APPENDIX B

HYDROLOGY REPORT

HYDROLOGY REPORT
FOR
SEWARD AIRPORT MASTER PLAN
PHASE II

FOR
DEPARTMENT OF TRANSPORTATION
AND
PUBLIC FACILITIES

JULY 25, 2006

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SEWARD AIRPORT MASTER PLAN
PHASE II

HYDROLOGY REPORT

DOT&PF Project No. 56525

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LIST OF ACRONYMS

cfs .... cubic feet per second
DHW .... Design High Water
DOWL .... DOWL Engineers
FEMA .... Federal Emergency Management Agency
FESWMS .... Finite Element Surface Water Modeling System
FIRM .... Flood Insurance Rate Map
fps .... feet per second
HEC-RAS .... Hydrologic Engineering Center's River Analysis System

SUMMARY

This report provides information regarding the hydrologic and hydraulic conditions that need to be considered in the formulation of the Seward Airport Master Plan and has been used in the associated Environmental Assessment. Two alternatives are presented (Alternative No. 1, “No Build,” and Alternative No. 2, “Raise Runway 12-30,” to prevent a Q_{25} flood event).

The Seward Airport runways have been flooded in 1966, 1974, 1986, and 1995 flood events. Using data from these storms as well as other hydrological data and methods, an analysis was performed to determine elevations of the Q_{25}, Q_{50}, and Q_{100} along the runway.

The effects of the Q_{25} flood event on the Seward Airport were evaluated and it became evident that the current Runway 12-30 would become overtopped during a Q_{25} flood event. Using the water surface profiles generated for the Q_{25}, an inundation map was created for the Q_{25} flood event and runway elevations for Alternative No. 2 were calculated. A second flood inundation map was then created to show the extent of the flooding for each of the two alternatives and to provide a comparison. With an average fill height of less than two feet, Alterative No. 2 is able to prevent the overtopping of Runway 12-30 and reduce the risk of erosion of the taxiway.

Alternative No. 2 recommends raising the runway elevations to prevent overtopping, therefore the embankment will need to be extended to accommodate the additional fill on the west side of the runway. Computations were performed to determine the type of protection required assuming a 12 feet per second design velocity. Class III stone is recommended for the southern half of Runway 12-30 to reduce the risks of impinging flow where the Resurrection River flows against the east runway embankment. Class II stone is recommended for the north half of the east embankment because of risks with parallel flow. Typical sections were used to calculate the total fill required below Ordinary High Water.

Alternative No. 2 reduces the risk of overtopping and therefore reduces the chance that the taxiway will be washed out by runway overtopping of the Resurrection River. Because the taxiway’s width must be widened to meet the Federal Aviation Administration’s guidelines,

it is recommended that the existing metal pipe be replaced with an 8 by 12-foot pipe arch with concrete headwalls and wingwalls.

In this report two alternatives were evaluated: Alternative No. 1, "No Build," which keeps Runway 12-30 at the existing elevation; and Alternative No. 2, "Raise Runway 12-30," which was determined to prevent overtopping and flooding of the runway. The recommendations offered within the report provide additional information regarding the airport and runway improvements and should be read in its entirety.

1.0 INTRODUCTION

The purpose of this report is to provide a general overview of hydrologic and hydraulic conditions that require consideration in the formulation of the Seward Airport Master Plan. It is a compilation of information from various sources and should be used as a tool to evaluate two alternatives (Alternative No. 1, "No Build"; and Alternative No. 2, "Raise Runway 12-30" to prevent a Q_{25} flood event) put forth in the Seward Airport Master Plan.

As part of Phase I of the Seward Airport Master Plan, it was established that the Seward Airport runways have been flooded in 1966, 1974, 1986, and 1995 flood events. Therefore, for the purposes of this report there will be a discussion on two alternatives:

Alternative No. 1	No change in the runway elevation.
Alternative No. 2	Raise Runway 12-30's shoulder elevation to an elevation to be determined in this report and identify shoulder protection against erosion.

2.0 LOCATION

The current Seward Airport is located at Latitude North 60°07'15.37, Longitude West 149°25'05.63."

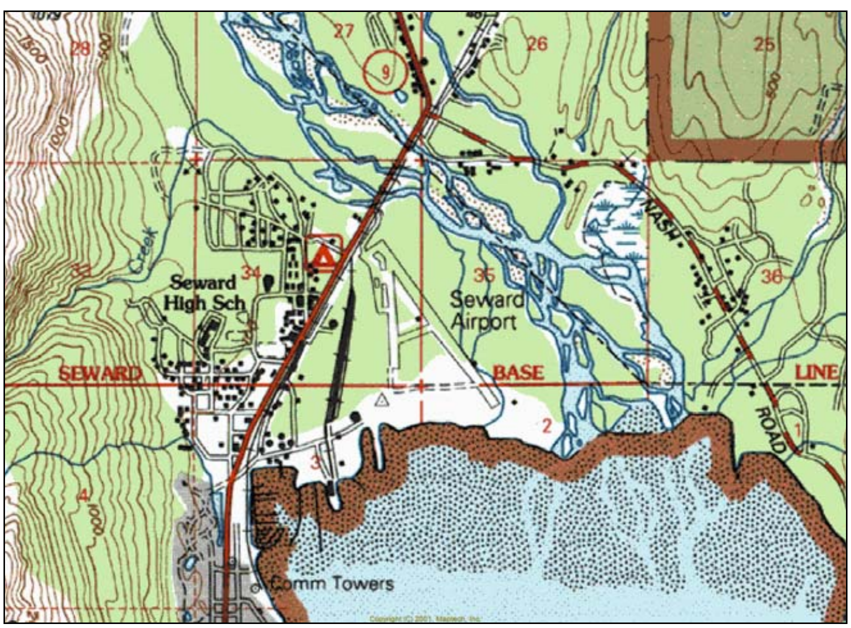

Figure 1: U.S. Geological Survey Location Map of Seward Area

3.0 HISTORY

3.1 Prior to Good Friday Earthquake

Prior to the 1964 Good Friday earthquake, Seward was known for over 50 years as the Gateway City. In fact, Seward was one of the very first Alaskan cities to make application long before the passage of the Territorial Enabling Act of 1949, and prior to the organization of the Territorial Department of Aviation.

Resurrection Bay was first inhabited by a branch of the Chugach Eskimo people. During the later half of the 18^{th} century, the Russians entered the bay and Alexander Baranov founded a short-lived shipyard near the present-day Seward in 1794.

Seward was founded in 1902 by surveyors for the railroad that would eventually become the Alaska Railroad. The city was named for William Henry Seward, U.S. Secretary of State, who negotiated the purchase of Alaska from Russia in 1867. The railroad, which runs from Seward through Anchorage to Fairbanks, was operated by the Federal Government for more than 60 years. By the time the Alaska Railroad was completed in 1923, Seward had a population of 1,500. From the time of its founding to 1964, Seward was the major port of entry for goods bound for Interior Alaska. The railroad was purchased by the State of Alaska in 1985.

The city boomed during World War II. Seward is the major port, and the southern terminus of the railroad and was heavily defended. Two army garrisons were constructed in 1943 with facilities for about 5,000 troops. The civilian population, especially contractors and those in the service professions, increased along with the military. The Seward Highway was finally completed in 1952, making Seward the only port in the state to be served by road, rail, and the Alaska Marine Highway (ferry system).

In the early 1950s the people of Seward demanded, and unquestionably deserved, a better airport. Even the best of the famous Alaska bush pilots were frequently baffled at Seward by dangerous crosswinds; by deep puddles that often assumed the proportions of small lakes; and by glare ice on the field during the winter. Yet the air traffic in and out of Seward was considerable, and small planes were making heroic efforts to maintain schedules on a daily-or-better basis.

The Seward Highway was connected with Anchorage in 1952.

The city's pre-earthquake economy was to a considerable extent dependent on its transportation industry that included extensive railroad yards and freight staging areas. Fish processing plants and storage facilities for petroleum products were also a part of the economy. All were located in the waterfront area.

Figure 2: Article Territory of Alaska Department of Aviation, Biennial Report, Progress and Finance 1951-1952. One of the largest crowds ever assembled in Alaska was at the dedication of the Seward Municipal Airport. The transport type aircraft on the runway can now serve this year-round seaport for civil or military needs.

Figure 3: Article Territory of Alaska Department of Aviation, Biennial Report, Progress and Finance 1951-1952. A free moose barbecue was served at the Seward Airport by the local Elks and American Legion on the opening day. The C-46 in background is the largest plane to land at Seward.

Figure 4: Article Territory of Alaska Department of Aviation, Biennial Report, Progress and Finance 1951-1952. Aerial view of old Seward runway that was too short for transport aircraft.

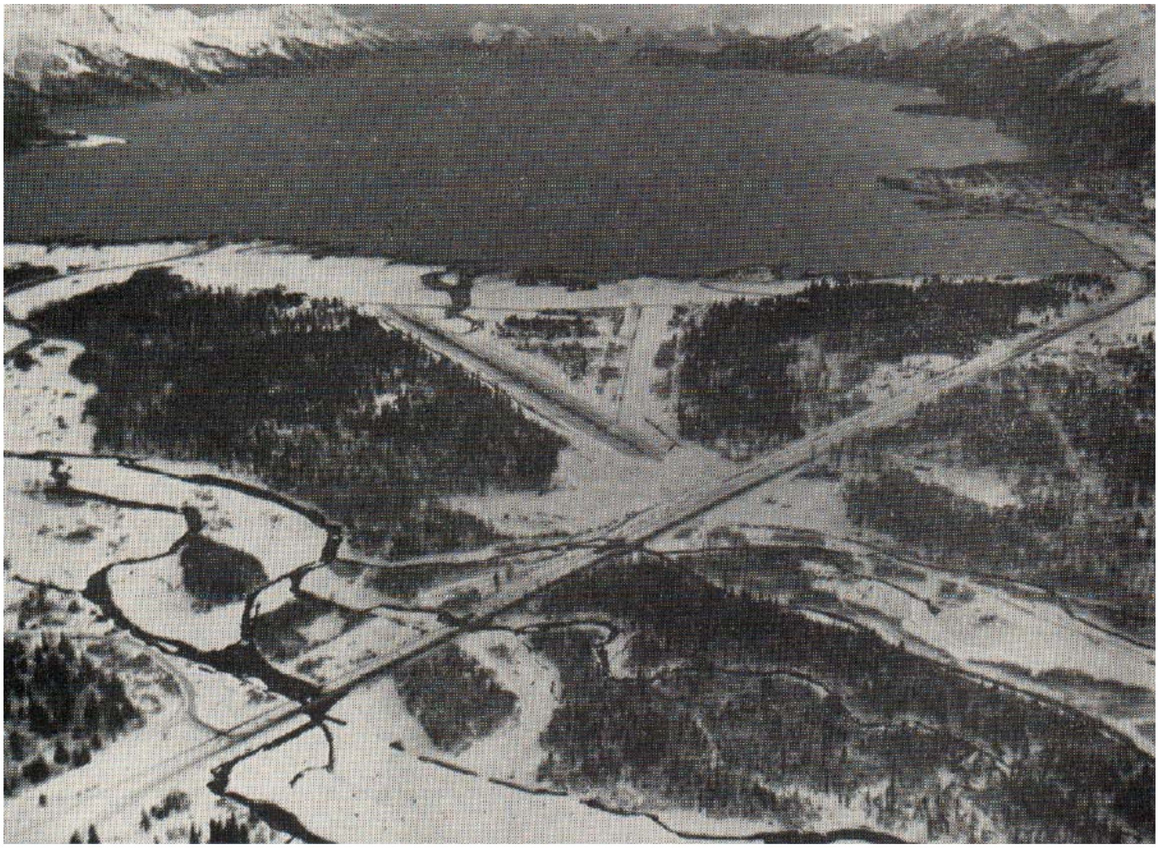

Figure 5: Article Territory of Alaska Department of Aviation, Biennial Report, Progress and Finance 1951-1952. The Seward Airport showing relation to City of Seward at right and entire Resurrection Bay.

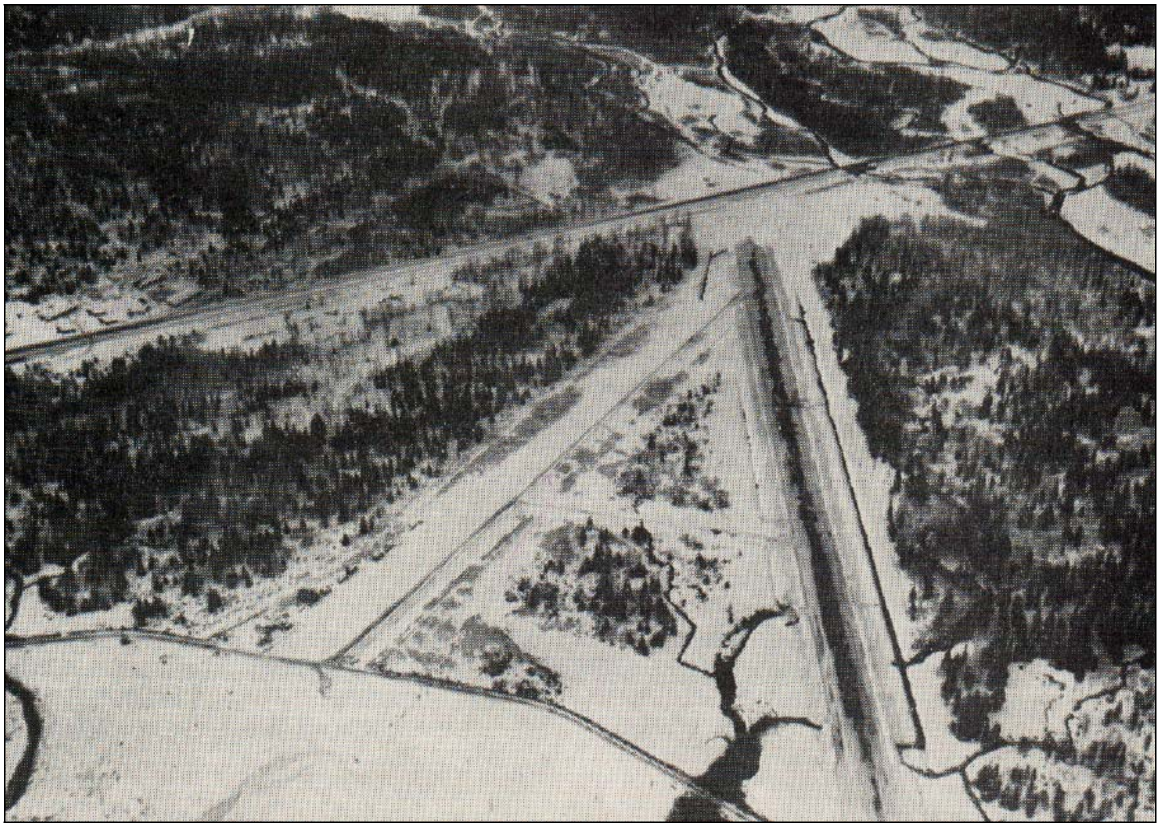

Figure 6: Article Territory of Alaska Department of Aviation, Biennial Report, Progress and Finance 1951-1952. The New Seward Airport runway constructed in 1952 that allows transport type airplane service.

3.2 1964 Good Friday Earthquake

After the war, Seward's economy faltered. The town was getting back on its feet when the Good Friday earthquake of 1964 hit. The earthquake was the strongest ever felt in North America, registering 8.5 on the Richter scale. Seward was one of the most devastated areas. A section of the waterfront 3,500 feet long and 300 feet wide slid into the bay, taking with it most of the port facilities and the railroad terminus. Thirteen people were killed and 95 percent of the local industry was destroyed. The town was so severely impacted that the employment rate stayed below pre-earthquake levels for 10 years. However, the hard work and civic spirit of the townspeople in responding to this disaster gained Seward the national designation of "All-American City" in 1964 and 1965.

Massive destruction of facilities along the waterfront was inflicted by submarine slides and tidal waves. An immediate result of the seismic shocks was the rupture of fuel storage tanks.

The fuel quickly caught fire and flames spread over half a mile of waterfront. Submarine landslides (underwater or marine landslides) caused the subsidence of about 4,000 feet of the waterfront into Resurrection Bay, and took with them storage tanks and other waterfront facilities including the municipal dock.

Six tidal waves, also called tsunamis, generated by the earthquake to a height of 30 feet destroyed the railroad docks and leveled the remaining facilities along the waterfront. Buildings, boats, and railroad cars were added to the debris already deposited by ground shocks and slides. The industrial area along the waterfront was completely destroyed and the petroleum offloading facilities, canneries, and docks were swept away. The standby power plant was destroyed and the small-boat harbor was rendered useless.

At that time, the improvement of the Seward Airport was important to other towns and villages of the Kenai Peninsula. Scores of "mercy flights" were made annually, bringing injured or seriously ill patients to the Seward General Hospital or transporting Seward doctors to the scene. In addition, a large number of charter flights were being made from Seward to outlying points in all directions; carrying business men, prospectors, commercial fisherman, government officials, and hunting and fishing parties into areas inaccessible by other means of transportation.

3.3 The Effects the 1964 Earthquake had on Hydrologic Regimen

Water-level measurements were made in wells Sew 5 and 6 on the Japanese Creek alluvial fan in June 1961 (Tryck-Nyman and Associates, 1961) and were reported to be a little more than 18 feet below land surface in each. One measurement made in each well on May 10, 1964, showed that the water level was still about 18 feet in Sew 5 and about 21 feet in Sew 6. Subsequent measurements could not be made to show any trends or to confirm the measurements. However, measurements made from July 9 to August 23, 1964, in a new well adjacent to Sew 6 showed that the water level lowered from 21.50 to 22.45 feet during this time. Hence, the water level of this new deep well seems to correlate with those of old wells of unknown depth and implies that they all tap the same aquifer.

The available evidence suggests that aquifers on the Japanese Creek fan are a complex of alluvial fan deposits and an underlying alluvial aquifer deposited by the Resurrection River.

The wells tap the deeper part of the aquifer complex. Comparison of water levels in the old wells with those so far determined in the new wells suggests that the earthquake had no permanent effects on the aquifers.

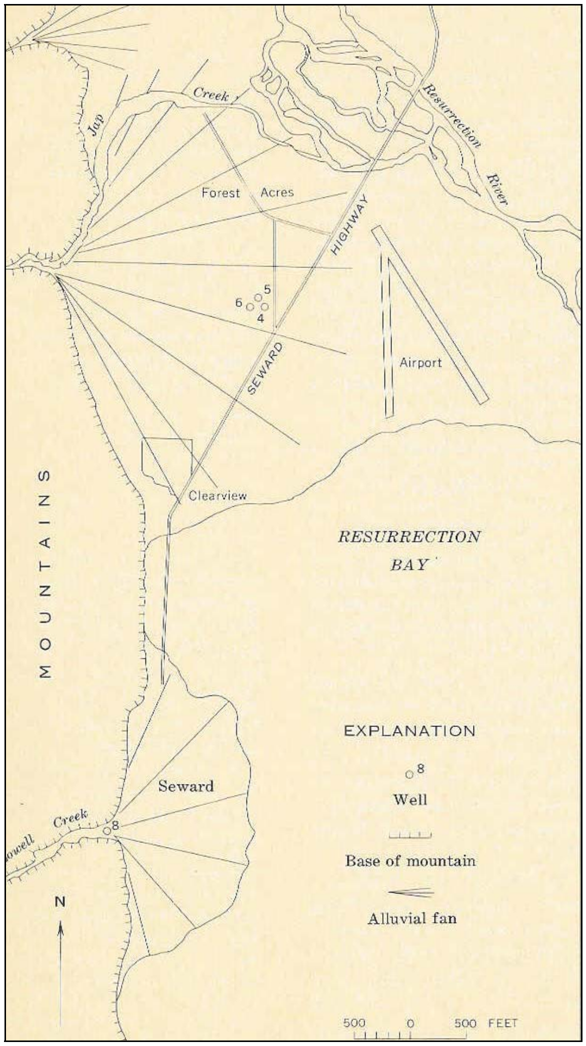

Figure 7: Sketch map of Seward at the base of Kenai Mountains, showing geomorphology and well locations.

Post earthquake drilling of test holes on the shore at the head of Resurrection Bay penetrated artesian aquifers having sufficient head to flow 10 gallons per minute at 6 feet above the surface. A water sample taken August 14, 1964, was analyzed by the U.S. Geological Survey, and found that the 61°F water had 25 parts per million chlorides, a hardness of 98, a pH of 8.0, and a specific conductance of 250 micromhos at 25°C. The water is probably from an aquifer correlative with the deep aquifer on the Japanese Creek alluvial fan. Lamke

(1966) believes this artesian system helped to reduce the stability of the submarine slopes that failed nearby during the earthquake.

3.4 Summary of earthquake damages to Alaska communities as a direct result of the 1964 earthquake

Table 1: Summary of Earthquake Damage to Alaskan Communities in 1964

TABLE 1.—*Summary of earthquake damages to Alaskan communities*

Place	Population [1] 1960	Deaths (total, 114)	Principal causes of damage								Townsite acreage (estimated)			Premises (estimated)		Type of structures damaged							
			Subsidence	Uplift	Landslides: Land	Landslides: Submarine	Ground cracks	Vibration	Waves	Fire	Total	Damaged	Percent	Total	Damaged	Homes	Business and public	Military	Harbor	Water supply	Other utilities	Highways	Airports
Afognak	190	0	X						X		20	2	10	38	23	X	X		X	X	0	X	
Anchorage	[2] 44,237	9			X		X	X			4,500	700	14	15,000	750	X	X	X	X	X	X	X	X
Cape St. Elias	4	1			X				X														
Chenega	80	23		X					X		20	20	100	20	20	X							
Chugiak	51	0												0	0					X			
Cordova	1,128	0		X			X		X		200	20	10	400	40	X	X		X	X	X		
Cordova FAA airport	40	0					X	X								X	X			X	X	X	X
Eagle River	130	0									20	1	5	0	0					X			
Ellemar	1	0		X													X						
Girdwood	63	0	X				X									X	X						
Homer	1,247	0	X			X		X									X		X			X	
Hope	44	0	X								10	3	30		10	X				X			
Kadiak Fisheries Cannery	2		X					X	X					15	15	X	X		X	X	X		
Kaguyak	36	3							X		15			15	15	X	X						
Kodiak	[3] 2,628	15	X						X		285	31	11	1,100	130	X	X	X	X	X	X	X	X
McCord	8							X	X							X	X						
Old Harbor	193	0							X		30			38	35	X	X		X	X	0		
Ouzinkie	214	0	X						X		50		10	38	6	X	X		X				
Point Nowell	1	1							X					1	1	X							
Point Whitshed		1		X					X						10	X							
Portage	71	0	X				X						20			X	X			0		X	
Port Ashton		1							X						0								
Port Nellie Juan	3	3							X						0			X	X				
Seldovia	460	0	X													X	X		X				X
Seward	1,891	13	X			X	X		X	X	400	400	100	700	200	X	X	X	X	X	X	X	X
Tatitlek				X															X				
Valdez	1,000	31	X			X	X		X	X	300	300	100	200	40	X	X		X	X	X	X	X
Whittier	70	13	X			X		X	X	X	30	10	35	10	8	X	X	X	X	X	X	X	X

[1] Alaska Depart. Health and Welfare (1964).
[2] 82,833 including military personnel.
[3] 4,788 including personnel at Kodiak Naval Station.

It is estimated that the total damage to public facilities exceeded $15,375,000 in 1964 dollars.

3.5 City of Seward Today

The City of Seward, with a current (2000) population of approximately 2,830 is located at the head of Resurrection Bay on the Kenai Peninsula, 125 miles south of Anchorage by highway. It is one of two ice-free ports in Alaska with road and rail connections to the state's interior. Seward's economy, traditionally based on its role as ocean terminus of the Alaska Railroad Corporation, is increasingly moving toward diversification. Seward has been the site of several major economic developments in recent years, including an international-scale coal shipping facility (just restarted) and a maximum-security prison. The city's leaders are actively seeking additional industries to further broaden their economic base.

The population grew in the late 1970s partly because of Seward's important role in shipping supplies to the North Slope for construction of the trans-Alaska oil pipeline. Several new projects, including the State prison and development of the Seward Marine Industrial Center, are driving the sharp current growth.

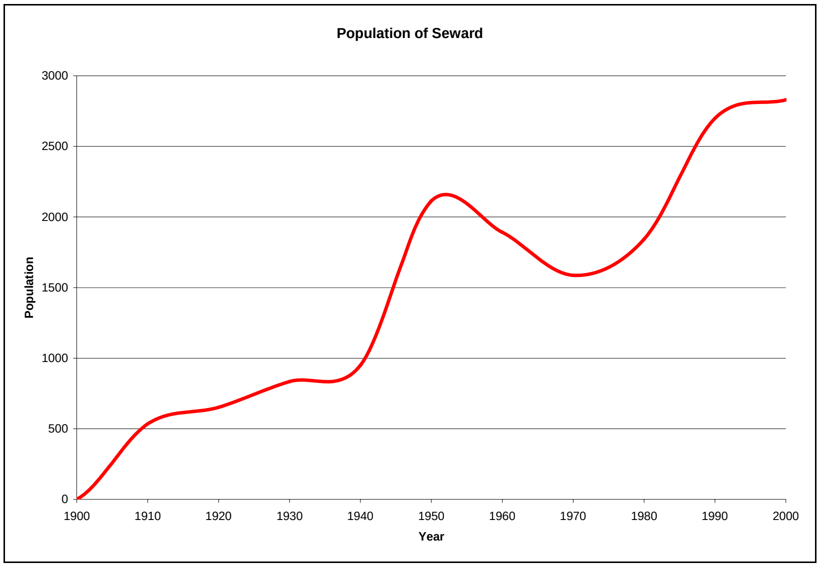

Figure 8: Yearly Population of Seward

4.0 CLIMATE

Seward experiences a maritime climate. Winter temperatures range from 17°F to 28°F; summer temperatures average 49°F to 63°F. The average annual precipitation includes 66 inches of rain and 80 inches of snowfall. The Resurrection River basin characteristics are as shown in the following table:

Table 2: Resurrection River Basin Characteristics

Description	Resurrection River at Seward Airport
Gage #	15237700
Latitude	60°08'24"
Longitude	149°25'12"
Years of Record	1965-67, 1987
Drainage Area (square miles)	169.00
Mean Channel Slope	0.73%
Stream Length (miles)	23.50
Elevation (feet)	2,270
Storage (square miles)	0.00
Lake Storage (square miles)	0.00
Forest (square miles)	41.70
Glacier (square miles)	37.18
Precipitation, mean annual (inches)	100
Intensity, 24 hour 2 year (inches)	4
Snow, mean annual (inches)	180
Temperature, mean minimum January (°F)	12
Flood of record (mm/dd/yy, cfs)	10/11/86, 19,000

5.0 GEOMORPHOLOGY

The Seward Airport is located at the head of Resurrection Bay. The bay is a typical “U” shaped fjord, 25 miles long and 5 miles wide, with a maximum recorded depth of 978 feet near Thumb Cove, 8 miles south of Seward. The last glaciation covering the area was the Naptowne, 10,000 to 14,000 years ago. Glaciers at Seward may have been thicker than 4,000 feet.

Figure 9: August 7, 1950, Aerial Photograph

As can be seen in Figure 9, the Resurrection River main channel formerly was located east of the runways where it remained until the 1993 flood when it started to move to the west towards the Seward Airport. It should also be noted that there is a privately owned subdivision that was located between the Resurrection River and the Seward Airport.

The Resurrection River Delta is comprised of alternating greywacke and phyllite constituter, which constitutes virtually all the bedrock in the immediate vicinity of Seward. Unconsolidated glacial and fluvial deposits, described in more detail below (from Lamke, 1967), overlie the bedrock except on the steep, higher slopes. These deposits are generally intermixed in the valley of the Resurrection River Delta. Stream bedload appears to consist primarily of phyllite and greywacke. The fairly competent greywacke can endure considerable stream transport without braking down significantly. The thinly bedded phyllite breaks down fairly quickly as it moves down the Resurrection River to the delta. The larger boulders and cobbles in the bedload are expected to be composed of competent greywacke, while the sand and gravel are a combination of phyllite and greywacke.

Remnants of lateral moraines flank the main valley of the Resurrection River and extend up the sides of tributary valleys to about 1,500 feet. The moraines are heavily vegetated in most places, but consist of rather loose gray till, composed principally of silt, sand, and gravel, with smaller amounts of clay-sized particles, cobbles, and large boulders. Glaciers in the Seward area have been retreating and thinning in recent years (Field, 1975). Continuation of this trend will create and leave additional areas of unconsolidated morainal material subject to accelerated erosion and deposition by streams. Terminal or recessional moraines in mountainous glaciated areas may be so well preserved that they dam the stream that replaces the melting glacier (Costa, 1985).

The Resurrection River delta deposits are comprised chiefly of silt, sand, and gravel, ranging in thickness from about 100 feet to several hundred feet. The alluvial fan depositional landform as the Resurrection River migrates across the delta’s surface, changing course primarily during major flood events such as 1986, 1993, and 1995. The Resurrection River can migrate laterally or suddenly shift its course during major flood events; therefore the entire delta apron surface is subject to flooding.

6.0 FLOODING PROBLEMS

The Resurrection River receives nearly 40 percent of its total annual precipitation in the months of September through November. These intense rainfall events occur when the lower elevations are snow-free and basins at higher elevations contain saturated snow. This situation can and has resulted in high runoff from area streams.

The narrow stream valleys, steep slopes, and large amounts of over steepened glacial material perched on stream valley walls are a characteristic of the Resurrection River basin. Debris dams, which may block narrow stream valleys temporarily storing water, often break causing “surge-release” and severe flooding and movement of debris into the Resurrection

River. Such damming and surge-release flooding occurred in October 1986 on Lost, Box Canyon, and Japanese Creeks (Jones and Zenone, 1988).

7.0 HISTORY OF GROUNDWATER AND FLOODING PROBLEMS

Table 3 provides a historical account of the type and extent of damage caused by either flooding or erosion problems at the existing Seward Airport.

Table 3: Historical Flooding and Erosion at Seward Airport

Year	Description of Damage
1951	During the process of stripping the old underbrush and topsoil, dozers uncovered subsurface springs, one after another, which spouted fresh water over the new surface and flooded the construction equipment out of the area. This necessitated a change in the original plans to include the installation of subsurface drains. A dragline had to be brought in, and the amount of steel culvert pipe greatly increased over the original estimate. The extra culvert pipe became strike-bound in transit, and the work was brought to a virtual halt. Since this occurred through no fault of the contractor, it was deemed fair to extend the deadline for the completion of the project. Another extension of time had to be granted because a combination of extraordinarily heavy rainfall and seasonal high tides that interfered with the normal drainage of the airport area, and made it impossible to obtain the correct mixture of gravel and fine materials for the foundation. Hence, the engineer in charge with the concurrence of the Civil Aviation Authority engineers granted an additional extension of time in the interest of obtaining a more substantial airport surface than would have been possible had the work been continued under the extreme wet conditions.
1961	500 feet of south end of the runway embankment was severely damaged by erosion. No further details available.
1964	The airport was damaged as a direct result of the 1964 earthquake; both runways experienced minimal damage. The airport was the only connection with the rest of Alaska for an extended period of time because the Alaska Railroad Corporation, Seward Highway, and port facilities were completely destroyed.
1966	North portion of both runways under water. No further details available.
1974	North portion of both runways under water. No further details available.
1986	North portion of both runways under water (see Figure 10). Approximately 200 feet of the south end of the airport's runway was damaged by floodwaters. Center taxiway between both runways was washed out in two locations.
1995	North portion of both runways was under approximately 1.5 to 2 feet of water. (Figures 11-13) Extensive erosion of the south end of the airport runway. Center taxiway between both runways was washed out. Department of Transportation and Public Facilities, Maintenance and Operations, spent in excess of $225,000 for riprap at the end of the runway during the actual flood event. In 1996, Department of Transportation and Public Facilities let a contract to provide erosion protection for the runway embankment.
2003	A combination of high water from the Resurrection River and surge high tides reached the edge of the runway pavement on the south end of the runway. There was no damage to the runway embankment. The north end of the runway was not flooded. According the National Oceanographic and Atmospheric Administration, the high water observed is to be considered representative of a wind driven high tide event. The elevations observed did not include wave run-up.

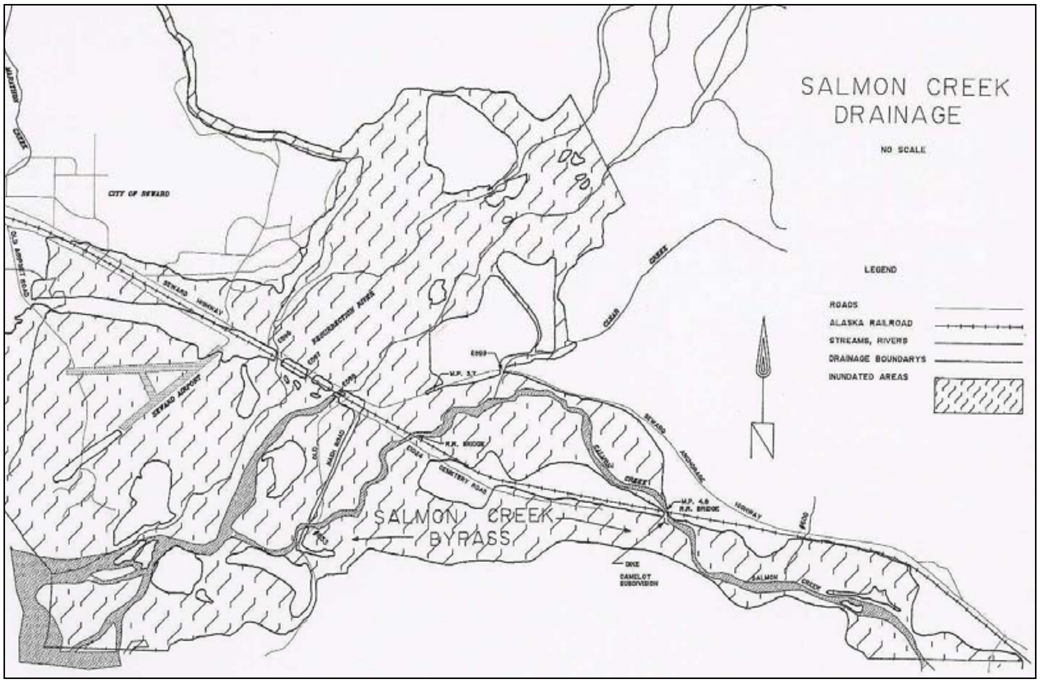

Figure 10: Graphical representation of 1986 flood event.

Figure 10 was generated by Dean Griggs, PE, State Hydraulics Engineer, Bridge Section, Department of Transportation and Public Facilities, using information provided by Stanley Jones, Hydraulics Engineer, U.S. Geological Survey, Water Resources Branch, in his documentation of the October 1986 flood event. As can be seen in Figure 10, the entire airport runway was under water with the exception of the southwestern portion of Runway 12-30. According to the field notes taken during the 1986 flood event by Stan Johns, Hydraulics Engineer, U.S. Geological Survey, Water Resources Branch, there was considerable flow which crossed the northeast portion of the airport property and passed between the two runways (the original 15-33, and newer Runway 12-30). The flow washed out the old road and taxiway between the two runways. Maintenance and Operations records reflect that the taxiway was washed out during the 1986 event.

During the 1995 flood event, approximately 80 percent of the main runway was under as much as 2.5 feet of water. While the surface of the runway did not sustain any damage, the south end of Runway 12-30 did sustain a considerable amount of embankment erosion. The Department of Transportation and Public Facilities spent in excess of $85,500 for emergency erosion protection with Class III Riprap in order to prevent the loss of the end of the runway.

Figures 20 and 21 shows the work in progress. The old road taxiway between the two runways was also washed out.

Figure 11: This isn't supposed to happen! September 19-24, 1995.

Figure 12: Looking to the south from runway shoulder on September 22, 1995.

Figure 13 is a graphical representation of the flow during the first day of the September 19-24, 1995, flood event. As a direct result of the September 19-24, 1995, flood event, the Department of Transportation and Public Facilities has increased the hydraulic conveyance by a total of 30 percent at the Seward Highway second or middle bridge. The Alaska Railroad Corporation is in the process of increasing the hydraulic conveyance of their second (middle) Resurrection River Railroad Bridge. During the September 19-24, 1995, flood, water crossed the Seward Highway and washed out the Alaska Railroad Corporation main line and then deposited in excess of 65,000 cubic yards of material in the Seward Small Boat Harbor.

Figure 13: Graphical Representation of the September 19-24 1995, flood event.

Figure 14: Looking North from the shoulder of the runway.

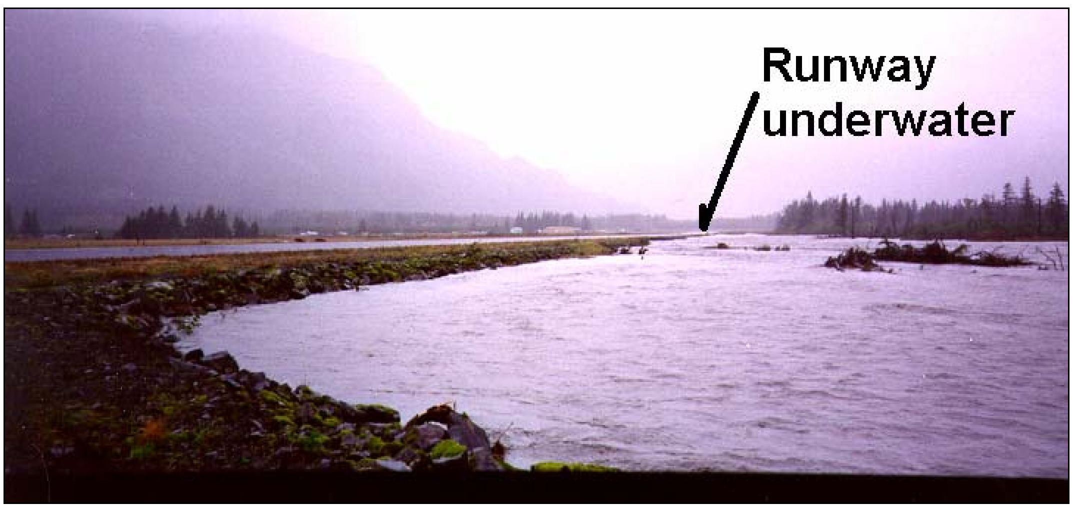

Figure 15: Looking North from the south end of the runway.

When the floodwaters started to recede, the measured velocities next to the runway embankment exceeded 12 feet per second (fps). This information was used in the design of the Seward Airport Erosion Control Project No. 51291 (Airport Improvement Program 3-02-0259-03). This project was originally supposed to be constructed in 1995, but because of permitting concerns expressed by the resource agencies, the construction was postponed. The Department added funding to this project to extend the erosion control to the north end of the runway.

Figure 16: Looking south on the last day of the flood event.

Figure 17: Looking north on the last day of the flood event.

Figure 18: Photograph taken of the old Army Air Corps radio facility.

Figure 19: Looking north as the high water begins to drop on September 22, 1995.

Figure 20: Maintenance and Operations crews doing emergency repairs to end of runway.

Figure 21: Maintenance and Operations crews doing emergency repairs to end of runway.

In 1996 the Seward Airport Erosion Control Project No. 51291 Airport Improvement Program No. 3-02-0259-03 was constructed.

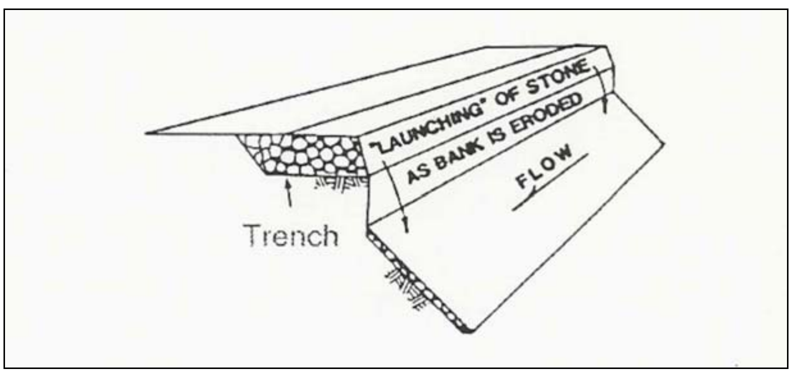

Figure 22: Conceptual design for Seward Airport Erosion Control Project.

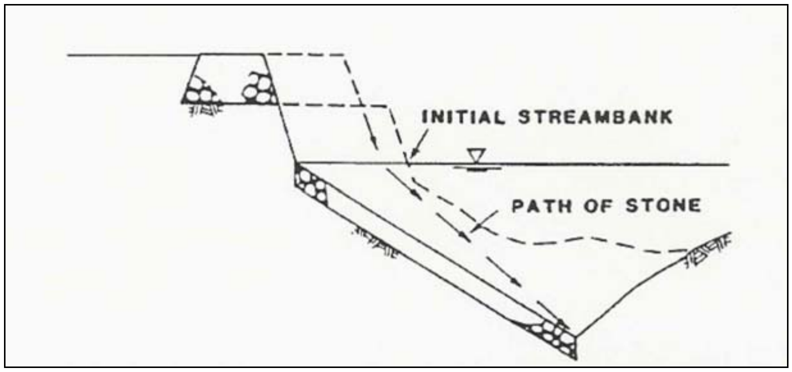

Figure 23: Conceptual design for Seward Airport Erosion Control Project.

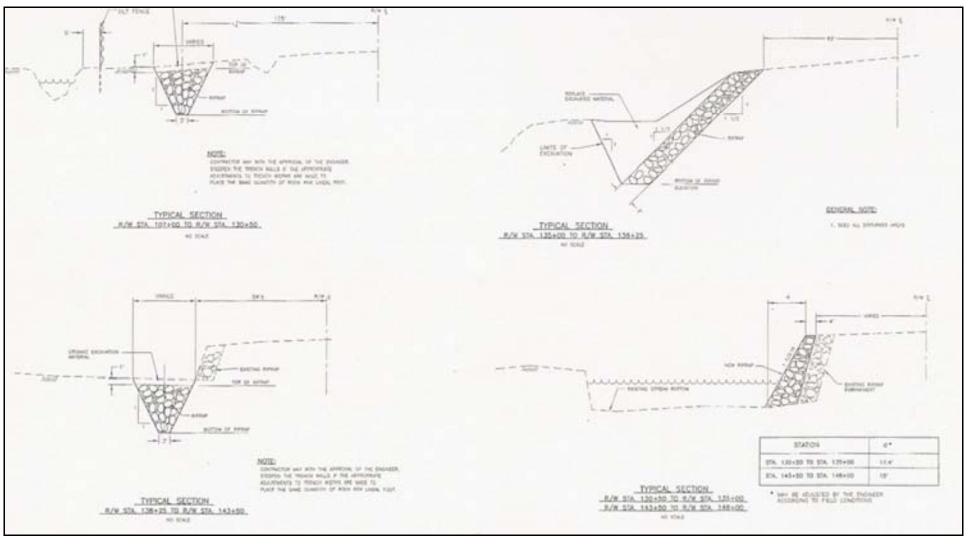

Figure 24: Typical sections of the Seward Airport Erosion Control Project No. 51291.

8.0 HYDROLOGY

8.1 Resurrection River Basin October 1986 Observations

The Resurrection River drains a 169-square-mile basin (16 percent perennial snow and ice) in which the annual precipitation is 100 inches. In its lower reaches, the Resurrection River is a braided alluvial stream with high velocities and an average gradient of 0.0038 ft/ft below Exit Glacier. The river's low banks are densely vegetated. Runoff from the steep glaciated mountain basins and tributaries to the Resurrection River deposit large quantities of coarse bed material at their mouths, forming large alluvial fans and providing high sediment loads to the river. The steep alluvial channels of Exit Glacier and Paradise creeks (0.015 ft/ft) deposit most of their coarse bed material at their confluence with Resurrection River.

The Exit Glacier Road traverses the northern edge of the Resurrection River floodplain from the Seward Highway (Mile 0.00) to Bridge 1390 at Mile 7.2 of Exit Glacier Road. Although the October 1986 storm caused flooding and erosion along Resurrection River adjacent to the Exit Glacier Road, the most destructive erosion and sediment deposition resulted from floodwaters discharging across the steep alluvial fans of several small basins traversed by Exit Glacier Road. Numerous washouts and overflows occurred along the road. The coastal mountain barrier effect on precipitation in the Resurrection River basin was pronounced – total precipitation for October 9-11, 1986, decreased from 17.97 inches at Seward, to 10.14 inches at Exit Glacier, to 8.43 inches at the Cooper Lake Project near the headwaters of the Resurrection River. As a consequence, runoff from the 106-square-mile basin of the Resurrection River above Bridge 1390 was less than the combined runoff from the several small mountain basins whose streams enter the river downstream from the bridge.

The stage of the October 11, 1986, flood peak on the Resurrection River at Bridge 1390 was 353.28 feet (Federal Highway Administration datum) 3 feet below low steel of the bridge. A comparison of cross-sections surveys made prior to the flood and on October 14 shows about 2 foot general scour occurred in the bridge section.

In the October 1986 flood, Bridge 1389 at Mile Post 4.7 of Exit Glacier Road is on the steep alluvial fan of a stream that drains a 3.11-square-mile basin. The floodwaters deposited streambed material both in the bridge opening and on the bridge deck (Figures 25, 26, and 27). The road was washed out at the east abutment of the bridge and at several other locations across the alluvial fan.

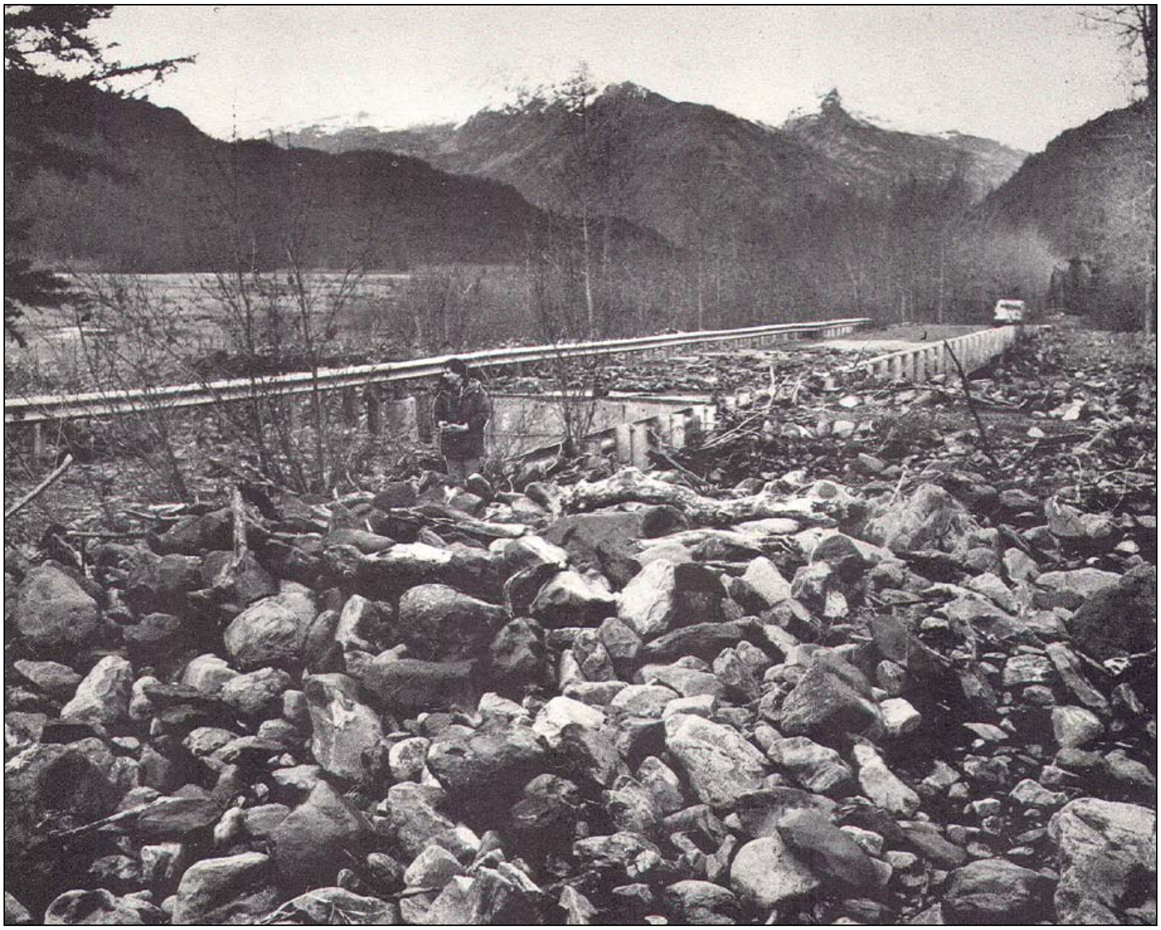

Figure 25: Cobbles and gravel deposits at Bridge 1389, Exit Glacier Road, October 13, 1986.

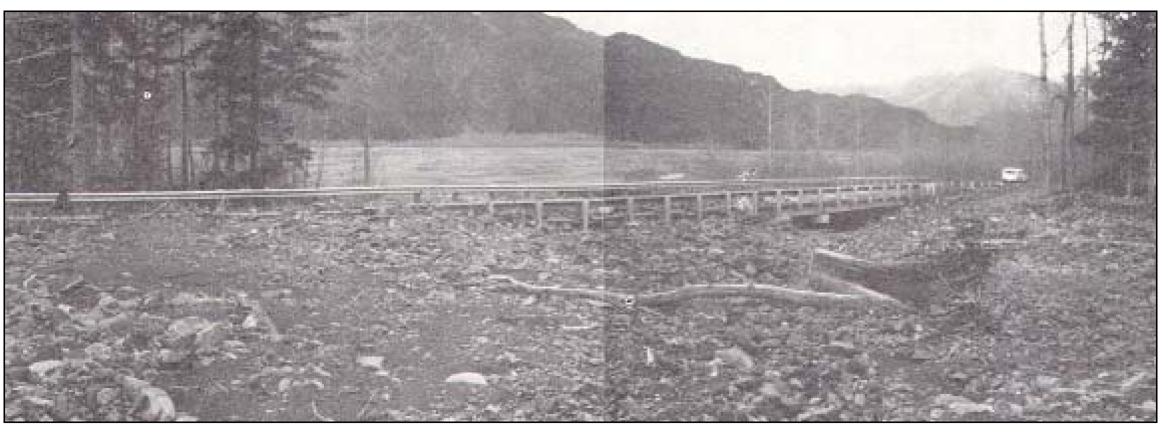

Figure 26: Cobble and gravel deposits at Bridge 1389, Mile Post 4.7 Exit Glacier Road. View downstream on October 13, 1986.

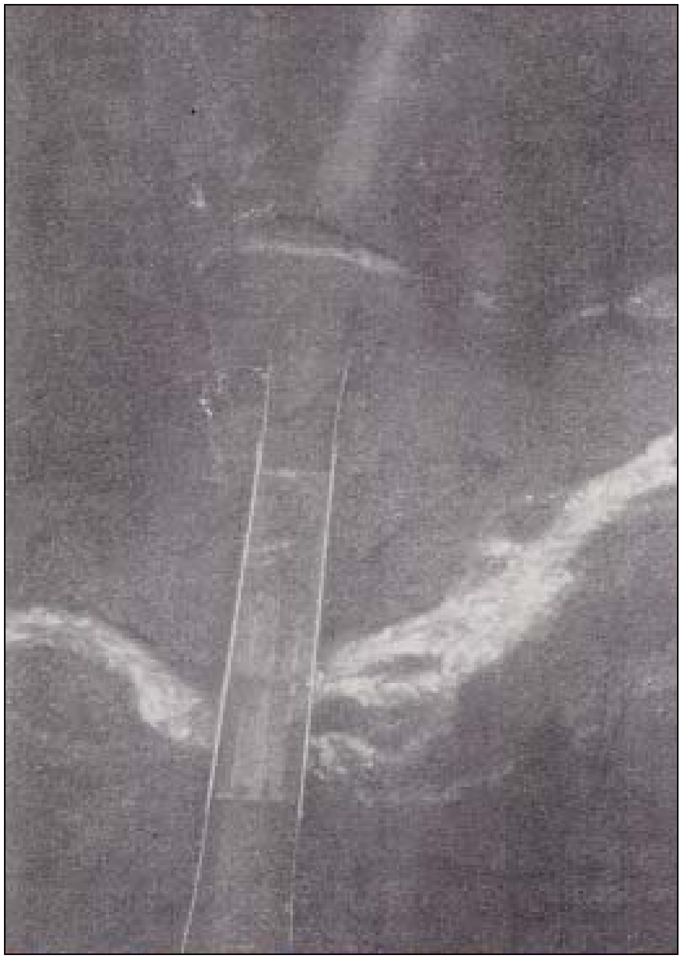

Figure 27: Aerial view looking east at Bridge 1389, Mile Post 4.7 Exit Glacier Road, October 13, 1986.

During the intense rainfall of October 10-11, 1986, several landslides in Box Canyon Creek, which drains a 12.1-square-mile basin and crosses Exit Glacier Road through Bridge 1295 at Mile Post 1.7, contributed to the high debris and sediment load in the Box Canyon Creek's basin. The landslides created temporarily dams within the drainage basin. These temporary dams prevented the movement of the flood flow from passing through the basin (Lamke, 1967, page 22). Eventually, the temporary dams failed or released the stored floodwater and debris downstream from the canyon. This, in affect, created a surge flood three to four times higher than the basin would normally create under similar circumstances. As an example, one of the older landslides (from a previous storm) 0.5 miles above the canyon mouth temporarily dammed the stream and subsequently released a debris-laden flood that caused a major channel shift at the canyon mouth. Downstream, the flood breached a manmade levee of streambed material on the southeast bank, spread over the entire alluvial fan surface, and washed out Exit Glacier Road between Miles 0.8 and 1.7. The debris-laden water was concentrated in an abandoned channel at Mile Post 1.2, where erosion exposed multiple root systems on 150-year old Sitka spruce trees to a depth of 7 feet below the pre-1986 flood fan surface and uncovered buried tree stumps cut during construction of the Alaska Railroad 85 years ago (Dr. Robert V. Kesling, Alaska Vocational and Technical School, oral communications, 1987). Near the apex of the Box Canyon alluvial fan, the active channel is artificially leveed at an elevation about 8 feet higher than the abandoned channel. Breaching of the levee by future floods would again result in diversion of flow to the abandoned channel and the inundation and erosion of Exit Glacier Road.

In October 1986, about 2,800 cubic feet per second (cfs) of floodwaters from Box Canyon Creek were diverted into Salmon Creek through Clear Creek at Bridge 599 at Mile Post 3.9 Seward Highway. Most of the water from Box Canyon Creek bypassed Bridge 1295 leaving it unaffected by either erosion or deposition of material. However, the water eroded and inundated the approaches of Bridge 1295 and came within 3 feet of the bridge low steel. The remaining floodwaters from Box Canyon Creek flowed southward along the embankment of the Seward Highway, flooding residential and commercial property and finally entering the Resurrection River at Bridge 598. The flood crest elevation at this bridge was 31.02.

The combined Resurrection River flow (20,400 cfs) at the three Seward Highway Bridges and a flow of an additional 10,000 cfs from Salmon Creek caused extensive flooding and damage to residential and commercial properties downstream of the Seward Highway. The extent of damage by inundation and erosion along both streams was intensified when trees and other debris were carried downstream to blocking bridge piers and other obstructions.

Japanese Creek originates in the high-altitude glaciated basin that drains through canyon walls that have been greatly over-steepened by glacial erosion. The mainstream channel through the 3.48 square mile basin above the canyon mouth has a slope of 0.19 ft/ft. At the canyon mouth, a broad fan 1.5 miles long and 1 mile wide extends to the valley alluvium of the Resurrection River. The slope of the stream channel is 0.082 ft/ft downstream from area of high deposition farther down the fan apron.

As in other alpine basins in the Seward area, retreating glaciers have left lateral moraines perched on steep slopes in the upper basins of Japanese Creek. A large landslide 0.1 mile above the canyon mouth, identified by Lemke (1967), was reactivated by the intense rainfall of October 10-11, 1986, and deposited rock and boulders as large as 6 feet in diameter in the stream channel. When the resulting debris dam failed, the flood washed out a manmade levee along the southeast stream bank at the apex of the fan and inundated and eroded abandoned channels to the south and east. Similar flooding and erosion occurred at this site in August 1966. The entrenched channel at the apex of the fan about 25 feet deep and 100 feet wide with a slope of 0.082 ft/ft, meanders across the 300-foot-wide apex. The flood fighting efforts of the City of Seward's maintenance bulldozer operators, working continuously through the night of October 10-11, 1986, combined Japanese Creek within this recent fan head trench (Frank Diegraeff, METCO, oral communication, 1986).

Figure 28: Looking upstream at apex of Japanese Creek alluvial fan (August 1966).

Figure 29: Looking upstream at apex of Japanese Creek alluvial fan (October 1986).

Debris-laden floods on Japanese Creek in August 1966, October 1969, September 1976, September 1982, October 1986, and October 1995 document the frequent recurrence of stream damming and surge-related flooding of sufficient volume to be transported past the canyon mouth to affect the lower portion of the alluvial fan. The fan head trench conveyed sediment-laden water to the lower portion of the fan where the active stream channel widens, the slope decreases to 0.020 ft/ft, and rapid bedload and debris deposition occurs. In October 1986, the flood migrated laterally, inundating and eroding subdivision roads west of Forest Acres Subdivision.

The U.S. Geological Survey in cooperation with the State of Alaska, Department of Transportation and Public Facilities, and the Federal Highway Administration maintains a series of gaging stations in the Seward area. Flood peak stage and discharge data were collected at the Seward Highway during the 1965-67. The National Weather Service has operated a flood stage warning station at the Seward Highway Bridge 598 since 1977.

8.2 Previous Hydrology Studies

8.2.1 <u>Seward Area Rivers, Flood Damage Prevention Interim Reconnaissance Report, U.S. Army Corps of Engineers, February 1994</u>

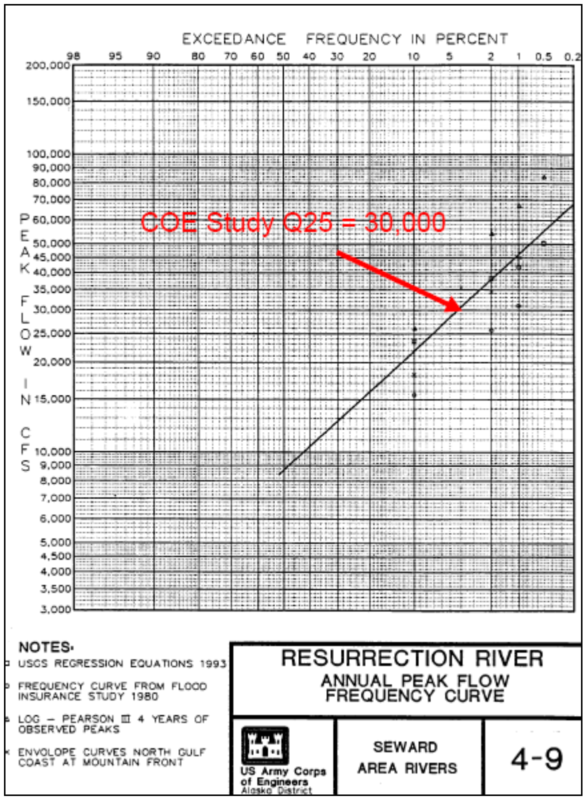

Figure 30: U.S. Army Corps of Engineers Recurrence Interval 1994.

8.2.2 <u>G. N. McDonald and Associates, July 23, 1994</u>

TABLE 1

ANNUAL PEAK FLOW FREQUENCY
FOR THE
RESURRECTION RIVER AT SEWARD, ALASKA

Exceedance Frequency (%)	Average Return Interval (years)	Peak Discharge (cfs)
0.5	500	55,000
1	100	46,000
2	50	38,000
5	20	28,000
6.7	15	25,000
10	10	22,000
......20	5	16,000
50	2	8,800

Figure 31: Report for Alaska Railroad Corporation 1994

8.3 Current hydrology conditions

Both the U.S. Army Corps of Engineers' computations and G. N McDonald and Associates based their computations on only four years of interrupted record (1965, 1966, 1987, and 1995). A review of their computations reveals that flood flows were not considered below the 1987 flood event. This skewed their computations to the high side. In fact, a completed Log Pearson Type III analysis was done that significantly reduces the design flood. Therefore, to determine the design flood event, a complete hydrologic and hydraulic analysis has been performed in order to better determine the "Design Flood" and the risks that the existing airport runways have of being overtopped or sustaining major damage because of severe scour conditions or embankment failure.

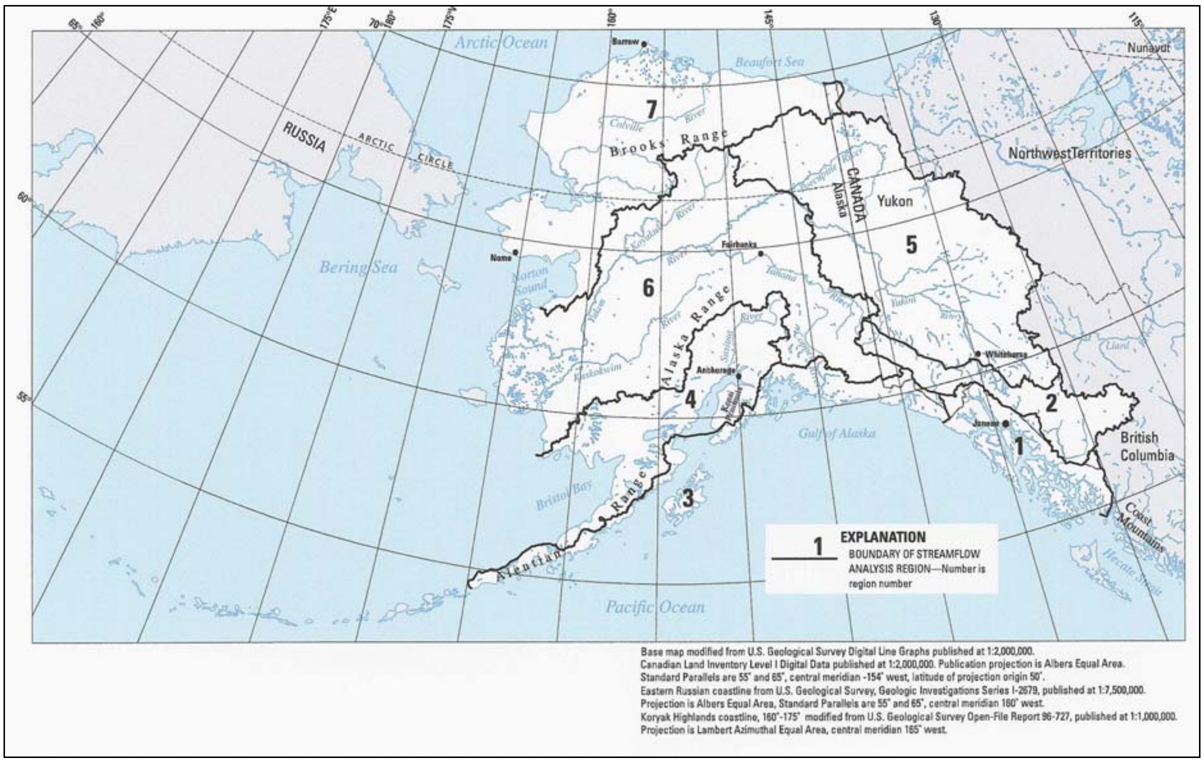

Figure 32: Map showing the Hydrologic Regions of Alaska

Per the cooperative agreement between the U.S. Geological Survey and the Department of Transportation and Public Facilities, the U.S. Geological Survey has updated the *"Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada, Water-Resources Investigations Report 93-4179,"* with *"Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada,* *Water-Resources Investigations Report 03-4188."* Because Water-Resources Investigation Report 03-4188 was published in October 2003, this report will provide an analysis using both methodologies described in reports 93-4179 and 03-4188.

8.3.1 Water-Resources Investigations Report 93-4179

In order to determine the Recurrence Interval for the 1995 flood event, we looked at several local gaged streams. Using this information, a Log Pearson Type III analysis was completed and comparison between these gages and the regression equations developed in WRIR 93-4179 were done in accordance with the methodologies prescribed in *"Guidelines for Determining Flood Flow Frequency, Bulletin 17B, Interagency Advisory Committee on Water Data, U.S. Geological Survey."*

8.4 Basin Characteristics

The Resurrection River flows in a southeasterly direction into the north end of Resurrection Bay.

Table 4: Basin Characteristics at Nearby Gage Stations

Description	Resurrection River at Seward Airport	Lost Creek near Seward	Spruce Creek near Seward
Gage #	15237700	15238000	1523600
Latitude	60°08'24"	60°12'00"	60°04'12"
Longitude	149°25'12"	149°22'12"	149°27'00"
Years of Record	1965-67, 1987	1949, 1963-76, 1987	1966-92
Drainage Area (square miles)	169.00	7.96	9.26
Mean Channel Slope	0.73%	4.66%	9.60%
Stream Length (miles)	23.50	8.10	5.50
Elevation (feet)	2,270	2,210	1,990
Storage (square miles)	0.00	0.56	0.00
Lake Storage (square miles)	0.00	0.56	0.00
Forest (square miles)	41.70	3.18	2.04
Glacier (square miles)	37.18	0.00	0.74
Precipitation, mean annual (inches)	100	100	120
Intensity, 24 hour 2 year (inches)	4	5	5
Snow, mean annual (inches)	180	150	100
Temperature, mean minimum January (°F)	12	12	12
Flood of Record (mm/dd/yy, cfs)	10/11/86, 19,000	1970, 619	10/11/86, 5,630

8.5 Resurrection River Gaging Records

The October 1986 peak discharges from small basins near Seward were the largest recorded since crest-stage stations were established in 1963. Comparison of the 1986 peak discharges with previous maximums shows that this flood had the largest unit runoff rates in the maritime area of South-Central Alaska.

The U.S. Geological Survey, Water Resources Branch, maintained a gaging station directly upstream from the Seward Highway crossing of the Resurrection River. The gaging station was installed after the Good Friday Earthquake in an effort to assist in evaluating peak flows on the Resurrection River. Because the hydraulic cross-section is extremely unstable at this location, the U.S. Geological Survey ceased maintaining at the close of the 1967 water year. We also have a miscellaneous discharge taken during the 1986 flood. Based on interviews of local residents, this was the highest peak since 1967.

8.6 Log Pearson Type III Analysis for Resurrection River

Using this information, we used this information in our Log Pearson Type III analysis.

Table 5: Log Pearson Type III Analysis for the Resurrection River

Year	Discharge (cfs)
1965	6,660
1966	18,900

Year	Discharge (cfs)
1967	18,000
1987	19,000

Exceedance Record	Recurrence Interval (yr)	WRC Estimate (cfs)	Systematic Record (cfs)	Expected Probability (cfs)	95% Confidence Lower (cfs)	95% Confidence Upper (cfs)
0.995	1.005025126		1,584			
0.99	1.01010101		2,259			
0.95	1.052631579		5,158			
0.9	1.111111111		7,362			
0.8	1.25		10,510			
0.5	2	18,240	16,860	18,240	17,250	19,210
0.2	5	19,030	21,500	19,290	18,290	21,140
0.1	10	19,480	22,870	20,100	18,680	22,560
0.04	25	20,010	23,660	21,480	19,060	24,340
0.02	50	20,360	23,920		19,300	25,640
0.01	100	20,700	24,050		19,510	26,920
0.005	200	21,020	24,120		19,710	28,180
0.002	500	21,430	24,160		19,960	29,850

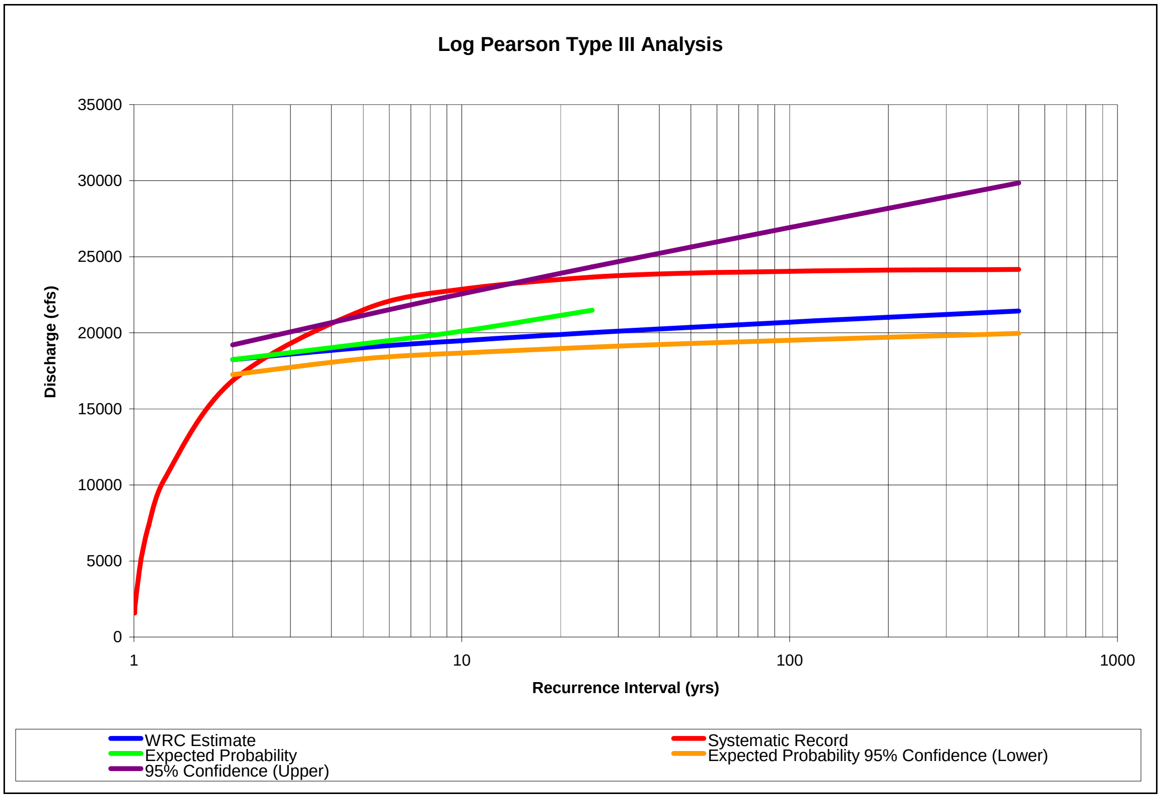

Figure 33: Log Pearson Type III Analysis for the Resurrection River at Seward.

8.7 Hydrology for Resurrection River

8.7.1 Water-Resources Investigations Report 03-4188

We can use this information to evaluate the degree of risk of the runway being overtopped as well as a reasonable estimate of the Design Flood Elevation using the hydraulic information collected during the 1995 flood event.

Given:

Da	=	169	Drainage area (square miles)
St	=	0.0	Storage area (square miles)
Pr	=	100	Mean annual precipitation (inches)
Te	=	12°	Mean annual January minimum temperature (F°)

Equations:

$$Q_2 := 0.004119 \cdot Da^{0.8361} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3590} \cdot Pr^{0.9110} \cdot (Te + 32)^{1.635}$$

$$Q_5 := 0.009024 \cdot Da^{0.8322} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3670} \cdot Pr^{0.8128} \cdot (Te + 32)^{1.640}$$

$$Q_{10} := 0.01450 \cdot Da^{0.8306} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3691} \cdot Pr^{0.7655} \cdot (Te + 32)^{1.622}$$

$$Q_{25} := 0.02522 \cdot Da^{0.8292} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3697} \cdot Pr^{0.7165} \cdot (Te + 32)^{1.588}$$

$$Q_{50} := 0.03711 \cdot Da^{0.8286} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3693} \cdot Pr^{0.6847} \cdot (Te + 32)^{1.559}$$

$$Q_{100} := 0.05364 \cdot Da^{0.8281} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3683} \cdot Pr^{0.6556} \cdot (Te + 32)^{1.527}$$

$$Q_{200} := 0.07658 \cdot Da^{0.8276} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3669} \cdot Pr^{0.6284} \cdot (Te + 32)^{1.495}$$

$$Q_{500} := 0.1209 \cdot Da^{0.8272} \cdot \left[\left(\frac{St}{Da} \cdot 100 \right) + 1 \right]^{-0.3646} \cdot Pr^{0.5948} \cdot (Te + 32)^{1.449}$$

Equation 1: Regression Equation for the Resurrection River at Seward Airport

Therefore:

Table 6: Regression Analysis for Resurrection River at Seward

Q_2 = 9,696 cfs	Q_5 = 13,499 cfs	Q_{10} = 16,163 cfs
Q_{25} = 19,584 cfs	Q_{50} = 22,236 cfs	Q_{100} = 24,840 cfs
Q_{200} = 27,649 cfs	Q_{500} = 31354 cfs	

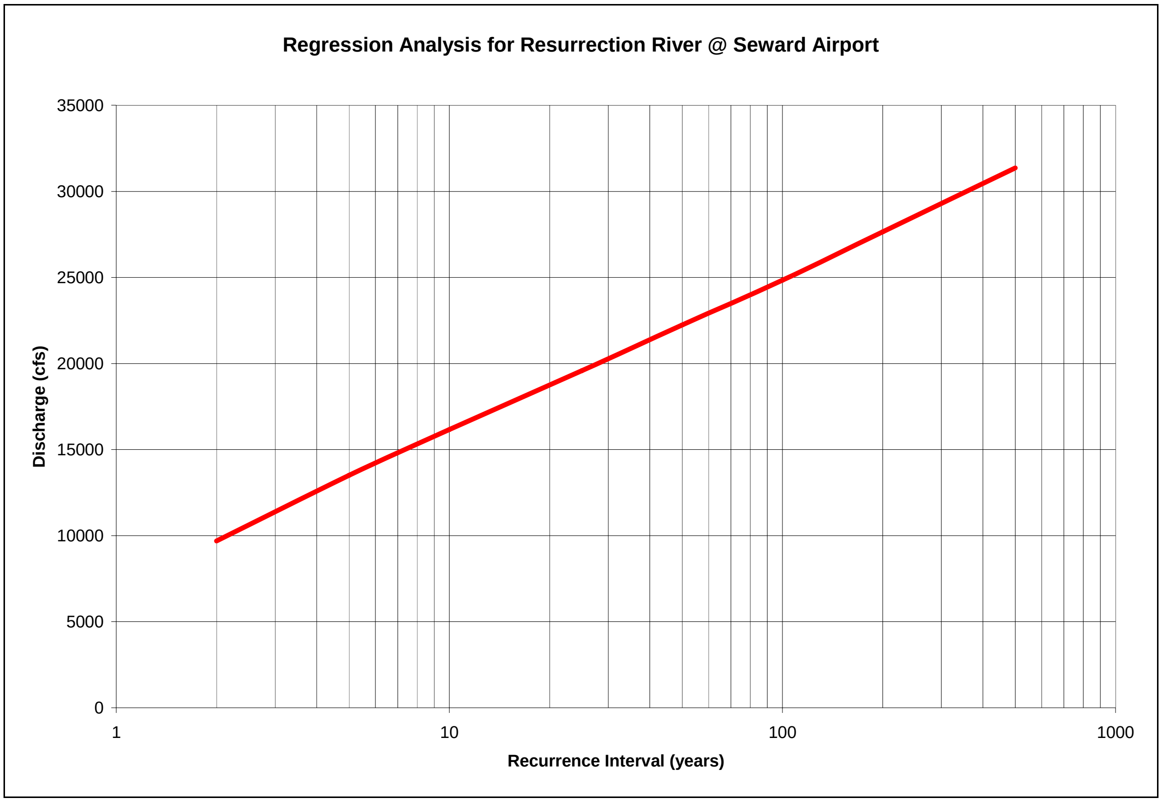

Figure 34: Regression Analysis for Resurrection River at Seward Airport.

In an effort to determine the recommended Recurrence Interval (Exceedance Probability) that should be used, a data search was done to look at what other agencies have recommended.

8.7.2 Regression Analysis

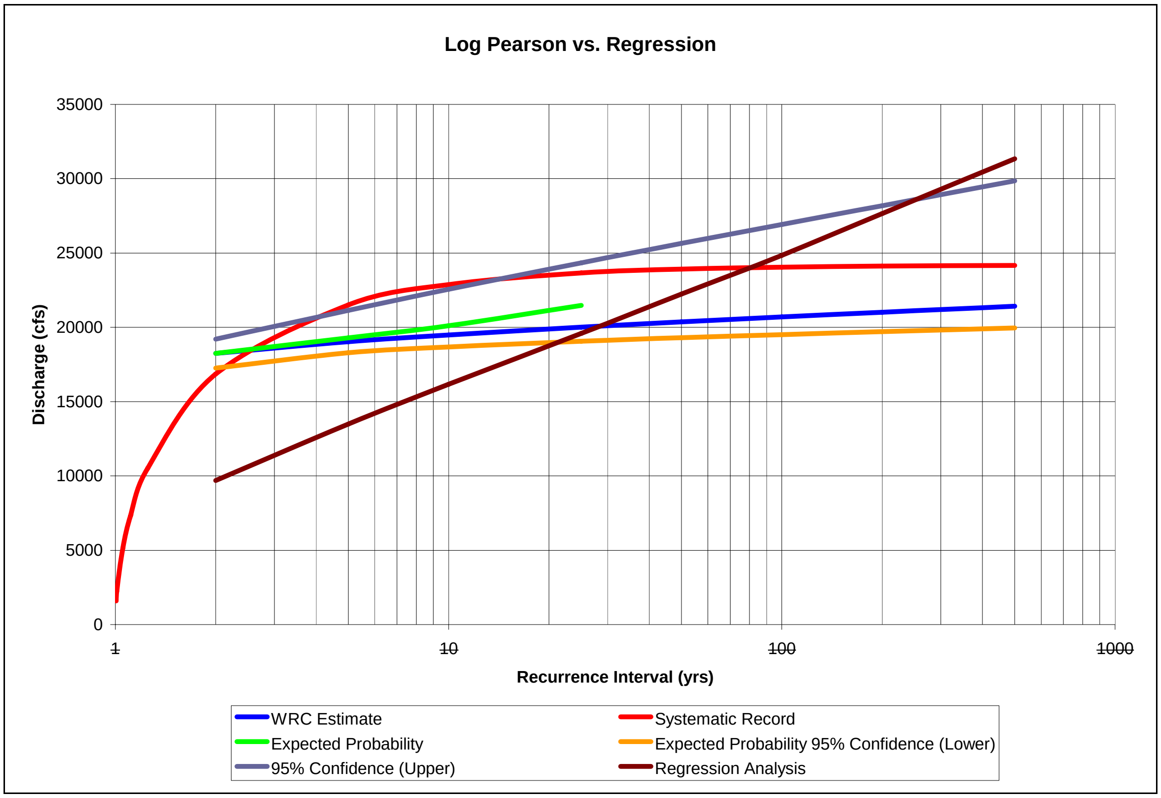

Figure 35: Comparison between Log Pearson Type III and Regression Analysis

Therefore, for the purposes of this report, the following Regression Analysis was used to determine the Design High Water (DHW) elevations for the Q_{25}, Q_{50}, and Q_{100}.

Q_{25} = 19,584 cfs	Q_{50} = 22,236 cfs	Q_{100} = 24,840 cfs

Figure 36: Aerial photograph taken after the October 1995 flood event.

Figure 36 shows the Resurrection River has established a new channel alongside the embankment of the Seward Airport abandoning its traditional channel. In fact, there was no flow in the old traditional channel at the time this aerial photograph was taken. After the 1986 flood event, using construction equipment, the Department of Transportation and Public Facilities moved in excess of 350,000 cubic yards of material to reestablish 75 percent of the Resurrection River's flow to its traditional channel. As a condition of the Title 16 Department of Fish and Game habitat permit, 25 percent of the flow remained in the newly established channel along the Seward Airport's east embankment.

A field inspection of the Resurrection River during the fall of 2002 reveals that during low flow events, 100 percent of the Resurrection River is flowing in the 1995 new channel which flows along the Seward Airport runway embankment.

Therefore, it is reasonable to assume that for the foreseeable future, the Resurrection River will remain in the current channel. It is important therefore, that any airport improvements are designed with that in mind.

8.8 U.S. Army Corps of Engineers (1976) National Flood Insurance Program Map

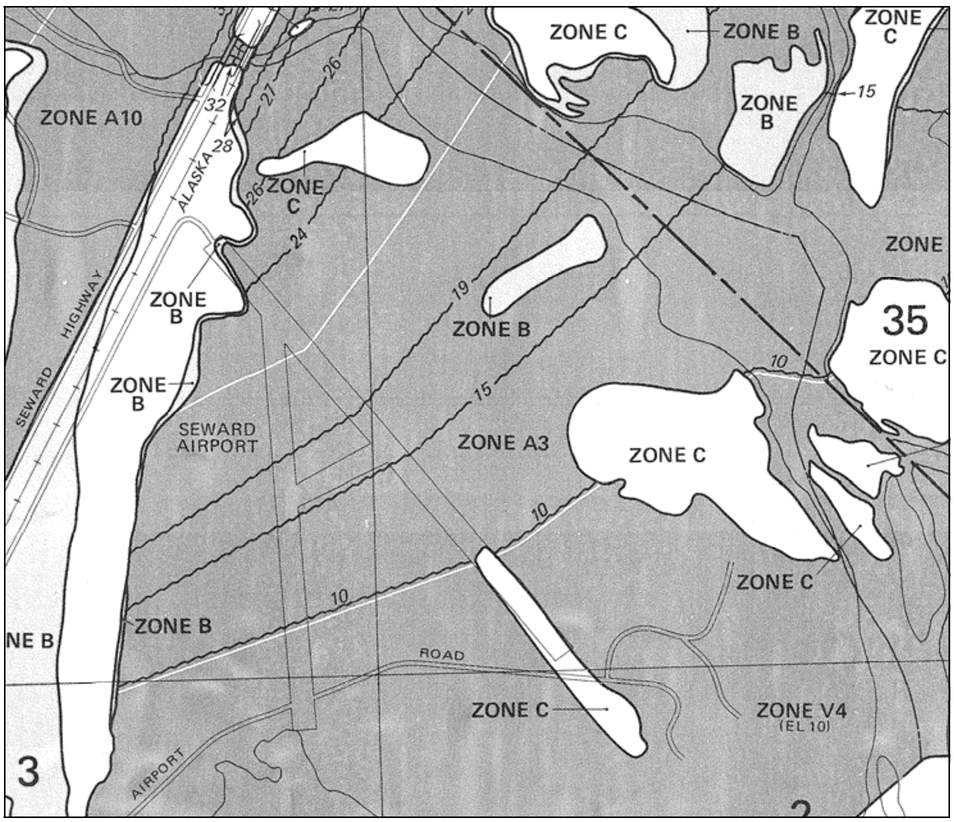

Figure 37: Flood Insurance Map showing the relationships between the Seward Airport and the Resurrection River's Flood elevation.

Figure 37 is a copy of the most current Flood Insurance Map of the area where the Seward Airport is located. It should be noted that most of the existing airport's runway system is below the regulated flood elevation. Using this information together with information collected from the 1986 and 1995 flood events, it is reasonable to recommend at this time that the minimum centerline elevation of the Seward Airport runways be 24 feet. It should be noted that the DATUM used in the Flood Insurance Rate Map (FIRM) is not the same as was used in this report. See Table 7 for recommended runway centerline elevations. The 1976 floodplain study did not take into account a major tidal event or wind driven tides. Both of these factors were considered in this report.

9.0 FLOOD INUNDATION MAP

The purpose of this section is to be used to evaluate the effect of a Q_{25} (25 year) flood event on the Seward Airport, and to develop a preliminary design recommendation for Runway 12-30. The inundation map generated for this report is to be used only for the purpose of preliminary design recommendations for Alternative No. 1 (no build), and Alternative No. 2 (elevate Runway 12-30 to prevent the risk of flooding for a Q_{25} flood event). The maps are not intended to be used as a regulatory flood-plain map.

Aerial photography from 1950 to 2005 was used to document historical changes in the Resurrection River's traditional channel geometry in the Resurrection River Delta.

Prior to 1986, the traditional natural channels of the Resurrection River have been to the eastern side (Nash Road side) of the Resurrection River Delta. After the 1986 flood event, approximately 20 percent of the total normal flow of the Resurrection River flowed to the west (airport side) of the delta.

Normally, computing floodwater elevations and flood inundation is done using numerical models such as the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) or Finite Element Surface Water Modeling System (FESWMS) computer-generated models. These models are considered the standard method.

Due to field conditions unique to the Resurrection River Delta, it was determined that the U.S. Army Corps of Engineers HEC-RAS numerical model had significant problems in balancing, causing unacceptable errors in its computations. These errors were caused by some of the following reasons:

- Delta Aggradation. Aggradation is the general and progressive buildup of the longitudinal profile of channels by deposition of sediment. This is well documented in the Resurrection River Delta.

- Alluvial Channels. Channels wholly in alluvium, no bedrock exposed in channel at low flow or likely to be exposed by erosion during major flow.

- Alluvium. Unconsolidated silt, sand, or gravel deposited by the Resurrection River in the channels of the Resurrection River Delta.

- Anabranched River/Braided River. An anabranched river is whose flow is divided at normal and lower stages by large islands. The width of individual islands or bars is greater than three times the normal or low flow water width. This is true in the southern portion of the Resurrection River Delta. A braided river is a river whose surface is divided at normal stage by small mid-channel bars or small islands. The individual width of bars and islands is less than three times the water width. A braided stream has the aspect of a single channel within which are subordinate channels. This is true in the northern portion of the Resurrection River Delta just downstream of the Seward Highway.

- Avulsion. Sudden changes in the course of channels. Documented movement of high and low flow to the west of the Resurrection River Delta.

- Backwater. Increase of water-surface profile, because of extreme tidal conditions in the Resurrection River.

- Highly erodible banks.

- Old or abandoned channels not permanently vegetated.

- High amounts of bed load. Documented of sediment that is transported in the Resurrection River moving along the bed of active channels within the bed layer.

- Bed Material. Documented sediment of particle size large enough to be found in appreciable quantities at the surface of the streambed.

In 1999 after Hurricane Floyd hit North Carolina, Federal Emergency Management Agency (FEMA) found that many of the flood inundation maps and National Flood Insurance Program’s maps did not accurately represent the actual conditions even though the maps had been updated less than five years prior to the hurricane. FEMA began to look at potential methods that could be used to update existing inundation maps with new data obtained by satellite imagery and newer ways of representing ground conditions such as Light Detection and Ranging systems. After Hurricane Katrina, FEMA used this technology to assist in making preliminary flood inundation maps.

For all of the above reasons the decision was made to use the methodology used by FEMA to evaluate their National Flood Insurance Program Maps after Hurricane Floyd and which were used as part of the updating process after Hurricane Katrina in Mississippi.

The following data was used to draft the preliminary flood inundation map for this report.

- Updated aerial photography of the Resurrection River Delta (September 21, 2004).
- Light Detection and Ranging System technology used to generate a two-foot contour map of the Resurrection River Delta.
- Documented water-surface elevations taken in 1984, 1985, 1986, 1993, and 1995.
- Flood flows taken in 1984, 1985, 1986, 1993, and 1995.
- Flood inundations maps drafted by U.S. Geological Survey, Water Resources Branch, and Department of Transportation and Public Facilities during the major floods of 1984 and 1995.
- High-water marks taken from vegetation such as trees and brush in the Resurrection River Delta.
- Comparison of aerial photography taken in 1952, 1983, 1985, 1986, 1991, 1995, and 2004.
- Flood Reports referenced in this report written by:
  - U.S. Geological Survey, Water Resources Branch
  - U.S. Army Corps of Engineers, Alaska Region

  - Department of Transportation and Public Facilities, Bridge Section
  - Department of Transportation and Public Facilities, Central Region

- Interview with the Department of Transportation and Public Facilities, Maintenance and Operations personnel.
- Hydrology files from the Department of Transportation and Public Facilities, Central Region.

Using this information, we were able to draft a hydraulic slope using actual water-surface elevations. Once this was accomplished, a stage discharge curve was created using standard U.S. Geological Survey methodology using conveyance calculations for the open channels. It was assumed that there was no flow in vegetated areas for the Q_{25}, Q_{50}, and Q_{100} (25, 50, and 100-year flood).

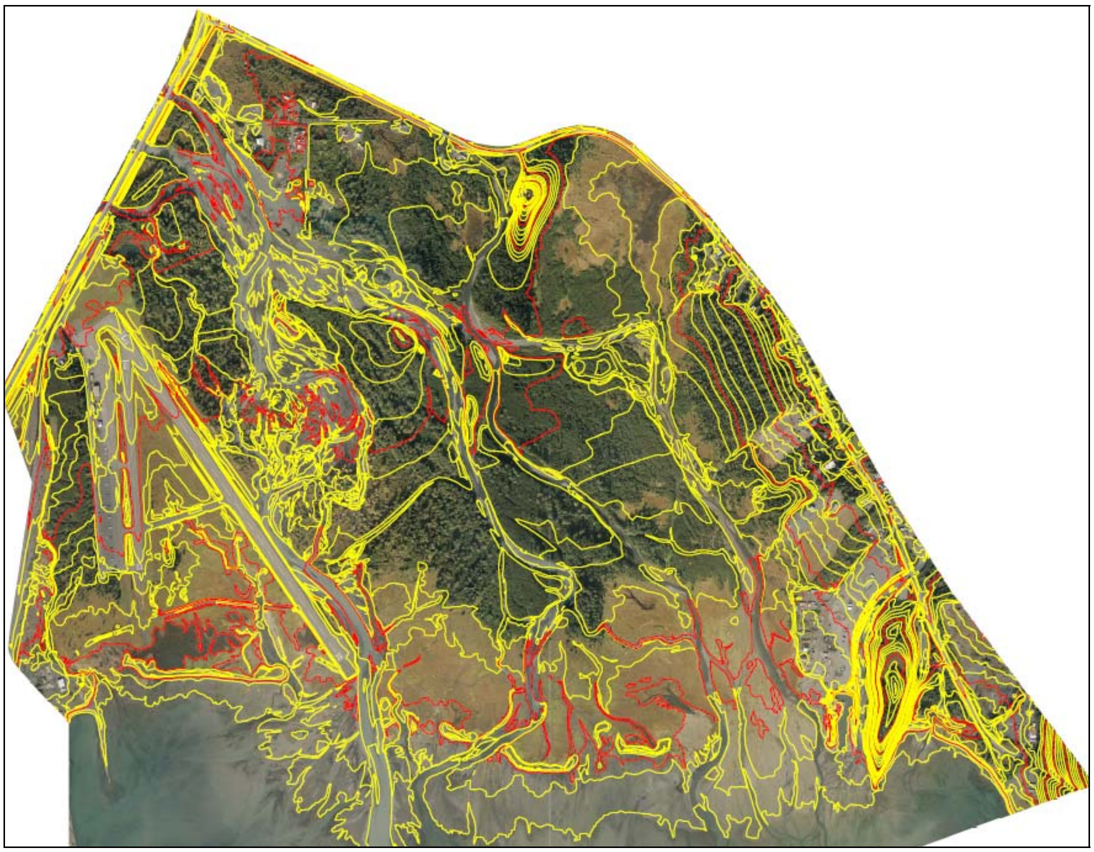

Figure 38: Aerial photograph with contours using Light Detection and Ranging System Data.

Figure 38 shows the computer-generated contours using the Light Detection and Ranging System data. Hydraulic cross-sections were generated for use in creating a HEC-RAS numerical model. Because of the physical limitations with HEC-RAS, it was found that this numerical model would not reliably provide projected DHW elevations for the Q_{25}, Q_{50}, and Q_{100}.

Figure 39: Aerial Photograph of Resurrection River Delta showing the location of hydraulic cross-sections.

Figure 39 shows the location of hydraulic cross-sections generated for the initial HEC-RAS evaluation. Although the HEC-RAS model was not used in this analysis, the cross-sections were used in the calculation of the conveyance for the stage discharge curves in Figure 41.

9.1 Stage Discharge Computations

Figure 40: Seward Airport Runway

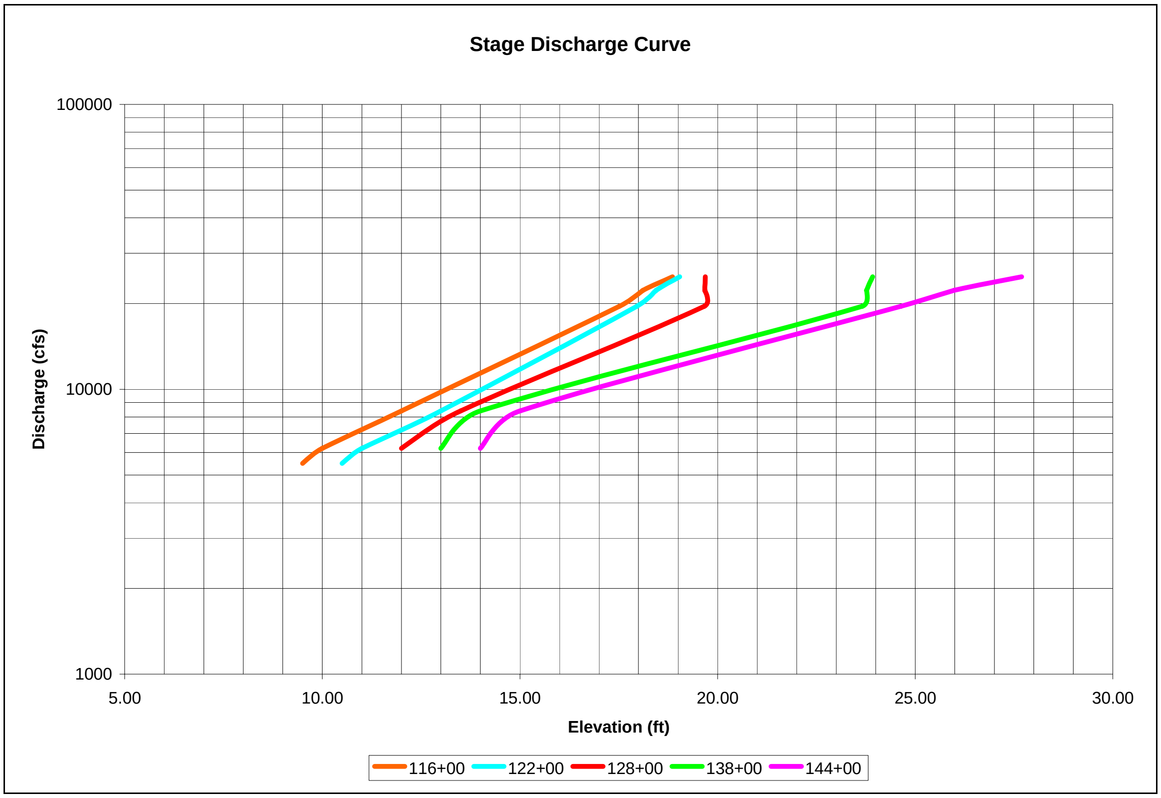

Figure 41: Stage Discharge Curve

Figure 41 is a graphical representation of the Stage Discharge Curve at Stations 116+00, 122+00, 128+00, 138+00, and 144+00. In order to construct the stage discharge curve, it was necessary to take known discharge information at the Seward Highway and at the same time document the water surface elevation at Stations 116+00, 122+00, 128+00, 138+00, and 144+00. It was assumed that the discharge at the Seward Highway remained static through the reach.

It should be noted that the stage discharge curve tends to make a radical upward climb for the Q_{100} for the stage discharge curves for Stations 128+00 and 138+00. It is believed the reason for this is the elevations where the channels to the east (Nash Road side of the delta) begin to carry a significant percentage of the design flood.

Based on known high-water marks during the 1965, 1966, 1987, and 1995 floods, stage discharge curves were generated using estimated flood flows for each of these events. These stage discharge curves were supplemented with actual lower flow events taken in 1986, 1995, 1996, and 1997 by the U.S. Geological Survey and the Department of Transportation and Public Facilities personnel.

Using the stage discharge curves, water-surface profiles were generated a along the eastern shoulder of the Seward Airport Runway 12-30.

Using the information generated, it became evident that the current runways would be overtopped during a Q_{25} (25 year) flood event. Therefore, two alternatives were created. Alternative No. 1 in this report is NO BUILD, and Alternative No. 2 is to raise the Runway 12-30 shoulder to an elevation above the Q_{25} (25-year flood event).

The methodology for determining the recommended proposed shoulder elevation is discussed later in this report.

9.2 Hydraulic Gradeline for Q_{25}, Q_{50}, Q_{100}, and Alternative No. 2

Table 7: Water-surface Profile Q_{25}, Q_{50}, and Q_{100}

Station (ft)	Q_{25} (ft)	Q_{50} (ft)	Q_{100} (ft)	Alternative No. 2 elevation (ft)
98+00	17.50	17.50	17.50	18.70
99+00	17.50	17.50	17.55	18.70
100+00	17.50	17.50	17.64	18.70
101+00	17.50	17.50	17.73	18.90
102+00	17.50	17.50	17.82	18.90
103+00	17.50	17.53	17.91	18.90
104+00	17.50	17.59	18.00	18.90
105+00	17.50	17.65	18.09	18.90
106+00	17.50	17.71	18.18	19.00
107+00	17.50	17.77	18.27	19.00
108+00	17.50	17.83	18.36	19.10
109+00	17.50	17.89	18.45	19.10
110+00	17.50	17.95	18.54	19.10
111+00	17.52	18.01	18.63	19.00
112+00	17.56	18.07	18.72	19.10
113+00	17.60	18.13	18.80	19.20
114+00	17.64	18.15	18.81	19.20
115+00	17.68	18.21	18.90	19.30
116+00	17.52	18.11	18.86	19.30

Station (ft)	Q_{25} (ft)	Q_{50} (ft)	Q_{100} (ft)	Alternative No. 2 elevation (ft)
117+00	17.76	18.27	18.92	19.30
118+00	17.50	18.06	18.78	19.30
119+00	17.84	18.32	18.94	19.30
120+00	17.88	18.35	18.95	19.30
121+00	17.92	18.38	18.96	19.30
122+00	17.96	18.44	19.04	19.40
123+00	18.00	18.46	19.05	19.40
124+00	18.30	18.66	19.13	19.40
125+00	18.65	18.93	19.29	19.87
126+00	18.99	19.13	19.30	20.34
127+00	19.33	19.39	19.46	20.81
128+00	19.67	19.68	19.69	21.28
129+00	20.01	20.02	20.03	21.75
130+00	20.35	20.36	20.38	22.22
131+00	20.69	20.70	20.72	22.69
132+00	21.05	21.70	21.72	23.16
133+00	21.65	21.69	21.71	23.63
134+00	22.25	22.37	22.39	24.10
135+00	22.86	22.89	22.91	24.57

Station (ft)	Q_{25} (ft)	Q_{50} (ft)	Q_{100} (ft)	Alternative No. 2 elevation (ft)
136+00	23.18	23.20	23.22	25.04
137+00	23.42	23.43	23.44	25.51
138+00	23.66	23.77	23.92	25.98
139+00	23.89	24.19	24.57	26.45
140+00	24.08	24.55	25.15	26.92

Station (ft)	Q_{25} (ft)	Q_{50} (ft)	Q_{100} (ft)	Alternative No. 2 elevation (ft)
141+00	24.22	24.91	25.78	27.39
142+00	24.36	25.26	26.42	27.86
143+00	24.50	25.66	27.13	28.33
144+00	24.64	25.98	27.69	28.80

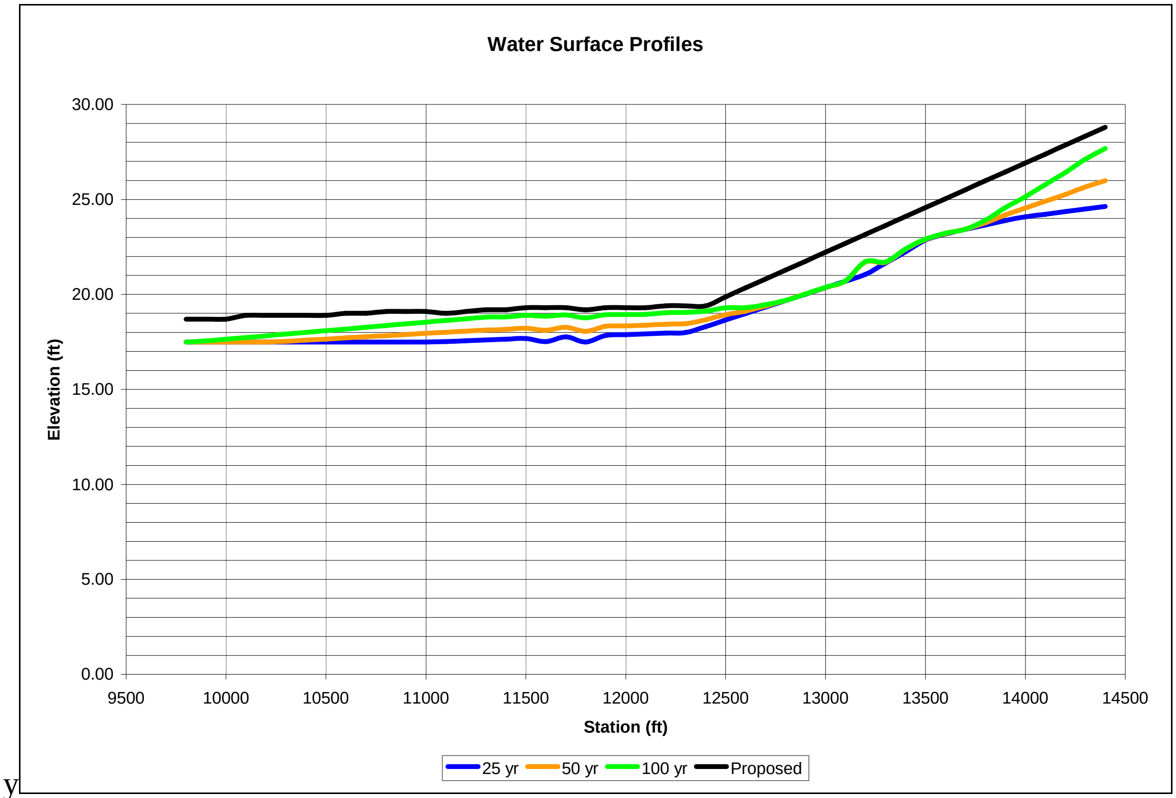

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Figure 42: Projected Water Surface for Q_{25}, Q_{50}, and Q_{100}

The water surface profiles represent conditions as of 2004 when field data was collected. Based on trends, it is reasonable to assume that these profiles will accurately predict the water surface within a plus or minus by one foot over the 25 year design life required for the design for the Seward Airport. It is reasonable to expect the Resurrection River will continue to move towards the west because the distance from the Seward Highway crossings over the Resurrection River is significantly shorter to tidewater, than the old traditional channels. It is also reasonable to assume that the deposition directly downstream from the Nash Road crossing over the Salmon River will continue to deposit a significant amount of material in the lower reaches of Eastern Resurrection Delta channels. This will mean that a higher percentage of the total flood flows will also migrate to the west, causing the channels to the west to become deeper and wider. This is in part because the Seward Airport's embankment has been hardened over the years.

Because of the large amount of woody debris that travels through the Resurrection River Delta, there is the distinct possibility that during a major flood event, the Resurrection River will re-establish itself in its traditional (eastern side of the delta) channels.

10.0 INUNDATION MAPS

Using the water surface profiles in Figure 42, an inundation map was created for the Q_{25} (25-year) flood event. Areas in red indicate that the area is flooded. This design event was requested by the Federal Aviation Administration as the design standard to be used for this report.

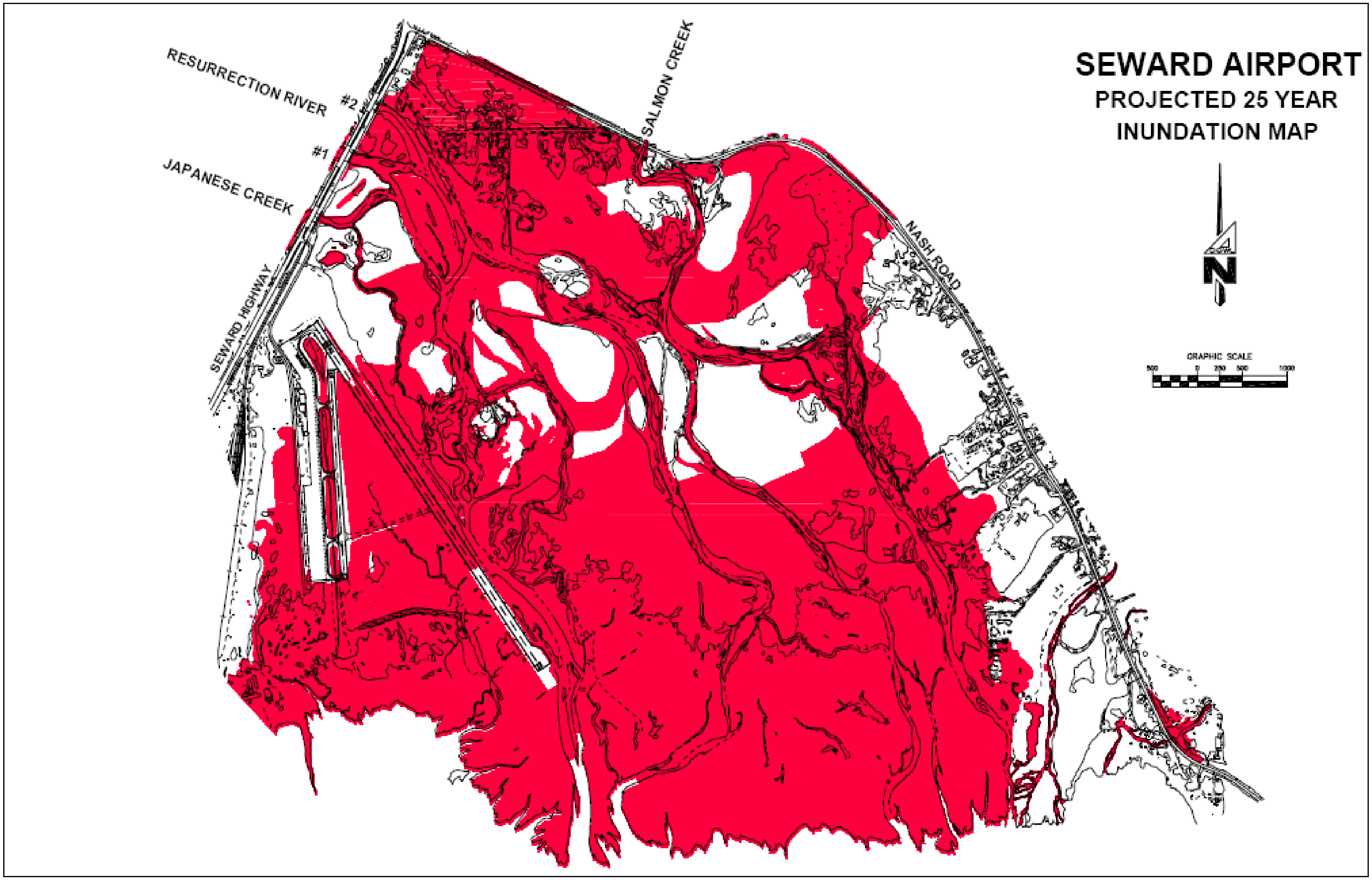


Figure 43: Alternative No. 1, Q_{25} Inundation Map under current conditions.

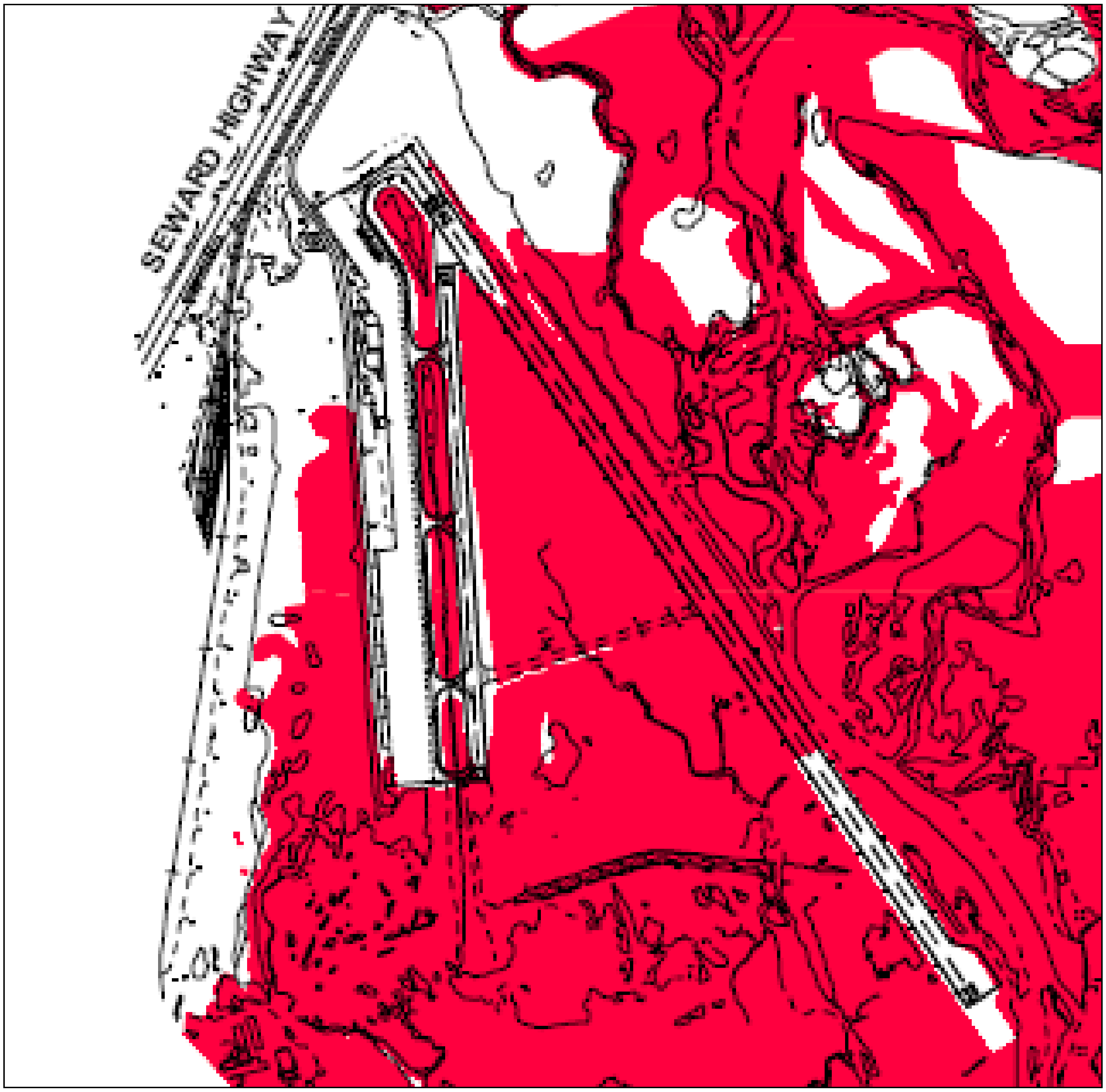


Figure 44: Alternative No. 1, Q_{25} Inundation Map under current conditions.

As can be seen in Alternative No. 1 (No Build), Runway 12-30 would be subjected to extensive flooding. Because of the overtopping there is an unacceptable risk of the Resurrection River cutting through the runway.

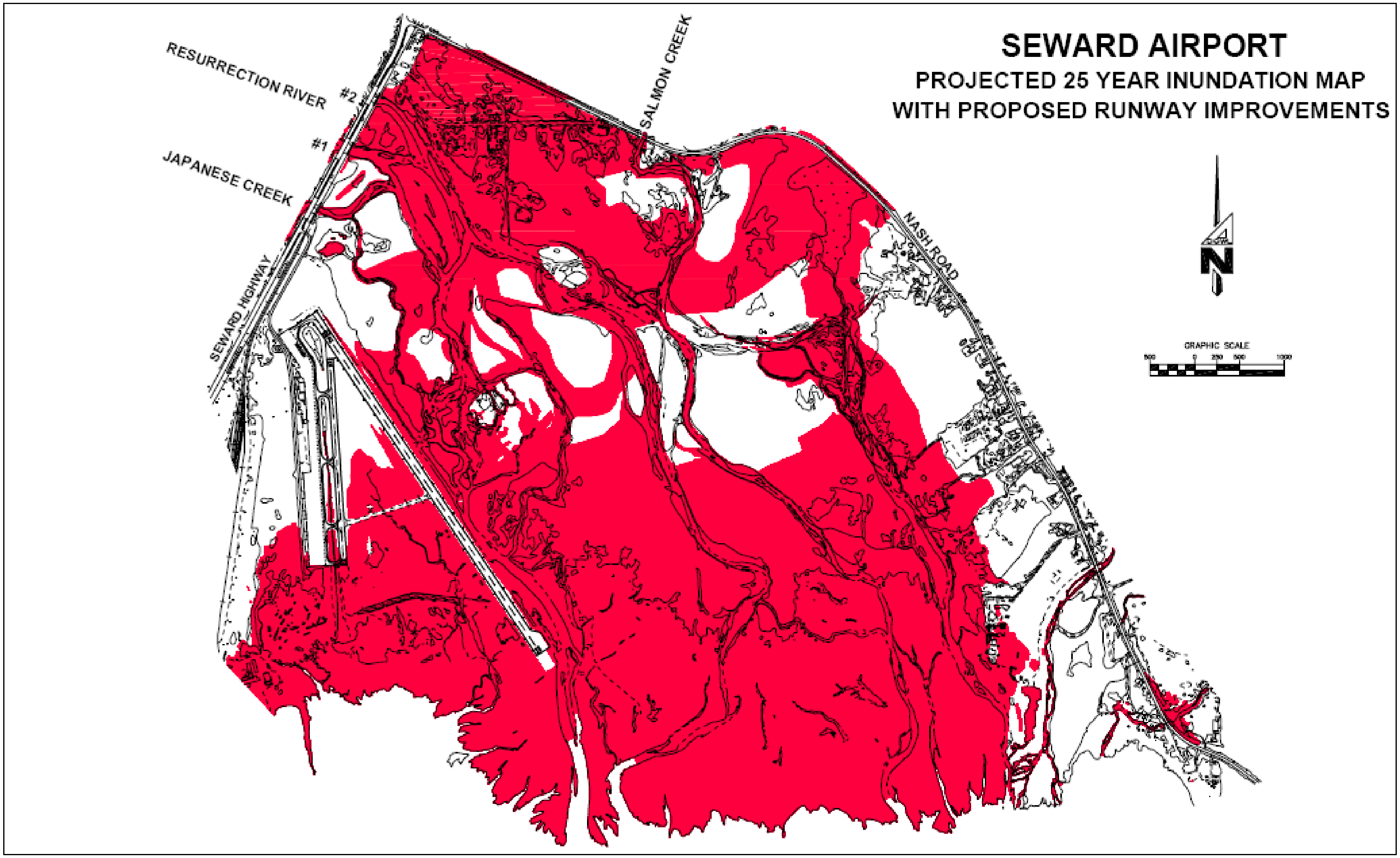


Figure 45: Alternative No. 2, Q_{25} Inundation Map if the Seward Airport is raised.

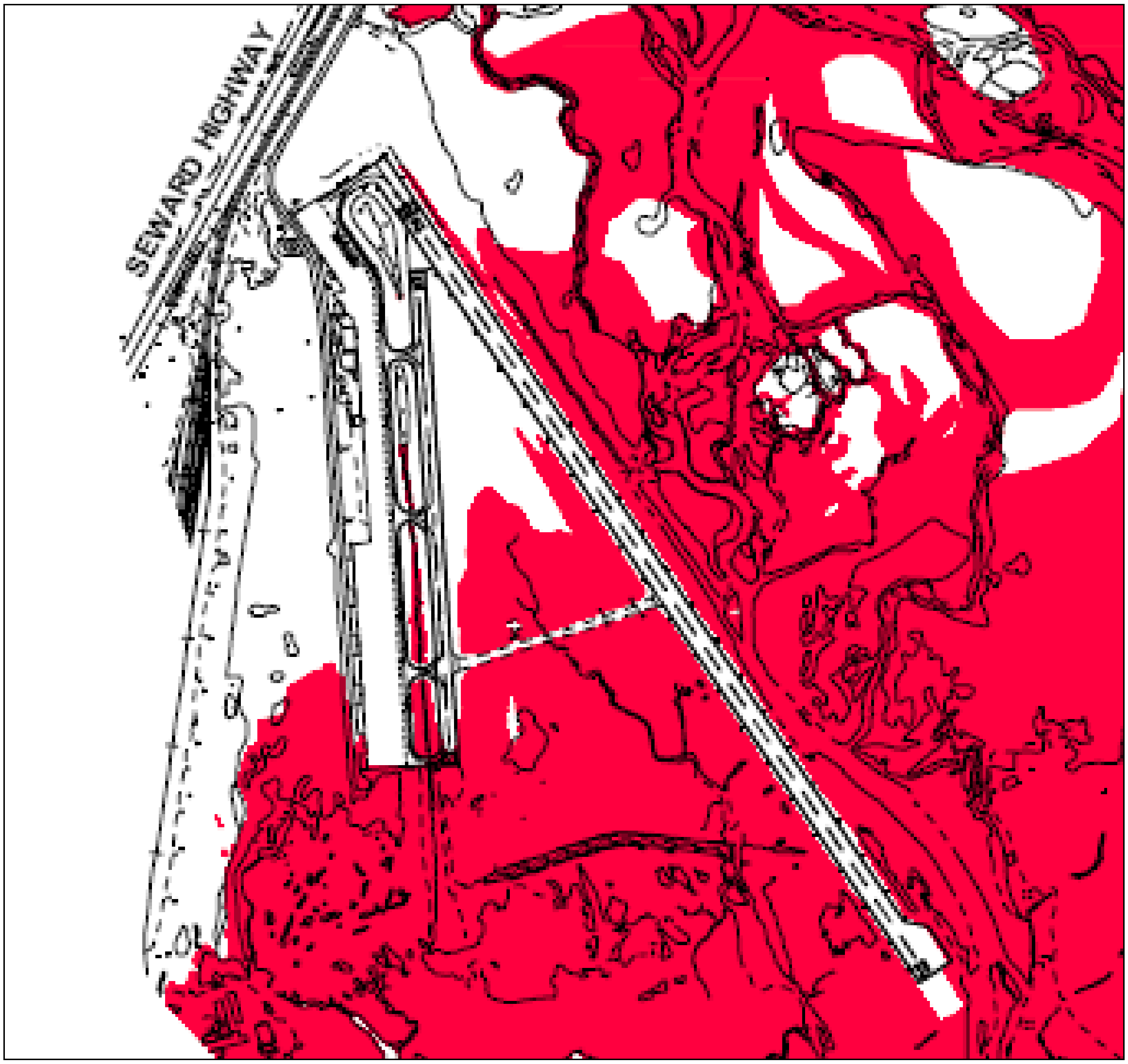


Figure 46: Alternative No. 2, Q_{25} Inundation Map if the Seward Airport is raised.

Figures 45 and 46 are a graphical representation of a Q_{25} flood inundation map showing the inundation if the Runway 12-30 shoulder is raised to an elevation shown in Table 7.

As can be seen in the graphic, the runway would not be inundated if raised as recommended.

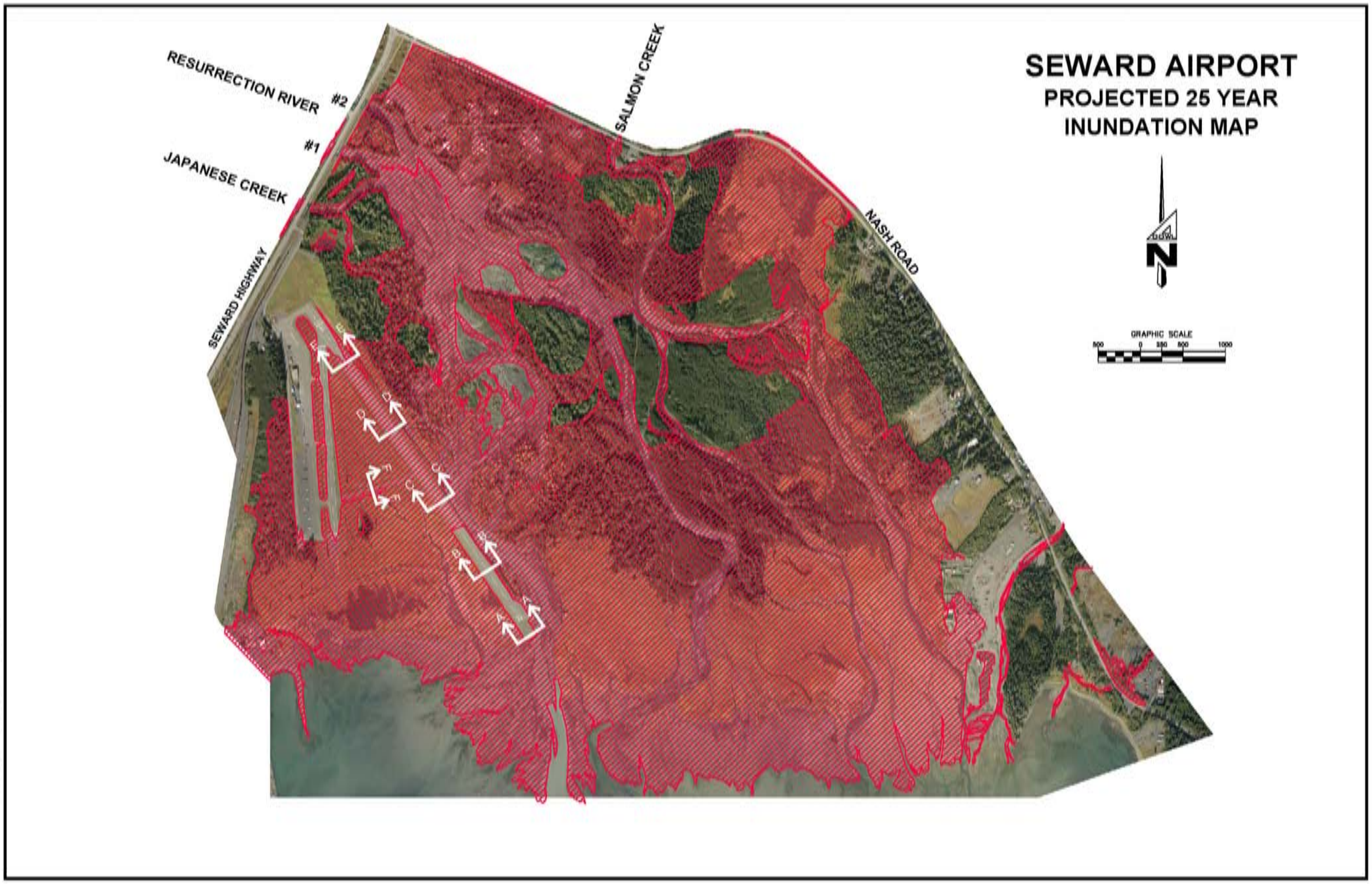


Figure 47: Alternative No. 1, aerial photograph showing inundation map.

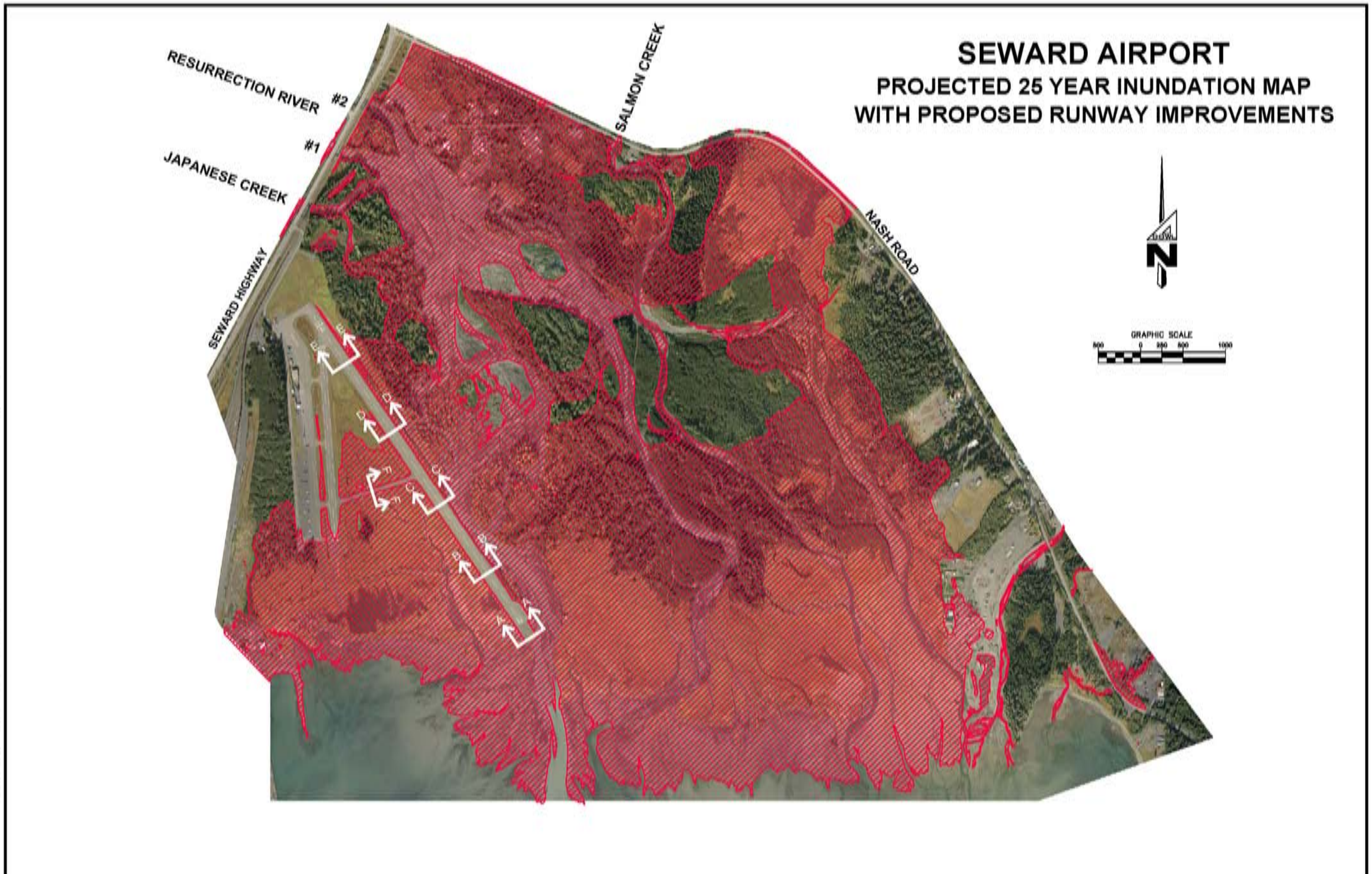


Figure 48: Alternative No. 2, aerial photograph showing inundation map.

11.0 TYPICAL SECTIONS FOR ALTERNATIVE NO. 2

Figures 49, 50, 51, 52, and 53 are typical sections showing a graphical representation required fill for Alternative No. 2 in below total fill required in Alternative No. 2 and fill below Ordinary High Water. The location of these sections is shown on Figures 47 and 48.

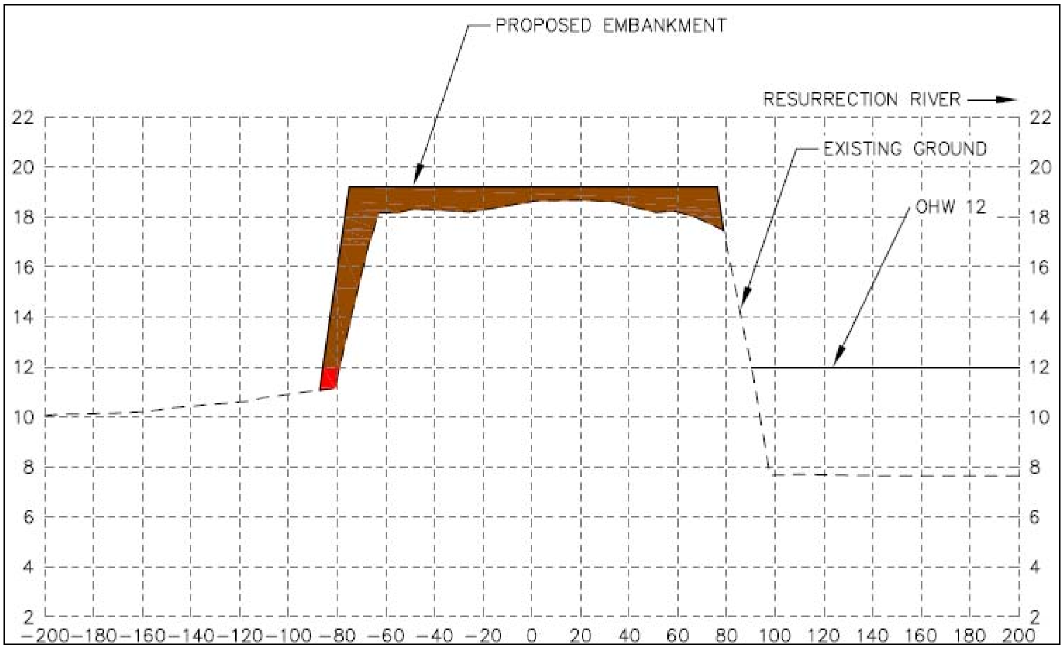


Figure 49: Alternative No. 2 Typical Section A-A.

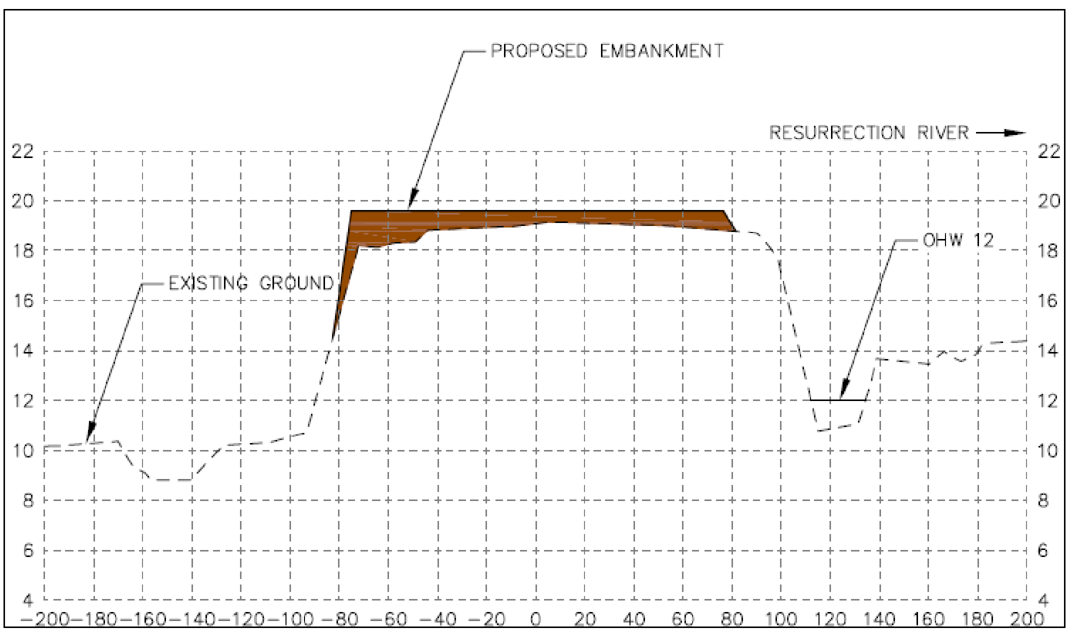


Figure 50: Alternative No. 2 Typical Section B-B.

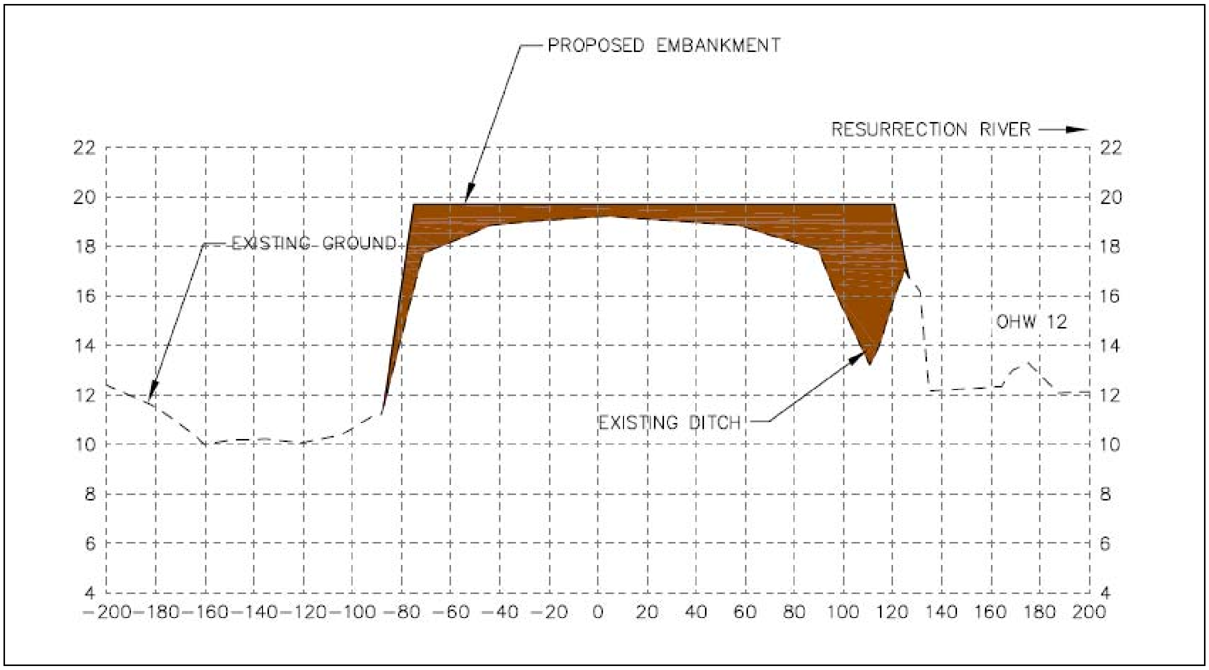


Figure 51: Alternative No. 2 Typical Section C-C.

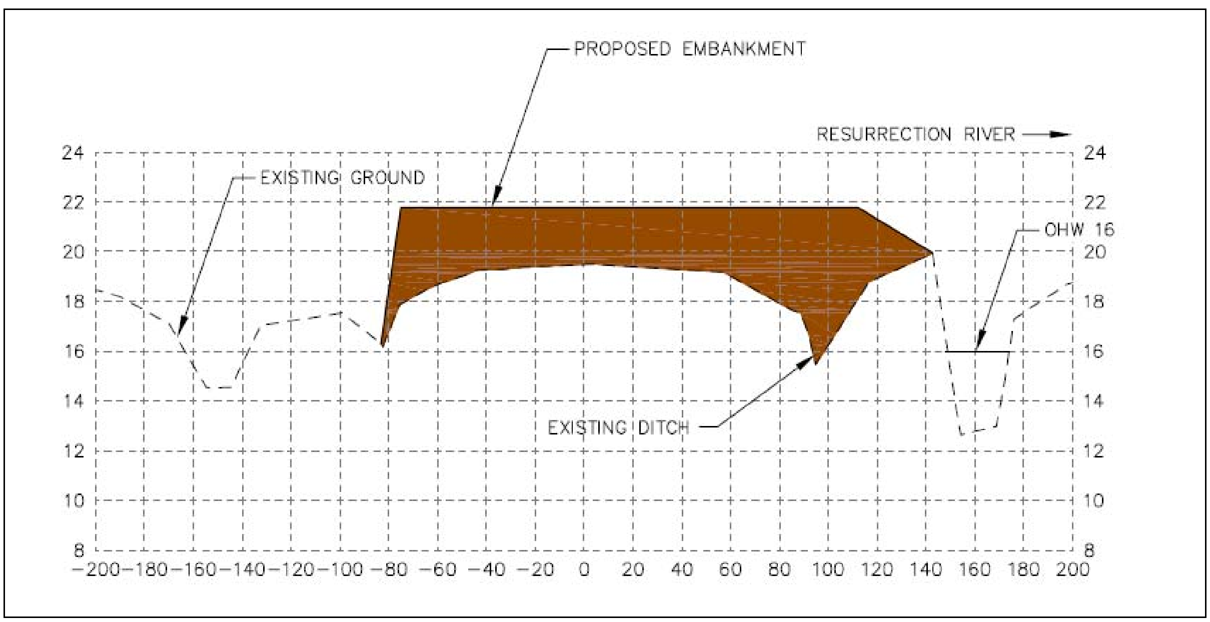


Figure 52: Alternative No. 2 Typical Section D-D.

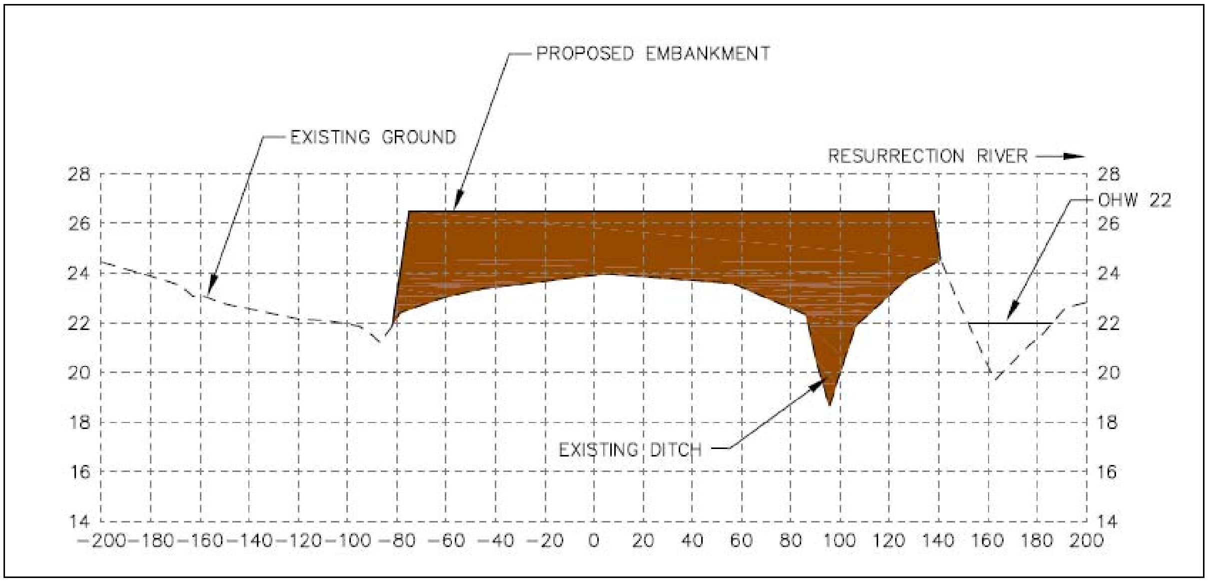


Figure 53: Alternative No. 2 Typical Section E-E.

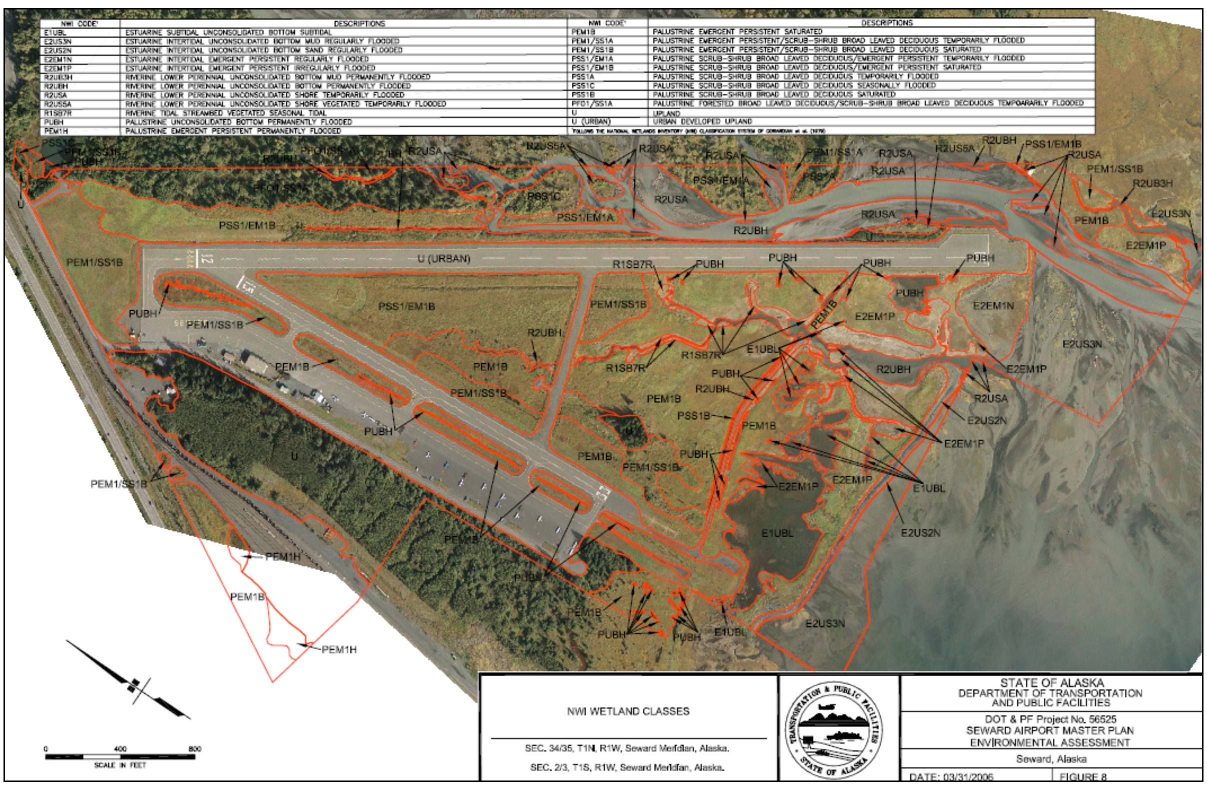


Figure 54: Wetlands Classification

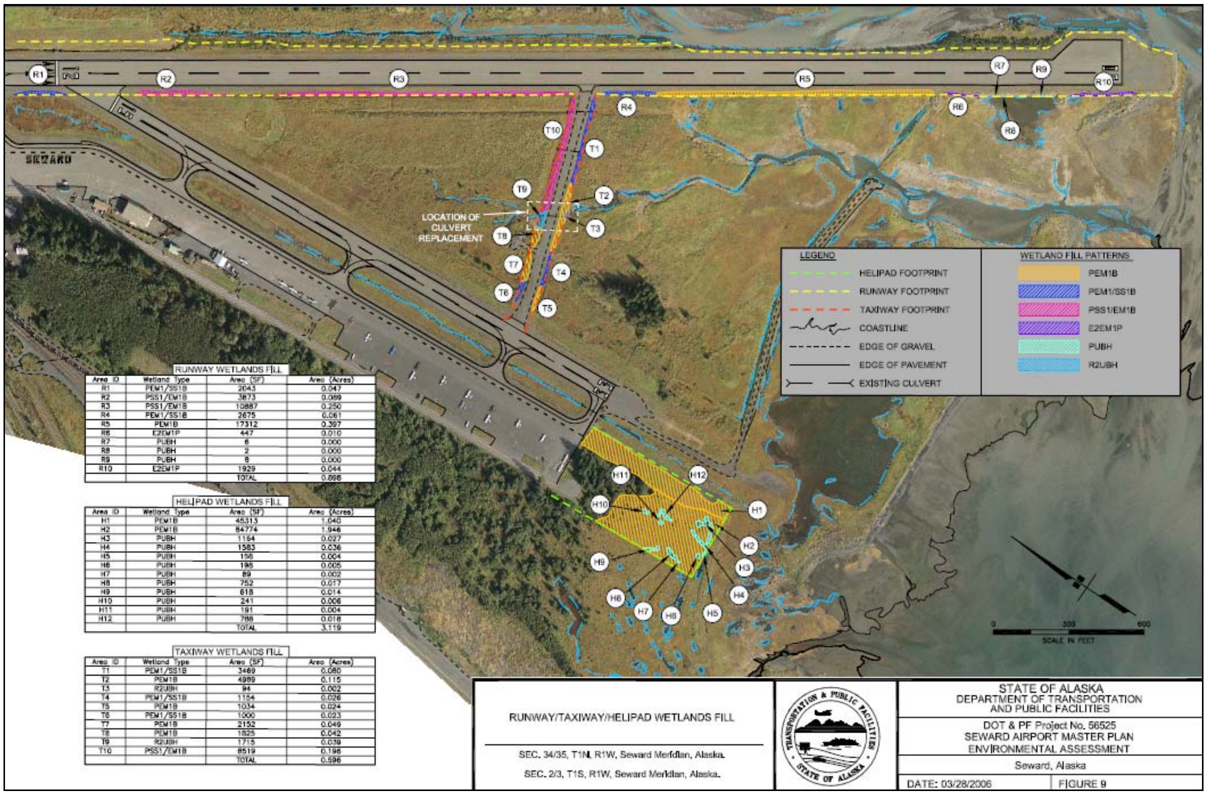


Figure 55: Graphical representation showing the inundation of fill in wetlands for Alternative No. 2.

12.0 EMBANKMENT PROTECTION

Based on observations during the 1995 flood event, a preliminary design recommendation has been drafted for the purposes of this report for the protection of the runway embankment. As stated previously, the estimated velocity during the 1995 flood event was 12+/- fps. Using this information, the following preliminary design recommendations for the purposes of estimating the costs for the various alternatives are:

Determine Minimum Stone Weight for impinging flow:

$V := 12.0$ Velocity for impinging flow in (fps)

$SGR := 2.65$ Specific gravity of riprap

$r := 70 \cdot deg$ ° (for randomly placed rubble, a constant)

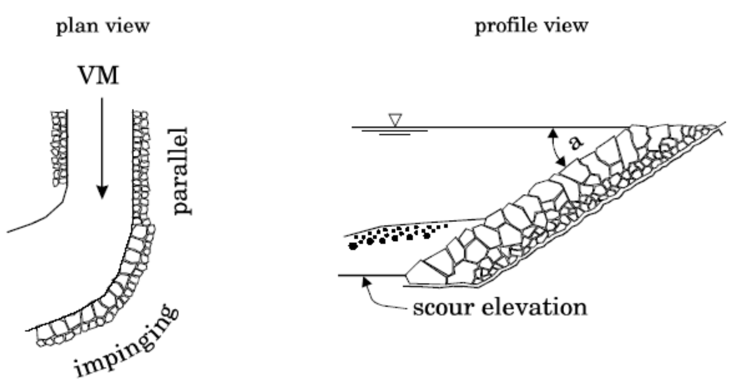
$S := 1.5$ Cross slope (e.g.. 2 to 1)

Therefore:

Equation #1

$$W_{impinging} := \frac{\left[0.00002 (V \cdot 1.33)^6 \cdot SGR\right]}{(SGR - 1)^3 \cdot \sin\left(r - \operatorname{atan}\left(\frac{1}{S}\right)\right)^3}$$

$W_{impinging} = 939.117$ Minimum Stone Weight (lbs)



Equation 1: Preliminary embankment protection recommendations southern half of the airport runway.

Therefore, using design velocity 12 fps, it is recommended that the embankment protection be a Class III stone for the southern half of Runway 12-30 embankment to reduce the risks associated with impinging flow where the Resurrection River flows against the runway embankment.

Determine Minimum Stone Weight for parallel flow.

Equation #2

$$W_{parallel} := \frac{\left[0.00002(V)^6 \cdot SGR\right]}{(SGR-1)^3 \cdot \sin\left(r - \operatorname{atan}\left(\frac{1}{S}\right)\right)^3}$$

$W_{parallel} = 169.672$ Minimum Stone Weight (lbs)

Equation 2: Preliminary embankment protection recommendations for north half of the airport runway.

Assuming that the design velocity is 12 fps, it is recommended that the embankment protection be a Class II stone for the north half of the runway embankment because of the risks associated with parallel flow.

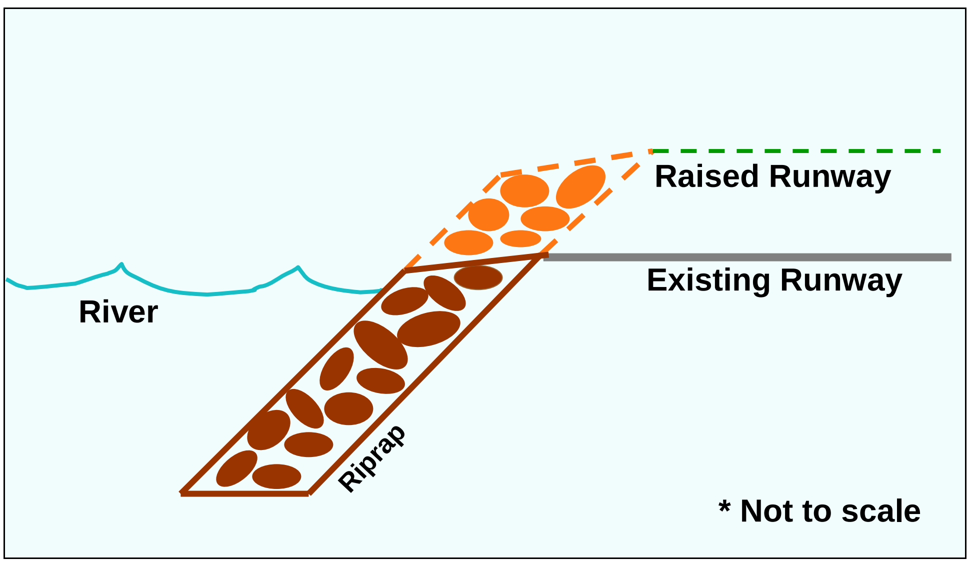


Figure 56: Typical Section for the south portion where embankment protection is currently exposed.

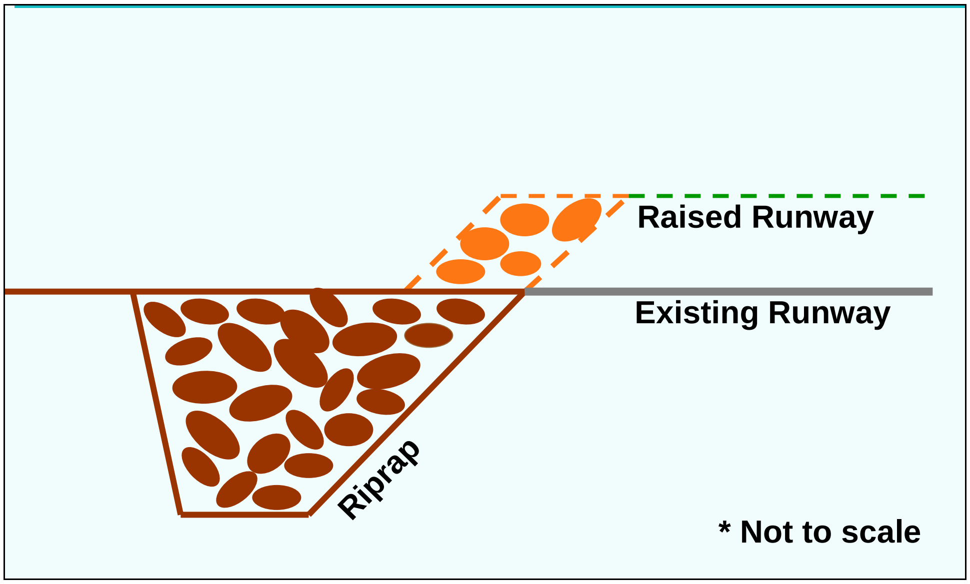


Figure 57: Typical Section for the area where the 1996 Erosion Control Project buried the embankment protection.

13.0 TAXIWAY

Under normal conditions, the existing hydraulic structures that allow surface-water drainage from inside of the airport to cross the taxiway are adequate, and according to information provided by the resource agencies do not currently inhibit fish passage.

There is however, a long history in 1967, 1986, 1995, and 1996 when the Resurrection River flooded Runway 12-30 where the hydraulic structures have washed out by the Resurrection River overflow. Alternative No. 2 will reduce this risk because it stops the Resurrection River from passing into the interior of the airport. The hydraulic structure (existing culvert) is only inundated during extreme high tides.

Because the taxiway's width must be widened to meet current Federal Aviation Administration guidelines, it is recommended that the existing culvert (approximately 72 inches) be replaced with an 8 by 12 foot culvert with concrete headwalls and 45° wingwalls on both the upstream and downstream ends. The culvert will be placed at a 0 percent slope with baffles designed to maintain natural or native bed material in the culvert. Requests were made by the National Marine Fisheries, the Department of Natural Resources, and Fish and Game Office of Habitat Management and Permitting to minimize the length of the proposed culvert, bury the structures to maintain native material in the culvert and set it at a 0 percent slope. After a review of this request it was found that wingwalls would enable the length of culvert to remain the existing length and therefore are recommended. Because the structure is under tidal influence, a 0 percent slope was recommended.

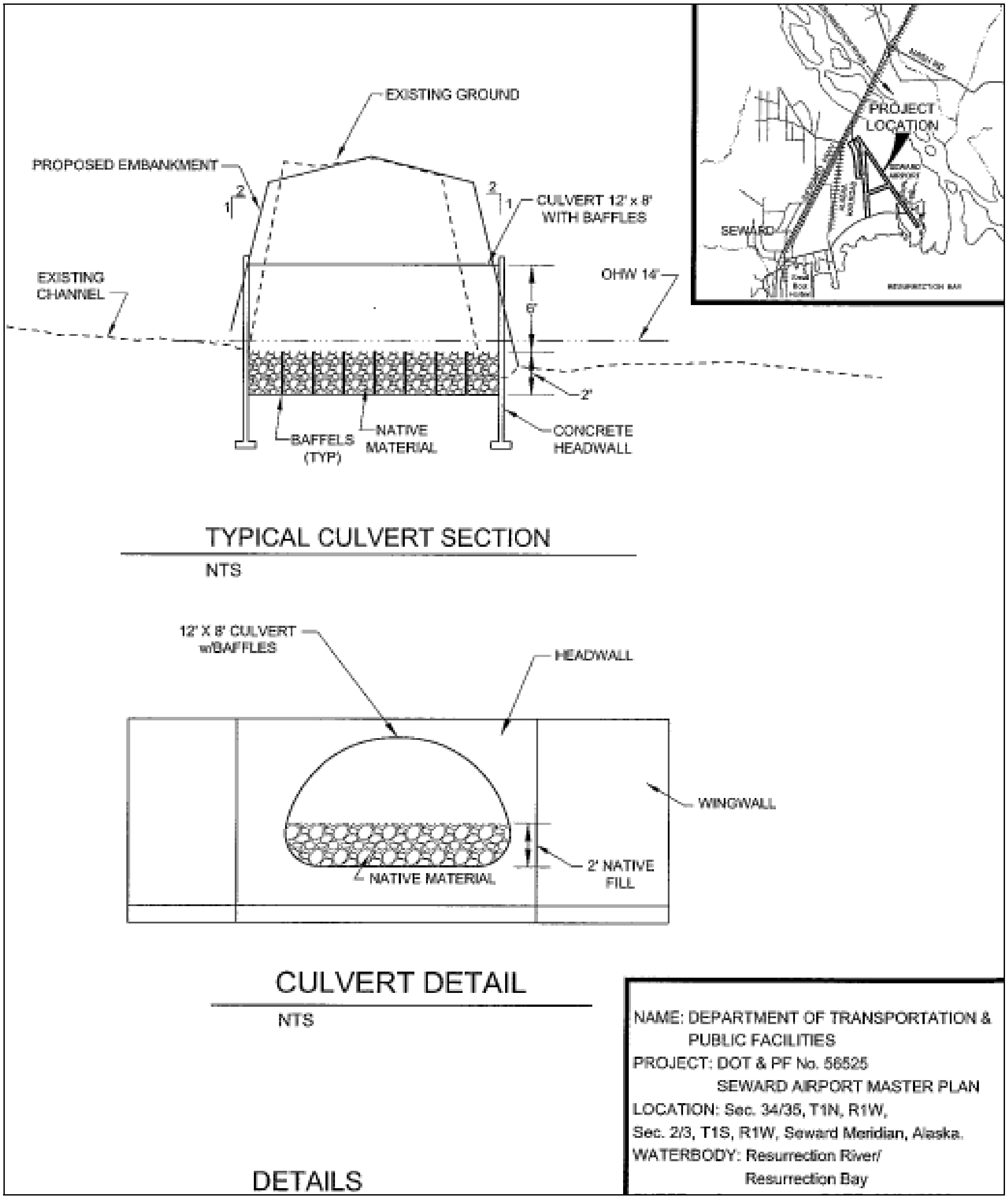


Figure 58: Typical Section of proposed culvert replacement.

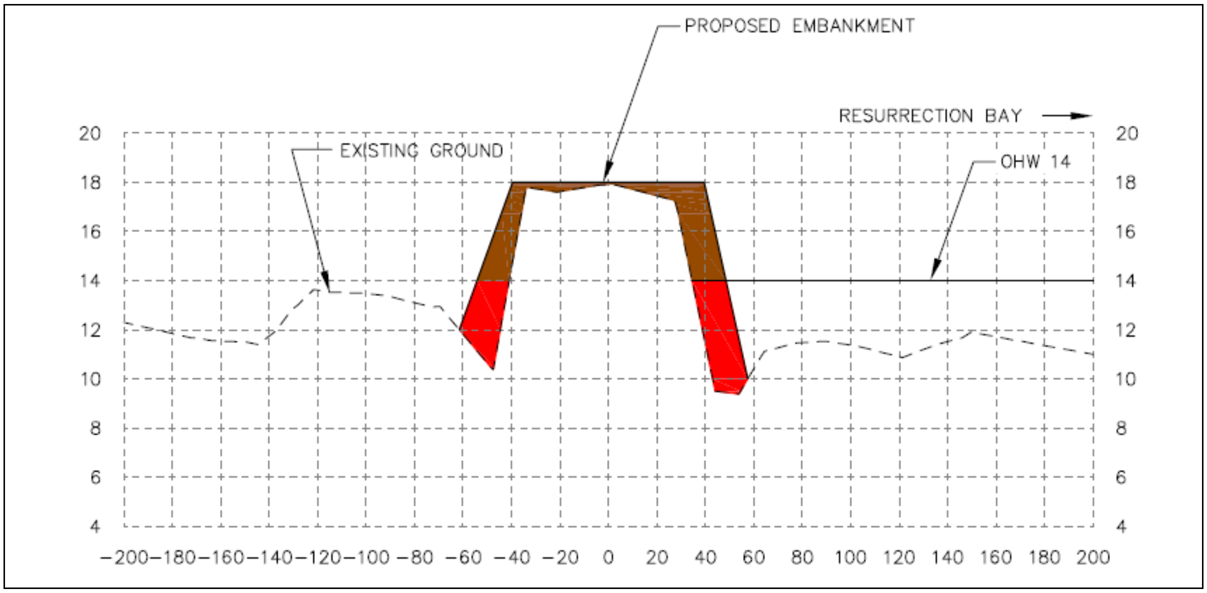


Figure 59: Typical Section F-F for Taxiway