US Army Corps of Engineers
Alaska District

Seward, Alaska, Planning Assistance to States Flood Risk Management

November 2011

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Seward Planning Assistance to States Report

1. Study Authority

- Section 22, WRDA 1974 (P.L.93-251), as amended
- Section 605, P.L. 96-597
- Section 221, WRDA 1996 (P.L. 104-303)

2. Study Purpose

The purpose of this Planning Assistance to States report is to provide 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.

3. Location of Project

Seward is located on Resurrection Bay (figure A1), on the east coast of the Kenai Peninsula, 125 highway miles south of Anchorage. It is one of three ice-free, deep-draft ports with all-weather air, road, and rail access to the major population and supply centers of Southcentral and Interior Alaska.

4. List of Prior Studies, Reports, and References

Numerous reports, papers, and articles have been prepared by many entities over the past several decades. The following were consulted in the preparation of this report. They are listed chronologically beginning with the most recent.

Prior Studies and Reports Referenced in This Report

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DNRb (http://dnr.alaska.gov/mlw/nav/nav_policy.htm#CRIT)

Prior Studies and Reports Not Referenced

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USACE, Alaska District. 1994. Seward Area Rivers Flood Damage Prevention Interim Reconnaissance Report, February 1994.

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5. Identified Problems

Floods and the occurrence and effects of mass sediment movement phenomena have caused major damage throughout the Seward area since its habitation. The drainage basins in and around Seward are characterized by steep gradient channels contained within narrow valleys that open onto broad alluvial fans as they near Resurrection Bay. The combination of steep channels and narrow valleys, together with the geologic makeup of the glacial deposits in these valleys, predisposes these streams to landslides and avalanches that can form natural dams across the channels, temporarily storing water that is later catastrophically released as dams fail or are overtopped. In addition, debris in the stream channels has the potential to form significant blockages, causing avulsions and diversion of flow to adjoining basins. These debris-related floods can result in unusually extreme discharges when compared with typical rainflood frequency (NHC 2007a).

Because of the steep, rugged, undevelopable terrain surrounding Seward, the majority of development has occurred on the alluvial fans located between the mountains and Resurrection Bay. Abundant and sometimes intense rainfall, coupled with a plentiful supply of unconsolidated landslide and glacial deposits, make these fan areas particularly subject to flooding and to the erosion and transport of material. As stream flows exit steep, confined valleys onto these alluvial fans, they are prone to spread out in a braided channel network down and across the fan. Particularly at high flows, these flow paths are uncertain and prone to drastic changes in stream paths (channel avulsions). Such braided stream systems across alluvial fans are areas of very active vertical scour, lateral erosion, rapid sediment deposition, and constant channel migration – all severe threats to development upon and adjacent to the alluvial fans. Table 1 contains a brief summary of the flood hazards in the Seward area.

Table 1. Seward Flood Hazard Summary

Condition	Resulting Flood Hazard
Intense late-summer rain events when lower elevations are snow free and higher elevations have saturated snowfields	High runoff potential
Presence of over steepened slopes and large amounts of unconsolidated material	Potential for debris dams and subsequent surge-release flooding
Presence of ice-core moraines, glaciers, and glacial lakes	Potential for surge-release flood
Development on alluvial fans and deltas, highly depositional areas	Frequent flooding or increased potential for flooding

Source: United States Army Corps of Engineers, 1994

Floods have repeatedly caused damage in the Seward area, and the potential for catastrophic, debris-laden floods is an ever-present threat to areas bordering the many steep mountain streams. Conventional flood-frequency analysis techniques are not applicable to peak discharges that are affected by surge-release phenomena (USGS 1988).

A particularly large debris avalanche is described in the USGS 1988 report, and is included here to provide a sense of magnitude of the potential threats in and around Seward. During the flooding event of October 1986, a debris avalanche occurred on the steep northern slopes of Spruce Creek, 0.8 mile upstream from its mouth (figure A2). The avalanche scar was about 3,500 feet long, averaged 460 feet in width, and was 800 feet wide at its base. The avalanche removed the entire vegetal cover, including the large trees, and bedrock was exposed the entire length of the scar. The amount of material moved was estimated to be 3 million cubic feet.

Flood threats in and around Seward are further compounded by the large amount of sediment and debris that are transported from steep mountain slopes to be deposited in the alluvial fans below. Such deposition can be drastic during flood events. An analysis by Northwest Hydraulic Consultants Inc. (NHC 2007b) estimated that approximately 200,000 cubic yards of material was deposited throughout the Japp Creek alluvial fan during a high flow event in October 2006. This resulted in more than 20 feet of deposition in some areas. All streams considered in this analysis, with the exception of Grouse and Scheffler creeks, may be subjected to such rapid rates of sediment deposition. Such deposition reduces the conveyance capacity of impacted stream channels. As active channels are infilled and elevated, they will migrate to paths of less resistance, making stream channels in such systems unpredictable and prone to rapid change during high flow events.

Despite recent improvement, a majority of flood mitigation efforts in the Seward area have been implemented on a case by case basis. Coordinated planning and mitigation are needed between entities whose infrastructure both influences and is impacted by flooding in and around Seward. These entities include the Alaska Railroad, Alaska Department of Transportation and Public Facilities, Kenai Peninsula Borough, City of Seward, Seward Bear Creek Flood Service Area, and individual private landowners.

Many of the threats and problems identified are unique to alluvial fan topographies. Hence, many conventional floodplain management techniques are not as effective on alluvial fans. A combination of adaption of standard flood mitigation measures and identification of flood mitigation measures specific to alluvial fan topographies will be required to best minimize future flood damages in the Seward area.

6. Stakeholders

Seward/Bear Creek Flood Service Area (SBCFSA)

http://sewardbearcreekfloodservicearea.org/

The SBCFSA, a service area of the Kenai Peninsula Borough, was created in 2003 to provide flood planning, and mitigation services to the Seward/Bear Creek community. The board is tasked to determine flood planning needs and to advise and facilitate flood hazard reduction measures. The boundaries of the SBCFSA are indicated in figure A1.

City of Seward

http://www.cityofseward.us/index.aspx?nid=865

Incorporated in 1912, Seward is a home-rule city within the Kenai Peninsula Borough. According to the 2010 U.S. Census, Seward has a population of 2,693 within city limits. In addition, an additional 1,956 people live within the Bear Creek census designated place (CDP) just outside the city boundaries to the north. Seward is one of five first-class and home-rule cities in the borough and is responsible for providing hospital, fire, emergency, recreation, and floodplain management services. The boundaries of Seward are indicated in figure A1.

Kenai Peninsula Borough (KPB)

http://www.borough.kenai.ak.us/gov01.htm

The KPB was incorporated in 1964 as a second-class borough under the authority of the State of Alaska Borough Act of 1961. The borough's governmental responsibilities are comparable with those of a county. The borough is responsible for area-wide education, solid-waste management, planning and zoning, and taxation and assessment. KPB is also responsible for floodplain management outside the Seward city limits. All of the area in figure A1 is within the KPB.

Alaska Railroad (AKRR)

http://www.alaskarailroad.com

Established in 1914, the AKRR was operated by the Federal government until it was purchased by the State of Alaska in 1985. The AKRR is a self-sustaining, full-service railroad serving ports and communities from the Gulf of Alaska to the Interior of Alaska. It is owned by the state, but is incorporated and run like a private business. AKRR provides year-round freight train service from Seward to Fairbanks-North Pole. AKRR owned and operated railroad tracks and bridges bisect the study area from south to north and are indicated in yellow in figure A1.

Alaska Department of Transportation & Public Facilities (AKDOT&PF)

http://www.dot.state.ak.us/

AKDOT&PF manages many of the roads in the study area as well as the local airport. AKDOT&PF roads in the study area include the Seward Highway, Nash Road, Salmon Creek Road, and Exit Glacier Road.

Kachemak Heritage Land Trust (KHLT)

http://www.kachemaklandtrust.org/

KHLT is a non-profit organization established in 1989 to preserve, for public benefit, land with significant natural, recreational, or cultural values by working with willing landowners on Alaska's Kenai Peninsula.

Coordination

The SBCFSA, KPB, and City of Seward have built up a cooperative relationship to share floodplain development information and plans, conduct joint meetings, and to partner on applications for grants and matching funds related to flooding issues. The three entities have listed the need to complete mitigation risk analysis and mitigation project prioritization in their individual Hazard Mitigation Plans.

7. Seward Watersheds

Eight watersheds that affect the Seward area are considered in this report: Salmon Creek, Box Canyon Creek, Scheffler Creek, Japp Creek, Fourth of July Creek, Spruce Creek, Lowell Creek, and Resurrection River (see figures 1 & A2). For clarity, the watershed boundary for Resurrection River is shown separately in figure 2. These watersheds, while not all hydraulically connected, tend to experience flooding at the same time during an event. Numerous reports and recommendations have been made by Federal and non-Federal entities to alleviate the flooding issues of these streams as the area has developed.

This section summarizes each watershed, its flooding history, and the previous flood mitigation recommendations presented in the studies listed in Section 4. This study has not evaluated historical recommendations and those implemented to date for their effectiveness in flood mitigation. They are presented herein solely as a historical record.

The previous Section 205 reports that were prepared by the Corps for Salmon Creek, Box Canyon Creek, and the Resurrection River are included in the historical recommendations. Costs estimated in the Section 205 reports have been escalated to 2012 dollars using Engineering Manual (EM) 1110-2-1304, Civil Works Construction Cost Index System. While recommendations made in the previous Section 205 reports may still be suitable for implementation, some additional study would be required to ensure that designs will successfully accommodate current flood threats.

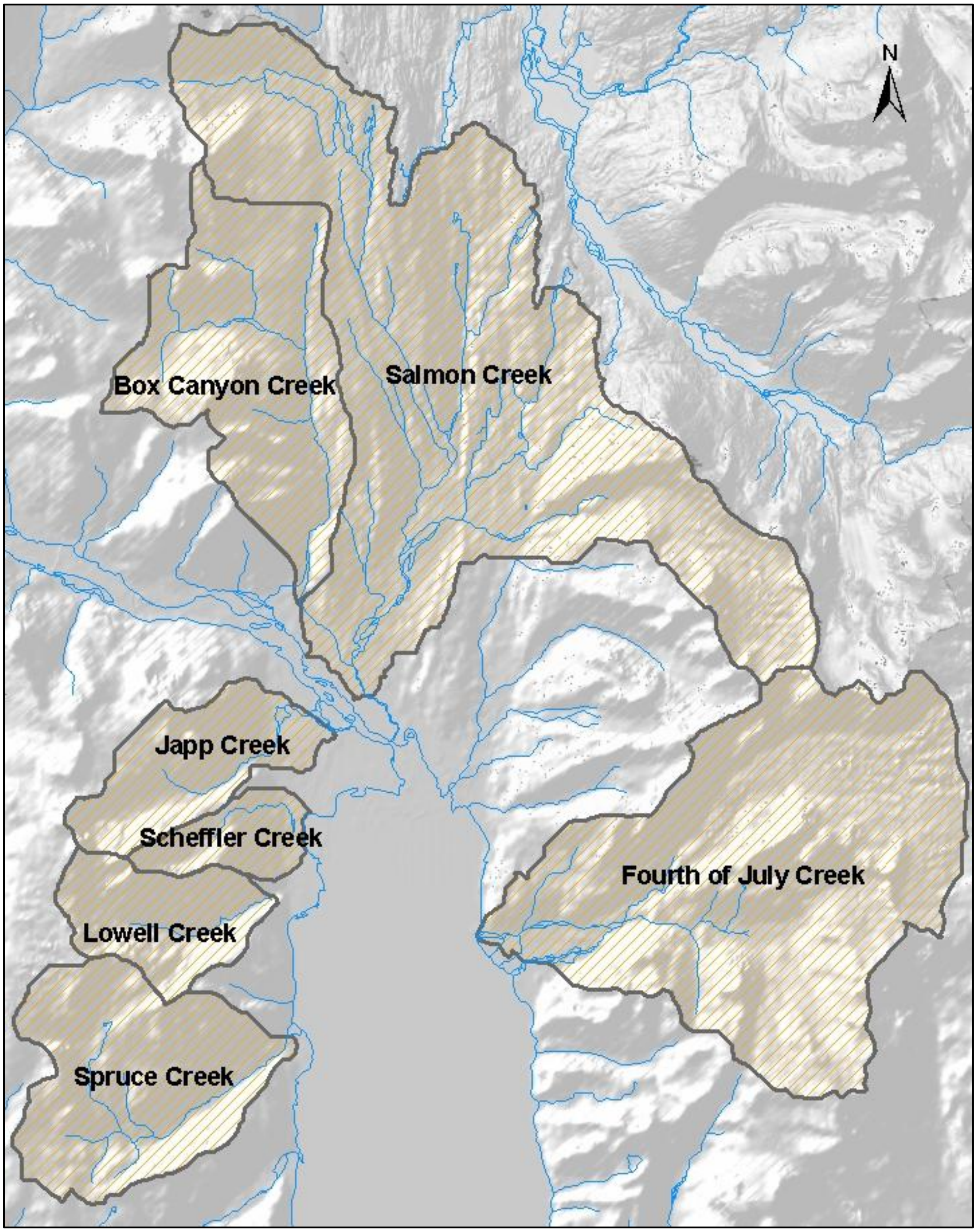

Figure 1. Overview of Seward Area Watersheds
(Resurrection River omitted for clarity**)**

<u>Salmon Creek</u>

<u>Description.</u> The Salmon Creek watershed includes Grouse, Lost, Glacier (Kwechak), Clear, and Sometimes creeks (figures 1 & A2). During flooding events, surface flows originating in Box Canyon Creek have overflowed into Salmon Creek via Clear Creek. Salmon Creek originates in the Kenai Mountains north of Seward

and flows southwest into Resurrection Bay via the Resurrection River. Salmon Creek is a glacier fed stream that also traverses a broad alluvial floodplain. Heavy debris and gravel bars cause shifting and frequent channel changes. Its watershed is approximately 36 square miles. Lost Creek is the largest tributary of Salmon Creek. The Alaska Department of Natural Resources (DNR) considers Salmon Creek to be navigable below its confluence with Clear Creek. Salmon, Grouse, and Clear creeks are anadromous.

Flooding History and Problems. Over the past 20 years, residential development has encroached on the Salmon Creek floodplain, most notably the Questa Woods and Camelot by the Sea subdivisions. The Camelot by the Sea subdivision was originally designed to have a levee along its north side. However, the developer never built the levee, and the area is periodically flooded. The 1986 flood was particularly damaging to the residents of this area. Several homes and commercial properties were flooded, and roads and bridges were washed out.

The United States Geological Survey (USGS) maintained four stage-discharge gages in the Salmon Creek watershed (see table 2). A list of years of all known floods within Salmon Creek and its tributaries is included in the river inventory table (table 3) following this watershed summary.

Table 2. USGS Gages in Salmon Creek Watershed

Gage No.	Location	Drainage Area (sq. miles)	Operational	Peak Discharge (cfs)	Date of Peak
15238010	Salmon Creek at highway bridge	23.6	Oct 1986 – Oct 2006	8,500	Oct 1986
15237900	Glacier Creek at Bruno Road	7.11	Oct 1986 – Aug 2001	4,200	Oct 1986
15237730	Grouse Creek at Grouse Lake Outlet	6.22	Jun 1998 – Oct 2008	901	Oct 2007
15238000	Lost Creek	8.42	Sep 1949 – Sep 1976, Oct 1986	14,000	Oct 1986

Historical Recommendations. Multiple studies have been conducted for this watershed (see Section 4) with the following historical recommendations for flood mitigation:

1. Include in future studies landslide and debris avalanches, floods on alluvial fans, and surge-release floods.
2. Assess the effects of flood-mitigating structures and land-use regulations.
3. Construct a levee along the right bank of Clear Creek and Salmon Creek from the highway bridge, downstream to within 1,000 feet of the railroad bridge;

and channelize Salmon Creek (Corps Section 205 Report, 1982), with an approximate cost for the levee of $175,000 to $250,000 plus additional annual maintenance costs.

4. Construct a 400-foot-long levee from the highway along Clear Creek.
5. Construct a levee along Clear Creek and remove gravel from Salmon Creek.
6. Construct a 3,000-foot-long levee along the right bank of Salmon Creek and remove gravel from Salmon Creek.
7. Construct a 300-foot-long levee tied into the Alaska Railroad levee along the south side of Salmon Creek.
8. Construct a 1,000-foot-long, armored levee at the north end of the Camelot by the Sea subdivision.
9. Construct a series of Bendway Weirs near the Glacier Creek confluence to keep stream from migrating.
10. Divert Salmon Creek into Resurrection River, avoiding most of the properties in danger.
11. Relocate structures outside the floodplain.
12. Replace culverts and make repairs to Salmon Creek and Nash roads.

Measures Implemented. The SBCFSA, KPB, and Natural Resources Conservation Service (NRCS) have attempted to mitigate flooding in this watershed by pushing river-run material with bulldozers to create embankments throughout the watershed.

These attempts include:

1. A 1,400-foot-long river-run material embankment is maintained by the SBCFSA to protect homes in the Meridian Park and Bear Lake subdivisions, and homes owned by the Pacific Rim Housing Authority (Photograph 1).
2. A 700-foot-long river-run material embankment was built by the KBP emergency response crews in 2008 to protect more homes downstream of the SBCFSA embankment (Photograph 2).
3. Near the Questa Woods subdivision, KPB maintenance crews and homeowners push river-run material from the center of the active stream channel to either side to keep the stream from overflowing its banks; some non-engineered riprap has been placed on these embankments for additional protection (Photograph 3).
4. At the confluence of Salmon Creek and Clear Creek, KPB operators and homeowners have constructed embankments of river-run material to protect

properties along Clear Creek when flood waters from Salmon Creek back up into Clear Creek (Photograph 4).

5. Several homes in the Old Mill subdivision are participating in the NRCS buyout program – these homes are purchased by NRCS then demolished and removed from the floodplain.

6. The Federal Emergency Management Agency (FEMA) has also recently completed Flood Insurance Rate Maps (FIRMs) for Kwechak, Glacier, Grouse, and Salmon creeks. The maps do not include Lost, Clear, and Sometimes creeks. At the time of this report, these maps were preliminary and waiting to begin their year-long review process. The community felt that the maps did not accurately account for the unique alluvial fan morphology of Salmon Creek and its tributaries (Seward City News 2010).

7. Between the AKRR crossing of Salmon Creek and the Nash Road crossing, flooding frequently closes Nash Road. The SBCFSA and KPB have plans to replace two restrictive 48-inch culverts with a 20-foot box culvert at the intersection of Nash Road and Salmon Creek.

8. KHLT received mitigation funds to permanently protect, through property acquisition or conservation easements, more than 22 acres of land within the Salmon Creek watershed. Properties considered for acquisition were located between the Questa Woods subdivision and the Alaska Railroad crossing and are indicated in figure A3. (McCarty 2011a). The sale of some of these properties for non-conservation purposes, however, has caused the abandonment of this effort. (McCarty 2011b).

9. The SBCFSA Board approved the use of gabion baskets at Kwechak Creek to extend the current embankment to 1,400 feet. The gabion baskets are understood to be a short-term solution to the flooding issues in the area.

Photograph 1. Near the end of 1,400-foot non-engineered levee protecting Meridian Park and Bear Lake subdivisions (looking downstream)

Photograph 2. Additional non-engineered levee farther downstream at Kwechak Creek (looking downstream)

Photograph 3. Non-engineered levee with rock placed by homeowner in the Questa Woods subdivision (looking downstream)

Photograph 4. Embankment constructed of river-run materials along Clear Creek near Salmon Creek confluence (looking upstream)

Box Canyon Creek

Description. Box Canyon Creek is a small tributary to the Resurrection River located directly north of Seward (figures 1 and A2). The stream originates at an alpine lake at an elevation of 1,860 feet. Its watershed is approximately 12.1 square miles and is about one-quarter covered by vegetation. The confluence to Resurrection River is approximately 3 miles upstream from Resurrection Bay. The stream is subject to debris-laden floods associated with the release of temporary, avalanche-formed dams. Box Canyon Creek is non-navigable and non-anadromous.

Flooding History and Problems. During the 1986 flood, a major channel shift occurred at the canyon mouth, diverting the flood waters over the entire alluvial fan and washing out Exit Glacier Road. During recent flood events, emergency crews have pushed the river-run material with a bull dozer to construct an embankment to protect nearby property from flood waters. Recent floods include those in 1995, 2006, and 2009.

Historical Recommendations. Previous studies on Box Canyon Creek resulted in the following recommendations for flood mitigation:

1. Include in future studies landslide and debris avalanches, floods on alluvial fans, and surge-release floods.
2. Assess the effects of flood-mitigating structures and land-use regulations.
3. Construct a debris basin and armored levee (Corps Section 205, 1992), with an approximate cost of $0.5 to $1 million, plus additional annual maintenance costs.
4. Construct a 30 to 40-foot-high levee with an impermeable membrane and riprap face with an additional lower levee to create a 100-foot-wide channel (Corps Section 205, 1992), with an approximate cost of $2 million to $3 million, plus additional annual maintenance costs.
5. Install a flood warning system for downstream residents.

Photograph 5. Non-engineered levee along Box Canyon Creek (looking upstream)

Measures Implemented. The KPB maintains a 3,000-foot-long non-engineered levee on an emergency basis to mitigate floods on Box Canyon Creek (Photograph 5). An Individual Permit for maintenance of this structure was issued July 2011 and expires July 31, 2021.

Scheffler Creek

Description. Scheffler Creek originates atop Mount Marathon and drains 3 square miles, discharging into the lagoon across the Seward Highway from the small boat harbor. The area surrounding the steep creek is highly developed by residential and commercial interests (Photograph 6). Scheffler Creek is non-navigable and non-anadromous.

Flooding History and Problems. High tides combined with high flows have caused damages concentrated below the lagoon. The outfall of Scheffler Creek may be impeded by high tides and storm surges where it drains into Resurrection Bay. This area is especially sensitive to the harbor patrons.

Historical Recommendations. There are no previous studies, and thus, no historical recommendations for flood mitigation on Scheffler Creek.

Measures Implemented. Sediment was cleared from the area shown in Photograph 6 by a homeowner after the 2006 flood. There were no other historical measures implemented for flood mitigation on Scheffler Creek at the time of this report.

Photograph 6. Close development along Scheffler Creek (looking downstream)

Japp Creek

Description. Japp Creek (Japanese Creek) is a tributary to the Resurrection River at the far north end of Seward (figures 1 and A2). The stream originates in an alpine moraine left by a retreating glacier. Its watershed is approximately 3.5 square miles. About 20 percent of this area is vegetated, and 10 percent is covered by glacier ice. The creek flows east through a steep canyon before entering a broad alluvial fan. The fan is prone to aggradation from high flow events. An estimated 200,000 cubic yards of material was deposited throughout the fan during a high flow event in October 2006 (NHCb 2007). This resulted in more than 20 feet of deposition in some areas. The Seward schools, Forest Acres subdivision, and other private residences are on the

Japp Creek fan. Additional development is planned for this area. Gravel is currently extracted in the lower portion of the creek. Japp Creek has been designated as non-navigable and anadromous.

Flooding History and Problems. Japp Creek has a history of stream damming and surge-release floods. Debris-laden floods were reported in August 1966, October 1969, September 1976, September 1982, and October 1986.

Historical Recommendations. Previous studies on Japp Creek have offered the following recommendations for flood mitigation:

1. Include in future studies landslide and debris avalanches, floods on alluvial fans, and surge-release floods.
2. Assess the effects of flood-mitigating structures and land-use regulations.
3. Abandon development in the area, in particular development behind the levee.
4. Clear and deepen the main channel by removing deposited material.
5. Extend the levee by 2,000 feet.

Photograph 7. Upper portion of NRCS Levee (looking downstream)

Measures Implemented. NRCS constructed a riprap protected 1,150-foot-long levee along the right channel bank at the apex of the fan that forces flow to the north, protecting homes and businesses (Photograph 7). The levee was constructed in December 1986 and continues to perform well under flood conditions. In September of 2011, the City of Seward completed extension of this levee to its intersection with the Seward Highway.

Fourth of July Creek

Description. Fourth of July Creek originates at the terminus of three glaciers and flows approximately three-quarters of a mile through a steep canyon (figures 1 and A2). It joins Godwin and Spring creeks to form a large segmented alluvial fan that flows into Resurrection Bay across from Seward. The 14.1-square-mile watershed is mostly covered by glaciers and is less than 20 percent vegetated. Fourth of July Creek has been designated as non-navigable and anadromous.

Flooding History and Problems. The October 1986 flood produced at least five debris dams and subsequent surge-release floods eroding new channels across the alluvial fan and depositing large quantities of coarse gravel, cobbles, and boulders.

Historical Recommendations. Previous studies on Fourth of July Creek have presented the following recommendations for flood mitigation:

1. Include in future studies landslide and debris avalanches, floods on alluvial fans, and surge-release floods.
2. Assess the effects of flood-mitigating structures and land-use regulations.
3. Construct additional levees.
4. Develop maintenance plan for existing levee.

Photograph 8. Fourth of July Creek levee (looking downstream)

Measures Implemented. A flood control levee (Photograph 8) was built in 1982 to protect the prison, quarry, and the Seward Marine Industrial Center from flood waters. Flood waters during the 1986 flood did not overtop the levee but caused erosion damage to the levee toe. In 1991, the city modified the existing levee to withstand the high-velocity flow generally experienced in this area. A Corps Section 205 Report in 1992 sited the repairs completed by the city and noted no further action.

Spruce Creek

Description. Spruce Creek flows into Resurrection Bay approximately 2 miles south of Seward at Lowell Point (figures 1 and A2) and drains a 9.26-square-mile watershed. Less than one quarter of the watershed is vegetated, and approximately 8 percent is glacier covered. The creek originates at a small glacier in the northwest corner of the watershed and flows nearly 5 miles to Resurrection Bay. A small lake in the upper basin presents a potential for surge-release flooding and land sliding. Spruce Creek has been designated as non-navigable and non-anadromous.

Development of both residential and commercial buildings at Lowell Point is primarily on the Spruce Creek alluvial fan, as is access to the adjacent Caines Head State Recreation Area. The Seward wastewater treatment plant is also on the fan adjacent to Spruce Creek.

Flooding History and Problems. Flood damage has been confined to the north side of the fan. The bridge over Spruce Creek is on the fan in a depositional area and is regularly plugged with sediment and debris.

The USGS maintained a stage-discharge gage approximately three-quarters of a mile upstream from the mouth of Spruce Creek. USGS #15238600 (drainage area of 9.26 square miles) operated from August 1966 to July 2009 and recorded a peak discharge of 13,600 cfs in October 1986.

Historical Recommendations. Previous reports recommended the following for flood mitigation on Spruce Creek:

1. Include in future studies landslide and debris avalanches, floods on alluvial fans, and surge-release floods.

2. Assess the effects of flood-mitigating structures and land-use regulations.

3. Remove debris from the upper portions of Spruce Creek and maintain channel from the bridge to creek mouth.

4. Prepare a regular maintenance plan for the Soil Conservation Service (SCS, now National Resources Conservation Service [NRCS]) constructed levee.

Measures Implemented. After the 1986 flood, the NRCS built a riprap protected levee on the south bank of the channel upstream of the bridge to entrain flow under the bridge opening, protecting most of the development on the fan including the wastewater plant. The levee has performed well despite the fact it has not been maintained since its construction (Photograph 9). The KPB has recently channelized the flow downstream of the Spruce Creek Bridge by pushing river-run material from the center of the active stream channel to either side to aid in conveyance (Photograph 10).

Photograph 9. NRCS constructed levee along Spruce Creek

Photograph 10. Channelized Spruce Creek (looking downstream) to Resurrection Bay

Lowell Creek

Description. Lowell Creek flows into Resurrection Bay perpendicular to the southwest end of Seward via a diversion dam and tunnel. It is a 3-mile-long stream that drains a 4-square-mile watershed. Nearly 70 percent of the watershed is free of vegetation. The diversion dam does not impound water, but a blockage in the tunnel has the potential to force flows over the emergency spillway and into downtown Seward via Jefferson Street. A separate study is underway by the Corps to evaluate the risks of this system.

Flooding History and Problems. In 1937, Congress authorized the Corps to construct a tunnel to replace the Railroad Commission's flume that diverted flood waters through the center of Seward into Resurrection Bay. Upon completion of construction, the City of Seward assumed responsibility for operation and maintenance. The diversion tunnel has been fraught with maintenance issues since its construction. To date, the diversion dam and tunnel have successfully protected downstream homes, the hospital, and water storage tanks from flood waters. However, because of the high potential of surge-release flows overtopping the dam, the Corps is currently reevaluating this area. Section 5032 of the Water Resources Development Act of 2007 instructed the Secretary of the Army to assume responsibility for the long-term maintenance and repair of the project until an alternate method for flood diversion is constructed and operational, or 15 years, whichever is sooner.

Current Actions. The Corps is conducting an inundation study for the outfall of the Lowell Creek Dam. Inundation maps are expected to be complete by the end of 2011. Public meetings will be conducted to discuss the study and the maps. Due to the nature of the separate Corps study, Lowell Creek is not discussed further in this report.

Resurrection River

Description. The Resurrection River is the largest stream in the Seward area. It has a drainage area of approximately 169 square miles, with its origin near Upper Russian Lake in the Chugach Mountains. From its headwaters, the river flows southeasterly for 22 miles, through the Chugach National Forest and privately owned land, to its outlet in Resurrection Bay (figure 2). Resurrection River has a braided channel and a steep gradient. During the preparation of this report, FEMA was in the process of updating its Flood Insurance Rate Maps (FIRMs) for the Resurrection River but they were yet to be finalized.

Flooding History and Problems. Resurrection River has a long history of overflowing its banks and causing damages to the developed areas nearby. The first recorded flood was in 1946 near the airport, with 400 acres inundated. Floods continued to be reported in 1951, 1957, 1960, 1962, 1986, 1989, 1993, 1995, 2006 and 2009. The USGS maintained a gage, "1523770, Resurrection River at Seward AK" from 1965 to 1986. The peak recorded stream flow was 19,000 cfs on October 11, 1986.

Current Actions. FEMA is in the process of issuing new FIRMs for the Resurrection River. The hydraulic analysis used by FEMA for the recent mapping effort could be used to support a larger, total watershed study.

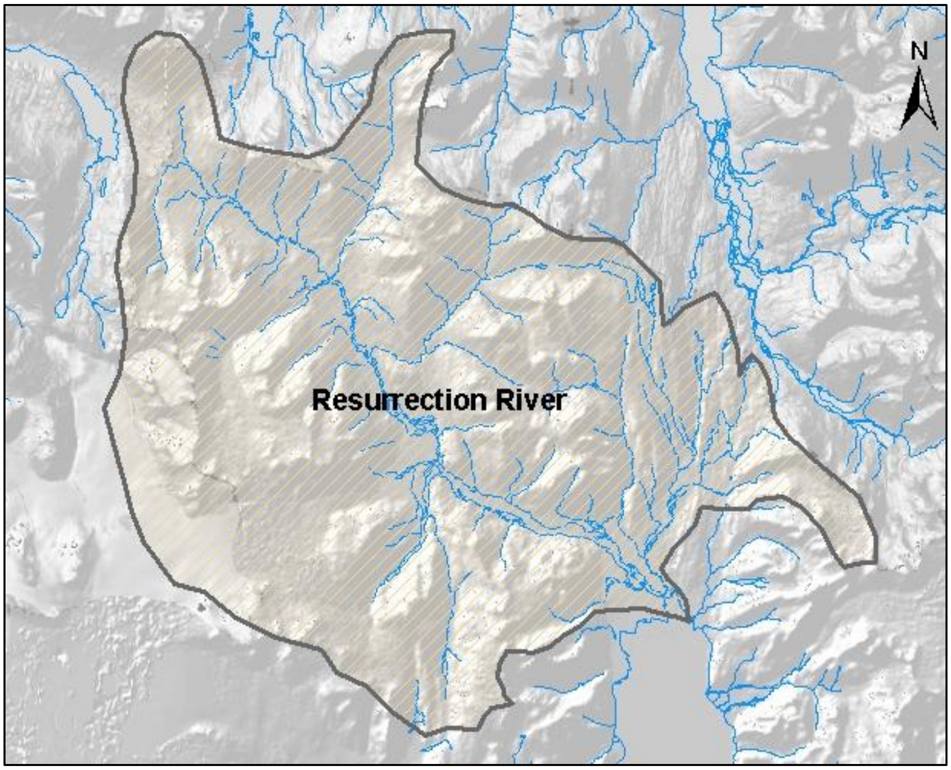

Figure 2. Resurrection River Watershed

Stream Inventory, Mass Movement and Surge Release Flood Risk Assessment

Stream specific characteristics that are important considerations to implementing potential flood mitigation measures are summarized in the table 3 stream inventory.

Table 3. Stream Inventory

Watershed	Stream	In City	In SBCFSA	Navigable	Anadromous	Flood Years[2]	Gage Data
Salmon Creek	**Salmon**	Y	Y	Y[1]	Y	1946 1949 1951 1957 1961 1974 1976 1986 1995 2006	86-06 86-01 98-08 63-76
	Lost	N	Y	N	N		
	Grouse	N	Y	N	Y		
	Glacier	N	Y	N	N		
	Sometimes	N	Y	N	N		
	Clear	N	Y	N	Y		
Box Canyon Creek	**Box Canyon**	N	Y	N	N	1986 1995 2006 2009	n/a
Japp Creek	**Japp**	Y	Y	N	Y	1966 1969 1976 1982 1986	n/a
Scheffler Creek	**Scheffler**	Y	Y	N	N	2006 2009	n/a
Fourth of July Creek	**Fourth of July**	Y	Y	N	Y	n/a	n/a
Spruce Creek	**Spruce**	N	Y	N	N	1995 2002 2006	66-09
Lowell Creek	**Lowell**	Y	Y	N	N	Many prior to 1940	65-95
Resurrection River	**Resurrection**	Y[3]	Y	Y	Y	1946 1951 1957 1960 1962 1986 1989 1995 2006 2009	64-86

[1]Salmon Creek is considered navigable downstream of its confluence with Clear Creek

[2]Flood Years are years in which a flood was recorded by a USGS gage, or specifically noted in watershed study reports (See Section 4).

[3]The Resurrection River watershed includes the Salmon Creek and Japp Creek watersheds.

USGS Water Resources Investigations Report 87-4278 (USGS 1988) assessed watershed specific levels of risk for landslide/debris avalanches, debris-laden floods, and surge release floods. This information is summarized in table 4.

Table 4. USGS Risk Assessment of Mass Movement and Surge Release Flood Events

			Surge Release Floods	
Watershed	**Landslide/Debris Avalanche**	**Debris-Laden Flood**	**Landslide Dam**	**Ice or Moraine Dam**
Fourth of July	High	High	High	High
Godwin	High	High	High	High
Glacier Creek (from Bear Lake Glacier)	Moderate	High	Moderate	Moderate
Grouse Creek	Low	Low	Low	Low
Lost Creek	High	High	High	Low
Lost Creek tributary	Low	High	Low	Low
Box Canyon	High	High	High	Low
Japp	High	High	High	Low
Scheffler	Low	Low	Low	High
Lowell	High	High	High	Low
Spruce	High	Moderate	High	High
Resurrection	Low	Moderate	Low	Low
Sawmill Creek	Moderate	High	Moderate	Low

Source: USGS, 1988

8. Existing Conditions

Historical Flooding, Emergency Response, and Damage Overview

In October 1986, rains from Typhoon Carmen dropped 18 inches precipitation in Seward over 3 days. This event constitutes the highest recorded 24-hour rainfall event for the Seward area in the last 100 years. The resulting flooding was the worst ever experienced in Seward. Major roads and the airport were under water and 200 people were left homeless. It was estimated that at least $10 million in damages resulted from that flood. The Alaska Railroad suffered $3 million worth of damages including the loss of two major bridges (SBCFSA 2010).

In a 24-hour period in September 1995, rains from Typhoon Oscar dropped more than 9 inches precipitation, the second highest 24-hour rainfall event recorded in the Seward area since 1908. This led to flooding of the Seward Highway and undermined buildings to the point of collapse, breached levees, etc. Lowell Creek bridge approaches were washed away and the bridge was buried in gravel. The KPB spent $500,000 in emergency funds for Seward flood relief and the U.S. Army Corps of Engineers estimated that at least $1.8 million worth of damage occurred to Seward public property (SBCFSA 2010).

In October 2002, two major storms resulted in 14.5 inches of rainfall in 1 week. This caused flooding to the Resurrection River and Salmon Creek. This flood eventually resulted in the creation of the Seward/Bear Creek Flood Service area in January 2004 (SBCFSA 2010).

October 2006 brought 9 to 15 inches of rain over 48 hours combined with high tides and warm temperatures. The Seward Airport, the Seward Highway, and Lowell Point Road were closed as a result of flooding. Overall, damages in excess of $9 million were reported (SBCFSA 2010). In July 2009, storm driven tides and heavy rain closed Lowell Point Road and the Seward Airport (SBCFSA 2010).

The above mentioned events do not fully document flooding in the Seward area. Heavy precipitation events contribute significantly to flooding in Seward, along with other factors including high tides, unseasonably warm temperatures resulting in snow melt, and outburst flooding, etc.

While total emergency response costs are difficult to quantify without significant effort, known emergency response costs by the Kenai Peninsula Borough are illustrated in table 5. Federal assistance costs related to flooding in Seward are illustrated in table 6. Likewise, the State of Alaska has had to fund emergency response actions within the Seward area. This should not be considered a comprehensive list, but rather a sample of floods that were experienced for which cost data was readily available. Compiling a list of all recent storms and the associated damages and response costs is beyond the scope of this Planning Assistance to States study.

Table 5. Flood Response Expenses by Kenai Peninsula Borough within the SBCFSA

Year of Response	Total Response Costs ($)
1996	54,893
1998	8,000
1999	8,000
2006	1,972,988
2009	85,000

Source: Dan Mahalak, Kenai Peninsula Borough, December 2010.
This should not be considered a comprehensive list of response costs.

Emergency flood expenses reflected in table 5 do not reflect damage costs, but merely the annual Kenai Peninsula Borough emergency response costs related to flooding. Flood response costs themselves are likely to be underestimated due to a lack of available data on personal flood fight responses (for example, individuals operating bull-dozers on their personal property or sandbagging). Actual damages resulting from the flood events are potentially much larger than the cost of the emergency response.

Table 6. Federal Assistance Related to Flooding in Seward

Year	Total Funding ($)
1990	529,552
1992	754,541
1998	548,744

Source: Data for 1990 and 1992 provided by the Grants Administration, State of Alaska Division of Homeland Security and Emergency Management, December 2010. Data for 1998 provided by Dan Mahalak, SBCFSA, February 2011. FEMA grant "Hazard Mitigation Grant Program DR-1072-0003 awarded Sept 29, 1998." This should not be considered a comprehensive list of response costs.

A comprehensive estimate of total flood damages would include response costs from the Federal, state, borough, city, and Flood Service Area levels of government along with individual response costs conducted by private citizens. It would also include the cost of damages and/or repairs to public property such as roads, bridges, and airports along with private property such as businesses and homes. These flood damage costs are expected to be significant. Calculating the total cost of flood response and damages would be a task for future studies.

Existing Floodplain Regulation

KPB manages a floodplain ordinance that addresses proper development to reduce flood risks and lessen the economic losses caused by flood events. The ordinance provides building standards for construction projects within the floodplain to ensure the availability of flood insurance through the National Flood Insurance Program. KPB entered the National Flood Insurance Program in 1986. These building requirements are also intended to minimize or prevent damages when flood events occur. The ordinance requires floodplain development permits for all projects in floodplains. While all rivers have floodplains, permits are only required for activities in FEMA mapped floodplains. Currently, only portions of the Resurrection River and Salmon Creek floodplains are mapped and are subject to such regulation. If recently completed FIRMs are approved by FEMA for Kwechak, Glacier, Grouse, and Salmon creeks, regulation could expand into those mapped floodplains.

On March 24, 2009, the KPB Assembly passed ordinance 2009-09, which enacted the Seward Mapped Flood Data Area (SMFDA). This ordinance creates a mapped area based on the inundation of flood waters from the 1986, 1995, and 2006 floods in the Seward area. This recently mapped area is illustrated in figure A4. This ordinance was passed in an attempt to regulate development until revised FEMA FIRMs are approved within the Salmon Creek watershed. The ordinance is effective indefinitely until the FIRMS are approved. This ordinance applies to those areas within the SBCFSA and outside the city of Seward.

For areas within the SBCFSA, there are now two possible regulatory requirements. The Special Flood Hazard Area, as shown on the FEMA FIRM maps for Resurrection River and

Salmon Creek, has had specific standards for development and required permitting since designated as such. Some areas that have not previously required construction to floodplain standards will be required to obtain a floodplain development permit from the KPB prior to the start of construction if construction occurs prior to the expiration of the SMFDA ordinance or following the approval of the updated FIRMs.

At the time of this report, enforcement capabilities of both KPB and the City of Seward were very limited. Representatives to monitor compliance are limited to a KPB compliance officer responsible for the entire Kenai Peninsula and a city building inspector. For those portions of the Seward area watersheds lacking a legally recognized, mapped floodplain (a vast majority of the study area), the permitting and land management officials do not have the tools and authority needed to make appropriate decisions.

Navigable Waters.

State ownership of the beds of navigable waters is an inherent attribute of state sovereignty protected by the United States Constitution. The Alaska State Constitution provides for free access and common use of public and navigable waters by any citizen of the United States or resident of the State of Alaska (DNRa). The Navigability Project of the State of Alaska Department of Natural Resources (DNR) Division of Mining, Land & Water enables the State of Alaska to assert ownership of lands beneath navigable waters through the determination of navigable waters. The State of Alaska considers waterbodies usable as a highway for the transportation of people or goods as navigable (DNRb).

Navigability determinations are an important consideration in flood risk management in the Seward area. Current DNR policies are to charge any entity removing substrate from a navigable water body fair market value for the material. At the time of this report, DNR charged $3.25 per cubic yard of material removed from the beds of navigable waters in the Seward area; however, public projects conducted by public agencies may be eligible to receive the gravel at a reduced rate of $0.50 per cubic yard (Cox 2011). This charge can amount to substantial amounts of money when attempting to maintain hydraulic capacity in flood-prone, aggrading, alluvial fan channels such as those present in the Seward area. Of the streams considered in this study, DNR determined Salmon Creek to be navigable downstream of its confluence with Clear Creek. Additionally, the State of Alaska claims ownership of any substrate beneath tidally influenced waters (Ogan 2011). This would include a portion of any of the streams discharging directly into Resurrection Bay. A statewide map showing navigability determinations can be found at http://www.navmaps.alaska.gov/navwatersmap/.

Structural Inventory

Several water diversion structures are located in the watersheds surrounding the Seward area. These structures include designed levees, river-run material embankments, bridges, culverts and one dam and tunnel system. Often, private property owners construct embankments to protect their particular property with little to no consideration of the structures' impacts upon other properties. It is not uncommon for such embankments to deflect and concentrate flows into adjacent, unprotected areas. A structural inventory is shown in figure A5. It should be noted that the locations of embankments built by private land owners are approximate.

Environmental Setting

Waterways draining the Seward area's watersheds are characterized by flashy flows and high to very high sediment loads due to the mountainous terrain, geologic makeup, and glacial history. Mass wasting events and debris flows associated with hydrologic flows are not uncommon. The degree of sediment transport is substantial enough that stream thalwegs (in some cases the middle) and lower ends of first order streams may move within the primary floodplain annually or with each substantial flow event.

Seward area watersheds draining into Resurrection Bay are within the coastal Sitka Spruce/Western Hemlock forest community, which is typical on moist coastal sites in this portion of Southcentral Alaska. Dominant species occurring at lower elevations include Sitka Spruce, Western hemlock, black cottonwood, balsam poplar, paper birch, Sitka alder, and American green alder (U. S. DOI 1994). Common understory species include alder, willow, devils club, elderberry, and rose. Wetter areas in the watersheds (benches and wetland borders) are dominated by numerous species of grasses, numerous species of sedges, and heath type plants such as blueberry, Labrador tea, and low bush cranberry. At higher elevations, alpine tundra predominates (USACE 1998). The primary ecological systems occurring within these watersheds are Sitka spruce, mountain hemlock, Sitka spruce-mountain hemlock, recently deglaciated tall shrub, active colluvial slope, glacial floodplain, and short and tall shrub (Boggs 2008).

Anadromous waterways include those shown in table 3. These waterways support some or all of the following during some life stages: sockeye, coho, pink, chum, and Chinook salmon as well as Dolly Varden. Essential fish habitat exists in all waterways with the exception of Lowell Creek. Lowell Creek ceased being potential fish habitat when the channel that formerly followed the current alignment of Jefferson Street was rerouted through the Lowell Creek tunnel, thus perching the outlet of the stream approximately 40 feet above the abutting downstream channel.

The upper end of Resurrection Bay has been nominated as an Area Which Merits Special Attention (AMSA's) within the Alaska Coastal Management Plan (ACMP). Resurrection River has not been designated as Wild and Scenic nor have any of the waterways been designated 4(f) resources. Large mammal species occupying these watersheds include mountain goats, moose, black and brown bears, wolves, and wolverines. At least 150 bird species including the American bald eagle and peregrine falcon occur within the area. No species listed as threatened or endangered under the Endangered Species Act occur within any of the watersheds.

9. Expected Future Conditions

The Salmon Creek and Box Canyon Creek areas are popular for housing development and will continue to see building and encroachment in the floodplain if this area is left unregulated. The embankments created with river-run material are a temporary solution to a continuing flood threat. The Japp Creek levee is currently under contract to be extended. This additional protection, in conjunction with regulated development, should alleviate some flood concerns.

Areas of Particular Flooding Concern

1. Salmon Creek

   An extension to the 1,400-foot non-engineered levee protecting the Meridian Park and Bear Lake neighborhoods near Kwechak Creek using gabion baskets is planned for late 2011. Gravel maintenance is of particular concern for the Salmon Creek watershed. Sediment management plans need to be addressed for each of the streams within this watershed. The SBCFSA would like to pursue a capital project to armor the existing non-engineered levee, obtain permitting for gravel maintenance, and consider other flood control measures.

2. Box Canyon Creek

   The SBCFSA is considering reshaping the non-engineered levee that diverts floodwaters. Permitting and maintenance of the non-engineered levee is of particular concern for this area.

3. Scheffler Creek

   Scheffler Creek enters the lagoon near the harbor. When storm surge and high tides cause flooding in Scheffler Creek, the overbank flow can reach portions of the Japp Creek fan. This adds to the already flooding Japp Creek area.

4. Japp Creek

   Japp Creek is in FEMA’s funding cycle for 2012 for floodplain mapping. Surveys are ongoing in the area. Aerial Light Detection and Ranging (LiDAR) survey data has been collected and compared over several years, and there is great concern about managing the sediment at the confluence of Japp Creek and the Resurrection River. Significant areas of aggradations have been noted.

5. Fourth of July Creek

   The levee on Fourth of July Creek has functioned without incident since construction. Recommendations for maintenance for continued flood control are needed. Recent LiDAR in the area has shown the channel is aggrading.

6. Spruce Creek

The USGS removed the water surface gage on Spruce Creek during the summer of 2010. The existing levee will need maintenance to continue functioning as designed.

10. Potential Flood Risk Reduction Measures

Flood risk is a combination of two components: the chance (or probability) of a particular flood event and the impact (or consequence) that the flood would cause if it occurred. Flood damage reduction measures can either reduce the chance of flooding or the impact of flooding. Structural measures such as dams, levees, and floodwalls alter the characteristics of the flood and reduce the probability of flooding in the location of interest. Nonstructural measures alter the impact or consequences of flooding and have little to no impact on the characteristics of the flood.

Common structural and nonstructural flood mitigation measures along with potential environmental impacts and concerns related to their implementation are discussed below. Potential watershed specific measures are presented in Table 7. The potential measures presented are based on the data available at the time of this study and previous studies conducted in the watershed.

Table 7. Watershed Specific Potential Flood Mitigation Measures

Watershed	Structural Measures					Nonstructural Measures					
	Debris Basin	Levees	Channel Modification	Non-engineered Levees	Bridge & Culvert Size Optimization	Elevation	Relocation	Buyout/ Acquisition	Flood proofing	Floodplain Management/ Regulation	Maintenance & Emergency Action Plan
Salmon Creek	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Box Canyon Creek	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Japp Creek	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Spruce Creek	N	Y	Y	N	N	N	N	N	N	Y	Y
Fourth of July Creek	N	Y	Y	N	Y	Y	N	N	Y	Y	Y
Resurrection River	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Scheffler Creek	N	Y	Y	Y	Y	Y	N	N	Y	Y	Y
Sawmill Creek*	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

*Sawmill Creek was not part of the initial scoping for this study. There is no reconnaissance information for this watershed in Section 7 of this report. The Sponsor asked that this watershed be added later.

Thorough development of designs and cost estimates for these items were beyond the scope of this study; however, a next step would be to do so. Section 11 contains an estimate by basin for what level of effort would be needed for preparing these designs.

Structural Measures

Debris Basins. Debris basins are specially engineered and constructed basins for storing large amounts of sediment moving in an ephemeral stream channel and are placed to protect and prevent downstream damage. Debris basins can be extremely expensive to construct and require commitment to annual maintenance.

The construction and maintenance of debris basins designed to retain 50 to 80 percent of stream load could have minor to substantial effects on salmon rearing, resting, and foraging habitats within the footprints of the basins because of temporary loss or modification of habitat. The same types of habitats downstream could see minor to moderate effects from modification of the quantity, type, and rate of sediment and organic input that comprise and refresh in-stream benthic habitat. This presumes that the debris basins regularly trap large percentages of silts, sands, and gravels and that maintenance removes these materials from the system.

Levees. Levees are embankments of natural or artificial slope to regulate water levels and are usually earthen and parallel to the course of a river. These structures are engineered using the hydraulic properties of the stream. Levees are constructed to a specific flood risk protection level and are designed to withstand extreme flows. Regular maintenance governed by an operations and maintenance manual is required for levees to perform as designed.

Construction and maintenance of levees have moderate to substantial effects on in-stream and riparian habitats, typically due to direct habitat loss. Habitats landward of levees typically become wetter or drier due to changes in local hydrologic flow regimes. Adjacent and downstream in-stream habitats are modified because of changes in in-stream flow rate, duration, velocity, deposition rates, large and small woody debris input, and nutrient input.

Floodwalls. Floodwalls are primarily vertical artificial barriers designed to temporarily contain floodwaters during seasonal or extreme weather events. Floodwalls are used mainly in locations where space is limited or where levees would interfere with existing structures or future development. These structures usually contain flood gates that would allow passage of flows when opened. Floodwalls can be expensive to construct and maintain.

The construction and maintenance of floodwalls can have very similar effects to those of levees, but there can be some marked differences. While the construction of levee toes tends to result in substantial footprints in and along waterways, floodwall construction typically affects a substantially narrower footprint. However, while the slope and covering (vegetation, rock, etc, but not concrete) of levees can still provide some minimal habitat benefits depending on flows, floodwalls typically are virtually devoid of habitat value. More importantly, floodwalls completely lock-up sediment input, can substantially restrict organic input, cut-off hydrologic flows through their footprints, and for these reasons interrupt biological, chemical, and physical processes that generate, refresh, or damage adjacent and downstream aquatic and terrestrial habitats.

Channel Modification/Dredging/Gravel Mining. River channels are frequently deepened, widened, or straightened to increase their capacity to convey streamflow. Such alterations require the design of a stable river channel.

The potential effects of dredging, mining, and maintenance within the footprints of the work would be largely similar to those of debris basin construction and maintenance assuming a similar interval of excavation and removal of the substrates from the system. If the rate of excavation (particularly related to an on-going mining operation) substantially exceeds a single annual excavation and maintenance event, there is a larger probability that in-stream habitats within the footprint and downstream could be negatively affected. As with debris basins, this presumes that a moderate to substantial quantity of silts, sands, and gravels are removed from the system. The positive or negative effects of channel modification can vary widely depending on where in the system they occur, the type of modification, the stability of the affected reach(s), and the intent of the modifications. The majority of the positive and negative in-stream and riparian effects discussed throughout this section may occur as a result of channel modifications.

Non-engineered Levees. Embankments constructed with river-run material to protect homes and facilities during large flow events are not permanent structures. These embankments cause changes in the natural sediment transport and deposition of the stream. During normal flows, a wider channel is less efficient at transporting bedload material and the channel slowly fills up. During high flow events, flows in the channel, aided by the embankments, may become deep enough to remobilize the large amount of deposited sediment and transport to a new location downstream. This "unnatural" deposition may cause changes in other downstream locations. Despite these drawbacks, construction and maintenance of such embankments may prove to be warranted on a short-term basis while funding and designs for longer term solutions are sought. Timely and effective maintenance of river-run material embankments in areas where they are deemed the most efficient form of flood protection is essential in alleviating damages from flood waters. Non-engineered levee construction and maintenance environmental effects are very similar to levee effects described above.

Bridge and Culvert Size Optimization. The ability of a river system to pass high flows can be compromised by undersized bridge and culvert openings. These "choke points" along a flow path can cause backwater flows into a smaller capacity stream, change the depositional properties of the stream, and cause flood waters to inundate areas that may have been previously dry.

Bridge or culvert size optimization primarily affects in-stream habitat. Long, steep culverts can impair fish passage because of high velocity currents and lack of resting areas for migrating fish. These actions, while having minimal negative effects to in-stream habitat via excavation, can have a moderate to substantially greater positive effect via restoration of a portion of the natural hydrologic flow regime resulting in a more natural rate, volume, and deposition pattern of stream load.

Raising and Armoring Roads. Flooding in Seward can be severe, and road access in and out of the city has historically been completely cut off. Raising and armoring select roads in the area would assist in evacuations and emergency flood fighting services.

Nonstructural Measures

Elevation. Elevation involves raising the buildings in place so that the structure sees a reduction in frequency and/or depth of flooding during high-water events. Elevation can be done on fill, foundation walls, piers, piles, posts or columns. Selection of proper elevation method depends on flood characteristics such as flood depth or velocity and presence of debris.

The primary environmental effects of increasing the lowest elevation of structures susceptible to flooding and debris flows within these watersheds would be a reduction in the pollution caused when non-elevated structures are flooded or destroyed. Because this flood reduction measure has the potential to substantially improve the survivability of structures within many floodplain locations, and therefore make structural occupation of floodplains more economically attractive, it can also be expected to extend the longevity of existing human effects within floodplains and potentially attract additional similar development.

Relocation. Relocation involves moving the structure to another location away from flood hazards. Relocation is the most dependable method of protection and provides the benefit of using the evacuated floodplain for recreation or wildlife viewing.

Presuming adequate clean up of formerly occupied properties and relocation to less sensitive habitats than originally occupied, relocation should have positive effects to riparian and riverine habitats affected primarily by floodplain occupation.

Buyout/Acquisition. Buyout/acquisition involves purchase and elimination of flood damageable structures, allowing for inhabitants to relocate to areas away from flood hazards. Land purchased is to remain undeveloped, often under the care of a land trust organization, to provide floodplain functions. Similarly, currently undeveloped land in the floodplain may be permanently preserved to provide floodplain functions as opposed to future development.

Flood Proofing. Flood proofing involves dry and wet flood proofing to mitigate flooding of structures.

> Dry Flood Proofing. Dry flood proofing involves sealing building walls with waterproofing compounds, impermeable sheeting, or other materials to prevent the entry of floodwaters into damageable structures. Dry flood proofing is applicable in areas of shallow, low velocity flooding. The environmental effects of dry flood proofing are largely similar to elevation in that it would likely result in extending the longevity of floodplain occupation.
>
> Wet Flood Proofing. Wet flood proofing measures allow floodwater to enter the structure. Vulnerable items such as utilities, appliances, and furnaces are relocated to higher locations or waterproofed. By allowing floodwater to enter the structure, hydrostatic forces on the inside and outside of the structure can be equalized reducing the risk of structural damage. The environmental effects of wet flood proofing are largely similar to elevation in that it would likely result in extending the longevity of floodplain occupation.

Floodplain Management/Regulation. The development and implementation of a comprehensive floodplain management plan is best handled at the local government level through planning, zoning, and building permit processes (FEMA 1989). Through these processes, future development can be planned and its effects on flood hazards adequately addressed. The management and regulation of future development is best coordinated at the local level among local government officials, planners, engineers, residents, and the development community through the establishment and effective enforcement of planning, zoning, and building laws.

Enforcement currently is a challenge. At the borough level, a single floodplain inspector is responsible for enforcement within an area larger than many states. Likewise, enforcement resources of the city and SBCFSA are limited.

The effects of additional regulations generated to minimize flood damages can be either positive or negative for the related environments. Regulations may act to expand floodplain protection or facilitate floodplain development.

Local Levees and/or Floodwalls. Local levees and/or floodwalls are freestanding structures located away from the building that prevent the encroachment of floodwaters. The environmental impacts of local levees and floodwalls would be similar to those described under structural measures above, but at a smaller scale.

Flood Warning System. Flood warning systems alert inhabitants in flood prone areas of impending high water. Depending on the type of warning system and advance time, inhabitants have the opportunity to evacuate damageable property and themselves from the flood prone area.

Education. The goal of education and outreach efforts should be to build a consensus to support the implementation of a comprehensive flood management plan that maximizes benefits to the region as a whole.

Levee Certification. Levee certification is a technical finding for floodplain mapping purposes as part of the National Flood Insurance Program (NFIP) that concludes there is reasonable certainty that the levee protecting the area will contain the base (1% annual chance exceedance, sometimes referred to as the 100-year) regulatory flood. The certification finding must be accomplished by either a registered professional engineer or a Federal agency with levee design and construction qualifications such as USACE. Areas protected by a certified levee system are eligible to receive a moderate flood risk hazard from FEMA and be eligible to lower NFIP flood insurance rates.

The basic policy governing levee certification for NFIP was issued by FEMA in 1986 as 44 CFR 65.10. This policy requires complete engineering analysis of hydrology, hydraulics, structural and geotechnical, and operations and maintenance of the levee undergoing study for certification determination. Protective structures constructed of river derived material, such as those found in Box Canyon Creek, Salmon Creek, Japp Creek, Fourth of July Creek, and Spruce Creek, do not meet FEMA design requirements and hence are not eligible to be certified as a levee.

Maintenance and Emergency Action Plan. Any of the described measures, or others not discussed, may be used in a flood emergency. Regular maintenance of flood control structures is paramount to their effectiveness during a flood event. Formally designed maintenance plans should be developed for the engineered levees and the non-engineered levees.

An Emergency Action Plan (EAP) is a formal document that identifies potential emergency conditions and specifies preplanned actions to be followed to minimize property damage and loss of life. The EAP specifies actions that should take place to moderate or alleviate the flood problems. It contains procedures and information to assist the stakeholders in issuing early warning and notification messages to responsible downstream emergency management authorities of the emergency situation. It also contains inundation maps to show the emergency management authorities the critical areas in case of an emergency.

11. Next Steps for Implementation

Additional regional and watershed specific analyses that would be needed to develop conceptual designs for the mitigation measures presented in Table 7 are described below.

Regional Analyses

Regional analyses to determine the active and inactive areas of the watershed fans, a rainfall threshold, and stream gaging are proposed. These regional analyses would cost approximately $75,000 to $250,000 for each.

Geomorphologic Investigation. An investigation to determine the active and inactive areas of each alluvial fan of all interested streams would be completed. This task would provide necessary information for planning and development, and further modeling efforts for sediment management.

Determine Rainfall Threshold. Stream gaging will help in determining a rainfall threshold that may be used for early warning of significant floods and sediment transport. Peak storm duration thresholds can be defined by identifying combinations of peak storm rainfall and duration likely to produce damaging floods and sediment flows.

Stream Gaging. Currently, there are no USGS stream gages in operation for the watersheds considered in this study. To correlate new stream data with historical stream gaging information, it is recommended that at least two real-time stage, discharge and precipitation gages be installed for a minimum of three years. One gage should be placed in a watershed where additional study is to be performed and one gage in Spruce Creek (historical record of 43 years).

Watershed Specific Analyses

Watershed specific analyses include sediment yield determinations and sediment management designs; the costs associated with these studies are shown in table 8. Sediment management in each of the watersheds is of particular concern. The relative watershed specific threats of sediment mass movement induced flooding can be one means to prioritize flood mitigation efforts. The risk of debris-laden floods for each watershed was extracted from the USGS (table 4 of this report) and included in table 8 as a means to prioritize flood mitigation efforts in the watersheds.

Determine Sediment Yield. The amount of sediment a stream can carry and deposit under varying flow conditions is a sediment yield. Calculating a sediment yield for the watershed is needed for determining the best sediment management measures for a particular area.

Sediment Management Designs. This effort would explore measures to effectively manage the sediment in the watershed. Structural and non-structural measures and considerations of state regulation of stream substrate will be developed. Conceptual construction designs would also be included in this effort.

Table 8. Watershed Specific Analyses

Watershed	Sediment Yield Determination	Sediment Management Designs
Salmon Creek	$200,000	$200,000
Box Canyon Creek	$150,000	$200,000
Japp Creek	$200,000	$300,000
Spruce Creek	$150,000	$150,000
Fourth of July Creek	$150,000	$150,000
Resurrection River	$200,000	$350,00
Scheffler Creek	$50,000	$150,000
Sawmill Creek*	$100,000	$300,000

*Sawmill Creek was not part of the initial scoping for this study. There is no reconnaissance information for this watershed in Section 7 of this report. The Sponsor asked that this watershed be added later.

(green)	Low	USGS Risk Assessment of Mass Movement and Surge Release Flood Events – Debris-Laden Flood, 1998 (Table 4, in this report)
(yellow)	Moderate	
(pink)	High	

12. Generalized Conclusions

Many of the threats and problems identified are unique to alluvial fan topographies. Hence, many conventional floodplain management techniques are not as effective on alluvial fans. A combination of adaption of standard flood mitigation measures and identification of flood mitigation measures specific to alluvial fan topographies will be required to best minimize future flood damages in the Seward area.

Comprehensive Floodplain Management Plan

A comprehensive approach to managing future and existing development that minimizes flood hazards in all of the watersheds affecting the Seward area would include:

- Developing special zoning areas for each watershed. For example, special zoning may include "populated repetitive loss areas" requiring flood proofing measures for new construction, "proposed property acquisition areas," and "no-development zones." The SBCFSA, City of Seward, and KPB should work jointly to determine the special zoning names and areas.

- Geomorphologic study of the Seward watersheds to provide a reconnaissance-level review. This study would assist in developing the zoning areas and determine areas requiring further analysis.

- A detailed hydraulic study of each stream to determine:

    - Watershed specific flood frequency flows.

    - The geomorphic and hydraulic characteristics of sediment transport and flood flows. The study would include scenario analysis of aggradation and sediment management. In some areas, a designed stabilized channel would require less maintenance than a forced channel alteration.

    - The optimal opening for culverts and bridges. This study would involve surveyed cross sections of each stream, a comprehensive bridge and culvert inventory, and a survey of each embankment and levee within the system.

    - The required data for the expansion of FIRM maps and special hazard mapping for the streams not already addressed by FEMA.

    - Specific first floor elevations for residential and critical structures in the floodplain of each stream.

    - The feasibility of engineered channels connecting debris basins. Sediment studies conducted for Salmon Creek and Japp Creek by NHC could be used for information as well as comparative LiDAR.

- A minimum crest height for river-run material embankments should be established as a maintenance benchmark. No river-run material embankment can be considered permanent and should not be solely relied upon for flood protection. In addition to the embankment, persons in the immediate vicinity should be prepared for evacuation should the flood waters breach the embankments.

- Flood and sediment management plans, based on the detailed hydraulic analyses, for the prioritized streams.

<u>Increased Regulation and Enforcement</u>

A combination of increased regulation and enforcement is needed to ensure that future development is done is the most sustainable manner practicable. A comprehensive approach to managing future and existing development that minimizes flood hazards is warranted. Increased enforcement by all parties is needed.

- Specific regulations that could be beneficial in the Seward area include:
    - Encourage construction of structures with the first floor elevation above a specified minimum elevation and use flood proofing measures for utilities and heating systems at lower elevations.
    - Prohibit raising structures above the calculated 100-year flood elevation by using fill material if they would be exposed to extremely high erosion potential from fairly shallow water flowing at high velocity.
    - Prohibit constructing non-engineered flood control diversion structures for individual buildings without thoroughly analyzing the impacts on the surrounding area.
    - Require that some arterial streets be laid out parallel to the flow path and be depressed below adjacent ground elevation.
    - Prohibit below grade crawl spaces and basements unless a licensed engineer, architect, or surveyor certifies that the building site is not subject to flooding, localized drainage, or high ground water.
    - Prohibit construction of new structures in the floodway (existing ordinance).
    - Require flood proofing measures on new buildings within the mapped floodplain.

- SBCFSA, City of Seward, and KPB should continue their public education and outreach efforts regarding the persistent flood hazards. In particular, the unusual nature and severity of the threats posed and their incompatibility with many typical flood management techniques (e.g. limitations of existing Digital Flood Insurance Rate Maps to accurately reflect flood hazards on alluvial fans) need to be conveyed to the public.

- Encourage the KPB, State of Alaska, City of Seward, and other interested Land Trusts (Kachemak Bay Land Trust) to acquire land for floodplain conservation.
- Identify structures that could economically use flood proofing measures to significantly reduce flood damages.
- Develop an agreement with DNR to remove sediment from the beds of navigable waters in the Seward area at no cost if the removal is deemed necessary to maintain hydraulic capacity of the stream.

Potential Future Corps Assistance

Planning Assistance to States – The additional technical studies listed in table 7 are the types of efforts that can be investigated using the Planning Assistance to States program just as this study was implemented. The cost sharing for such efforts would be 50 percent Federal and 50 percent local.

Section 205 Small Flood Control projects – The Corps has already received five requests for assistance under the Section 205 program. This program would allow for the planning design and construction of a flood control project with a Federal cost not to exceed $7 million. The cost sharing for this program is 50 percent Federal and 50 percent local for the study and 65 percent Federal and 35 percent local for construction. At present, nationwide funding for this program is quite limited.

Specifically authorized study – Because of the magnitude of the problem in the Seward area, a specifically authorized study and project would likely be needed to develop a comprehensive solution. Similar to the Section 205 program, cost sharing for this program is 50 percent Federal and 50 percent local for the study and 65 percent Federal and 35 percent local for construction. A specifically authorized study would require a congressional study resolution and a new study start in the Corps' annual appropriation bill.

Watershed study – A watershed study is similar to a specifically authorized study in how it is initiated; however, the cost sharing and end product are somewhat different. The purpose of a watershed study would be to develop a watershed plan that would help local entities address flooding and any other water resource issue. This is a study only authority, with the cost sharing being 75 percent Federal and 25 percent local. Any Corps implementation of action items in the watershed plan would be done utilizing the other Corps construction authorities.

All of these suggested methodologies are dependent upon adequate funding and approvals to proceed.