.

Alternative	Alt. Description	Total Cost	Average Annual Cost (1000s)	[redacted]	Cost-Effective
No Action	No Action Plan	$0	$0	[redacted]	Best Buy
Alt 2	Improve Existing Tunnel	$53.8M	$2,372	[redacted]	Cost-Effective
Alt 3A: 18-ft	Enlarge Existing Tunnel 18-ft	$157.3M	$6,671	[redacted]	Non-Cost Effective
Alt 3B: 24-ft	Enlarge New Tunnel 24-ft	$314.8M	$12,835	[redacted]	Non-Cost Effective
Alt 4A: 18-ft	Construct New Tunnel 18-ft	$124.6M	$5,228	[redacted]	Best Buy
Alt 4B: 24-ft	Construct New Tunnel 24-ft	$175.0M	$7,191	[redacted]	Best Buy
Alt 4C: 16-ft	Construct New Tunnel 16-ft	$122.6M	$5,155	[redacted]	Best Buy
Alt 4D: 14-ft	Construct New Tunnel 14-ft	$121.6M	$5,078	[redacted]	Best Buy
Alt 6A	Floodway Through the city	$368.7M	$15,528	[redacted]	Non-Cost Effective
Alt 6B	Relocation of All Structures in Lowell Canyon	$114.7M	$5,646	[redacted]	Non-Cost Effective
Alt 6C	Relocation of All Structures in Lowell Canyon Except the Hospital	$54.5M	$3,270	[redacted]	Cost Effective
Alt 6D	Relocation of Residential Structures in Lowell Canyon	$43.8	$2,881	[redacted]	Best Buy

Note: Highlighted rows correspond to Best Buy plans.

Figure 29 shows the graphical representation of the cost effectiveness analysis. Alternative 3 options are not cost effective due to the additional cost associated with expanded time needed for construction. Alternatives 2, and 6C are cost effective but are not best buys. However, the Alternative 4 options and Alternative 6D are best buys. Alternative 4A has only a minimal cost difference from 4C and 4D while providing more benefits at a higher level of certainty. Alternative 6D provides significantly fewer benefits compared to the Alternative 4 options.

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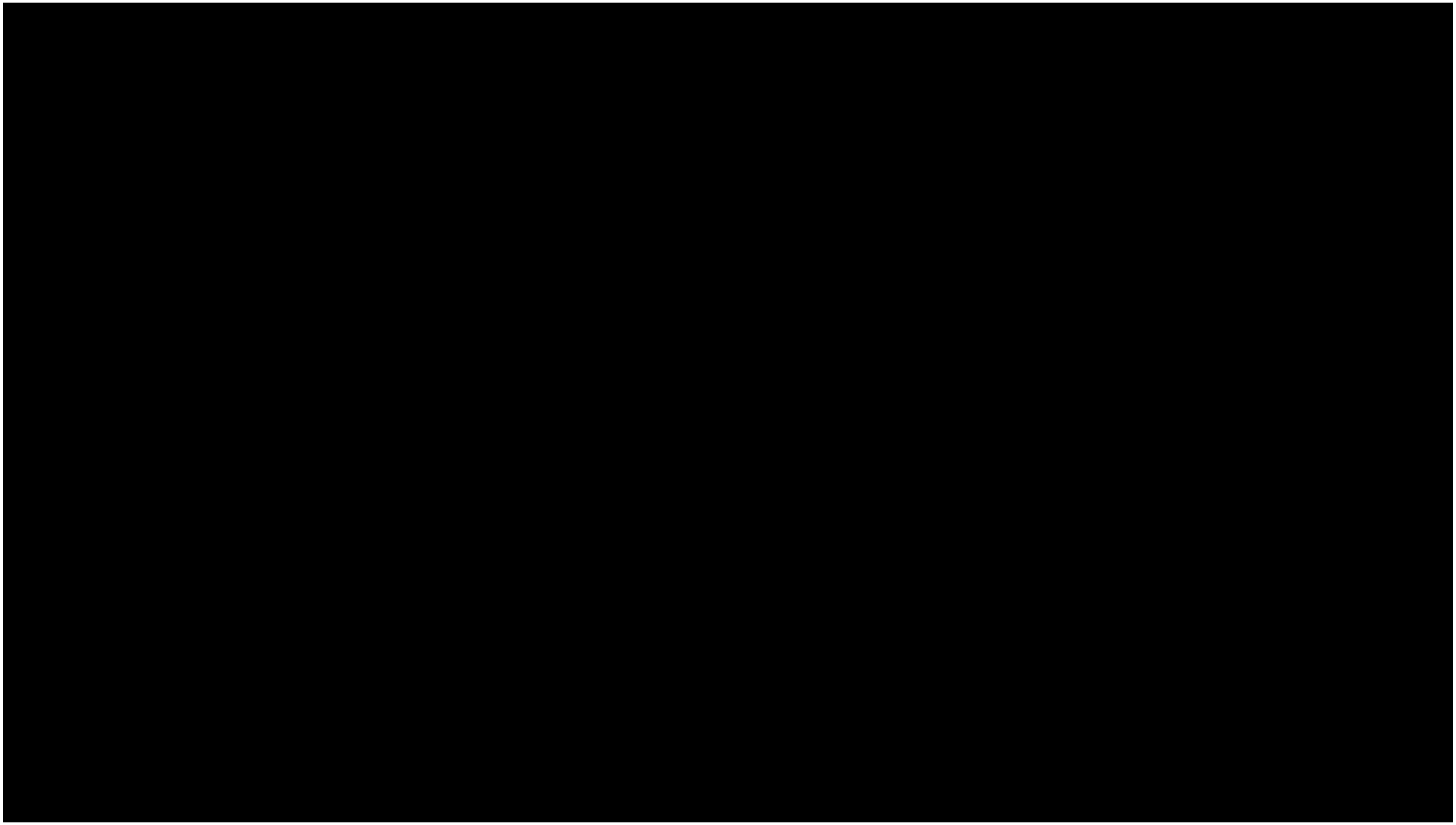

[redacted]

6.8 Risk Comparison of Alternatives

This section provides a comparison of alternatives based on the results of the risk node analysis provided in Section **5.3.1.1**. The risk analysis found no risk reduction for the Existing Condition, Alternative 1, Alternative 5, or the Alternative 6 options. Alternative 2 reduced the risk minimally and had no reduction in risk with surge release (PFM 6A), which is the primary risk driver for life safety. There is very little that can be done to reduce risk with a surge release other than constructing a larger tunnel. Although Alternatives 4C and 4D do provide reduction to life loss, these alternatives do not provide adequate protection in surge events and would be overwhelmed in events smaller than the PMF but larger than the flow capacity of the tunnel. Thus, Alternatives 3A, 3B, 4A, and 4B were found to be the only alternatives that reduce risk within the system from the higher flows associated with surge release in larger events and also provide the greatest reduction in AALL.

6.8.1 Alternative 2

Select tree removal would affect Nodes 1 and 2 of PFM 3 by reducing the large debris capable of blocking the tunnel and which could not be flushed out by the head pressure. For PFM 5A, Alternative 2 provides a canopy at the tunnel entrance which would reduce the risk of landslides from above the tunnel blocking the tunnel, thus affecting Node 1 in the event tree. In the event of a landslide at the tunnel entrance, Node 2 would be affected due to the reduced amount of soil and rocks that make their way to the tunnel entrance and thus could be flushed more readily.

The primary risk driver at Lowell Creek, PFM 6A, would have no nodes affected by Alternative 2. Refurbishment of the current tunnel would provide some protection and effects to PFM 21 specifically at Nodes 1, 2 and 3. The refurbishment would reduce the probability of the flaw need to initiate PFM 21 as well as some added protection to the system if such a flaw developed, however, if the events in PFM 21 progressed there would be no affect preventing an uncontrolled release.

[redacted]

6.8.2 Alternatives 3A and 3B

Both Alternatives 3A and 3B affected the same nodes for all PFMs, though the overall probabilities varied due to the different tunnel sizes. For PFMs 3, 5A and 21, the effects would be similar to those presented by Alternative 2. Alternatives 3A and 3B would have effects on Nodes 3 and 4 of PFM 6A resulting from the larger diameter of the tunnels not being as prone to blockage as the existing tunnel and being able to build more head pressure to flush the tunnel if a blockage occurred.

[redacted]

6.8.3 Alternatives 4A,4B,4C and 4D

Alternatives 4A, 4B, 4C, and 4D again produce effects on identical nodes differing only in their tunnel diameter sizes. Alternatives 4A, 4B, 4C, and 4D represent a redundant system as the existing system is left in place, which leads to a more complex chain of events resulting from two distinctly different possibilities. For each PFM, the team analyzed these alternatives for the PFM occurring at both tunnels simultaneously and also for the PFM occurring at the new tunnel overflowing and the PFM then occurring at the second tunnel as both tunnels would have to be blocked for a failure.

For PFMs 3 and 5A, the nodes affected are similar to the other alternatives due to the fact that the non-structural measures prevent large debris capable of blocking the tunnels from being brought down with the water and prevent landslides at the tunnel entrance. In addition, due to the larger size and redundancy of the system, there would conceivably be more time for intervention in the case that the tunnels were blocked sequentially.

PFM 6A would have affected nodes similar to Alternatives 3A and 3B with the increased tunnel diameters making it less probable that a blockage would occur after surge release and providing greater head pressure to increase chances that, if such a blockage occurred, it would be flushed. In the scenario of sequential blockage, the new tunnel would also have more time to flush a blockage before water would flow to the old tunnel and initiate a blockage there.

In the PFM 21 scenario, installation of Alternatives 4A, 4B, 4C, and 4D would reduce the likelihood of flaws in the tunnel liner as well as affect the progression of the event via scouring action due to new materials in both tunnels. If, however, a scenario arose that did scour both tunnels to the point of collapse the other nodes would not be affected.

[redacted]

[redacted]

[redacted]

[redacted]

6.8.4 Alternative 5

Alternative 5 was developed in an attempt to identify a NED plan that used maintenance costs to produce a positive BCR. The alternative consisted of an upstream debris retention basin that was intended to accumulate 25,000 cy of debris. The risk team did not believe that the removal of this material would affect the total risk of the project. The basin was likely to fill up relatively quickly during even a small event and, once filled, would have the same risk as the previously elicited existing risk. For this reason, no elicitation of experts was conducted on Alternative 5, and the total risk remained the same as the existing risk.

6.8.5 Alternatives 6A, 6B, 6C and 6D

Alternative 6 options were added late in the study and were not included in the risk assessment. However, it can be noted that although these alternatives would remove portions of the population from the areas of highest risk, these alternatives do nothing to address any of the risk nodes from the risk assessment. Such actions would not reduce the risk to life safety to levels acceptable to the community.

6.9 Summary of Accounts

The USACE planning guidance establishes four accounts to facilitate analysis and display the effects of alternative plans. The team performed plan formulation for this study with a combined focus on CE/ICA benefits and NED benefits as well as consideration of all effects, beneficial or adverse, to each of the four evaluation accounts identified in the Principles and Guidelines. Plan selection weighted the projected effects of each alternative on the four evaluation accounts. The PDT reviewed qualitative and quantitative information for major project effects and major potential effect categories.

6.9.1 NED

This study conducted a NED analysis of changes in the economic value of the national output of goods and services. The NED analysis revealed that none of the alternative plans had positive net NED benefits. The BCRs for all alternatives range from 0.01 to 0.49. The smallest scale alternative, Alternative 5 – Debris Basin Upstream from the Current System, yielded the highest BCR of 0.49. As no NED plan was identified, the team supplemented the economic analysis with CE/ICA consistent with the Implementation Guidance for Section 5032 of WRDA, as amended.

6.9.2 Regional Economic Development

Regional economic development benefits are those which accrue to the region, but not necessarily the nation, including increased income and employment associated with the construction of a project. The Regional Economic Development (RED) analysis includes the use of regional economic impact models to provide estimates of regional job creation, retention, and other economic measures such as sales or value-added.

The team used the input-output macroeconomic model Regional Economic System (RECONS) to address the impacts of the construction spending associated with the project alternatives. Based on RECONS analysis, all alternatives other than the No Action plan would provide varying levels of:

- Jobs created in the region
- Increased gross regional product
- Increased economic output

The total cost input into the RECONS model for each alternative was the project cost, which excludes pre-construction engineering and design (PED), construction management, and IDC. The wide range in benefits reflect the various scopes of the alternatives. For the structural alternatives, of the total expenditures, $11.5M to $230M would be captured within the local area. The remainder of the expenditures will be captured within the state and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added). The regional economic effects are shown for the local, state, and national impact areas (Table 38).

In summary, the expenditures would support between 193 and 3,837 full-time equivalent jobs, $10.7M to $4213.3M in labor income, $11.6M to $231.5M in the gross regional product, and $18.8M to $375.4M in economic output in the local impact area. More broadly, these expenditures support between 309 and 6,164 full-time equivalent jobs, $21M to $418M in labor income, $25.2M to $502.9M in the gross regional product, and $43.7M to $870.1M in economic output in the nation. Alternatives 3A and 3B show more benefits than the Alternative 4 options due to the expanded time required for project implementation, while the limited scope of Alternatives 2 and 5 would provide significantly fewer benefits. The RED benefits associated with the Alternative 6 options contain a large degree of uncertainty due to the majority of the cost for these alternatives being related to acquisition of property rather than construction. A summary of total impacts is provided in Table 38. The detailed RED analysis can be found in Appendix D: Economics.

Table 38. RED Summary of Impacts.

Area	Local Capture	Output	Jobs (FTE)	Labor Income	Value Added
Local					
Alt 2	$38,731,000	$63,269,000	647	$35,948,000	$39,022,000
Alt 3A	$114,806,000	$187,540,000	1,917	$106,556,000	$115,668,000
Alt 3B	$229,817,000	$375,414,000	3,837	$213,302,000	$231,543,000
Alt 4A	$89,730,000	$146,576,000	1,498	$83,281,000	$90,403,000
Alt 4B	$125,992,000	$205,812,000	2,103	$116,938,000	$126,938,000
Alt 4C	$89,490,000	$146,185,000	1,494	$83,059,000	$90,162,000
Alt 4D	$88,760,000	$144,993,000	1,482	$82,382,000	$89,426,000
Alt 5	$11,533,000	$18,840,000	193	$10,704,000	$11,620,000
Alt 6A	$296,062,000	$483,627,000	4,943	$274,786,000	$298,284,000
Alt 6B	$92,118,000	$150,478,000	1,538	$85,498,000	$92,809,000
Alt 6C	$43,066,000	$70,350,000	719	$39,971,000	$43,389,000
Alt 6D	$35,037,000	$57,234,000	585	$32,519,000	$35,300,000
State					
Alt 2	$41,663,000	$57,651,000	455	$34,599,000	$33,371,000
Alt 3A	$123,498,000	$170,887,000	1,350	$102,557,000	$98,916,000
Alt 3B	$247,216,000	$342,079,000	2,702	$205,296,000	$198,009,000
Alt 4A	$96,523,000	$133,561,000	1,055	$80,156,000	$77,310,000
Alt 4B	$135,530,000	$187,536,000	1,481	$112,549,000	$108,553,000
Alt 4C	$96,265,000	$133,204,000	1,052	$79,942,000	$77,104,000
Alt 4D	$95,480,000	$132,118,000	1,044	$79,290,000	$76,475,000
Alt 5	$12,406,000	$17,167,000	136	$10,302,000	$9,937,000
Alt 6A	$318,476,000	$440,683,000	3,481	$264,473,000	$255,084,000
Alt 6B	$99,092,000	$137,116,000	1,083	$82,289,000	$79,368,000
Alt 6C	$46,327,000	$64,103,000	506	$38,471,000	$37,105,000
Alt 6D	$37,689,000	$52,152,000	412	$31,299,000	$30,187,000
National					
Alt 2	$50,384,000	$146,650,000	1,039	$70,447,000	$84,751,000
Alt 3A	$149,347,000	$434,698,000	3,079	$208,818,000	$251,217,000
Alt 3B	$298,961,000	$870,171,000	6,164	$418,007,000	$502,882,000
Alt 4A	$116,726,000	$339,749,000	2,407	$163,206,000	$196,345,000
Alt 4B	$163,898,000	$477,050,000	3,379	$229,162,000	$275,693,000
Alt 4C	$116,414,000	$338,842,000	2,400	$162,771,000	$195,820,000
Alt 4D	$115,465,000	$336,078,000	2,381	$161,443,000	$194,223,000
Alt 5	$15,003,000	$43,668,000	309	$20,977,000	$25,236,000
Alt 6A	$385,136,000	$1,120,996,000	7,941	$538,497,000	$647,837,000
Alt 6B	$119,833,000	$348,791,000	2,471	$167,550,000	$201,570,000
Alt 6C	$56,023,000	$163,064,000	1,155	$78,332,000	$94,237,000
Alt 6D	$45,578,000	$132,662,000	940	$63,728,000	$76,667,000

Note: Recommended Plan is highlighted.
FTE = Full Time Equivalent

6.9.3 Environmental Quality (EQ)

The EQ account displays the non-monetary effects of the alternatives on natural resources. Lowell Creek's current environmental baseline condition in which its entire surface flow is diverted through Bear Mountain and discharges into Resurrection Bay would not be affected by any of the considered alternatives. However, USACE has identified that non-monetary effects to natural resources would be most likely occur in the form of the inadvertent release of environmentally persistent compounds as a result of catastrophic flooding damage to commercial and residential properties. Flood damage could liberate industrial and household solvents, fuels, detergents, lubricants, heavy metals, pesticides, and various other anthropogenic compounds into the waters of Resurrection Bay where they may negatively affect natural resources. Non-monetary effects to natural resources are only recognized in that a considered alternative may reduce the risk of environmental degradation and that the existing flood control system, the no action alternative, does not reduce this risk. Similarly, because the existing flood control system has not failed, the degree to which incremental perturbations of each structural alternative considered would affect a quantifiable reduction in non-monetary effects to natural resources cannot be determined. A qualitative assessment of each alternative's potential to reduce risk of environmental degradation associated with flood damage is presented in **Table 39**.

Table 39. EQ Analysis Summary.

Alternative	Changes the Existing Environmental Baseline	Reduces Risk of Environmental Degradation Through Flood Damage
Alt 1: No Action	No	No
Alt 2: Improve Existing Tunnel (no change in diameter) + 150-ft Outfall Flume	No	Possibly
Alt 3: Enlarge Existing Tunnel Diameter	No	Yes
Alt 4: Construct New Flood Diversion System	No	Yes
Alt 5: Construct Debris Retention Basin	No	No
Alt 6A: Floodway Through Seward	No	Yes
Alts 6B, 6C, 6D: Relocation of Structures	No	No

6.9.4 OSE

The OSE account includes impacts on life safety, vulnerable populations, local economic vitality, and community optimism. Impacts on these topics are a natural outcome of civil works projects and are most commonly qualitatively discussed in the OSE account.

[redacted]

[redacted]

6.9.5 Four Accounts Evaluation Summary

Based on this analysis of the four accounts, each alternative has positive effects for the EQ, RED, and OSE accounts and no positive BCR for the NED account. A summary of the four accounts for the alternatives is shown in Table 40**.** Table 41 does not reflect certified costs; final BCR may be different than what is reported in the table.

Table 40. Four Accounts Summary.

Alt.	Net Annual Benefits & BCR*	EQ	RED	[redacted]
2	($1,792,000) 0.24	Possibly Beneficial	Increased employment and income for the community	[redacted]
3A	($4,802,000) 0.28	Positive	Increased employment and income for the community	[redacted]
3B	($10,966,000) 0.15	Positive	Increased employment and income for the community	[redacted]
4A	($3,359,000) 0.36	Positive	Increased employment and income for the community	[redacted]
4B	($5,322,000) 0.26	Positive	Increased employment and income for the community	[redacted]
4C	($3,286,000) 0.36	Positive	Increased employment and income for the community	[redacted]
4D	($3,209,000) 0.37	Positive	Increased employment and income for the community	[redacted]
5	($801,000) 0.42	Not Beneficial	Increased employment and income for the community	[redacted]
6A	($15,331,300) 0.01	Positive	Increased employment and income for the community	[redacted]
6B	($5,323,310) 0.02	Not Beneficial	Increased employment and income for the community	[redacted]
6C	($3,155,311) 0.04	Not Beneficial	Increased employment and income for the community	[redacted]
6D	($2,770,240) 0.04	Not Beneficial	Increased employment and income for the community	[redacted]

Note: Recommended Plan is highlighted.

6.10 Plan Selection Rationale

The NED analysis did not identify a plan with positive net benefits. Thus, the team utilized CE/ICA with a metric of reduction in AALL to analyze the alternatives, which resulted in six Best Buy plans. Along with the No Action alternative, Alternatives 4A, 4B, 4C, 4D and 6D were identified as best buys.

Alternative 2 would provide very minimal reduction in risk to life safety as it does nothing to address the primary risk driver of PMF 6A. Although some benefits would be afforded with the canopy and select tree removal, overall Alternative 2 would remain very similar to the no action plan in terms of risk to life safety.

Alternatives 3A and 3B do address PMF 6A by enlarging the tunnel from its existing size; however, they do not provide the added protection afforded by the redundancy of two tunnels as in the Alternative 4 options and, due to the requirement to only work during low-flow periods of the year, construction must be spread over several more years resulting in a much higher cost ($157M–$315M) than Alternative 4 options with similar benefits. [redacted]

Alternatives 4A, 4B, 4C, and 4D address PMF 6A with a new, larger tunnel upstream and provide added protection by keeping the old tunnel in place and functional. This not only allows added benefits by (and flexibility in) the timing of maintenance activities, but also allows for the tunnel to be constructed within a shorter time which greatly reduces the cost ($123M–$173M) compared to Alternative 3 options. [redacted]

Even with the relatively low cost of $16M, Alternative 5 does not approach a positive BCR. While Alternative 5 could reduce the sediment deposition at the outfall, it does not address any of the risk nodes or PMFs and does not provide any reduction in risk to life safety.

Alternatives 6A, 6B, 6C, and 6D would provide some reduction in risk to life safety [redacted] however, they do not provide as much as the Alternative 3 and 4 options, and address none of the risk nodes from the risk assessment. [redacted] Also, the community strongly opposed Alternative 6 options. These options would disrupt the unity of the community and some (Alternative 6A) would physically divide the community. This would have a profound impact on the movement of the population within the community, producing bottlenecks at the proposed bypasses over the floodway. Such a situation would be compounded in emergency situations. The smaller options would also disrupt the utilities and critical infrastructure within the community all while providing less reduction in risk to life safety. Although the costs for Alternatives 6C and 6D ($59M and $48M, respectively) are lower than the tunnel options, there is high remaining uncertainty regarding cost effectiveness and impact on the community. In addition, the authority for this project precludes selection of non-structural alternatives without additional authorization.

The environmental quality assessment shows that Alternatives 5, 6B, 6C, and 6D are not beneficial since they do not prevent flood flows through the city or the release of environmentally persistent compounds during such flows. Alternative 2 may provide minimal EQ benefits, but the options of Alternatives 3 and 4 as well as Alternative 6A provide positive benefits to the EQ account.

The evaluation of National Criteria clearly shows the superiority of the options in Alternatives 3 and 4 in comparison to the other alternatives. Alternative 4A is shown to be the only alternative that meets all four of the National Criteria at a high level. Details of the evaluation are in Section 6.2.

Although Alternative 4B does pass higher flows (including PMF with surge), and does reduce AALL compared to Alternative 4A but the cost for the added reduction in Alternative 4B entails an exponentially higher incremental cost. Therefore, Alternative 4A provides a substantial reduction of AALL over all flow frequencies, including surge, at a much lower incremental cost when compared to other best buy alternatives. Although Alternative 4C does appear to have almost as much reduction in risk to life safety as Alternative 4A, the analysis did not take into consideration that the system in Alternative 4C would be overwhelmed in events smaller than the PMF but larger than tunnel capacity and the resulting risk to life safety from those flows. Thus, Alternative 4A was carried forward as the Recommended Plan.

6.11 Risk Node Screening of Alternatives

This section provides a risk node analysis by alternative. The team evaluated the alternatives in a manner similar to that for the evaluation of the individual measures. The team analyzed the alternatives to determine which risk nodes each alternative addressed within the identified PFMs from the risk assessment. Although the risk nodes were very similar to the individual measure risk nodes, there were some differences in the pathways to failure, especially regarding Alternative 4 with its two tunnels. Descriptions of the risk nodes are presented in **Table 41**. The last column of Table 41 presents the risk nodes within the PFMs addressed by each alternative. These results were used to support a Recommended Plan. [redacted] Alternative 6 options were excluded from **Table 41** due to the fact that these alternatives do not address any of the risk nodes analyzed.

Table 41. Risk Node Descriptions for Alternative Analysis.

Alternative	Node Description		Risk Nodes Addressed
Alternative 1: No Action	PFM 3: Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area	Node 1 – Debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the tunnel Node 2 – Head fails to flush the debris plug Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	*None*
	PFM 5A: Landslide blocks tunnel entrance leading to flow into consequences impact area	Node 1 – Soil and rock on steep slopes above tunnel become saturated, slide into the tunnel entrance, and block it Node 2 – Head fails to flush the landslide debris out of the tunnel Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	*None*
	PFM 6A: Upstream landslide forms dam that overtops, breaches, sending surge release flow into consequences impact area	Node 1 – Soil and rock on steep slopes become saturated, and a large landslide forms a dam in the canyon upstream of the project Node 2 – The landslide dam breaches, releasing a surge of water and debris down the canyon Node 3 – Debris blocks flow through the tunnel Node 4 – Water pressure fails to flush the landslide debris out of the tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Uncontrolled release	*None*
	PFM 21: Scour of tunnel liner which leads to liner/rock failure and tunnel blockage	Node 1 – Un-remediated void in the tunnel liner Node 2 – The scour action continues undermining the concrete liner and invert into the rock Node 3 – Scour action continues to remove tunnel liner Node 4 – Tunnel liner collapse with rock mass blocking tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Blockage occurs, and uncontrolled release	*None*
Alternative 2: Improve Existing Flood Diversion System	PFM 3: Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area	Node 1 – Debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the tunnel Node 2 – Head fails to flush the debris plug Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	Node 1, 2
	PFM 5A: Landslide blocks tunnel entrance leading to flow into consequences impact area	Node 1 – Soil and rock on steep slopes above tunnel become saturated, slide into the tunnel entrance, and block it Node 2 – Head fails to flush the landslide debris out of the tunnel Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	Node 1, 2

Alternative	Node Description		Risk Nodes Addressed
	PFM 6A: Upstream landslide forms dam that overtops, breaches, sending surge release flow into consequences impact area	Node 1 – Soil and rock on steep slopes become saturated, and a large landslide forms a dam in the canyon upstream of the project Node 2 – The landslide dam breaches, releasing a surge of water and debris down the canyon Node 3 – Debris blocks flow through the tunnel Node 4 – Water pressure fails to flush the landslide debris out of the tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Uncontrolled release	*None*
	PFM 21: Scour of tunnel liner which leads to liner/rock failure and tunnel blockage	Node 1 – Un-remediated void in the tunnel liner Node 2 – The scour action continues undermining the concrete liner and invert into the rock Node 3 – Scour action continues to remove tunnel liner Node 4 – Tunnel liner collapse with rock mass blocking tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Blockage occurs, and uncontrolled release	Node 1, 2, 3
Alternative 3A/3B: Enlarge Current Diversion System to Convey Larger Flow	PFM 3: Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area	Node 1 – Debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the tunnel Node 2 – Head fails to flush the debris plug Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	Node 1, 2
	PFM 5A: Landslide blocks tunnel entrance leading to flow into consequences impact area	Node 1 – Soil and rock on steep slopes above tunnel become saturated, slide into the tunnel entrance, and block it Node 2 – Head fails to flush the landslide debris out of the tunnel Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	Node 1, 2
	PFM 6A: Upstream landslide forms dam that overtops, breaches, sending surge release flow into consequences impact area	Node 1 – Soil and rock on steep slopes become saturated, and a large landslide forms a dam in the canyon upstream of the project Node 2 – The landslide dam breaches, releasing a surge of water and debris down the canyon Node 3 – Debris blocks flow through the tunnel Node 4 – Water pressure fails to flush the landslide debris out of the tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Uncontrolled release	Node 3, 4

Alternative	Node Description		Risk Nodes Addressed
	PFM 21: Scour of tunnel liner which leads to liner/rock failure and tunnel blockage	Node 1 – Flaw (un-remediated void in the tunnel liner) Node 2 – Initiation (the scour action continues undermining the concrete liner and invert into the rock) Node 3 – Progression (scour action continues to remove tunnel liner) Node 4 – Tunnel liner collapse with rock mass blocking tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Blockage occurs, and uncontrolled release	Node 1, 2
Alternative 4A/4B/4C/4D: Construct New Flood Diversion System	New Tunnel		
	PFM 3: Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area	Node 1 – Flaw initiation (debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the new tunnel) Node 2 – Progression (head fails to flush the debris plug) Node 3 – Unsuccessful detection and intervention Node 4 – Flaw Initiation (debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the old tunnel) Node 5 – Progression (head fails to flush the debris plug) Node 6 – Unsuccessful detection and intervention Node 7 – Uncontrolled release	Node 1, 2, 4, 5
	PFM 5A: Landslide blocks tunnel entrance leading to flow into consequences impact area	Node 1 – Flaw (soil and rock on steep slopes above tunnel become saturated, slide into the new tunnel entrance, and block it) Node 2 – Progression (head fails to flush the landslide debris out of the new tunnel) Node 3 – Unsuccessful detection and intervention Node 4 – Flaw (soil and rock on steep slopes above old tunnel become saturated, slide into the tunnel entrance, and block it) Node 5 – Progression (head fails to flush the landslide debris out of the old tunnel) Node 6 – Unsuccessful detection and intervention Node 7 – Uncontrolled release	Node 1, 2, 4 ,5

Alternative	Node Description		Risk Nodes Addressed
	PFM 6A: Upstream landslide forms dam that overtops, breaches, sending surge release flow into consequences impact area	Node 1 – Flaw (soil and rock on steep slopes become saturated, and a large landslide forms a dam in the canyon upstream of the project) Node 2 – Initiation (the landslide dam breaches, releasing a surge of water and debris down the canyon) Node 3 – Debris blocks flow through the new tunnel Node 4 – Progression (water pressure fails to flush the landslide debris out of the new tunnel Node 5 – Initiation (the landslide dam breaches, releasing a surge of water and debris down the canyon) Node 6 – Debris blocks flow through the old tunnel Node 7 – Water pressure fails to flush the landslide debris out of the old tunnel Node 8 – Unsuccessful detection and intervention Node 9 – Uncontrolled release	Node 3, 4
	PFM 21: Scour of tunnel liner which leads to liner/rock failure and tunnel blockage	Node 1 – Un-remediated void in the new tunnel liner Node 2 – The scour action continues undermining the concrete liner and invert into the rock Node 3 – Scour action continues to remove new tunnel liner Node 4 – Tunnel liner collapse with rock mass blocking tunnel Node 1 – Un-remediated void in the old tunnel liner Node 2 – The scour action continues undermining the concrete liner and invert into the rock Node 3 – Scour action continues to remove old tunnel liner Node 4 – Tunnel liner collapse with rock mass blocking tunnel Node 5 – Unsuccessful detection and Intervention Node 6 – Blockage occurs, and uncontrolled release	Node 1, 2, 3
Alternative 4A/4B/4C/4D: Construct New Flood Diversion System	Old Tunnel		
	PFM 3: Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area	Node 1 – Water flows to old tunnel Node 2 – Debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the tunnel Node 3 – Head fails to flush the debris plug Node 4 – Unsuccessful detection and intervention Node 5 – Uncontrolled release	Node 1, 2, 3, 4

Alternative	Node Description		Risk Nodes Addressed
	PFM 5A: Landslide blocks tunnel entrance leading to flow into consequences impact area	Node 1 – Water flows to old tunnel Node 2 – Soil and rock on steep slopes above tunnel become saturated, slide into the tunnel entrance, and block it Node 3 – Head fails to flush the landslide debris out of the tunnel Node 4 – Unsuccessful detection and intervention Node 5 – Uncontrolled release	Node 1,2,3,4
	PFM 6A: Upstream landslide forms dam that overtops, breaches, sending surge release flow into consequences impact area	Node 1 – Water flows to old tunnel Node 2 – Soil and rock on steep slopes become saturated, and a large landslide forms a dam in the canyon upstream of the project Node 3 – The landslide dam breaches, releasing a surge of water and debris down the canyon Node 4 – Debris blocks flow through the tunnel Node 5 – Water pressure fails to flush the landslide debris out of the tunnel Node 6 – Unsuccessful detection and intervention Node 7 – Uncontrolled release	Node 1
	PFM 21: Scour of tunnel liner which leads to liner/rock failure and tunnel blockage	Node 1 – Water flows to old tunnel Node 2 – Un-remediated void in the tunnel liner Node 3 – The scour action continues undermining the concrete liner and invert into the rock Node 4 – Scour action continues to remove tunnel liner Node 5 – Tunnel liner collapse with rock mass blocking tunnel Node 6 – Unsuccessful detection and intervention Node 7 – Blockage occurs, and uncontrolled release	Node 1
Alternative 5: Construct Debris Retention Basin	PFM 3: Debris (sediment-laden flow) blocks tunnel leading to flow into consequences impact area	Node 1 – Debris in stream channel becomes mixed with floodwaters, producing a debris flow and blocking the tunnel Node 2 – Head fails to flush the debris plug Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	None
	PFM 5A: Landslide blocks tunnel entrance leading to flow into consequences impact area	Node 1 – Soil and rock on steep slopes above tunnel become saturated, slide into the tunnel entrance, and block it Node 2 – Head fails to flush the landslide debris out of the tunnel Node 3 – Unsuccessful detection and intervention Node 4 – Uncontrolled release	None

Alternative	Node Description		Risk Nodes Addressed
	PFM 6A: Upstream landslide forms dam that overtops, breaches, sending surge release flow into consequences impact area	Node 1 – Soil and rock on steep slopes become saturated, and a large landslide forms a dam in the canyon upstream of the project Node 2 – The landslide dam breaches, releasing a surge of water and debris down the canyon Node 3 – Debris blocks flow through the tunnel Node 4 –Water pressure fails to flush the landslide debris out of the tunnel Node 5 – Unsuccessful detection and intervention Node 6 – Uncontrolled release	None
	PFM 21: Scour of tunnel liner which leads to liner/rock failure and tunnel blockage	Node 1 – Un-remediated void in the tunnel liner Node 2 – The scour action continues undermining the concrete liner and invert into the rock) Node 3 – Scour action continues to remove tunnel liner Node 4 –Tunnel liner collapse with rock mass blocking tunnel Node 5 – Unsuccessful detection and Intervention Node 6 – Blockage occurs, and uncontrolled release	None

7. RECOMMENDED PLAN

7.1 Description of the Recommended Plan

The PDT held an Agency Decision Milestone meeting with the USACE Vertical Team on 25 January 2021. During the meeting, the team received approval of the Recommended Plan (Alternative 4A) from the Chief of Planning and Policy Division. Alternative 4A includes the construction of a dam upstream of the existing dam to divert all of the Lowell Creek flow into a new 18-ft-diameter tunnel which conveys this flow to the outfall that discharges onto the existing Lowell Creek alluvial fan, a canopy over the both tunnel entrances to prevent blockage from a landslide, and a 150-ft outfall that conveys the Lowell Creek flow over Lowell Point Road onto the alluvial fan (Figure 31). The new 18-ft tunnel would reduce risks associated with flows up to 8,500 cfs. Debris and rubble generated by the tunneling process, likely through drilling and blasting or some type of mechanical excavation such as Tunnel Boring Machines (TBM), would not come into contact with surface flows and would be disposed of in the same manner as the sedimentation debris, being trucked away for disposal at a nearby rock quarry, which is owned and operated by the City of Seward.

The existing diversion system will remain to provide additional capacity in the event the new diversion dam is overtopped or if the Lowell Creek flow needs to be diverted to facilitate maintenance activities associated with the new diversion system. The existing 10-ft-diameter tunnel will be refurbished so it can serve this role.

The Recommended Plan also incorporates the measure for Select Tree Removal in the Lowell Canyon area upstream of the dam, which would remove trees that are large enough to get caught in the tunnel (see Figure 31). Verification of the location, number, and size of the trees that are recommended for removal will be conducted during PED.

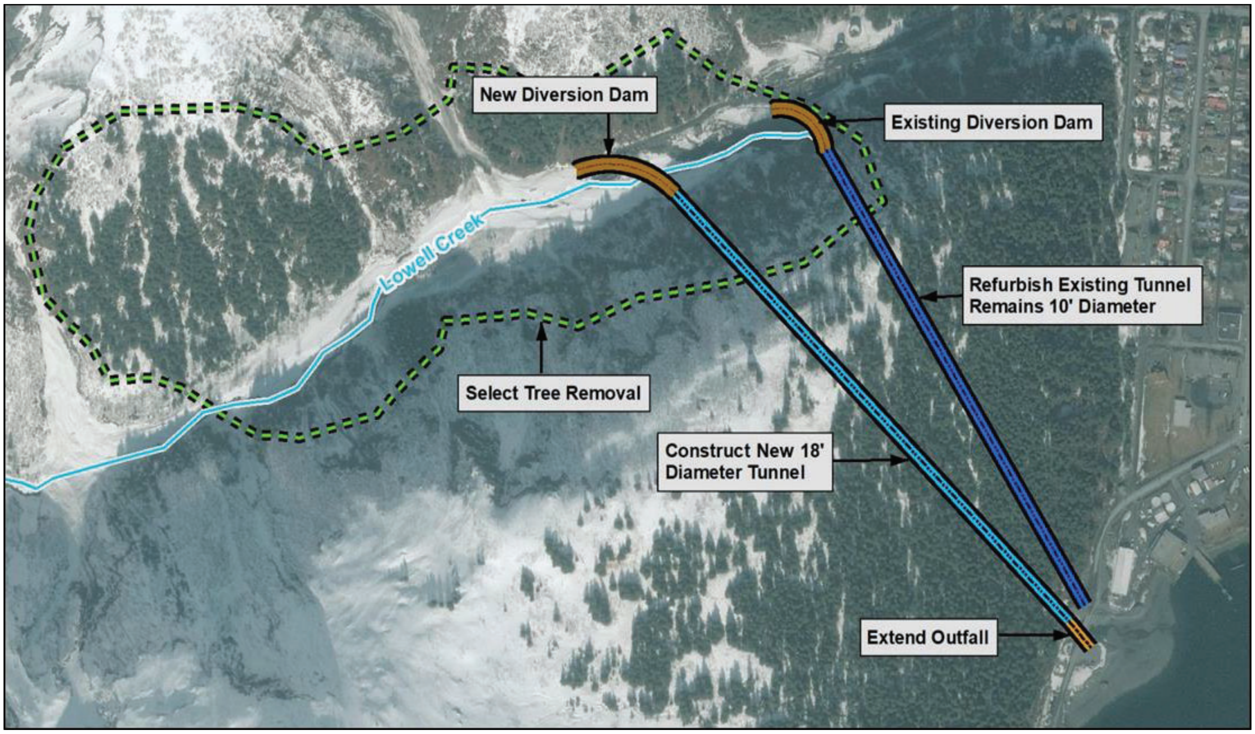

Figure 31. Recommended Plan for Lowell Creek Feasibility Study.

7.2 Plan Components and Construction Methodology

The significant plan components for Alternative 4A include:

- New diversion dam
- New 18-ft-diameter tunnel
- Tunnel inlet portal canopy over the new tunnel
- Extended 150-ft outfall for the new tunnel
- Refurbishment of the existing 10-ft-diameter tunnel
- Select tree removal in Lowell Canyon
- Automated stream gage within the tunnel

The sections below discuss each component above in more detail.

7.2.1 New Diversion Dam

The diversion dam, spillway, and intake transition designs are largely based on the existing dam configuration. Any new intake transition design will require physical modeling during PED to confirm performance. The diversion dam height above the adjacent streambed will be similar to that of the existing dam. It is assumed that the diversion dam will be constructed of roller-compacted concrete; however, the intake transition will require formed and carefully controlled concrete screeding and finishing. The details of combining these construction methods will need to be further evaluated during design.

7.2.2 New Tunnel

Cost Engineering experience suggests that efficiencies with using a TBM are realized only for tunnels 3 miles in length or longer. The proposed tunnel is less than 3,000 feet long, which is well below this threshold. Due to this and the available technical expertise within Alaska that the cost estimate for construction of the new tunnel was based on drill and blast methods. With drill and blast methods, controlled blasting techniques may be required to minimize overbreak and blasting effects outside the excavation lines. Additionally, the monitoring and analysis of blast vibration near critical structures due to blasting will be required before and during construction. The construction of the new tunnel is anticipated to produce approximately 20,000 cy of debris which will be disposed of by the same process as the sedimentation debris at the outfall.

The initial size of the tunnel would be excavated to a larger size than the final design requires, to allow for the placement of the concrete liner. Prior to forming and placing the final layer(s) of concrete for the liner, a stabilizing shotcrete liner with reinforcing wire mesh netting would be installed. The use of rock bolts may be required to decrease the loading of any unstable surrounding rock mass. The final concrete liner is assumed to be a single layer reinforced concrete design with weep holes. The geologic structuring and loading of the surrounding rock will define the length of the constructed sections based on the geotechnical and geological analysis performed on the existing tunnel and surrounding rock mass. Prefabricated concrete paneling may also be used for the tunnel liner. Contact grouting will be accomplished after the concrete liner is placed to ensure full contact at the tunnel crown and invert connections. The invert will have a final armor of high strength concrete. A stream gage would be installed within the tunnel to provide operational benefits. A typical cross-section of the proposed tunnel, also referred to as the flume, is shown in Figure 32.

The final alignment of the tunnel and outfalls for 4A will be established in PED. The centerline of the tunnel inlet for the Recommended Plan is approximately 440 feet upstream of the centerline of the existing tunnel inlet and will be approximately 20 feet higher in elevation than the existing tunnel inlet. The centerline of the new tunnel and outfall comes within approximately 72 feet of the centerline of the existing tunnel and outfall.

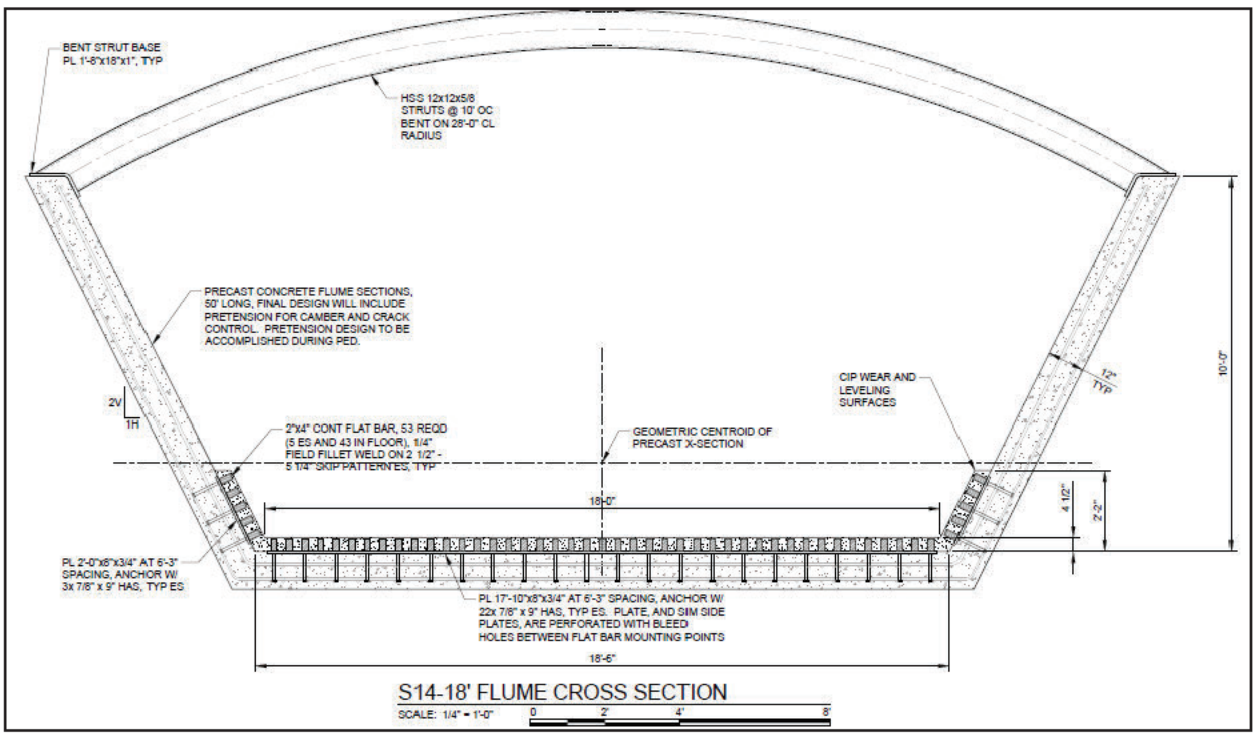

Figure 32. 18-ft Flume Cross-Section.

7.2.3 Portal Treatment

The tunnel portal is a very critical feature for correct operation of the system. Due to the extreme terrain of the project location, the portal must be protected against possible rockfall and landslides from above. In order to provide such protection a canopy will be installed above the inlet of both tunnels. The tunnel inlet portal canopy is designed as a steel-frame structure with concrete footings tied into bedrock and a combination of site-cast and pre-cast concrete decking. Design live load capacity was set at 600 pounds per square ft to provide substantial resistance to landslide-related loading. No composite action was assumed between the steel girders and the deck slabs; however, this could be incorporated during PED to either provide some cost reduction or increase the structure's load capacity. At this time, no architectural treatment has been included; however, it is assumed that a large structure of this type in a natural setting should consider aesthetics for the final design. Other options for reinforcing slopes or retaining potential slide material will also be explored during PED. Further geotechnical investigations and mapping are also planned during PED. The anticipated design of the tunnel inlet portal canopy is shown in Figure 33.

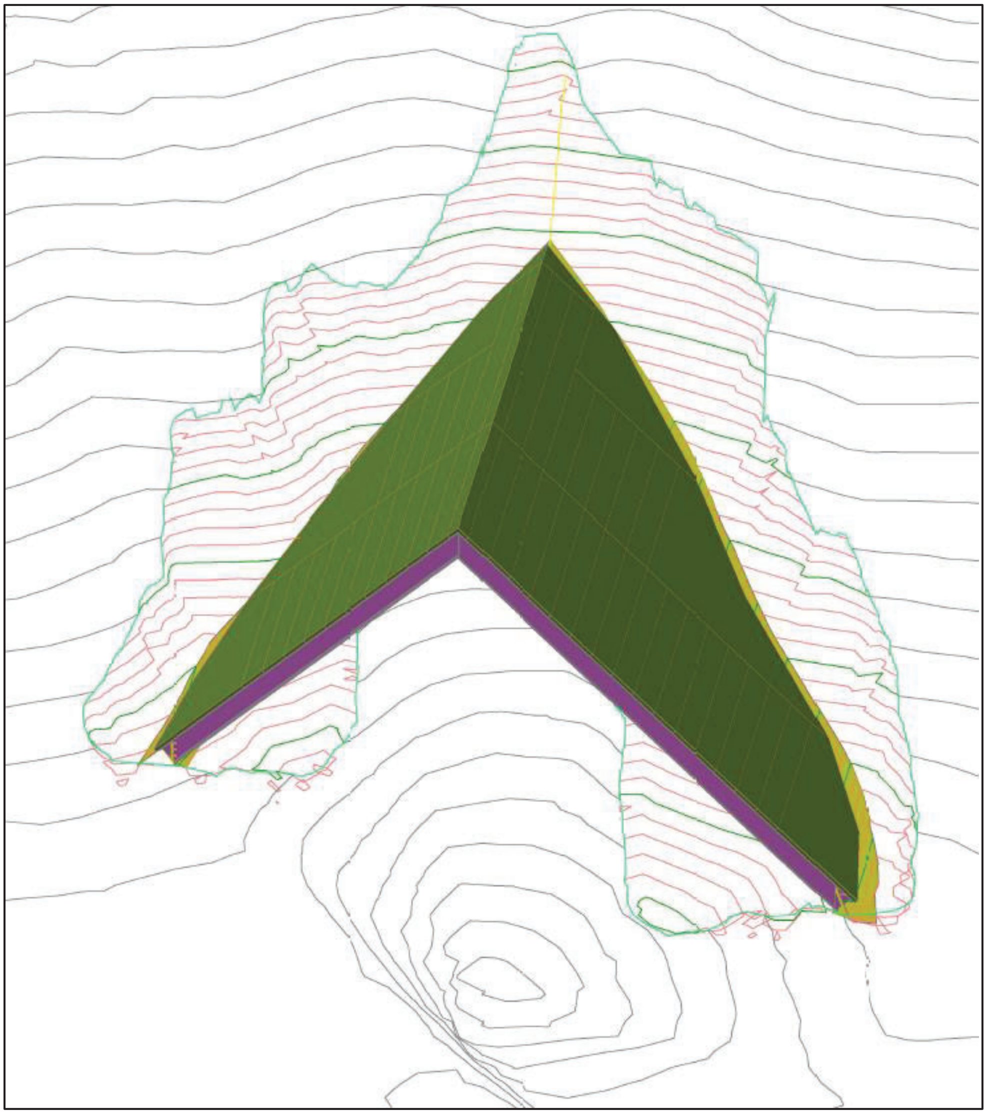

Figure 33. Entrance Portal Canopy (Oblique View).

7.2.4 Extended Outfall – 150 ft

The outfall is a pre-cast concrete open-channel flume placed on drilled piers with pier caps similar to those typically used in bridge construction. Piers are concrete-filled steel pipes with a rebar cage. The pre-cast flume sections have bent tube-steel struts across the top of the walls to facilitate lifting and placing as well as reinforcing the sidewalls of the flume for lateral loads. Armoring is field-welded and encased in concrete to form a replaceable wear surface, allowing for a uniform slope. The system has been designed for a mounded gravel live load to prevent flume failure should a blockage occur. Seismic loads perpendicular to the length of the flume have been accounted for, however, further work must be done to account for seismic loads along the length of the flume. A rigid connection to the supporting rock where the flume is tied to Bear Mountain would prevent the piers from seeing lateral loads for seismic forces in this direction, which would make for a large load over a small area. For the 150-ft-long outfall extension under consideration, these large forces may be manageable, but further evaluation is needed during PED. The new flume slope past the tunnel exit is 7% for 200 feet with the tunnel/flume junction at approximately +73.8 feet MLLW. The end of the new outfall extension is +59.8 feet MLLW. In Alternative 4A, the new tunnel would be carrying the vast majority of the flow with the existing tunnel only used during maintenance or in an extreme event which resulted in overflow of the new spillway. Thus, an extended outfall at the existing tunnel in this alternative would not be necessary. The proposed outfall design is shown in Figure 34.

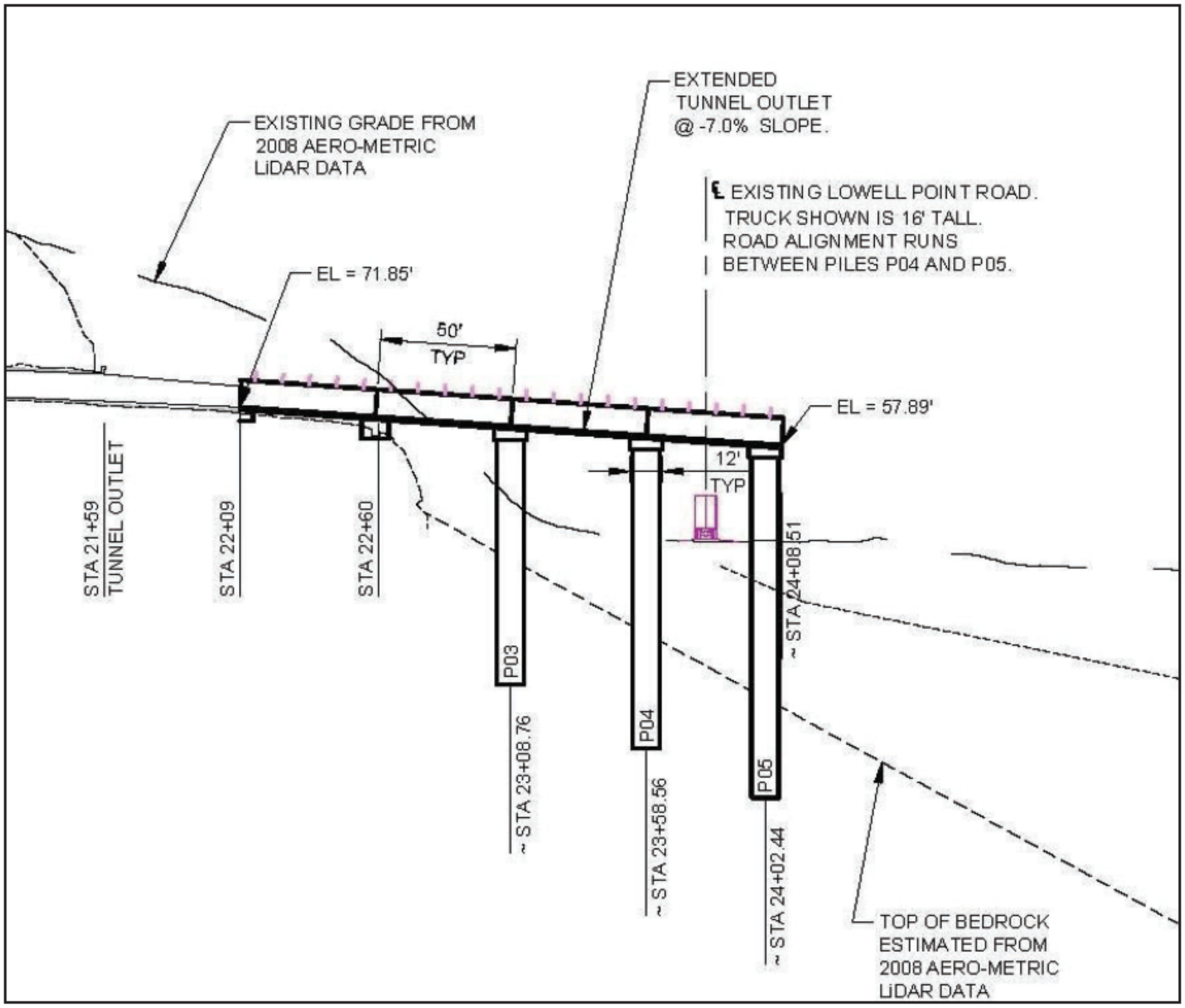

Figure 34. Proposed Design of Extended Outfall (Side View).

7.2.5 Refurbishment of the Existing Tunnel

Refurbishing the existing tunnel entails selective demolition of the existing concrete liner and finishing the entire invert and damage to the walls and crown with 10,000 psi silica fume concrete.

7.2.6 Select Tree Removal

This measure includes selective tree removal of those trees exhibiting a 48 inch or greater diameter at chest height or multiple trunks of 30 inches in diameter at chest height in a portion of the upper watershed. The objective of this measure is to remove trees that are large enough to cause blockage in the tunnels should they fall and be swept into the tunnel(s) during storm events. The select tree removal specifications will be re-evaluated during PED because the tree specifications reported here were developed for the existing 10-ft-diameter tunnel and the new 18-ft-diameter tunnel may tolerate larger trees without blockage.

[redacted]

[redacted]

7.4 OMRR&R

The historic tunnel and upstream dam face repair cycle is 10 to 15 years. OMRR&R of the outfalls falls within the same category as the tunnel lining. Experience shows that damage becomes progressively less severe with distance down the tunnel, so it is expected that the outfalls will have less abrasion damage and repairs on this cycle than the rest of the system. Through repairs and major rehabilitation efforts, it is expected that the dam and tunnel system will be maintained indefinitely therefore no estimate for replacing the tunnel system or any component in its entirety has been developed. Repairs to the tunnel lining will be focused on the invert where water and debris have been flowing as well as completing contact grouting of the tunnel crown. Repairs would be cast in place concrete overlays controlled to maintain the design slope and grade of the tunnel invert. Canopy OMRR&R consists of clearing landslide material intercepted by the canopy as well as surface concrete repairs. The assumed cost for maintaining the concrete surfaces of the Recommended Plan is based on a review of maintenance activities over the history of the existing project. After construction, maintenance was performed in 1945 to improve the rail reinforcement of the concrete. The cost of this effort is not known. Since 1945, USACE records show that $19,714,235 (adjusted to 2020 dollars) has been spent on project maintenance, primarily consisting of concrete repairs to the tunnel invert and intake transition. Over a 75-year period of record, this produces an average annual cost of maintenance of $262,856.

The current discharge gage on the system measures water depth and velocity at the tunnel exit every 15 minutes. Data is maintained by the USGS and made publicly available on the National Water Information System webpage. Maintenance of the discharge gage includes providing station power, calibrating the sensors, quality checking the data, and performing site maintenance as necessary to keep the data collection platform functional. The current gage costs $50,000 annually to operate.

In addition to the expected maintenance and repairs to the structure and the maintenance of the stream gage, the outfall of the project must be maintained to prevent material buildup that would jeopardize adjacent facilities or block the system. The USACE will develop an OMRR&R manual during the construction phase of the project. It is expected that the system will deposit approximately 25,000 cy of material annually onto the alluvial fan. Over time, this material would accumulate; sediment handling is expected to be similar to what currently takes place with heavy equipment pushing and moving the sediment towards deep water. Annual costs for OMRR&R sediment handling are estimated to be $178,000. A summary of the OMRR&R costs for the Recommended Plan are presented in **Table 42**.

Table 42. OMRR&R Cost for Recommended Plan.

OMRR&R Item	Cost
New Dam & Tunnel	$390,000
Existing Tunnel	$50,000
Extended Outlet	$26,000
Protect Tunnel Inlets - New & Existing	$30,000
Stream Gage	$25,000
Sediment Handling	$178,000
Total:	**$699,000**

7.5 Integration of Environmental Operating Principles

The following environmental operating principles have been integrated into the planning process:

- **Foster sustainability as a way of life throughout the organization:** Planning for this project incorporated consideration for the sustainability of environmental resources in the project area.

- **Proactively consider environmental consequences of all USACE activities and act accordingly:** Environmental consequences were considered throughout the planning process, and every effort has been made to avoid, minimize, or mitigate anticipated impacts.

- **Create mutually supporting economic and environmentally sustainable solutions:** The plan allows value engineering of the tunnel outlet to determine if a more effective solution can be found.

- **Continue to meet corporate responsibility and accountability under the law for activities undertaken by the USACE, which may impact human and natural environments:** A full environmental assessment (EA) has been conducted as required by the NEPA. In addition, the principles of avoidance, minimization, and mitigation will be enacted to the extent possible throughout design and construction.

- **Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs:** For this study, extensive coordination has taken place to determine the impacts and subsequent mitigation actions regarding anticipated environmental impacts.

- **Leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner:** USACE worked closely with the City of Seward throughout this study. The City of Seward and other agencies that work at Seward are very knowledgeable about the environment surrounding Lowell Creek.

- **Employ an open, transparent process that respects the views of individuals and groups interested in the USACE activities:** USACE made every effort to be responsive to stakeholder concerns. Public input was solicited and used for both environmental and economic analysis purposes. Before this study started, a meeting took place to solicit feedback from the City of Seward and stakeholders on problems the community faces and the impacts on flooding with the existing conditions in the Seward area. The group defined objectives, opportunities, and constraints for this study and discussed alternative ideas.

7.6 Real Estate Considerations

Removal of selected trees upstream from the tunnel and the construction of the canopy for inlet protection from landslides will require easements. In addition, staging areas will be required at both ends of the tunnel for construction. The NFS will negotiate to secure and acquire all necessary real estate interests in the lands required for the project. The features, owners, acres, and the standard estate required for the Recommended Plan Lands, Easements, Rights of Way, Relocations, and Disposal Area (LERRD) are described in **Table 43**.

Table 43. Recommended Plan LERRD Requirements.

Tract ID	Feature	Owner	Acres	Minimum Estate Required
1	Tree Removal	State of Alaska	45.51	Estate # 15, Temporary Work Area Easement
2	Tree Removal	NFS	32.41	*Temporary Work Area Easement
3	Dam and Tunnel Canopy	NFS	21.71	Fee
4	Outfall Area	Federal Government	0.01	Public Domain
5	Outfall	NFS	0.19	Fee
6	Upper Staging Area	NFS	1.55	*Temporary Easement
7	Refurbish Existing Tunnel	NFS	13.55	Fee
8	Staging	NFS	2.5	Fee
9	Material Placement Site	NFS	2	Fee
		Total Acres	119.42	

*NFS owns the land in fee estate and meets the minimum estate requirements.

The Federal Government may only exercise navigation servitude for Congressionally authorized projects or measures that are related to navigation or pursuant to regulatory authorities to protect navigation. Navigation servitude is not being applied to this project. The City of Seward is the owner of the electric, telephone, water, and sewer facilities located in the project footprint. It will be determined during the PED phase if these facilities will be impacted by the construction, either temporarily or permanently. Public Law 91-646 relocations (relocation of persons) are not anticipated. There are no other Federal Projects that would be affected by the project footprint. Further information about real estate requirements for the project is available in Appendix F: Real Estate Plan.

7.7 Risk and Uncertainty

In any planning decision, it is important to consider the risk and uncertainty that is invariably present. For this study, there were risk and uncertainty categories that were identified and evaluated during the planning process. The risk and uncertainty of items remaining for this project are summarized in **Table 44**.

Table 44. Risk and Uncertainty Summary.

Assumption or Estimate	Risk Level	Risk Comment
Lack of Data	Medium	Assumptions were made due to lack of gaged (rainfall/runoff) data.
Bedrock Depth	Medium	The depth of bedrock has been assumed and will be further investigated during PED.
Material Properties	Medium	The properties of materials may affect design, engineering, and implementation of project.
Sedimentation Quantity	Medium	The quantity of sedimentation is estimated based on estimates of deposition during historical events.
Weather Delays	Low	The project area is prone to extreme weather conditions that could impact data collection and construction.
Unanticipated cultural resources	Low	There is minimal risk of encountering unanticipated cultural resources.
Surge sensitivity	High	The uncertainty inherent in the surge multiplier may lead to under or overestimating the life loss.
Landslides and debris flow	High	Landslide numbers, locations, estimated sizes, material types, and other characteristics will control the number and size of surge flows.
Tunnel diameter	Medium	Without further analysis on tunnel diameter, misidentification of optimal project performance and cost effectiveness could occur.
Early warning system	Low	If a way could be found to expand warning times, an early warning system might provide some benefits.
Floodplain relocation	Low	Could miss opportunities to remove most critical structures from Lowell Creek floodplain.

No appreciable gaged data exist for Lowell Creek. For the study, the team utilized data from Spruce Creek and translated it for Lowell Creek. This method gives an approximate estimate of data for Lowell Creek leading to a degree of uncertainty.

The depth of bedrock and material properties in the area has not been determined during the study; this risk will be managed by additional geotechnical surveys during PED.

No data exist to accurately determine the sedimentation quantities. This risk has been managed using historical data from events to calculate estimates for sedimentation. The use of such data for sedimentation estimates may underestimate the quantity of sedimentation at the outfall resulting in higher OMRR&R costs.

Alaska is known for its severe weather. Although Seward's climate is milder than other parts of the state, severe weather events are known to occur which may lead to weather delays. This risk is low in the project area and will be tolerated.

Although the current flood control system is listed on the National Register of Historic Places, it is very unlikely that unanticipated cultural resources will be encountered during this project due to the highly disturbed nature of the area. If cultural resources are encountered, work would be stopped until the resources could be evaluated. This risk will be tolerated.

The sensitivity to surge specifically results from lack of data for Lowell Creek. Surge data for five other streams in the area from the 1986 flood event were utilized to elicit a 2.5 surge factor for analysis. As surges may result in flows either larger or smaller than 2.5 surge factor flow rate used and the only available data come from one event, there remains uncertainty in the surge factor. Landslide characteristics would impact the number and size of surge events. While eliminating the uncertainty may provide more confidence in the data, it would be very unlikely to change the Recommended Plan and would entail additional time and funds; thus, the uncertainty will be tolerated.

There is a correlation between flow capacity and tunnel diameter in the effort to reduce risk to life safety. Though additional tunnel diameters were added to the alternatives and the team conducted preliminary assessments of these diameters, some uncertainty remains. To eliminate the uncertainty further would require additional time and funds and, with the minimal cost between the additional tunnel diameters and the Recommended Plan, it was determined that the risk would be tolerated.

An early warning system could produce some benefits to the community if ample warning time could be provided. Analysis showed that it is unlikely that the system evaluated could provide ample warning time. Other forms of detection may expand the warning time but have not been pursued. As the risk is low, the risk will be tolerated.

Relocation of structures from the floodplain were considered with a preliminary assessment. While such alternatives may remove the most susceptible structures from the floodplain, the assessment did not take into account risk to life safety associated with the uncertainty of the flows once the water is on the alluvial fan. The assessment also indicated that the structure relocation scenarios evaluated would result in a much lower reduction in risk to life safety than the Recommended Plan. These factors, as well as the cost and time to perform more detailed analysis and lack of community support for such alternatives, led to the determination the risk of leaving the structures would be tolerated.

7.8 Project Cost and Cost Sharing

According to the implementation guidance for Section 5032 of the WRDA, the design and construction of the approved plan shall be accomplished at Federal expense with the NFS providing, at no cost to the Government, all needed lands, easements, rights-of-way and disposal areas (**Table 45**). The project design and construction of the approved project will not be cost shared and are 100% Federal expense. The $725,000 Non-Federal share includes $719,000 for utility relocations during construction of the project. Details on the utility relocations can be found in Appendix F: Real Estate. **Table 45** reflects the certified project first cost of $185,225,000.

Table 45. Cost Share for Recommended Plan.

Item	Total Cost	Federal Share	%	Non-Federal Share	%
Construction Estimate Total	$138,627,000	$138,627,000	100	$0	00
LERRD	$726,000	$1,000	0	$725,000	100
Planning, Engineering & Design	$18,212,000	$18,212,000	100	$0	-
Construction Management	$27,660,000	$27,660,000	100	$0	-
TOTAL PROJECT FIRST COST	$185,225,000	$184,500,000	99.6	$725,000	0.4
Note: the $1,000 in the Fed Share column for LERRDs is Fed administrative review costs.					

7.9 Project Schedule

The construction of the project alternative is expected to begin in the year 2022. It will continue for three years. Major construction features for Alternative 4A include a new 18-ft diversion tunnel and dam, inlet canopy, and outfall extension. Project specifications would detail time restrictions for the contractor to conduct certain activities during specified time periods.

Construction sequencing would likely be similar to the following:

- Drilling and construction of a tunnel
- Extension of outfall construction
- Construction of diversion dam
- Install stream gage within the tunnel
- Construction of canopy

- Tree Removal
- Refurbish old tunnel

This construction sequence was developed to provide the best scenario for cost-effective project implementation, based on USACE's experience with previous projects constructed. However, there is inherent risk and uncertainty in appropriation of funds by Congress, which can influence the Recommended Plan construction schedule and sequencing scenario developed during the feasibility study phase. Construction sequencing developed during the feasibility study may have to be revisited to inform appropriation decisions that may potentially be based on what project components or feature(s) have priority considering the associated benefits.

Priorities for Recommended Plan components are influenced by engineering considerations, O&M needs, the benefits associated with the project components, and the priorities expressed by the NFS. There is also a cost risk if construction sequencing for the entire Recommended Plan cannot be optimized due to inadequate funding.

Total project costs could increase due to, but not limited to:

- If more contractor mobilizations are required than assumed to complete the Recommended Plan.
- If insufficient appropriations prevent the scheduling and construction of the entire Recommended Plan under one contract such that efficiencies associated with optimized construction sequencing are not realized.

Environmental mitigation measures developed for this project are summarized in Section 8.4.

8. ENVIRONMENTAL CONSEQUENCES*

The initial array of alternatives carried forward included Alternatives 1 through 5 and their associated variations (see Table 16). These alternatives exhibit similar project footprints and were thoroughly analyzed not only within POA, but also in coordination with external resource agencies and the public. Each footprint is bound by the uninhabited confines of Lowell Canyon, and does not alter the current environmental baseline where the entire surface flow of Lowell Creek is routed through Bear Mountain to discharge into Resurrection Bay.

Alternatives 6A, 6B, 6C, and 6D were added relatively late in the project study timeline to evaluate the risk reduction benefits of different non-structural project scenarios for the general non-structural measure of relocation of structures that had been previously screened out from further analysis. USACE recognizes that because of their late inclusion to the project as alternatives carried forward, a robust analysis of the potential impacts to the natural and human environment was not feasible. A complete analysis of the non-structural alternatives, specifically Alternative 6A, would require the development and implementation of intricate surveys, as well as additional coordination with resource agencies, the NFS, and the public. Although these alternatives were added as alternatives for plan selection, they did not meet the purpose and need of the project or address the specific directive in Section 5032; therefore, they are not considered ‘reasonable alternatives’ under NEPA and were thus not analyzed.

The potential effects to the natural and human environment from Alternatives 4C and 4D, which were similarly added later in the project study timeline to assess the potential for cost savings and optimization of the preferred alternative, did not differ from Alternatives 4A and 4B, and are reflected in the subsequent analysis. Table 46 provides a summary of the environmental consequences.

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Table 46. Environmental Consequences Summary.

	Alternative 1: No Action	Alternative 2: Improve Existing + 150-ft Outfall Flume	Alternative 3A and 3B: Enlarge Existing + 150-ft Outfall Flume	Alternative 4A, 4B, 4C, and 4D: Construct New + 150-ft Outfall Flume	Alternative 5: Construct Debris Basin
Aesthetics	Aesthetics would be unaffected by Alternative 1.	The tunnel entrance would be covered by a reinforced canopy structure; original aspects of the project would be permanently altered.	The 150-ft outfall flume would be the most readily observed permanent effect to the existing aesthetic properties of the location. Similarly, enlargement of the diversion dam and tunnel system would be permanent.	The 150-ft outfall flume would be the most readily observed effect to the existing aesthetics. The existing diversion system would not be affected. A new, permanent alteration of the aesthetic baseline would occur as a result of the implementation of a new, larger diversion system above the existing.	The aesthetic qualities of the upper watershed would be affected on a recurring annual basis as the debris basin was reestablished. Dump truck traffic in Seward would increase during the wintertime as this effort was implemented.
Water Quality	Water quality may be negatively affected by debris, household, and industrial compounds as a result of catastrophic flooding through Seward.	The alternative would not affect baseline water quality conditions.	Alternatives would mimic existing conditions and would likely not affect baseline water quality conditions.	Alternatives would mimic existing conditions and would likely not affect baseline water quality conditions.	Increased turbidity in the vicinity of and downstream of active earthwork. Likely requires surface flow diversion for construction.

	Alternative 1: No Action	Alternative 2: Improve Existing + 150-ft Outfall Flume	Alternative 3A and 3B: Enlarge Existing + 150-ft Outfall Flume	Alternative 4A, 4B, 4C, and 4D: Construct New + 150-ft Outfall Flume	Alternative 5: Construct Debris Basin
Noise	Ambient noise levels would likely not be impacted by the implementation of Alternative 1.	Ambient noise levels would increase in proximity to areas of active construction but would not exceed those of a normal construction site.	Ambient noise levels would increase in proximity to areas of active construction but would not exceed those of a normal construction site.	Ambient noise levels would increase in proximity to areas of active construction but would not exceed those of a normal construction site.	Ambient noise levels would increase during periods of active work but would be limited to the upper portions of the Lowell Creek watershed.
Existing Infrastructure and Facilities	Seward's infrastructure downstream of the existing diversion structure could be subject to catastrophic damage. Similarly, infrastructure located in proximity to the existing outfall structure may be subject to flood damage.	Seward's infrastructure downstream of the existing diversion structure could be subject to catastrophic damage. The risk of flood damage to infrastructure in proximity to the outfall would persist until the construction of the new outfall was complete.	Alternative 3 would carry the same risk as to the No Action Alternative until fully constructed.	Constructing a new, upstream diversion structure and tunnel would carry the same risk as to the No Action Alternative until the diversion and tunnel structure were capable of conveying surface flows.	Seward's infrastructure downstream of the existing diversion structure could be subject to catastrophic flooding damage if the tunnel were blocked.
Cultural Resources	Cultural resources would not be affected by the No Action Alternative.	Alterations to the existing structure would require re-initiation of Section 106 consultation.	Alterations to the existing structure would require re-initiation of Section 106 consultation.	Cultural resources would not be affected by Alternative 4.	Cultural resources would not be affected by Alternative 5.

	Alternative 1: No Action	Alternative 2: Improve Existing + 150-ft Outfall Flume	Alternative 3A and 3B: Enlarge Existing + 150-ft Outfall Flume	Alternative 4A, 4B, 4C, and 4D: Construct New + 150-ft Outfall Flume	Alternative 5: Construct Debris Basin
Environmental Justice	Catastrophic flooding would likely disproportionately affect members of the population who may be disabled or have hearing or vision impairment.	Catastrophic flooding would likely disproportionately affect members of the population who may be disabled or have hearing or vision impairment.	Protracted construction time may prolong the risk associated with catastrophic flooding.	The redundancy of two tunnels potentially eliminates disproportionate risk to members of the population who may be disabled or have hearing or vision impairment.	The alternative would not reduce the risk of catastrophic flooding to members of the population who may be disabled or have hearing or vision impairment.
Protected Tribal Resources	There would be no impact on any known Tribal Resource.	There would be no impact on any known Tribal Resource.	There would be no impact on any known Tribal Resource.	There would be no impact on any known Tribal Resource.	There would be no impact on any known Tribal Resource.
Terrestrial Habitat	Terrestrial habitat would not be affected by the no-action alternative	Terrestrial habitat in the area of the existing project would not be affected. Terrestrial habitat in the tree removal area may become successional.	Effects to terrestrial habitat in the area of the diversion and tunnel inlet would resemble the existing condition. Vegetation in the tree removal area may become successional. Terrestrial habitat in the vicinity of the outfall would resemble the existing baseline condition.	Effects to the terrestrial habitat in the area of the new diversion dam and tunnel inlet would strongly resemble the habitat at the existing diversion site. Vegetation in the tree removal area may become successional. Terrestrial habitat in the vicinity of the outfall would strongly resemble the existing baseline condition.	Effects to terrestrial habitat in the upper watershed would include an annual disturbance regime that does not currently exist.

	Alternative 1: No Action	Alternative 2: Improve Existing + 150-ft Outfall Flume	Alternative 3A and 3B: Enlarge Existing + 150-ft Outfall Flume	Alternative 4A, 4B, 4C, and 4D: Construct New + 150-ft Outfall Flume	Alternative 5: Construct Debris Basin
Birds, including Bald and Golden Eagles	Birds, Bald Eagles and Golden Eagles may be inadvertently impacted by exposure to household and industrial compounds released as a result of catastrophic flooding.	Birds, Bald Eagles and Golden Eagles would not be impacted directly. Indirect impacts from tree removal would be difficult to quantify. Birds, Bald Eagles and Golden Eagles may be dissuaded from foraging or nesting in close proximity to active construction.	Birds, Bald Eagles and Golden Eagles would not be impacted directly. Indirect impacts from tree removal would be difficult to quantify. Birds, Bald Eagles and Golden Eagles may be dissuaded from foraging or nesting in close proximity to active construction.	Birds, Bald Eagles and Golden Eagles would not be impacted directly. Indirect impacts from tree removal would be difficult to quantify. Birds, Bald Eagles and Golden Eagles may be dissuaded from foraging or nesting in close proximity to active construction.	Birds, Bald Eagles and Golden Eagles would not be impacted directly; indirect effects would be difficult to determine; birds, Bald Eagles and Golden Eagles may be dissuaded from forging in the immediate area of active construction.

8.1 Physical Environment

Existing physical environmental conditions that have been carried forward for analysis (see Section 3.5) are presented below.

8.1.1 Aesthetics

8.1.1.1 No Action Alternative

Implementation of the No Action Alternative would not affect the aesthetic characteristics of the existing project

8.1.1.2 Alternative 2: Improve Existing Flood Diversion System

Implementation of Alternative 2 would affect the aesthetic characteristics of the existing project by constructing a protective structure above the tunnel's mouth to prevent landslides from blocking the tunnel. Improving the existing flood diversion system would have only a small physical effect, roughly the size of the tunnel entrance itself, on the existing aesthetic value of the system overall.

8.1.1.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

Implementation of Alternatives 3A and 3B would affect the existing aesthetic characteristics at the diversion structure and tunnel entrance invert by replacing these structures. However, the structures would appear relatively similar to the existing but would be larger. Impacts on the aesthetic characteristics at the diversion dam and tunnel intake area would be the noticeable change in size to the existing structure regardless of whichever Alternative 3A or 3B were implemented. However, the replacement structure would be similar in appearance to the existing structure.

Aesthetic characteristics at the point of outfall would be modified by the implementation of Alternatives 3A and 3B. A 150-ft pile-supported elevated flume would follow the slope of the tunnel, span the existing roadway, and would change Lowell Creek's depositional action to the seaward side of the road. The existing outfall would no longer discharge (effectively removing the existing scenic waterfall) unless there was an overtopping event from the new diversion dam, or the creek flow was intentionally diverted for maintenance purposes. Despite such a change in appearance, it is likely that the new outfall would still represent a point of curiosity for tourists and locals alike because it will be even more prominent than the existing structure. In total, however, the Lowell Creek outfall structure represents a minuscule fraction of Resurrection Bay and its surrounding viewshed. It would not be more than a minor impact on the aesthetic characteristics of the area.

8.1.1.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

Implementation of Alternatives 4A and 4B would not affect the aesthetic characteristics of the existing project. However, the creation of a new diversion dam and tunnel inlet system just upstream of the existing would permanently affect the aesthetic characteristics of upper Lowell Canyon. Although the effect on aesthetics would be permanent, the overall impact would not be remarkable as it would not be visible to the public in most situations. It would not detract from the overall viewshed of Resurrection Bay.

Impacts to aesthetic characteristics at the point of outfall are similar to those evaluated in Section 8.1.1.3, with the exception that the elevated flume would exit Bear Mountain south of the existing outfall because it would be following the grade of a new tunnel. Despite such a change in appearance, likely, the new outfall would still represent a point of curiosity for tourists and locals alike because it will be even more prominent than the existing structure. In total, however, the Lowell Creek outfall structure represents a small fraction of Resurrection Bay and its surrounding viewshed.

8.1.1.5 Alternative 5: Construct Upstream Sediment Basin

Implementation of Alternative 5 would not affect the aesthetic characteristics of the existing project. However, the construction and annual maintenance of the sediment basin would require an increased presence of heavy equipment not only in Lowell Canyon but along Seward’s streets as the material was being excavated and transported to staging areas. Similarly, the sediment basin itself would be an alteration to the natural setting of upper Lowell Canyon.

Construction of Alternative 5 would occur during the period of lowest surface flow, which corresponds with the winter months in Seward. Aesthetic effects to the surrounding environment would be temporary in terms of construction and support equipment presence, and likely unremarkable within the canyon itself as it is not a heavily trafficked area or a point of particular interest. Also, the inherent danger of the system may serve as a deterrent to those who might seek to observe the project area.

8.1.2 Water Quality

8.1.2.1 No Action Alternative

Implementation of the No Action Alternative would likely have no discernable effect on existing water quality characteristics. However, the potential risk to water quality as a result of catastrophic flooding and damage to buildings and infrastructure resulting in the inadvertent release of environmentally persistent or fouling compounds is not reduced by the implementation of the No Action Alternative.

8.1.2.2 Alternative 2: Improve Existing Flood Diversion System

From a hydraulic perspective, the No Action Alternative and Alternative 2 are identical. Implementation of a reinforced structure at the entrance of the tunnel to protect it from rockslides would not affect water quality. However, Alternative 2 incorporates selective tree removal of those trees exhibiting a 48 inch or greater diameter at breast height or multiple trunks of 30 inches in diameter at breast height in a portion of the upper watershed, which may facilitate an increased degree of erosion compared to the No Action Alternative. Quantification of such an increase and its potential effect upon water quality would be difficult to characterize. During periods of high flow, the surface waters of Lowell Creek are typically saturated with suspended sediments, and the bed load quantity is only an approximation. As a result, the degree that selective tree removal and potential subsequent elevated erosion would have on its baseline condition is unknown.

Alternative 2 would also incorporate improvements to the existing low-flow diversion system that helps to facilitate seasonal maintenance of the diversion dam, tunnel invert, tunnel, and existing outfall flume. Although maintenance efficiencies would be realized, there would be no overall impact on water quality.

As with the No Action Alternative, the potential risk to water quality as a result of catastrophic flooding and damage to downstream buildings and infrastructure resulting in the inadvertent release of environmentally persistent or fouling compounds is not reduced by the implementation of Alternative 2.

8.1.2.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

Implementation of Alternative 3A and 3B would entail the enlargement of the existing system in the form of an 18-ft or 24-ft-diameter tunnel and their supporting structures. Implementation of Alternatives 3A and 3B would replace the tunnel's intake transition and diversion dam, selectively remove trees in portions of the upper watershed, and would incorporate an extended 150-ft outfall flume.

Effects on water quality as a result of replacing the existing diversion dam and tunnel intake transition would be unlikely because construction would have to be performed during the period of lowest surface flow, typically the winter months when precipitation falls as snow. Similar to the system's existing maintenance protocol, Lowell Creek's surface water flows would be diverted around the active construction and into the storm sewer or through a segmented pipe running through the tunnel itself. Surface waters would not have the opportunity to interact with concrete or construction-related materials or surfaces until they were cured. Some residual construction-related dust would be expected to be scoured by surface waters once the construction diversion was removed, but this would not be expected to affect surface water quality more than temporarily and for a very short duration.

Alternatives 3A and 3B would likely employ the most common methodology for tunnel creation, the drill and blast method, which is comprised of drilling blast holes and filling them with explosives; detonating the blast, followed by ventilation to clear blast fumes; removal of the blasted rock; scaling the crown and walls to remove loose rock; installing supports, and advancement of all utilities and machinery to support subsequent blasts. Enlarging the existing tunnel to a diameter of either 18 or 24 ft represents a multiple-year effort to accomplish, with those years being curtailed into the season of the lowest surface water flows. Despite the multiple-year effort required, effects on water quality would be not be expected because of the same reasons for the replacement of the intake transition and diversion dam. Surface flows would be diverted around the active construction area and would not be allowed to flow through the tunnel until construction crews and support equipment had been removed. Some residual construction-related dust would be expected to be scoured by surface waters once the construction diversion was removed, but this would not be expected to affect surface water quality or turbidity more than temporarily and for a very short duration. Debris and rubble generated by the tunnel expansion process, likely through drilling and blasting, would not come into contact with surface flows and would be trucked away for on-land disposal. The duration of construction efforts, in terms of year or seasons, is the primary difference between the 18 or 24-ft tunnels. Otherwise, the overall effect upon water quality is the same.

Alternatives 3A and 3B would incorporate a 150-ft concrete outfall flume at the point where the tunnel exited Bear Mountain so that sediment deposition in proximity to the Lowell Point Bridge would occur on its downstream side rather than the existing upstream side. Implementation of the extended outfall flume would not extend into the intertidal waters of Resurrection Bay and would not affect those existing water quality characteristics. Like the construction of the tunnel intake transition, diversion dam, and tunnel itself, construction of the outfall flume would occur during the period of lowest surface water flows.

Alternatives 3A and 3B incorporate selective tree removal of those trees exhibiting a 48 inch or greater diameter at breast height in a portion of the upper watershed, which may facilitate an increased degree of erosion compared to the No Action Alternative. Quantification of such an increase and its potential effect upon water quality would be difficult to characterize. During periods of high flow, the surface waters of Lowell Creek are typically saturated with suspended sediments. Thus, to what degree selective tree removal and potential subsequent elevated erosion would have on its baseline condition is unknown.

8.1.2.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

Construction of a new flood diversion dam and tunnel intake transition would occur upstream of the existing project and would be limited to the periods of lowest surface flows. Any surface water flows would be diverted around the active construction area and would be allowed to return to the main channel downstream and diverted through the existing tunnel as would normally happen. The effects on water quality as a result of the construction of these elements would not be expected.

Construction of the tunnel, regardless of the diameter, could theoretically occur year-round if conducted from the downstream side because it would not be subject to surface flows during the high flow period. Alternatives 4A, 4B, 4C, or 4D would likely employ the most common methodology for tunnel creation, the drill and blast method, which is comprised of drilling blast holes and filling them with explosives; detonating the blast, followed by ventilation to clear blast fumes; removal of the blasted rock; scaling the crown and walls to remove loose rock; installing supports, and advancement of all utilities and machinery to support subsequent blasts. Debris and rubble generated by the tunnel expansion process, likely through drilling and blasting, would not come into contact with surface flows and would be trucked away for on-land disposal.

Alternatives 4A, 4B, 4C, or 4D would incorporate a 150-ft concrete outfall flume at the point where the tunnel exited Bear Mountain so that sediment deposition in proximity to the Lowell Point Bridge would occur on its downstream side rather than the existing upstream side. Implementation of the extended outfall flume would not extend into the intertidal waters of Resurrection Bay and would not affect those existing water quality characteristics. Construction of the tunnel intake transition, diversion dam, the tunnel itself, and the outfall flume would occur during the period of lowest surface water flows.

Alternatives 4A, 4B, 4C, or 4D would incorporate selective tree removal of those trees exhibiting a 48 inch or greater diameter at breast height in a portion of the upper watershed, which may facilitate an increased degree of erosion compared to the No Action Alternative. Quantification of such an increase and its potential effect upon water quality would be difficult to characterize. During periods of high flow, the surface waters of Lowell Creek are typically saturated with suspended sediments, and the bed load quantity is only an approximation, so to what degree selective tree removal and potential subsequent elevated erosion would have on its baseline condition is unknown. Further analysis will occur during the design phase to better define the criteria for selective removal, which will help determine if the 48 inch diameter is warranted, and may consider factors such as trunk shape, and removal of dead, downed, and unstable trees.

8.1.2.5 Alternative 5: Construct Upstream Sediment Basin

Alternative 5 would construct a catchment basin for bedload material above the existing diversion dam and the tunnel entrance. Like Alternatives 3A, 3B, 4A, 4B, 4C, and 4D, the basin would only be able to be constructed and/or maintained during the period of lowest surface flows. The catchment basin would be capable of storing approximately 25,000 cy of material, the approximate average annual depositional volume generated by Lowell Creek. Surface waters would be diverted around areas of active excavation and would likely not come into contact with newly exposed sediments until the excavation was complete.

The catchment basin would require annual maintenance to perform as envisioned. Excavated sediments would be trucked via dump truck to material staging areas before utilization in other projects such as road base or general fill. Assuming the standard dump truck has an operating volume of 16 cy, approximately 1,560 individual trips would be required to meet project assumptions of 25,000 cy. Sediment composition in Lowell Canyon above the existing diversion is generally a heterogeneous mix of boulders, cobbles, and gravels, which would preclude vehicle operations if a road were not installed.

The amount of ground disturbance required to construct the catchment basin could affect water quality by temporarily increasing turbidity levels once surface flows and bedload were to interact with those disturbed areas. However, the signature of such an impact would likely be muted by Lowell Creek’s natural tendency to mobilize large quantities of bedload and fine sediments during precipitation events. Overall, any increase in turbidity would be temporary. The increased turbidity of Lowell Creek’s surface waters flowing into Resurrection Bay would cause a visible plume of suspended sediments. It would temporarily affect water quality until they settled out of suspension or came into equilibrium with the background levels of the Bay. Normally, because many of the streams that feed into Resurrection Bay are glacial, following precipitation events the waters of Resurrection Bay can be occluded by elevated fine particulate (glacial dust) suspended sediments for hours to days before returning to pre-precipitation values. It would be difficult to attribute elevated turbidity levels as a result of the implementation of Alternative 5 to the overall turbidity values observed in Resurrection Bay following even a normal precipitation event.

8.1.3 Noise

8.1.3.1 No Action Alternative

Ambient noise levels would not be affected by the implementation of the No Action Alternative. Other than the existing heavy equipment operations at the outfall area where sediments accrete, and recurring maintenance to the structure, there would be no other anthropogenic influence upon the existing ambient noise climate in the vicinity of the existing project.

8.1.3.2 Alternative 2: Improve Existing Flood Diversion System

Implementation of Alternative 2 would have only highly localized impacts on ambient noise levels. The majority of work would occur at the existing tunnel's entrance and would likely incorporate the operation of heavy equipment. However, given the naturally attenuating attributes of the existing environment, it is likely that the short-lived construction noise generated by the project would only be perceived by those at the project site. The nearest residential structure to the existing diversion dam is approximately 300 meters downstream around a slight bend in the canyon at the canyon mouth.

8.1.3.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

Except for duration, implementation of Alternatives 3A and 3B would likely have similar impacts to the ambient noise levels as Alternative 2 concerning the construction of the diversion dam and tunnel entrance invert and who may be able to perceive it.

Drilling and blasting would also likely have a minimal impact on ambient noise levels. Drilling by itself does not constitute more than average construction site noise. Blasting, however, would be confined so that explosive charges were stemmed with an inert material that directs the force of the explosion towards the rock, thereby reducing the potential for rapidly expanding gasses escaping the borehole and generating a high energy sound pressure wave. Also, as the drilling and blasting cycles moved into Bear Mountain, the capacity for perception of such noise is similarly reduced.

Construction of the 150-ft elevated outfall flume would generate increased construction-related noises in the vicinity of the existing outfall. Pile driving the support piers for the extended flume likely represents the greatest potential for impacts to ambient noise levels. However, because of its location immediately adjacent to Resurrection Bay, construction related noises would be subject to the attenuating effects of the ambient wind, wave action, and nearby boat and automobile traffic noises. Effects on the ambient noise levels as a result of the construction of the elevated outfall would be temporary and likely heavily attenuated by natural noise sources.

8.1.3.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

Implementation of Alternatives 4A, 4B, 4C, or 4D would likely have similar impacts upon the ambient noise levels as Alternatives 2, 3A, and 3B concerning the construction of the diversion dam and tunnel entrance invert and who may be able to perceive it.

Drilling and blasting required to implement Alternatives 4A, 4B, 4C, or 4D would result in the same impacts on ambient noise levels as Alternatives 3A and 3B, as evaluated above.

Construction of the 150-ft elevated outfall flume under Alternatives 4A, 4B, 4C, or 4D would have the same overall impact on ambient noise levels as evaluated in Alternatives 3A and 3B above.

8.1.3.5 Alternative 5: Construct Upstream Sediment Basin

The implementation and maintenance of a sediment basin in the upper Lowell Creek watershed above the diversion dam structure would require annually recurring impacts on the area's ambient noise levels from the operation of heavy equipment. Sounds associated with the excavation of sediments in the upper watershed would not likely be perceived by anyone not present or in very close proximity to the activity site.

A secondary source of noise associated with Alternative 5 would be traffic to and from the site by dump trucks and other heavy equipment, which would have to utilize surface streets through Seward to move sediments to staging areas. Increased traffic associated with Alternative 5 would impact ambient noise levels. Still, it would likely not exceed any threshold for disturbance because the sounds of traffic are generally part of the ambient noise profile.

8.1.4 Existing Infrastructure and Facilities

8.1.4.1 No Action Alternative

Implementation of the No Action Alternative does not decrease the inherent risk posed by catastrophic flooding and damage from debris to infrastructure and facilities resources downstream of the existing diversion structure. Inundation modeling results (Section 4.9) suggest that Seward's infrastructure and facilities; including roadways, buildings, and utilities radiating out from Jefferson Street would be affected by floodwaters and debris.

8.1.4.2 Alternative 2: Improve Existing Flood Diversion System

Implementation of Alternative 2, like the No Action Alternative, does not reduce the inherent risk posed by catastrophic flooding and damage from debris to infrastructure and facilities resources downstream of the existing diversion structure.

8.1.4.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

Implementation of Alternatives 3A and 3B would reduce but not eliminate the inherent risk posed by catastrophic flooding and damage from debris to infrastructure and facilities resources downstream of the existing diversion structure. Construction would take multiple years because it would have to occur during the lowest surface flow periods. Also, there would be no redundant flood diversion capacity during periods of construction.

8.1.4.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

Alternatives 4A, 4B, 4C, or 4D reduce the inherent risk posed by catastrophic flooding and damage from debris to infrastructure and facilities resources downstream of the existing diversion structure to the maximum extent practicable. Although construction could be expected to take multiple years, the existing diversion structure would ensure redundancy during that period, and throughout the life of the project as additional functional overflow capacity.

8.1.4.5 Alternative 5: Construct Upstream Sediment Basin

Implementation of Alternative 5 does not reduce the inherent risk posed by catastrophic flooding to infrastructure resources downstream of the existing diversion structure. Implementation of Alternative 5 would transfer debris management activities from below the point of the outfall to above the diversion structure and assumes an average annual rate of bedload migration by Lowell Creek.

8.1.5 Cultural Resources

8.1.5.1 No Action Alternative

The No Action Alternative would have no significant impacts on known cultural resources. The Lowell Creek Diversion Tunnel will continue to receive repairs and maintenance, which will not impact the structure's listing on the NRHP in the foreseeable future.

8.1.5.2 Alternative 2: Improve Existing Flood Diversion System

Alternative 2 would involve significant modifications to the Lowell Creek Diversion Tunnel (SEW-00011), which would have an adverse impact on the historic property. USACE would work with the SHPO and the City of Seward to resolve the adverse effect per 36 CFR § 800.6.

8.1.5.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

Alternative 3 would involve significant modifications to the Lowell Creek Diversion Tunnel (SEW-00011), which would have an adverse impact on the historic property. USACE would work with the SHPO and the City of Seward to resolve the adverse effect per 36 CFR § 800.6.

8.1.5.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

Alternative 4 would have no impact on historic properties in the area. Furthermore, Alternative 4 would both protect the physical integrity of the existing Lowell Creek Diversion Tunnel (SEW-00011) and its significance through continued use as a back-up in the occurrence of a surge event.

8.1.5.5 Alternative 5: Construct Upstream Sediment Basin

Alternative 5 would have no impact on historic properties in the area. This project would be upriver of the project and would not impact the Lowell Creek Diversion Tunnel (SEW-00011) or its significance.

8.1.6 Environmental Justice

8.1.6.1 No Action Alternative

The No Action Alternative may have an adverse impact on any vulnerable disabled populations downriver during a surge event and may also impact persons with handicaps who could not exit the impact area quick enough to escape a surge event. A 2018 survey of health needs in Seward identified that 66% of surveyed population are overweight or obese and 21% of the surveyed population had a chronic disease (PSMCC 2018).

8.1.6.2 Alternative 2: Improve Existing Flood Diversion System

The Alternative 2 proposal would not have any adverse impact on minority or vulnerable disabled populations as the alternative seeks to develop infrastructure to protect portions of the city with these populations.

8.1.6.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

The Alternative 3 proposal would not have any adverse impact on minority or vulnerable disabled populations as the alternative seeks to develop infrastructure to protect portions of the city with these populations.

8.1.6.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

The Alternative 4 proposal would not have any adverse impact on minority or vulnerable disabled populations as the alternative seeks to develop infrastructure to protect portions of the city with these populations.

8.1.6.5 Alternative 5: Construct Upstream Sediment Basin

The Alternative 5 proposal would not have any adverse impact on minority or vulnerable disabled populations as the alternative seeks to develop infrastructure to protect portions of the city with these populations.

8.1.7 Protected Tribal Resources

8.1.7.1 No Action Alternative

Under the No Action Alternative, no known Tribal Resources would be adversely affected by the existing structures and methods of handling Lowell Creek flood events.

8.1.7.1.1 Alternative 2: Improve Existing Flood Diversion System

The Alternative 2 design would not impact any known Tribal Resources in the project area or the vicinity.

8.1.7.1.2 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

The Alternative 3 design would not impact any known Tribal Resources in the project area or the vicinity.

8.1.7.1.3 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

The Alternative 4 design would not impact any known Tribal Resources in the project area or the vicinity.

8.1.7.1.4 Alternative 5: Construct Upstream Sediment Basin

The Alternative 5 design would not impact any known Tribal Resources in the project area or the vicinity.

8.2 Biological Resources

8.2.1 Terrestrial Habitat

8.2.1.1 No Action Alternative

Implementation of the No Action Alternative would not affect terrestrial habitat in Lowell Canyon or at the point of the outfall.

8.2.1.2 Alternative 2: Improve Existing Flood Diversion System

Implementation of Alternative 2 would not affect terrestrial habitat in locations of the existing project. However, Alternative 2 would affect terrestrial habitat in the upper Lowell Creek watershed by selectively removing trees with a single trunk diameter at breast height that was 48 inches or larger, or multiple trunked trees where those trunk diameters at breast height exceeded 30 inches. Currently, USACE does not know what percentage of trees in Lowell Creek's upper watershed meet this criterion. However, because the area designated for selective tree removal is known to be sparsely vegetated, USACE does not expect that many trees would meet its criteria. Yet the effect of selectively removing large trees is generally cascading. It leads to the succession of understory vegetation until smaller trees become large enough to crowd out light to the understory, which results in the subsequent reduction of the understory vegetation. The selective removal of larger trees in a portion of Lowell Creek's upper watershed would affect highly localized vegetation successional events in the short term. However, long-term effects associated with selective tree removal would be negated by natural processes.

Effects on terrestrial habitat resulting from the installation of a protective structure above the existing tunnel entrance and invert would be difficult to detect because the original habitat attributes are already disturbed by the existing diversion system, and the footprint of the protective structure is roughly the size of the tunnel entrance.

8.2.1.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

Implementation of Alternatives 3A and 3B would result in the same effects to terrestrial habitat in the upper watershed as Alternative 2.

The effects on terrestrial habitat within the footprint of Alternative 3's new diversion dam would most closely resemble the site's existing conditions due to the site's existing poor habitat quality attributes. The area identified for the new diversion dam is relatively devoid of vegetation, highly disturbed, and consists almost entirely of boulders, cobbles, and gravels. Furthermore, an improved road already services the structure to a point just upstream of the outer edge of the existing diversion structure.

Effects on terrestrial habitat as a result of enlarging the existing tunnel system for both Alternatives 3A and 3B would be similar. They would closely resemble the existing site's baseline conditions and would not affect the site's existing poor habitat quality attributes. Drilling and blasting and the subsequent extraction of blasted materials would require the operation of heavy machinery in the vicinity of the existing, heavily disturbed tunnel entrance area. The area above the tunnel is heavily scoured multiple times a year by Lowell Creek's bedload, which precludes the establishment of any vegetation.

Effects to terrestrial habitat as a result of implementing a 150-ft elevated outfall flume at the point where the tunnel exits Bear Mountain would likely be similar to the existing baseline condition because of the site's existing poor habitat quality attributes. Lowell Creek's bedload and hydraulic forces continuously scour the area from the existing point of the outfall to the surface waters of Resurrection Bay, as evident in Figure 9 and Figure 10 above. The site is entirely devoid of vegetation and is comprised entirely of bedload sediments. Additional impacts to terrestrial habitat as a result of the implementation of a 150-ft elevated outfall flume include those to the alluvial accretion of bedload sediments beyond the existing Lowell Point Bridge. However, these impacts would likely be indiscernible from the existing condition at the site.

8.2.1.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

Implementation of Alternatives 4A, 4B, 4C, or 4D would result in the same effects to terrestrial habitat in the upper watershed as Alternative 2.

The effects on terrestrial habitat within the footprint of Alternative 4's new diversion dam would be similar to those observed by the presence of the existing structure due to the site's existing poor habitat quality attributes. The area identified for the new diversion dam is highly disturbed by bedload scour, devoid of vegetation, and consists almost entirely of boulders, cobbles, and gravels. An improved road extending from the existing structure to the site of the new structure would be required to service and construct the diversion system. The effects on terrestrial habitat by the emplacement of this road extension would resemble the existing condition because of the high degree of bedload scour the area currently receives. However, once operational, the in-channel area between the new structure and existing structure would be subject to far less scour and would likely experience some degree of natural vegetation establishment.

Effects on terrestrial habitat as a result of drilling and blasting to create a new tunnel system for Alternatives 4A, 4B, 4C, or 4D would be similar. Effects to terrestrial habitat from drilling and blasting and the subsequent extraction of blasted materials for the creation of a new tunnel would resemble those for Alternatives 3A and 3B except for the required removal of a small portion of hillside habitat at the entrance and exit points of the newly created tunnel. However, the areas of sparsely vegetated hillside habitat that would be affected represent a small fraction of the overall undisturbed surrounding areas. Despite their permanence, effects to terrestrial habitat as a result of creating the new tunnel entrance and exit points would not be expected to affect the area's overall habitat continuity and complexity.

The effects on terrestrial habitat as a result of implementing a 150-ft elevated outfall flume would be the same as those evaluated under Alternatives 3A and 3B.

8.2.1.5 Alternative 5: Construct Upstream Sediment Basin

Effects on terrestrial habitat as a result of the construction of an upstream sediment basin would be relegated to those heavily disturbed in-channel surface areas required for the emplacement of a service road and in the area of sediment excavation. These areas would be subject to annual disturbance by heavy equipment and anthropogenic presence as a requirement of the maintenance of the sediment basin. However, because this area is entirely located within the bankfull limits of Lowell Creek, it would also be subject to bedload scour and sediment accretion, which would preclude vegetation establishment.

Although the implementation of Alternative 5 would add an annual disturbance regime to the terrestrial habitat between the existing diversion structure and the upstream sediment basin, it would likely only be temporary and short-lived in the context of Lowell Creek's existing capacity for habitat disturbance within its channel.

8.2.2 Birds

8.2.2.1 No Action Alternative

Implementation of the No Action Alternative would have no effect upon birds.

8.2.2.2 Alternative 2: Improve Existing Flood Diversion System

Implementation of the protective structure above the tunnel entrance and invert would not affect birds because the construction of that element would occur during the period of lowest surface flows (winter) and would therefore not coincide with migratory or resident bird's breeding and nesting season (late spring and summer). Also, the existing project site is highly disturbed and provides poor habitat for birds during the nesting and breeding season.

Selective removal of trees in the upper watershed that meets USACE's criteria for removal may indirectly affect birds by reducing the overall quantity of nesting, foraging, roosting, and breeding habitat in a small area of Lowell Creek's upper watershed. Eagles typically prefer mature trees for nesting and the rearing of their young. Therefore, selective removal of larger trees may disproportionately affect the quality and quantity of eagle nesting habitat in a small portion of the upper watershed of Lowell Creek. However, direct effects to migratory and resident birds would be avoided by conducting selective removal efforts during the non-breeding/nesting months. The USACE would also conduct eagle nest surveys within the upper watershed area identified for selective tree removal to determine whether any of its criteria trees support eagle nests. Criteria trees supporting eagle nests would be left standing.

Construction actions associated with the implementation of Alternative 2 may inadvertently pose a nuisance attraction for some birds that may be attracted to anthropogenic activity and unsecured trash. As such, construction activities would maintain refuse management discipline in an attempt to deter nuisance attraction.

8.2.2.3 Alternative 3A and 3B: Enlarge Existing System + 150-ft Outfall

Implementation of elements of Alternatives 3A and 3B would not affect resident or migratory birds because they would not occur during the breeding and nesting season and would not be affecting preferential breeding, foraging, roosting, or nesting habitat. These elements include:

- Construction of the new diversion dam
- Construction of the protective structure above the tunnel entrance
- Construction of the tunnel, to include all drilling, blasting, and excavation

- Construction of the 150-ft elevated outfall flume

The effects upon resident and migratory birds as a result of selective tree removal actions for Alternatives 3A and 3B are the same as those of Alternative 2. The USACE would also conduct eagle nest surveys within the upper watershed area identified for selective tree removal to determine whether any of its criteria trees support eagle nests. Criteria trees supporting eagle nests would be left standing.

8.2.2.4 Alternative 4: Construct New Flood Diversion System with New Tunnel and 150-ft Outfall Extension – 4A: 18-ft Tunnel, 4B: 24-ft Tunnel, 4C:14-ft Tunnel, 4D:16-ft Tunnel (4A = Recommended Plan)

Implementation of elements of Alternatives 4A, 4B, 4C, or 4D would not affect resident or migratory birds because they would not occur during the breeding and nesting season and would not be affecting preferential breeding, foraging, roosting, or nesting habitat. These elements include:

- Construction of the new diversion dam
- Construction of the protective structure above the tunnel entrance
- Construction of the tunnel, to include all drilling, blasting, and excavation.
- Construction of the 150-ft elevated outfall flume

The effects upon resident and migratory birds as a result of selective tree removal actions for Alternatives 4A, 4B, 4C, or 4D are the same as those of Alternative 2. The USACE would also conduct eagle nest surveys within the upper watershed area identified for selective tree removal to determine whether any of its criteria trees support eagle nests. Criteria trees supporting eagle nests would be left standing.

8.2.2.5 Alternative 5: Construct Upstream Sediment Basin

Implementation of Alternative 5 would not affect resident or migratory birds because all construction work would be completed outside of the breeding/nesting window. Furthermore, the construction of Alternative 5 would not affect preferential breeding, foraging, roosting, or nesting habitat within the Lowell Creek channel.

8.3 Unavoidable Adverse Impacts

As currently proposed, the Recommended Plan, Alternative 4A, would not have any unavoidable adverse impacts on any of the aforementioned resource categories, whether dismissed or analyzed in depth.

8.4 Summary of Mitigation Measures

In order to comply with the Bald and Golden Eagle Protection Act of 1940, as amended, the USACE would conduct pre-construction bald and golden eagle nest surveys in the portion of Lowell Creek's upper watershed identified for selective tree removal. Large trees that met the USACE's removal criteria that supported eagle nests would be left standing.

Best Management Practices would be included in a Stormwater Pollution Prevention Plan that would be developed by the project contractor and approved by the Alaska Department of Environmental Conservation under the requirements of their Construction General Permit.

8.5 Cumulative Effects

"Cumulative effects" are the impacts on the environment that result from the incremental impact of the action when added to past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from minor but collectively significant actions taking place over a period of time (40 CFR § 1508.7). There are no other Federal projects planned for the Lowell Creek watershed.

9. PUBLIC AND AGENCY INVOLVEMENT

9.1 Public/Scoping Meetings

The Lowell Creek Flood Diversion Planning Charrette was conducted on 25–26 October 2016. The planning charrette was required as part of the planning process to initiate the feasibility study. The charrette involved PDT members and the USACE Vertical Team including POA, POD, and HQUSACE. Representatives from the City of Seward were present. Other agencies present included the State of Alaska (Department of Transportation and Public Facilities, Department of Natural Resources, and Department of Fish and Game), NMFS, USFWS, the Seward Bear Creek Flood Service Area, Federal Emergency Management Agency (FEMA), and the Kenai Peninsula Borough. A key goal of the planning charrette was to obtain buy-in during the initial stages of project development from all parties involved with the project.

Outcomes of the charrette included reaching a consensus on the problem statement and objectives of the proposed project. It included a discussion of the considerations and constraints for engineering, economic analysis, environmental analysis, and planning. It also articulated the important historical, social, and political factors involved in the project. Existing data and current work were presented by the USACE (Hydraulics & Hydrology Branch) and a local perspective was presented by the City Manager of Seward.

Public meetings were held with the City and the SeaLife Center on 20–21 October 2020 during the public comment period. Several comments were received from these meetings both as questions during the meeting and as emails following the meeting. Comments received are included in Appendix G: Correspondence. All comments were considered and addressed by the team. Primary concerns raised at the meetings regarded the deposition of sediment at the outfall and its effects on the adjacent facilities. Continuation of current operations will cause further accretion and require these facilities' owners to perform maintenance dredging in future years.

The SeaLife Center's two water intake lines may need to be modified or relocated in future years to avoid unwanted turbidity concerns. These are Non-Federal facilities constructed after the Lowell Creek project was completed, and their respective owners will carry out future operational costs to maintain or modify these systems. Outfall extensions may alter the deposition pattern, but the overall rate of accumulation will remain the same. Due to this process, the FWP Conditions for accretion of the alluvial fan are the same as the FWOP Conditions.

No impacts on navigation will result from the construction of the project. A force main sewer and other underground utilities are located in the road and under the bridge in the outfalls' vicinity. Design of the outfall extensions would account for existing underground utilities and either incorporate modifications to utilities or, more likely, avoid them entirely.

9.2 Government to Government Consultation (if applicable)

Government to Government consultation letters to the Chugach Corporation, the Chugachmiut Native Corporation, and the Qutekcak Native Tribe were sent on 09 December 2020, 12 October 2020, and 30 September 2020, respectively. No responses have been received.

9.3 Federal and State Agency Coordination

From 2016 to 2020, multiple in-person meetings were held between biologists from the Environmental Resources Section and biologists with the NMFS (Protected Resource Division and Habitat Division), USFWS (Project Planning and Marine Mammal Management Divisions), and the ADFG (Marine Mammals, Sport Fish, Commercial Fish, and Habitat Divisions).

USACE formally requested coordination with USFWS under the precepts of the FWCA. USFWS provided a response letter on 21 January 2020 stating, “The Service has reviewed the project and has no objections at this time. Due to limited expected impacts on trust resources, we will not pursue further investigation or a report under the Fish and Wildlife Coordination Act Report.”

USACE initiated coordination with NMFS early in the project planning phase regarding potential impacts to threatened or endangered marine mammals and those marine mammals not covered by the ESA and EFH. Since the initiation, it has been determined that USACE’s project will not affect resources under the regulatory purview of NMFS.

USACE conducted a pedestrian survey and produced a Survey Report and a Finding of Effect letter per Section 106 of the NHPA and its implementing regulations. The SHPO concurred with the USACE’s assessment that the Recommended Plan would result in no adverse effect on historic properties on 08 November 2019.

In March 2020, the USACE coordinated via telephone with the ADFG regarding selective tree removal and appropriate coordination actions prior to entering State Lands.

USACE coordinated with ADEC’s Division of Water regarding potential effects to water quality through the regulatory framework of the CWA, specifically Sections 401 and 404, and through the National Pollutant Elimination Discharge System permitting process. ADEC personnel confirmed that an Alaska Pollutant Elimination Discharge System permit was unwarranted because the implementation of the project would not make it a point source for pollutants. Also, ADEC provided USACE with a Certificate of Reasonable Assurance for the placement of dredged and/or fill material in the waters of the U.S. on 21 December 2020.

USACE coordinated with the ADNR Dam Safety and Construction Unit (Dam Safety) to determine applicability of state regulations to the project. POA determined that the requirements of the Alaska Dam Safety Program will pertain to the project. The PDT will continue to coordinate with the Dam Safety office through PED to ensure compliance. Potential design uncertainty that may arise from compliance with state dam safety requirements has been documented in the risk register and modeled within the overall project contingency. The cost for state reviewers, as required per state dam safety requirements, has been included in the PED cost estimate.

The compliance status with relevant Federal and State regulations and with relevant EOs is summarized in Table 47.

Table 47. Environmental Compliance.

Federal Statutory Authority	Compliance Status	Compliance Date/Comment
CAA	FC	This project is not reasonably expected to impact air quality negatively, nor is it in a non-attainment area.
Clean Water Act	FC	Certificate of Reasonable Assurance received from ADEC on 21 December 2020.
Coastal Zone Management Act	N/A	The State of Alaska withdrew from the voluntary National Coastal Zone Management Program on 1 July 2011. Therefore, within the State of Alaska, Federal agencies are not required to ensure their activities are consistent with an approved State coastal management plan.
ESA	FC	The project, as proposed, would not affect threatened or endangered species or their designated critical habitat.
MMPA	FC	The project, as proposed, would not affect marine mammals.
Magnuson-Stevens Fishery Conservation and Management Act (MSA)	FC	The project, as proposed, would not negatively affect EFH. Section 305 of the MSA and associated EFH consultation is satisfied. Official NOAA correspondence received 19 Oct 2020.
FWCA	FC	Coordination is complete. Due to limited expected impacts on trust resources, USFWS will not pursue further investigation under the FWCA. Official correspondence was received on 21 January 2020.
Marine Protection, Research, and Sanctuaries Act	FC	The project, as proposed, does not affect ocean waters outside of the territorial sea.
Migratory Bird Treaty Act (MBTA)	FC	The project does not seek to take avian species covered under the MBTA.
NHPA	FC	No Historic Properties Adversely Affected Determination by SHPO received 08 November 2020.
EO 11988: Floodplain Management	FC	The project, as proposed, does not occur within or affect the base floodplain.
EO 11990: Protection of Wetlands	FC	Lowell Creek is not included in the National Wetlands Inventory. Impacts to the waters of Resurrection Bay are reviewed in the 404(b)(1) Analysis.
EO 12898: Environmental Justice	FC	The project does not disproportionately affect underserved communities.
EO 13045: Protection of Children from Environmental Health Risks and Safety Risks	FC	The project does not disproportionately affect the health or well-being of children.
EO 13186 Protection of Migratory Birds	FC	The project would not impact migratory birds.
NEPA	PC	Full compliance will be reached upon signing the Finding of No Significant Impact

Note: FC=Fully Compliant / PC= Partially Compliant / N/A=Not Applicable

9.4 Views of the Sponsor

The NFS for this study, the City of Seward, Alaska, is supportive of the Recommended Plan and provided a letter of support expressing their support, which is included in Appendix G: Correspondence. The City's primary concern is life safety, though they expressed that the redundancy provided in the Recommended Plan would support improved maintenance to the system by allowing the diversion of flow and the ability to perform maintenance year-round. Currently, maintenance must be done during the winter when the flows are minimal. The City also verified that they understood the costs and requirements for OMRR&R of the system.

10. PREPARERS OF THE ENVIRONMENTAL ASSESSMENT

The Environmental Assessment was prepared by members of the USACE Alaska District (Table 48). The Environmental Resources Section provided the environmental analyses incorporated into this IFR/EA.

Table 48. Preparers of the Environmental Assessment.

Name	Title	Degree	Responsibilities
Christopher Hoffman	Biologist	Biology (B.S.)	Existing Conditions
Michael Rouse	Fisheries Biologist	Environmental, Population, & Organismic Biology (B.S.)	Oversight and guidance of EA development
Michael Salyer	Chief of Environmental Resources	Biology (M.S.)	Environmental Consequences
Joseph Sparaga	Archaeologist	Anthropology (M.A.)	Existing Conditions and Consequences for Cultural Resources

11. CONCLUSIONS & RECOMMENDATIONS

11.1 Conclusions

The team evaluated the alternatives carried forward using the NED analysis (Section 6.5) and CE/ICA for OSE (Section 6.7). In this case, OSE was evaluated based upon quantified reduction in residual risk to life safety. No NED plan was identified. The CE/ICA analysis identified 8 cost effective plans, of which six were Best Buy alternatives (No Action, Alternatives 4A, 4B, 4C, 4D and 6D). The two plans that were only cost-effective but not Best Buys included Alternatives 2 and 6C. Alternatives 3A, 3B, 6A, and 6B were not cost effective. Although Alternative 4D is a cost-effective plan, it provides fewer benefits that either 4A, 4B or 4C at a similar cost as 4a and 4C. Alternative 6C provide significantly fewer benefits than the structural alternatives and do not enjoy community support. Although Alternative 4B does pass higher flows (including PMF with surge), and does reduce AALL compared to Alternative 4A but the cost for the added reduction in Alternative 4B entails an exponentially higher incremental cost. Alternative 4C costs minimally less than Alternative 4A and provides similar benefits, however, there is a higher level of uncertainty incorporated into Alternative 4C. Alternative 6D, similar to Alternatives 6A, 6B and 6C, provides fewer benefits than the structural alternatives and does not have community support. Alternative 4A also provides reduction in risk to life safety and increased protection against tunnel failure, neither of which the No Action plan can provide. The team ultimately identified Alternative 4A as the Recommended Plan because it is a Best Buy plan which has been optimized by combining various measures to minimize project cost and project risk and still meets the identified objectives and avoids the identified constraints.

The Recommended Plan would construct a new flood diversion system upstream from the current system. The benefits of the proposed flood diversion system will result from savings in damages avoided and reduced flood-fighting efforts. [redacted] The Recommended Plan would have the capability to transport much higher flows than the current system and would retain the current system to divert flows during maintenance or in the unlikely event that a flow overtopped the new system.

Ongoing coordination with Federal and State resource agencies shall seek to ensure that all practical means to avoid or minimize adverse environmental effects will be analyzed and incorporated into the Recommended Plan.

The incorporation of reasonable and prudent measures will likely be required by the coordinating environmental agencies to mitigate potential short-term environmental impacts. However, over the longer term, the project will reduce the potential for flooding in Seward. Reduced flooding would result in a reduction in the potential for the inadvertent release of petroleum, oils, and lubricants (POL) and other locally persistent contaminants into the environment. This long-term potential reduction in the introduction of environmental contaminants will outweigh the short-term impacts of project construction.

The Recommended Plan has an estimated project first cost of approximately $185.2M (FY21 dollars). This plan maximizes total net benefits and has a BCR of 0.25. The NFS, the City of Seward, supports the Recommended Plan.

The proposed construction of the Recommended Plan, as discussed in this document, would have short-term environmental impacts during construction that would be largely minimized by pre-construction nesting bird surveys. Long-term impacts would be negligible, as discussed in this report. This assessment supports the conclusion that the proposed project does not constitute a major Federal action, significantly affecting the quality of the human environment. Therefore, a Finding of No Significant Impact (FONSI) has been prepared. The Alaska District Office of Counsel has reviewed this document and has issued a certification of legal sufficiency.

11.2 Recommendations

The Alaska District recommends that the selected flood risk management plan at Seward, Alaska, be constructed generally in accordance with the Recommended Plan herein, and with such modifications thereof as in the discretion of the Director of Civil Works may be advisable at an estimated project first cost with contingency of $185,225,000.

Federal implementation of the recommended project would be subject to the NFS agreeing to enter into a written PPA, as required by Section 221 of Public Law 91-611, as amended, to provide local cooperation satisfactory to the Secretary of the Army. Entering into the PPA will ensure compliance with Federal laws and policies, including but not limited to:

a. *Provide, at no cost to the Government, all real property interests, including placement area improvements, and perform all relocations determined by the Government to be required for the project;*

b. *Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) that might reduce the level of flood risk reduction the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function;*

c. *Inform affected interests, at least yearly, of the extent of risk reduction afforded by the flood risk management features; participate in and comply with applicable Federal floodplain management and flood insurance programs; prepare a floodplain management plan for the project to be implemented not later than one year after completion of construction of the project; and publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with the project;*

d. *Operate, maintain, repair, rehabilitate, and replace the project or functional portion thereof at no cost to the Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal laws and regulations and any specific directions prescribed by the Government;*

e. *Give the Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project to inspect the project, and, if necessary, to undertake work necessary to the proper functioning of the project for its authorized purpose;*

f. *Hold and save the Government free from all damages arising from design, construction, operation, maintenance, repair, rehabilitation, and replacement of the project, except for damages due to the fault or negligence of the Government or its contractors;*

g. *Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601-9675, that may exist in, on, or under real property interests that the Federal government determines to be necessary for construction, operation and maintenance of the project;*

h. *Assume, as between the Government and the non-Federal sponsor, complete performance and financial responsibility for all necessary cleanup and response actions and costs of any hazardous substances regulated under CERCLA that are* *located in, on, or under real property interests required for construction, operation, maintenance, repair, rehabilitation, or replacement of the project;*

i. *Agree, as between the Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the owner and operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and*

j. *Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended, (42 U.S.C. 4630 and 4655) and the Uniform Regulations contained in 49 C.F.R Part 24, in acquiring real property interests necessary for construction, operation, and maintenance of the project including those necessary for relocations, and placement area improvements; and inform all affected persons of applicable benefits, policies, and procedures in connection with said act.*

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However, prior to transmittal to the Congress, the sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

10 May 2021

DAMON A. DELAROSA — Date

Colonel, U.S. Army

Commanding

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