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Hydrology, Geomorphology, and Flood Profiles of Lemon Creek, Juneau, Alaska

Scientific Investigations Report 2005-5186

U.S. Department of the Interior
U.S. Geological Survey

Cover. Lemon Creek looking upstream from cross-section 13, June 20, 2005. Photograph taken by Randy Host, U.S. Geological Survey

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By Randy H. Host and Edward G. Neal

In cooperation with the Alaska Department of Fish and Game and City and Borough of Juneau

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U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia: 2005

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
yard (yd)	0.9144	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F - 32)/1.8$$

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Elevations used in this report are referenced to Mean Lower Low Water (MLLW), which is a local datum. This datum is 8.2 feet below the National Geodetic Vertical Datum of 1929.

WATER YEAR

Water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 2002, is called the "2002 water year."

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Abstract

Lemon Creek near Juneau, Alaska has a history of extensive gravel mining, which straightened and deepened the stream channel in the lower reaches of the study area. Gravel mining and channel excavation began in the 1940s and continued through the mid-1980s. Time sequential aerial photos and field investigations indicate that the channel morphology is reverting to pre-disturbance conditions through aggradation of sediment and re-establishment of braided channels, which may result in decreased channel conveyance and increased flooding potential. Time sequential surveys of selected channel cross sections were conducted in an attempt to determine rates of channel aggradation/degradation throughout three reaches of the study area. In order to assess flooding potential in the lower reaches of the study area the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System model was used to estimate the water-surface elevations for the 2-, 10-, 25-, 50-, and 100-year floods. A regionally based regression equation was used to estimate the magnitude of floods for the selected recurrence intervals. Forty-two cross sections were surveyed to define the hydraulic characteristics along a 1.7-mile reach of the stream. High-water marks from a peak flow of 1,820 cubic feet per second, or about a 5-year flood, were surveyed and used to calibrate the model throughout the study area. The stream channel at a bridge in the lower reach could not be simulated without violating assumptions of the model. A model without the lower bridge indicates flood potential is limited to a small area.

Introduction

In 2002, the U.S. Geological Survey (USGS), in cooperation with the City and Borough of Juneau (CBJ) and Alaska Department of Fish and Game (ADF&G) began a study to investigate the hydrology and geomorphology of Lemon Creek in Juneau, Alaska. Mining of gravels from within the channel of Lemon Creek from the 1940s to mid-1980s previously maintained reduced streambed elevations, but with the cessation of mining in the study area, CBJ and ADF&G are concerned that active deposition of sediments may be increasing flood potential and bank erosion, and adversely modifying fish habitat. City planners currently are using a 1990 flood insurance study (Federal Emergency Management Agency, 1990), which is based on survey data from the late 1960s, to make decisions on potential flood hazard.

The following report discusses the history of channel changes in the lower reaches of Lemon Creek in relation to current channel conditions and processes. Water-surface profiles were generated for floods of 2-, 10-, 25-, 50-, and 100-year recurrence intervals to enable planners and managers to assess changes in flood potential. The study reach begins 1,400 feet (ft) downstream of Glacier Highway and continues upstream for 1.4 miles (mi). The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) model was used to determine water-surface profiles in the study area (U.S. Army Corps of Engineers, 2002a, b, and c). The flood-discharge values for the selected flood-recurrence intervals were computed using regression-based estimates as described by Curran and others (2003). This report further describes the hydrologic and hydraulic analyses of pertinent data and the calibration and application of the HEC-RAS model to compute the flood profiles.

Description of Study Area

Juneau is situated on the mainland of Alaska, surrounded by the archipelago of Southeast Alaska (fig. 1). Approximately 600 mi southeast of Anchorage, Alaska and 900 mi northwest of Seattle, Washington, Juneau is the largest population center in Southeast Alaska and has grown from a population of 9,045 in 1959 to 30,684 in 1998 (K.J. Bailey, City and Borough of Juneau, written commun., 2001). Lemon Creek flows through Lemon Creek Valley, which is approximately 8 mi northwest of the city of Juneau.

Southeast Alaska is influenced predominately by maritime climate. Storms generated in the Gulf of Alaska typically track toward southeast Alaska. Winters are characterized as mild while summers are cool. Consequently Juneau has moderate temperatures, little sunshine, abundant precipitation, and high humidity. The mountainous topography is an orographic barrier that causes patchy differences in both temperature and precipitation. Mean annual precipitation is 93 inches at downtown Juneau compared to 53 inches at the Juneau International Airport which is only 10 mi to the northwest, but “sheltered” by Douglas Island. Regional storms dominate the fall months and produce the highest values for monthly precipitation. The lowest monthly precipitation occurs during the spring months (National Oceanic and Atmosphere Administration, 2003).

Lemon Creek drains a 24.3 square miles (mi^2) watershed, including Lemon Creek and Ptarmigan Glaciers, along the western side of the Juneau Ice Field. The watershed is bounded by Heintzleman Ridge to the north and Blackerby Ridge to the south. Elevations range from sea level to 5,600 ft, with vegetative cover consisting primarily of spruce forest and muskeg. Lemon Creek receives additional inflows from Canyon Creek and Sawmill Creek along with several smaller unnamed tributaries before emptying into Gastineau Channel 1.5 mi east of the Juneau International Airport (fig. 1).

Lemon Creek is designated by the Alaska Department of Fish and Game as an anadromous fish stream that supports stocks of chum, pink, and coho salmon; steelhead/rainbow trout, and Dolly Varden (Benjamin Kirkpatrick, ADF&G, written commun., 2004). During summer, the water is naturally turbid due to its glacial source and is thus used primarily as a migration route by anadromous fish bound for clearwater tributary habitat. Lemon Creek provides fish-rearing habitat in the winter when turbidity is reduced (Bethers and others, 1995).

Hydrology of Lemon Creek

Melt waters from Lemon and Ptarmigan Glaciers are the primary source for Lemon Creek, but Canyon Creek, Sawmill Creek, and several other smaller unnamed tributaries contribute flow throughout the basin. The smaller tributaries flows are influenced primarily by rainfall. Peak flows are generally during the late summer and early fall as a result of heavy rains coupled with high temperatures which enhance glacial melting.

Continuous streamflow data have been collected by the USGS on Lemon Creek at two locations. The gaging station Lemon Creek near Juneau (station number 15052000, fig. 1) was operated from August 1951 to November 1953, July 1954 to September 1973, and May 2002 to present (U.S. Geological Survey, 1964, 1971, 1973, 1976, 2002-03). The gaging station is 4.5 mi upstream from the mouth at Gastineau Channel, with a drainage area of 12.3 mi^2. Mean annual flow at the station is 156 cubic feet per second (ft^3/s) and mean monthly flows range from a minimum of 5.84 ft^3/s in February to a maximum of 464 ft^3/s in August. During the period of record, the lowest daily mean discharge was 0.70 ft^3/s on February 13, 1966 and the instantaneous peak discharge was 3,370 ft^3/s on August 13, 1961. An instantaneous peak discharge of 5,900 ft^3/s, estimated on the basis of flood marks at the station, occurred on October 20, 1998, when the station was not operational.

The second gaging station, Lemon Creek near mouth near Juneau (station number 15052009, fig. 2) was operated from October 1982 to September 1986 (U.S. Geological Survey, 1983-1986). This station, with a drainage area of 22.9 mi^2, was on the right bank next to the Lemon Creek Correctional Center, 1.0 mi upstream from the mouth of the creek at Gastineau Channel. Lemon Creek has since migrated east, abandoning the channel at the former streamflow-gaging site. Mean annual flow at the second station was 214 ft^3/s and mean monthly flows ranged from a minimum of 44.7 ft^3/s in February to a maximum of 584 ft^3/s in August. During the period of record, the lowest daily mean discharge was 17.0 ft^3/s on February 20 and December 29-30, 1983, and the instantaneous peak discharge was 4,510 ft^3/s on August 23, 1983.

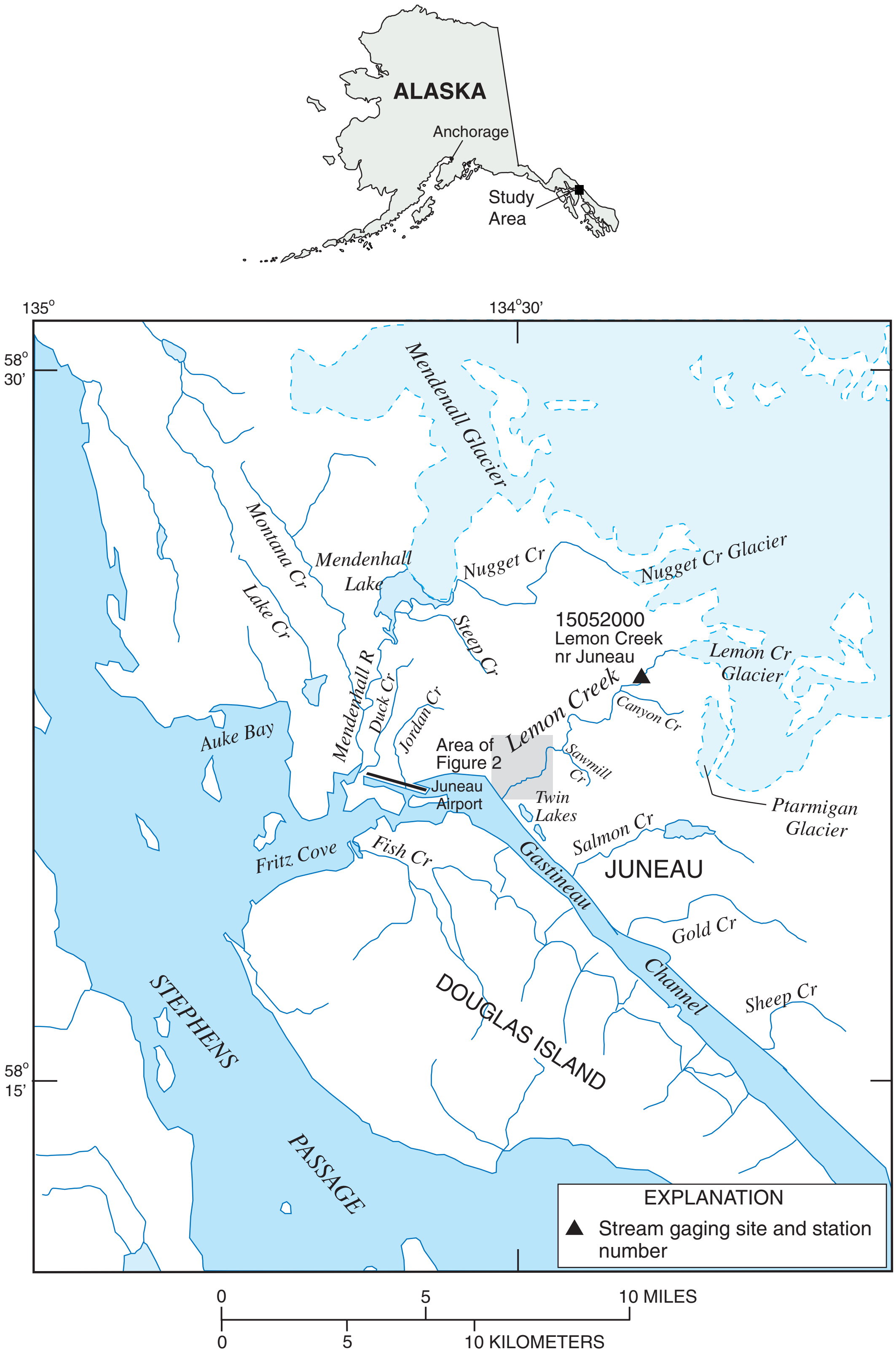

Figure 1. Location of Lemon Creek in Juneau, Alaska.

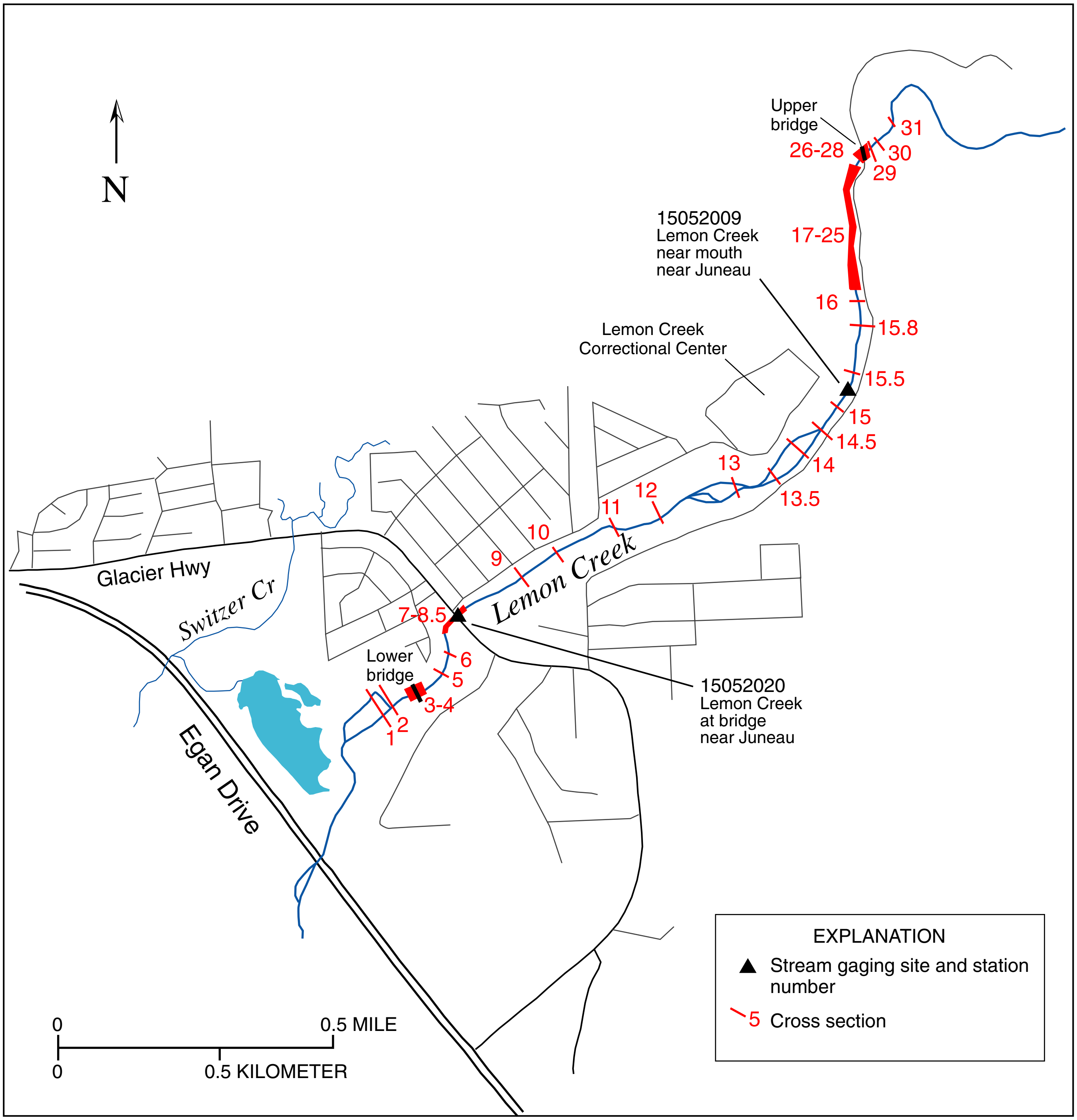

Figure 2. Location of cross sections on Lemon Creek in Juneau, Alaska.

Geomorphology of Lemon Creek

The Lemon Creek basin naturally produces large quantities of suspended and coarse bedload sediment owing to its glacial source. Meandering and braiding of the stream channel are a component of the sediment transport process in streams like Lemon Creek. Historical accounts of placer mining and instream gravel mining along with examination of historical aerial photographs, suggest that within the study area, channel configurations of Lemon Creek have been largely influenced by these anthropogenic disturbances. Instream gravel mining directly alters the channel geometry and bed elevation, and may also induce channel incision, bed coarsening, and lateral channel instability (Kondolf, 1994). Sediment removal from stream channels, and/or the armoring of banks in order to prevent lateral channel migration, disturbs any preexisting equilibrium between sediment supply and transport capacity. The following discussion provides a brief history of the level and types of disturbances in Lemon Creek dating back to about 1870. Also provided is a brief discussion of current channel conditions and the presentation of surveyed channel-geometry, which provides a baseline that will be useful to assess future changes in the channel morphology of Lemon Creek.

History of Channel Changes

Lemon Creek is said to have been named for John Lemon, who was reported to have prospected and placer mined on the creek in the 1870s. Placer claims were recorded on Lemon Creek in 1884 and mining operations were carried on for many years, although operations were not highly productive. Prior to 1900, Vanderbilt gold mine, located upstream of the study area, employed approximately 50 people. Gravel mining on Lemon Creek began around 1940. Before gravel extraction began, the banks of the creek were at road level (Thomas Horn, property owner along Lemon Creek, oral commun., 2002). Lemon Creek has been dredged several times since 1945, including 10-15 ft of channel excavation in the 1970s. In the mid-1980s, gravel mining within the study area ended, but gravel mining continues upstream (Ralph Horency, property owner along Lemon Creek, oral commun., 2004).

Prior to extensive gravel mining and bank hardening projects within Lemon Creek Valley, Lemon Creek transported sediments through a network of braided channels. The braided channels traversed a broad alluvial fan at the outlet of the canyon adjacent to the Lemon Creek Correctional Center, where the channel slope abruptly decreases. The channel migrated back and forth across the alluvial fan, creating new channels as older ones became filled with sediment and debris and were abandoned. During and after gravel extraction, the lower Lemon Creek channel was deepened and straightened, which increased channel conveyance and reduced flooding potential. When gravel excavation ceased, the lower stream channel began to fill, potentially reducing the stream's conveyance and increasing flooding potential.

Examination of a series of aerial photos of Lemon Creek dating from 1962 to 2002 indicates considerable changes in channel morphology. Photographs of the reach between cross sections 9.0 and 17.0 (fig. 3A) taken in 1962 and 1974 show Lemon Creek as a braided channel with numerous sand and gravel bars. A 1984 photograph of the same reach shows that the braided segment upstream from Glacier Highway Bridge had been excavated and straightened. This excavation reduced the channel elevation by as much as 20 ft through this reach (Daniel Miller, Inter-Fluve, written commun, 2004). Post-1984 aerial photographs indicate that the channel is transforming back to pre-excavation conditions. During a survey of this reach in 2002, the channel exhibited a braided pattern with numerous sand and gravel bars. Bank erosion was apparent on the left bank between cross sections 14.5 and 13.0 (fig. 3A), indicating the channel may be attempting to reestablish meanders.

Current Channel Conditions

The City and Borough of Juneau is concerned that channel changes in the study reach of Lemon Creek may pose hazards to streamside structures and developments within the valley. Channel aggradation in some reaches may be reducing the channel capacity, which could increase the frequency of over-bank flooding. Lateral migration of the channel also may be threatening access roads and streamside structures. In an attempt to quantify spatial differences in the rate of channel aggradation or degradation, the study area was divided into three reaches: an upper reach, a transitional reach, and a lower reach. In order to determine rates of channel aggradation or degradation, channel cross sections were selected as representative of the three predefined channel reaches. After the initial April 2002 survey, these cross sections were resurveyed in January 2003 and in April 2004 to document ongoing aggradation/degradation of the streambed. All surveys were tied to a common datum using two reference marks of known elevations (appendix 1).

Upper Reach

The upper reach extends downstream from cross section 31.0 to cross section 15.5 (figs. 2, 3A, and 3C). The bank material in this reach consists primarily of large angular boulders, cobbles, gravels, and bedrock. The steep gradient and associated sediment-transport capacity in this reach has resulted in the removal of most of the fine-grained material from the streambed. Active downcutting through the streambed and eroding of the left bank indicates one function of this reach is that of sediment supply to the downstream reach.

The streambed slope reaches a maximum of 0.025 ft/ft between cross sections 25.0 and 15.5, which is the steep-

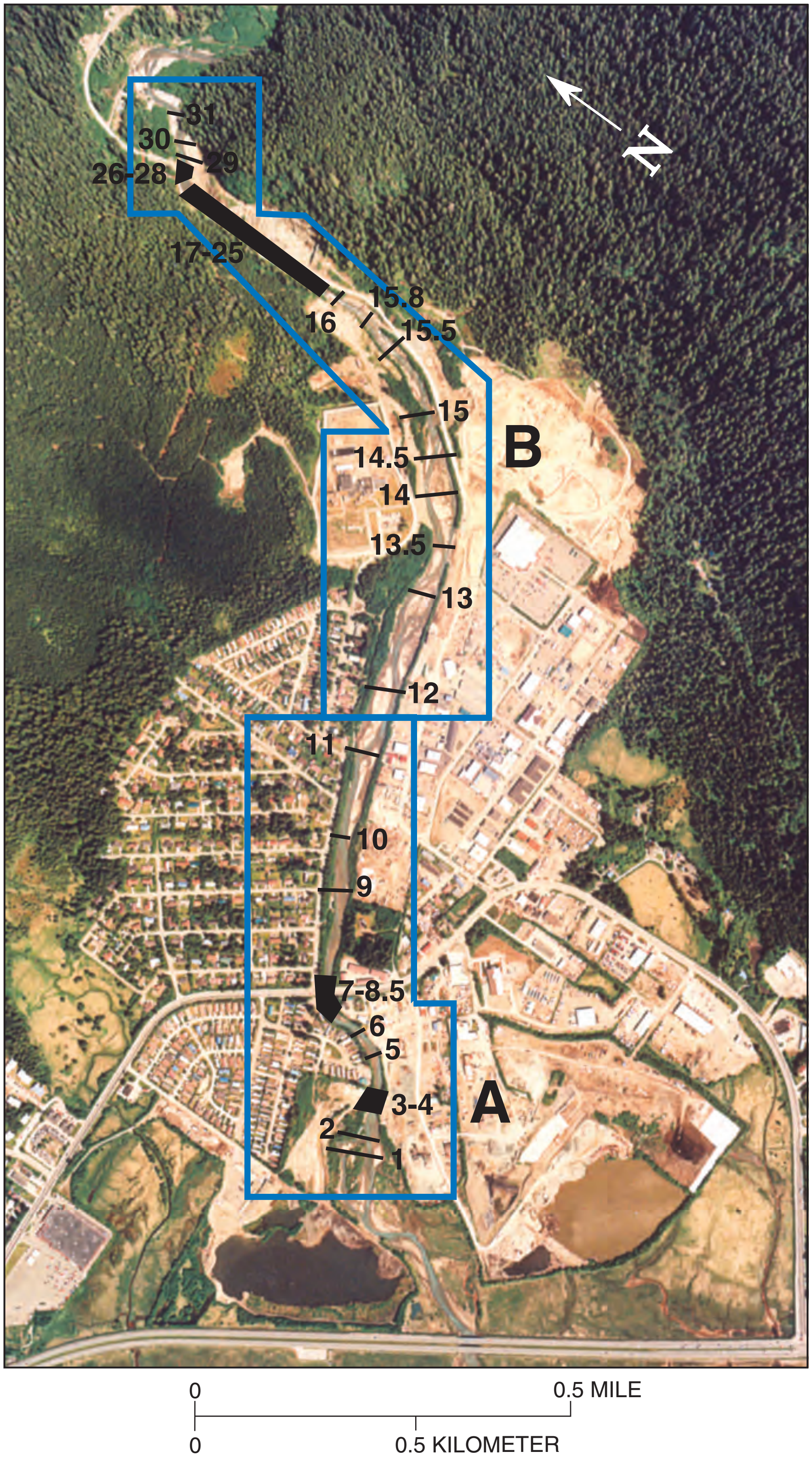

Figure 3A. Aerial view of Lemon Creek showing selected cross sections. (Aerial photograph of June 8, 2001, provided by R&M Engineering.)

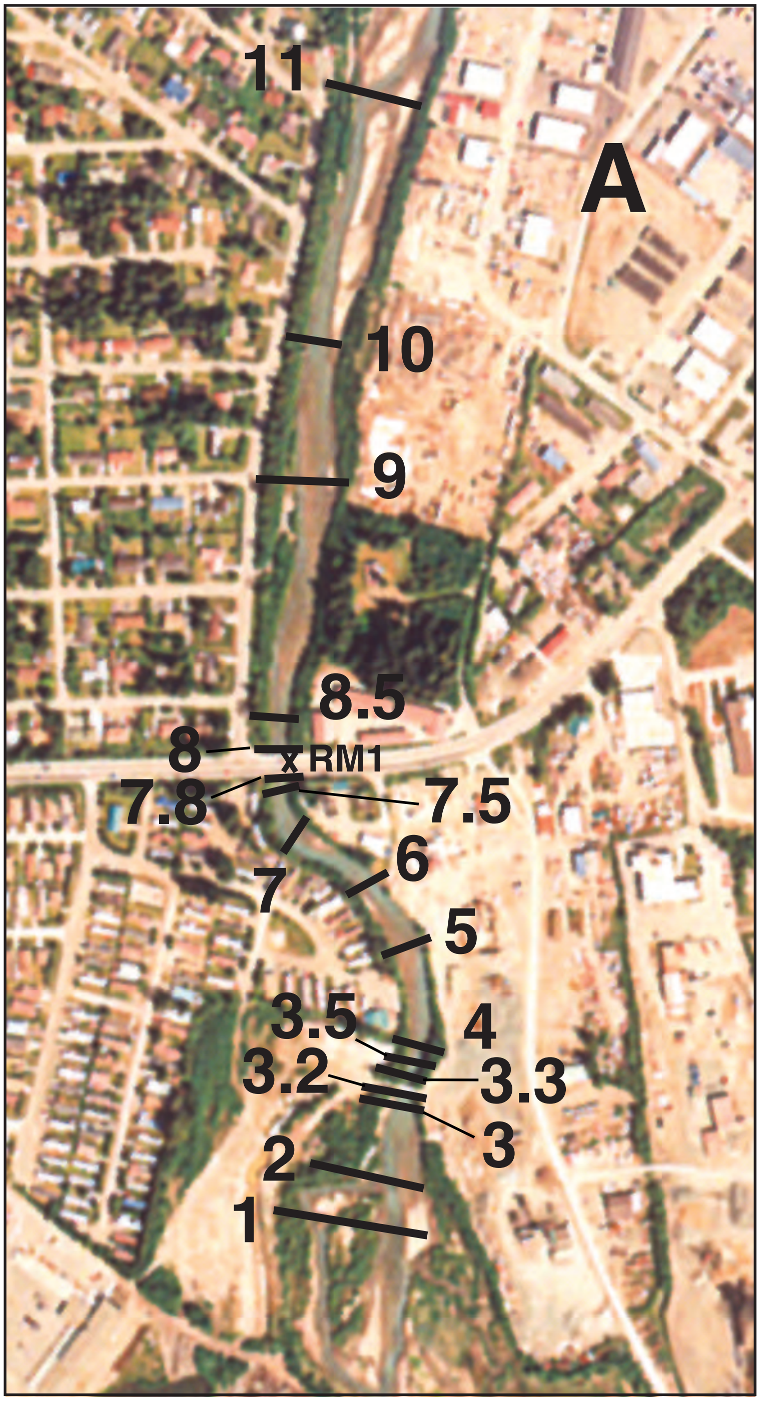

Figure 3B. Cross sections 1 to 11 and survey point RM1 on Lemon Creek in Juneau, Alaska. (Enlargement of section A is 2.5 times aerial view in figure 3A.)

Only one cross section (31.0) was selected to represent the upper reach of the study area, as there has been little development adjacent to this reach; however, the upper bridge just downstream from cross section 31.0 (fig. 2) has been washed out and replaced several times. Cross section comparisons show that approximately 10-15 ft of the left bank has been scoured between April 2002 and April 2004 and the thalweg scoured approximately 4.5 ft and migrated about 25 ft toward the left bank (fig. 4). The cross section was scoured an average of 2.0 ft from April 2002 to January 2003. An additional 0.4 ft was scoured from January 2003 to April 2004.

Table 1. Total computed stream-bed slopes between the given cross sections on Lemon Creek, Juneau, Alaska

[Selected cross-section locations are shown on figures 3A-3C]

Cross section numbers	Slope of the stream-bed [feet/feet]
1.0 to 9.0	0.003
9.0 to 13.0	0.004
13.0 to 15.5	0.007
15.5 to 25.0	0.025
25.0 to 31.0	0.007
30.0-31.0	0.012

Transitional Reach

Lemon Creek transitions from a confined, steep-gradient stream to a less confined, lower-gradient stream between cross sections 15.5 and 13.0 (figs. 2, 3A, and 3C). The streambed slope through this reach is 0.007 ft/ft (table 1) and the bed materials are composed of cobbles and gravels. Although the decrease in slope and associated increases in sediment deposition might normally result in the formation of an alluvial fan in the proximity of this reach, the stream currently is confined to its channel by rip-rapped banks along the entire left bank and along the right bank adjacent to Lemon Creek Correctional Center, thereby preventing lateral channel migration. The toe of the reinforced, riprapped left bank has been undermined along some sections, however, creating the potential for further erosion.

est segment of stream channel within the study area (table 1, figs. 2, 3A, and 3C). The bed materials between these cross sections consist of large angular boulders, cobbles, and inter-mixed gravels. A gravel road following the left bank of Lemon Creek constricts the channel in several locations along this reach.

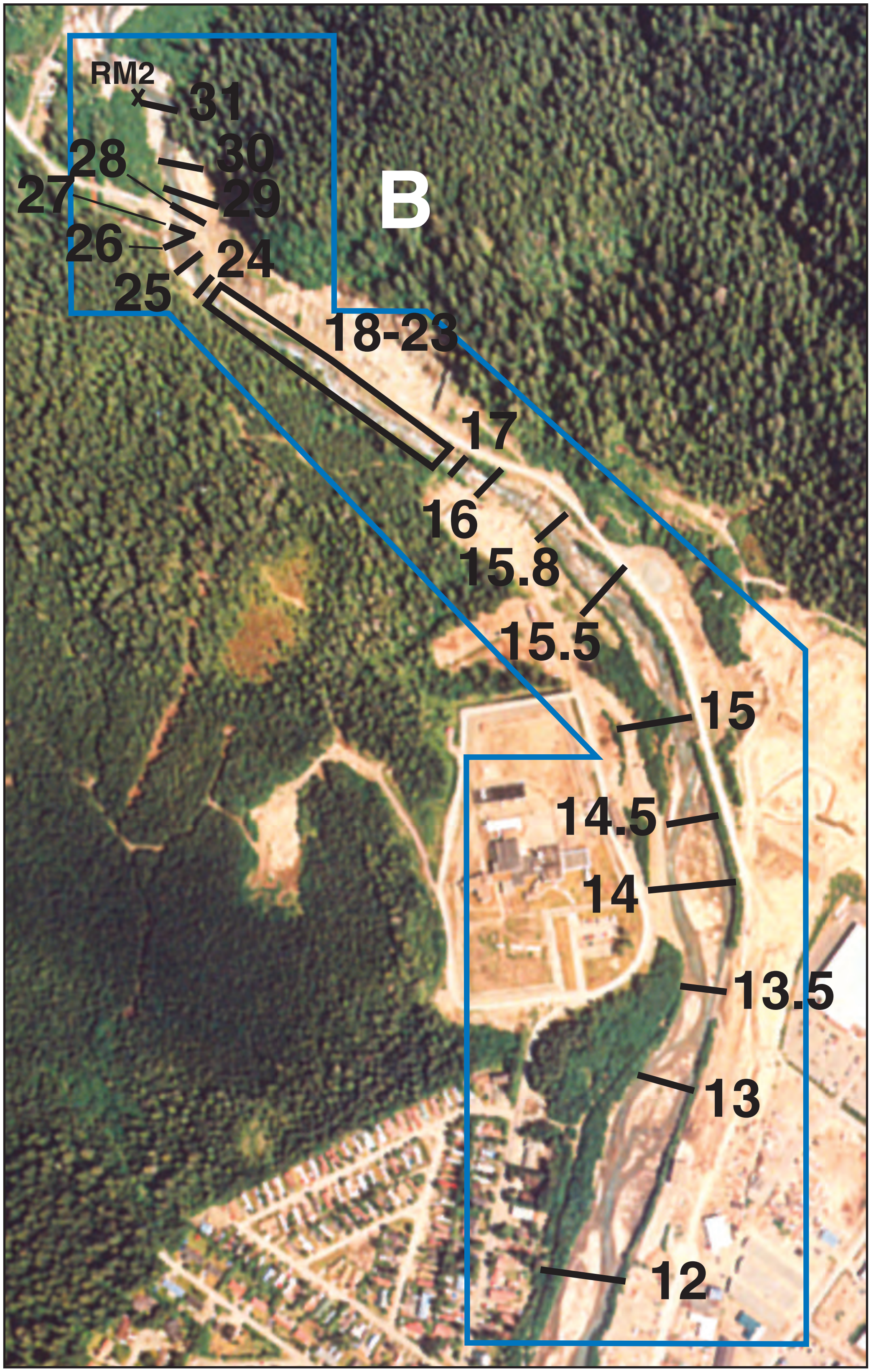

Figure 3C. Cross sections 12 to 31 and survey point RM2 on Lemon Creek in Juneau, Alaska. (Enlgargement of section B is 2.5 times aerial view in figure 3A.)

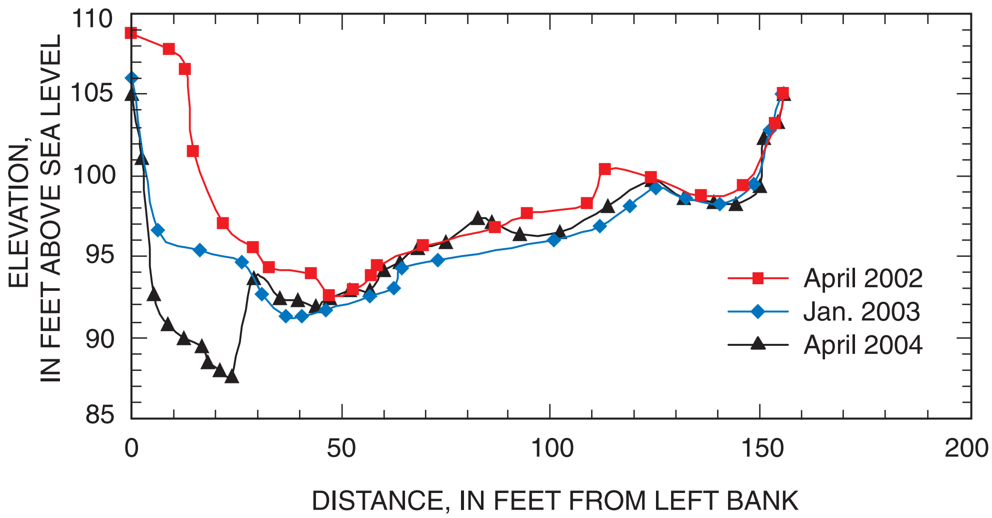

Figure 4. Cross section 31.0 showing changes over time in channel geometry.

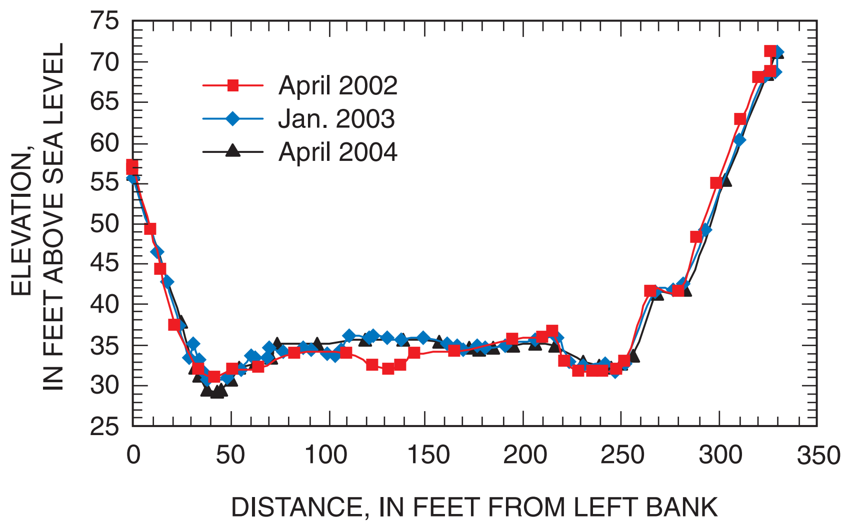

Figure 5. Cross section 14.0 showing changes over time in channel geometry.

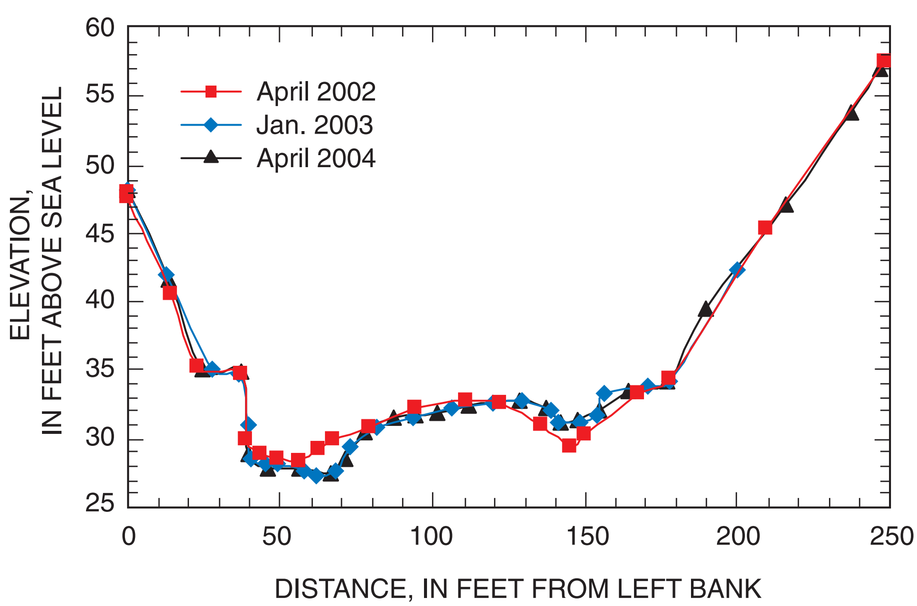

Figure 6. Cross section 13.5 showing changes over time in channel geometry.

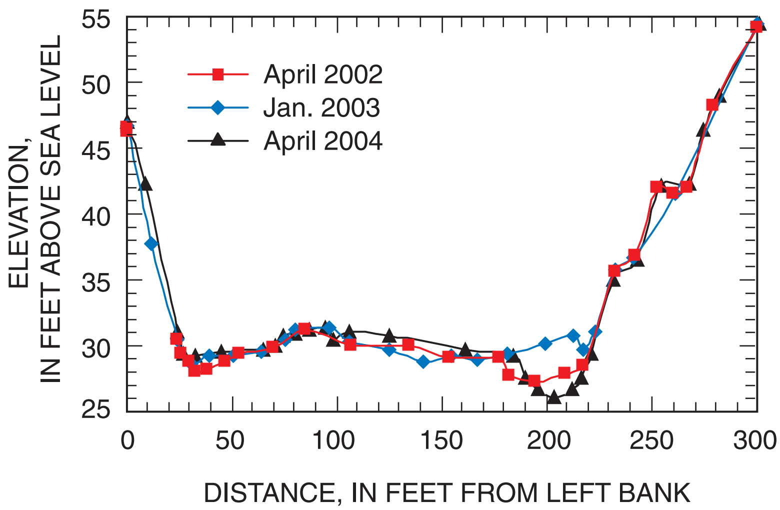

Figure 7. Cross section 13.0 showing changes over time in channel geometry.

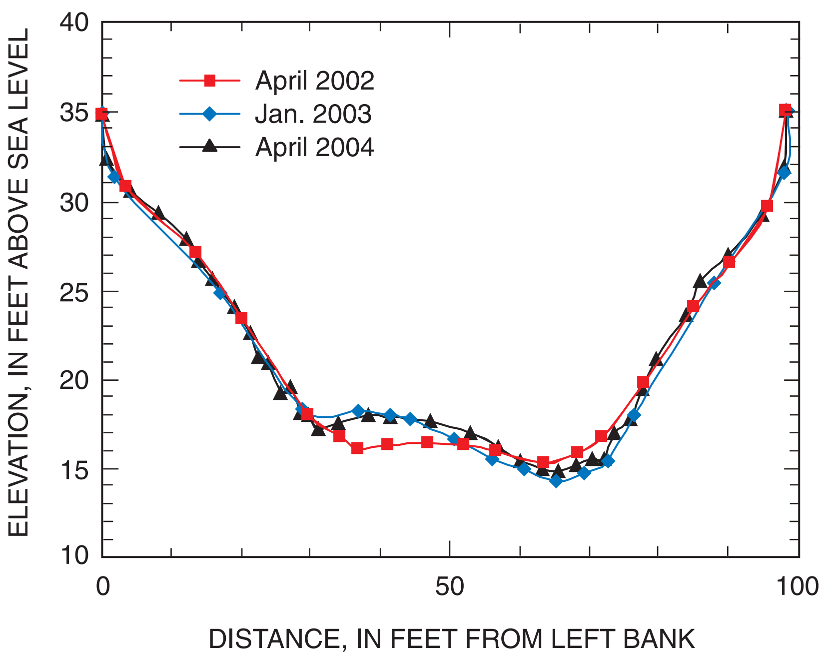

Figure 8. Cross section 8.0 showing changes over time in channel geometry.

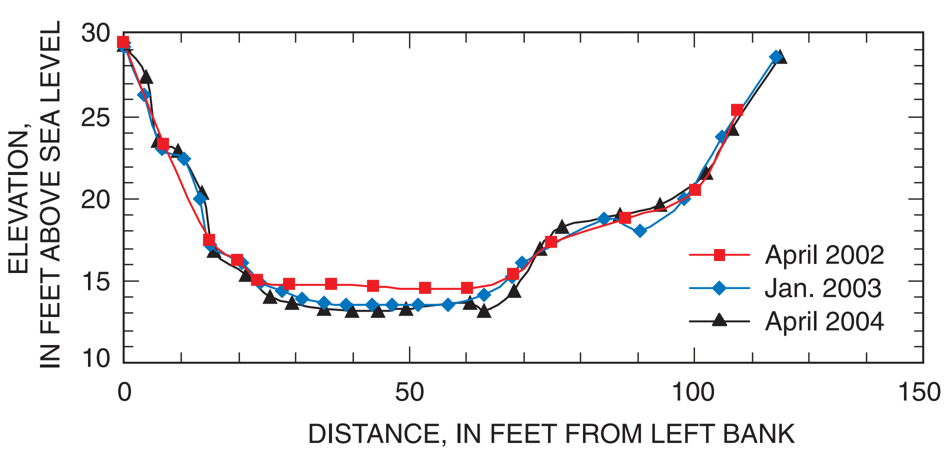

Figure 9. Cross section 3.0 showing changes over time in channel geometry.

Cross sections 14.0, 13.5, and 13.0 were selected to represent the transitional reach. Cross section 14.0 showed an overall fill condition, with the average elevation increasing by 0.6 ft from April 2002 to January 2003 and an additional 0.1 ft from January 2003 to April 2004 (fig. 5). Cross sections 13.5 and 13.0 showed no clear evidence of either scour or fill from April 2002 to April 2004 (figs. 6 and 7).

Lower Reach

The lower reach extends downstream from cross sections 13.0 to 1.0 and is within the urbanized area of Lemon Creek valley (fig. 2, 3A, and 3B). The channel slope is 0.0035 ft/ft (table 1) and bed-material composition transitions from gravel and small cobbles at cross-section 13.0, to sand with intermittent gravel deposits at cross section 1.0. Lemon Creek is influenced by extreme (20 ft) high tides from cross section 1.0 to cross section 9.0. The right bank is armored with riprap from cross section 8.0 to the lower bridge (fig. 2).

Cross sections 8.0 and 3.0 were selected to represent the lower reach of the study area. Cross section 8.0 showed an overall fill condition, with the average elevation increasing by 0.6 ft from April 2002 to April 2004 (fig. 8). Cross section 3.0, just downstream of the lower bridge, showed an overall scour condition, with the average elevation decreasing by 1.0 ft from April 2002 to April 2004 (fig. 9).

Flood Profiles

Flood profiles are useful in the determination of flooding potential in areas adjacent to a stream and can aid managers and planners in evaluating and prescribing bank protection and stabilization methods. Although flood profiles have been previously estimated for Lemon Creek (Federal Emergency Management Agency, 1990), changes over time in channel geometry and morphology result in the need for refined flood profiles. Statistical estimates of the magnitude and frequency of large floods can also be refined as more stream discharge data are made available.

Flood profiles typically are based on a statistical analysis of discharge records which provide estimates of the frequency of peak discharges. These peak discharges then are incorporated into a hydraulic model which integrates factors such as channel geometry, slope, and roughness and the structural geometry of bridges to estimate water-surface elevations. Estimates of water-surface elevations can be further improved through calibration of the hydraulic model when water-surface elevations measured during a flood can be compared to model results.

Hydrologic Analysis

The magnitudes of floods that are expected to be equaled or exceeded once on average during any 2-, 10-, 25-, 50-, and 100-year period (recurrence interval) were selected by CBJ and ADF&G for analysis. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, large floods can occur at short intervals or even within the same year. The probability of a flood of a given recurrence interval occurring in a specified time period can be determined using the equation given by Zembrzuski and Dunn (1979, p. 22):

$$P = 1 - (1 - 1/t)^{n},$$

where

P = the probability of at least one exceedence within the specified time period,

n = the specified time period,

and

t = the recurrence interval.

P can be multiplied by 100 to obtain the chance of exceedence. For example, the risk of having a flood that equals or exceeds the 100-year flood (1 percent chance of annual occurrence) in any 50-year period is about 40 percent, and for any 90-year period, the risk increases to about 60 percent.

Hydrologic analyses were performed to determine the peak discharge-frequency relations for floods on Lemon Creek. Flood-discharge values are based on a statistical analysis of discharge records at the streamflow gaging stations. The gaging station, Lemon Creek near Juneau (station number 15052000) has 25 years of peak-flow records (1951-53, 1954-73, 2002-03) available for analysis. Flood-discharge values for the gaging station Lemon Creek at bridge near Juneau (station number 15052020) were based on procedures for estimating peak streamflow magnitude and frequency described by Curran and others (2003). The equation for an “ungaged site on a gaged stream” was used to estimate the streamflow magnitude at the ungaged station, Lemon Creek at bridge near Juneau, on the basis of data from the gaging station Lemon Creek near Juneau, using the respective drainage areas and basin characteristics of the sites (Curran and others, 2003) (table 2). Lemon Creek at bridge near Juneau has a drainage area

Table 2. Summary of the estimated 2-, 10-, 25-, 50-, and 100-year discharges at Lemon Creek near Juneau and Lemon Creek at bridge near Juneau, Alaska

[mi^2, square miles; see figure 1 for locations]

USGS stream-gaging station and number	Drainage area (mi^2)	Flood discharge (in cubic feet per second) at indicated recurrence interval				
		2 year	10 year	25 year	50 year	100 year
Lemon Creek near Juneau (15052000)	12.3	1,600	2,690	3,400	3,990	4,660
95 percent confidence limits for Bulletin 17B[a] estimates		1,410-1,800	2,330-3,300	2,850-4,430	3,260-5,450	3,710-6,650
Lemon Creek at bridge near Juneau (15052020)[b]	24.3	3,840	5,790	6,430	6,780	6,940

[a]U.S. Interagency Advisory Committee on Water Data (1982)

[b] Methods described in Curran and others, 2003

of 24.3 mi^2, of which 0.11 percent is lakes and ponds (storage), mean minimum January temperature of 22.0 degrees Fahrenheit (°F), and an annual mean precipitation of 142 inches. Lemon Creek near Juneau has a drainage area of 12.1 mi^2, of which 0.0 percent is lakes and ponds, mean minimum January temperature of 22.0 °F, and an annual mean precipitation of 180 inches.

Peak discharges at the gaging station were analyzed for selected recurrence intervals (table 2) by the standard log-Pearson type III method (U.S. Interagency Advisory Committee on Water Data, 1982). Discharge values for floods of these recurrence intervals were published by Curran and others (2003). The values reported in this report are different from those of Curran and others (2003) because an additional 2 years of streamflow data were used in the analysis. The 100-year peak discharge for the gaging station Lemon Creek near Juneau is 4,660 ft^3/s; the 100-year peak discharge for Lemon Creek at bridge near Juneau is 6,940 ft^3/s.

Hydraulic Analysis

The U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) model was used to compute water-surface elevations for the 2-, 10-, 25-, 50-, and 100-year probability floods (U.S. Army Corps of Engineers, 2002a). The computational method of this model is based on the solution of the one-dimensional energy equation that is able to model flows that are subcritical, supercritical, and a combination of the two (mixed flow). Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). Several assumptions are inherent in the analytical expressions used in HEC-RAS: flow is steady, flow is gradually varied (except at hydraulic structures), flow is one-dimensional so the velocity components in directions other than the direction of flow are not accounted for, and river channels have slopes less than 10 percent (U.S. Army Corps of Engineers, 2002b).

The HEC-RAS model used surveyed channel cross sections of Lemon Creek to define the hydraulic characteristics of the channel. Cross-section locations were selected to represent the hydraulic characteristics of a reach and to define the channel geometry. Forty-two cross sections were surveyed during April 2002. Structural geometry and elevations also were obtained for three bridges. Additional cross sections were surveyed immediately upstream and downstream from the bridges to allow the model to simulate flow through the bridges. Figure 10 shows the channel cross section at the Glacier Highway Bridge.

Flood-profile elevations are influenced by the channel roughness, which creates resistance to flow. Roughness coefficients (Manning's *n*) are a compilation of several factors that cause resistance to flow. The size and shape of the streambed and bank materials are the primary factors. Other factors include variation in channel geometry; channel surface irregularities; water depth; density and type of vegetation; obstructions; and the degree of channel meandering (Coon, 1998, p. 2). Values used for the roughness coefficients along Lemon Creek range from 0.035 to 0.079 for the main channel and from 0.055 to 0.08 for the banks (appendix 2). Channel substrate material ranged in

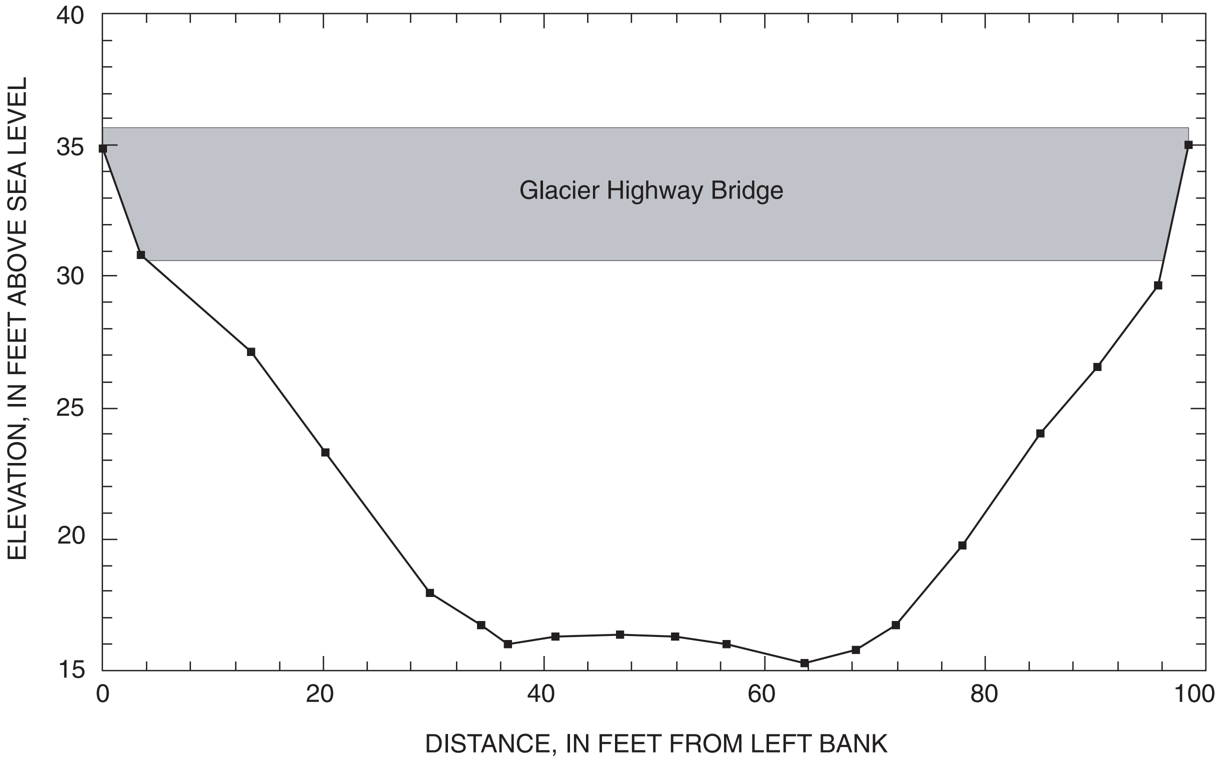

Figure 10. Cross section 7.8 of Lemon Creek at the downstream side of the Glacier Highway Bridge.

size from boulders to sand. Bank vegetation was variable and ranged from no vegetative cover to grasses and dense stands of alders.

At several locations within the study area, insufficient channel-geometry data limits the accuracy of hydraulic data. To accommodate for the lack of over-bank topography, HEC-RAS vertically extends the top of bank (cross section end-points) . This technique routes all of the selected discharges within the channel and allows no flow area outside of the channel.

Calibration of the Hydraulic Model

Calibration of a hydraulic model is achieved through an iterative process of varying model input parameters, typically roughness coefficients, until computed values for water-surface elevations and velocities are comparable to measured values. The HEC-RAS model developed for this study was calibrated to a discharge of 1,820 ft^3/s, measured on September 27, 2003, at the Glacier Highway Bridge (Lemon Creek at bridge near Juneau, fig. 2). The discharge peak was associated with an intense rainstorm that produced 2.07 inches of rainfall on September 27 at the Juneau International Airport. In the preceding 4 days, 1.75 inches of rain fell at the airport, resulting in saturated soils before the start of the September 27 storm (National Oceanic and Atmosphere Administration, 2003).

The discharge measurement of Lemon Creek on September 27, 2003 is thought to have started either at or immediately after the peak flow at Glacier Highway. High-water marks left by the flood and/or flagged during the discharge measurement were surveyed at several locations near or at previously surveyed cross sections along the creek. Hydraulic properties and channel-roughness coefficients were adjusted to generate water-surface profiles that matched the measured high-water marks. The high-water mark elevations and computed water-surface profiles for the September 27 peak are shown on figure 11.

At cross sections where no flood marks were surveyed, channel-roughness coefficients used in the hydraulic computations were based on interpretation of the channel and flood-plain area with references to Barnes (1967) and Hicks and Mason (1991). Roughness coefficients for a given reach of stream can be expected to change slightly with increases or decreases in discharge. Because it was not possible to survey water-surface profiles for a range of discharges, the n values determined from calibration at a discharge of 1,820 ft^3/s were used for

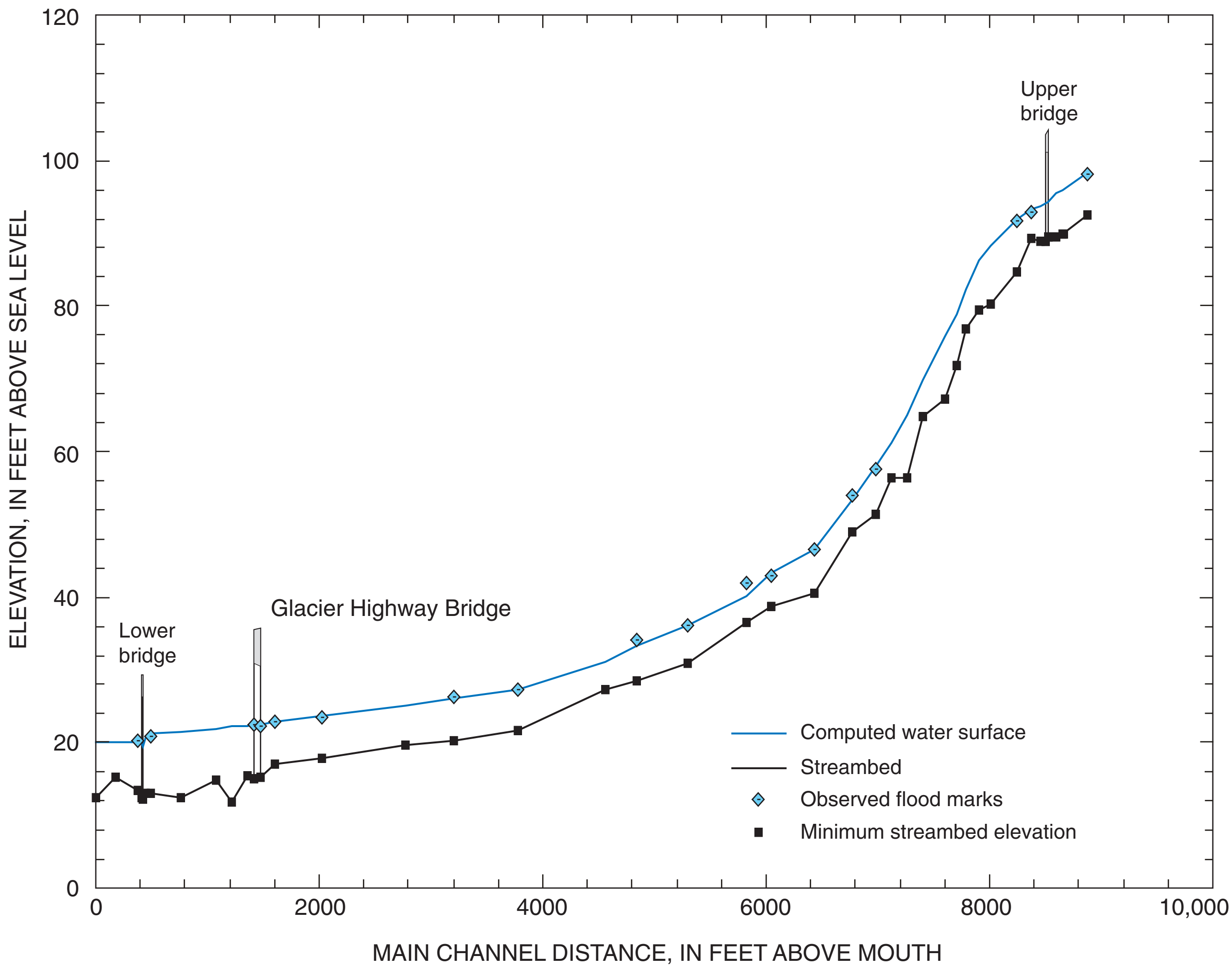

Figure 11. Profile of computed water-surface elevations for the peak flow of September 27, 2003, streambed elevations and surveyed flood marks, Lemon Creek, Juneau, Alaska.

water-surface profiles at all discharges analyzed. Coon (1998, p. 131) noted, “on low-gradient, wide channels with large relative smoothness, the computed *n* values remain relatively constant with increasing flow depth. On high-gradient channels with low relative smoothness, the computed roughness coefficient decreased with increased depth.” Therefore, the selected roughness coefficients likely will remain valid for the lower reaches of the study area over the range of discharges analyzed. The high-gradient reach of Lemon Creek (cross sections 24.0-15.5, fig. 3C) has larger roughness coefficients that may decrease slightly with the increasing water depths associated with 50-and 100-year flood discharges. This would result in actual water-surface elevations that may be slightly lower than the computed water-surface profiles for the high-gradient reach of the creek.

Flood Profile Computations

The discharge value of 7,340 ft^3/s was used to compute the 100-year flood profile throughout the study area. Flood-profile elevation computations begin at the downstream end of the study area, where the water-surface elevation will be constrained by the water-surface elevation of the tide. The starting water-surface elevation (20.0 ft) used to compute the 2-, 10-, 25-, 50-, and 100-year flood profiles was determined from a high tide that would occur during months in which peak flows of the 100-year recurrence interval were likely to occur (Federal Emergency Management Agency, 1990). The 2-, 10-, 25-, 50-, and 100-year flood profiles assume the peak tide cycle of 20.0 ft will coincide with the peak discharges. If these peak discharges coincide with tides of smaller magnitude, or during the low end of the tide

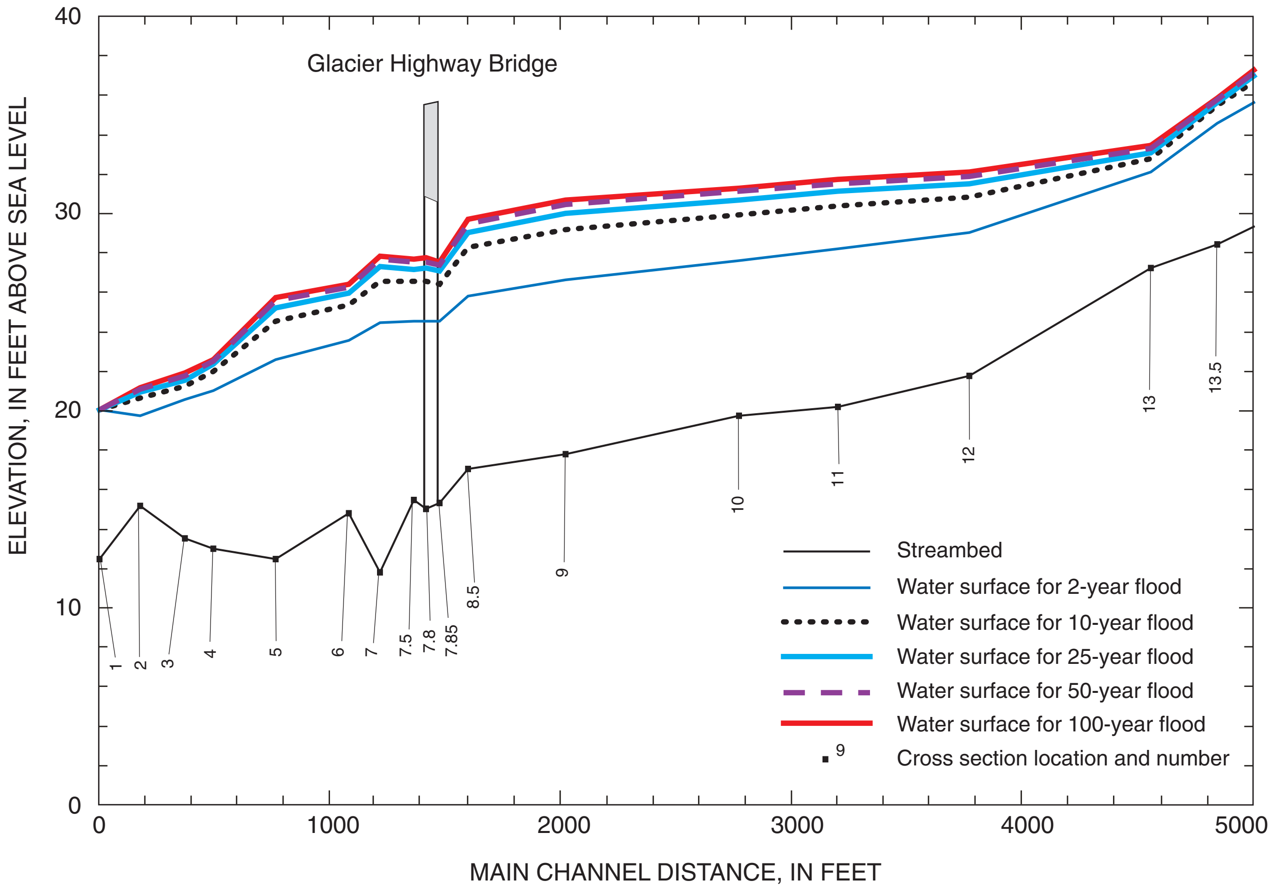

Figure 12. Profile of computed water-surface elevations, streambed elevations, and locations of cross sections on lower Lemon Creek for 2-, 10-, 25-, 50-, and 100-year floods, with the lower bridge channel geometry removed.

cycle, the actual water-surface elevations would be lower than water-surface elevations predicted in this report in the lower reaches of the study area. Modeling results indicate that water-surface elevations upstream from cross section 9.0 are not likely to be affected by tides during the 100-year flood.

The stream channel at each of the three bridges within the study area is constricted at the bridge opening. At cross section 4.0 just upstream from the approach to the lower bridge the channel width is 65 ft, which is reduced to 37 ft at the approach section (cross section 3.5), and further reduced to 30 ft at the bridge opening. Hydraulic conditions generated by the constrictions associated with the lower bridge violate the assumption of gradually varied flow implicit in the equations HEC-RAS uses to model streams as stated in the previous section, *Hydraulic Analysis*. Consequently, the HEC-RAS model cannot provide realistic simulations of the 10-, 25-, 50- and 100-year flood profiles in the vicinity of the lower bridge (table 3). It is important to note that the modeling results assume that there will not be any contraction scour at the bridge or any erosion along the approaches to the bridge abutments. If any contraction scour occurs it would likely increase the stream conveyance and possibly reduce some of the backwater.

Due to the inability of HEC-RAS model to provide credible simulations of flow through the lower bridge, the lower bridge, and cross sections 3.2, 3.3, and 3.5 were eliminated from the model. Figure 12 shows water-surface profiles for the 2-, 10-, 25-, 50-, and 100-year flood simulating conditions as they would exist if the lower bridge were to be removed. Although the profiles in figure 12 do not represent existing conditions, they do show that overbank flow would occur only at cross section 8.5 (table 4).

The water-surface profiles for the 2-, 10-, 25-, 50-, and 100-year floods (table 3) were computed for a 1.7-mi reach of Lemon Creek starting approximately 1,400 ft downstream of Glacier Highway. The 2-, 10-, 25-, 50-,

Table 3. Estimated computed water-surface elevations for the 2-, 10-, 25-, 50-,and 100-year flood discharge, Lemon Creek, Juneau, Alaska [a, not determined. Selected cross-section locations are shown on figures 3A-3C]

Cross section number	Distance upstream from mouth (feet)	Water-surface elevation (feet above sea level) at indicated recurrence interval				
		2 year	10 year	25 year	50 year	100 year
31	8877	101.5	103.7	104.0	104.2	104.3
30	8659	98.1	100.4	101.2	101.6	101.8
29	8593	98.4	101.2	102.0	102.5	102.7
28	8524	96.5	98.9	99.7	100.1	100.2
27.5	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge
27	8505	96.3	98.7	99.5	100.0	100.1
26	8453	96.6	99.4	100.2	100.7	100.9
25	8378	96.8	99.5	100.4	100.8	101.0
24	8247	95.4	97.9	98.6	99.0	99.2
23	8014	91.3	93.4	94.0	94.4	94.5
22	7906	89.2	91.2	91.8	92.2	92.3
21	7794	84.6	86.5	87.1	87.4	87.5
20	7704	80.3	82.7	83.3	83.6	83.8
19	7600	78.6	80.7	81.3	81.6	81.8
18	7408	72.3	74.0	74.5	74.8	74.9
17.5	7263	67.3	69.2	69.8	70.1	70.2
17	7123	64.8	66.7	67.2	67.5	67.6
16	6985	60.0	61.7	62.2	62.4	62.5
15.8	6772	55.7	57.2	57.5	57.8	57.9
15.5	6436	48.9	50.4	50.8	51.0	51.2
15	6042	45.7	46.9	47.2	47.4	47.5
14.5	5820	43.2	44.1	44.4	44.5	44.6
14	5293	37.6	38.8	39.3	39.5	39.6
13.5	4845	34.6	35.4	35.4	35.6	35.7
13	4559	32.0	32.7	33.7	34.1	34.2
12	3771	29.1	31.7	33.2	33.6	33.8
11	3204	28.4	31.4	33.0	33.5	33.6
10	2770	27.9	31.2	32.8	33.3	33.5
9	2020	27.3	a	a	a	a
8.5	1597	26.7	a	a	a	a
8	1472	25.9	a	a	a	a
7.85	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge
7.8	1413	26.0	a	a	a	a
7.5	1361	25.9	a	a	a	a
7	1213	25.9	a	a	a	a
6	1078	25.5	a	a	a	a
5	764	25.3	a	a	a	a
4	493	25.0	a	a	a	a
3.5	446	23.5	a	a	a	a
3.3	419	21.2	a	a	a	a
3.25	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge
3.2	404	a	a	a	a	a
3	372	a	a	a	a	a
2	174	a	20.5	20.6	20.9	21.0
1	20.0	20.0	20.0	20.0	20.0	18.7

Table 4. Estimated water-surface elevations for the 2-, 10-, 25-, 50-, and 100-year flood discharges without the lower bridge, Lemon Creek, Juneau, Alaska

[a, left overbank; b, both the left and right overbank. Selected cross-section locations are shown on figures 2A-2D]

Cross section number	Distance upstream from mouth (feet)	Water-surface elevation (feet above sea level) at indicated recurrence interval				
		2 year	10 year	25 year	50 year	100 year
13.5	4845	34.5	35.4	35.6	35.6	35.7
13	4559	32.1	32.7	33.0	33.1	33.2
12	3771	28.9	30.6	32.2	31.6	31.7
11	3204	28.1	30.2	30.8	31.2	31.3
10	2770	27.5	29.7	30.4	30.7	30.9
9	2020	26.5	29.0	29.7	30.1	30.2
8.5	1597	25.7	28.0	a28.7	b29.1	b29.3
8	1472	24.4	26.2	26.8	27.1	27.2
7.85	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge
7.8	1413	24.5	26.4	26.9	27.2	27.4
7.5	1361	24.4	26.3	26.9	27.2	27.4
7	1213	24.3	26.4	27.0	27.3	27.5
6	1078	23.5	25.2	25.7	26.0	26.1
5	764	22.5	24.3	24.9	25.2	25.4
4	493	21.0	21.9	22.3	22.4	22.4
3	372	20.6	21.2	21.3	21.5	21.6
2	174	20.0	20.5	20.8	20.9	21.0
1	20.0	20.0	20.0	20.0	20.0	20.0

and 100-year water-surface elevations from cross sections 3.3 to 9.0 are not determined due to the erroneous results generated by the effects of the lower bridge. The profiles show the computed water-surface elevations, the minimum streambed elevations, and the locations of bridges and the cross sections used in the hydraulic analysis. The flood elevations reported are considered valid if no debris obstructions or bank failures occur and no hydraulic structures fail during flooding. These simulated profiles represent channel conditions at the time of the survey; water-surface elevations could vary as a result of channel aggradation and degradation through the reach.

All field surveys and elevations are referenced to Mean Lower Low Water, which is a local datum that is 8.2 ft below the National Geodetic Vertical Datum of 1929. Vertical reference marks were established during the field surveys with the approximate locations shown on figures 3B, and 3C as 'RM' and given a description in the appendix 1. Coordinates of any given cross-section within the study area and bank elevation are located in appendix 3.

Summary

The flow of Lemon Creek is strongly influenced by glacial melt water and large floods are most likely when heavy rains fall during periods of high snow melt runoff and glacial melting. Prior to extensive gravel mining activities, Lemon Creek transported and deposited sediments through a network of braided channels within the study reach. As a result of gravel extraction, the lower reaches of the channel were deepened and straightened. Gravel mining in the channel ceased in the mid-1980s and subsequent aerial photos and field investigations indicate that the channel morphology is reverting to pre-disturbance conditions through aggradation of sediment and re-establishment of braided stream channels.

Selected channel cross sections of Lemon Creek were surveyed to determine rates of channel aggradation/degradation. Results of these surveys indicate no clear trend in either aggradation or degradation with the exception of one cross section in the upper reach, which indicated a mean reduction in bed elevation of 2.4 ft over a 2-year period from April 2002 to April 2004.

Data from 42 cross-sections were collected from field surveys of a 1.7-mi reach of Lemon Creek. Manning's roughness coefficients were estimated using flood marks from a known discharge and field observations. Water-surface elevations were calculated for the 2-, 10-, 25-, 50-, and 100-year floods using the USACE HEC-RAS streamflow model. It was assumed that the flow of Lemon Creek would peak concurrently with a 20-ft high tide, resulting in conservative estimates of flood water-surface elevations downstream from cross section 9.0, 475 ft upstream from the Glacier Highway Bridge.

The hydraulic conditions generated by the lower bridge (1,000 ft downstream from the Glacier Highway Bridge) and the channel geometry at the bridge violate assumptions implicit in the equations HEC-RAS uses to model streams. The model cannot provide realistic simulations of the 10-, 25-, 50- and 100-year flood profiles. A model that does not include the lower bridge or associated channel constriction indicates that over bank flooding would occur only at one section during the 25-year flood or higher.

References Cited

Barnes, H.H., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Bethers, Mike, Munk, Kris and Seifert, Cheryl, 1995. Juneau fish habitat assessment: Douglas, Alaska, Alaska Department of Fish and Game, Division of Sportfish, 128 p.

Coon, W.F., 1998, Estimation of roughness coefficients for natural stream channels with vegetated banks: U.S. Geological Survey Water-Supply Paper 2441, 133 p.

Curran, J.H., Meyer, D.F., and Tasker, G. D., 2003, Estimating the magnitude and frequency of peak streamflows for ungaged sites on streams in Alaska and conterminous basins in Canada: U.S. Geological Survey Water-Resources Investigations Report 03-4188, 101 p.

Federal Emergency Management Agency, 1990, Flood insurance study, City and Borough of Juneau, Alaska: Report revised, 1990, 42 p.

Hicks, D.M., and Mason, P.D., 1991, Roughness characteristics of New Zealand Rivers: DSIR Water Resources Survey, 329 p.

Kondolf, G.M., 1994, Geomorphic and environmental effects of instream gravel mining: Landscape and Urban Planning, v. 28, p. 225-243.

National Oceanic and Atmosphere Administration, 1943-2003, Local climatological data: U.S. Department of Commerce, (published annually).

U.S. Army Corps of Engineers, 2002a, HEC-RAS river analysis system—User's manual, version 3.1: Hydrologic Engineering Center CPD-68, variously paged.

——2002b, HEC-RAS river analysis system—Hydraulic reference manual, version 3.1: Hydrologic Engineering Center CPD-69, variously paged.

——2002c, HEC-RAS river analysis system—Applications guide, version 3.1: Hydrologic Engineering Center CPD-70, variously paged.

U.S. Geological Survey, 1950-60, Compilation of Records of Surface Waters of Alaska, October 1950 to September 1960: U. S. Geological Survey Water-Supply Paper 1740.

——1961-65, Surface Water Supply of the United States, 1961-65, Part 15, Alaska: U. S. Geological Survey Water-Supply Paper 1936.

——1966-70, Surface Water Supply of the United States, 1966-70, Part 15, Alaska: U. S. Geological Survey Water-Supply Paper 2136.

——1971-1973, Water resources data for Alaska, 1971-73, Part 1, Surface water records: U. S. Geological Survey Water-Data Reports AK-71 to AK-73 (published annually).

——2002-2003, Water resources data for Alaska, water years 2002-2003: U.S. Geological Survey Water-Data Reports AK-02-1 to AK-03-1 (published annually).

U.S. Interagency Advisory Committee on Water Data, --1982, Guidelines for determining flood-flow frequency: Hydrology Subcommittee Bulletin 17B, 28 p. [available from the National Technical Information Service as report PB-86-157278/AS].

Zembrzuski, T.J., Jr., and Dunn, Bernard, 1979, Techniques for estimating magnitude and frequency of floods on rural unregulated streams in New York State excluding Long Island: U.S. Geological Survey Water-Resources Investigations 79-83, 82 p.

Appendixes 1-3

Appendix 1. Datum and reference marks for cross sections.

The project basis of the horizontal and vertical control is based on the U.S. Coast and Geodetic Survey monument "EDDIE" at the Juneau International Airport (NGS Data Sheet, PID-UV1458). The horizontal location is North 6,468,455.756 East 525,208.338 in UTM North, Zone 8, NAD 1983. Elevation of the monument is 18.40 ft Mean Lower Low Water. The elevations of the following reference marks should be accurate to within 0.05 ft. Location of the reference marks (RM) are shown on figures 3B and 3C.

RM 1 Brass cap on the upstream left bank side of the sidewalk on the Glacier Highway Bridge. Elevation is 35.04 ft.

RM 2 A 10D nail in a log on the right bank end of cross-section 31.0. Elevation is 105.05 ft.

Appendix 2. Estimated roughness coefficients after calibration, Lemon Creek, Juneau, Alaska [Selected cross-section locations are shown on figures 3A-3C]

Cross section number	Manning roughness coefficient (*n*)			Cross section number	Manning roughness coefficient (*n*)		
	Left bank	Channel	Right bank		Left bank	Channel	Right bank
31	0.08	0.04	0.04	14	0.08	0.045	0.08
30	0.10	0.04	0.08	13.5	0.08	0.04	0.08
29	0.10	0.04	0.08	13	0.08	0.037	0.08
28	0.055	0.04	0.055	12	0.08	0.031	0.08
27	0.055	0.04	0.055	11	0.08	0.035	0.08
26	0.08	0.04	0.08	10	0.08	0.035	0.08
25	0.08	0.04	0.04	9	0.08	0.035	0.08
24	0.08	0.06	0.08	8.5	0.08	0.035	0.08
23	0.08	0.079	0.08	8	0.055	0.035	0.055
22	0.08	0.079	0.08	7.8	0.055	0.035	0.055
21	0.08	0.079	0.08	7.5	0.08	0.035	0.08
20	0.08	0.079	0.08	7	0.08	0.035	0.08
19	0.08	0.079	0.08	6	0.08	0.035	0.08
18	0.08	0.079	0.08	5	0.08	0.035	0.08
17.5	0.08	0.079	0.08	4	0.08	0.03	0.08
17	0.08	0.07	0.08	3.5	0.08	0.03	0.08
16	0.08	0.067	0.08	3.3	0.03	0.03	0.03
15.8	0.08	0.06	0.08	3.2	0.03	0.03	0.03
15.5	0.08	0.055	0.08	3	0.08	0.03	0.08
15	0.08	0.055	0.08	2	0.08	0.03	0.08
14.5	0.08	0.045	0.08	1	0.08	0.03	0.08

Appendix 3. Location of elevation of cross section ends, Lemon Creek, Juneau, Alaska in UTM North, Zone8, elevation in Mean Lower Low Water (MLLW) [LB, left bank; RB, right bank: m, meters; ft, feet]

Cross Section	North (m)	East (m)	Elevation (ft)	Cross Section	North (m)	East (m)	Elevation (ft)
1 LB	6468215.60	529023.93	27.10	15.5 LB	6469293.80	530486.71	77.59
1 RB	6468365.99	528946.26	31.56	15.5 RB	6469314.42	530418.46	75.26
2 LB	6468272.65	529055.20	31.66	16 LB	6469497.64	530493.87	91.17
2 RB	6468361.05	529000.06	27.95	16 RB	6469451.99	530465.65	67.49
3 LB	6468325.02	529090.78	29.46	17 LB	6469497.13	530490.90	78.12
3 RB	6468357.46	529078.09	28.58	17 RB	6469493.36	530460.90	77.53
3.5 LB	6468336.91	529107.83	26.21	17.5 LB	6469538.78	530489.37	94.42
3.5 RB	6468354.83	529100.64	24.44	17.5 RB	6469537.99	530463.23	72.31
4 LB	6468337.23	529122.47	28.87	18 LB	6469583.54	530484.60	85.86
4 RB	6468362.85	529112.02	27.66	18 RB	6469579.81	530456.15	87.50
5 LB	6468389.92	529191.49	29.17	19 LB	6469640.54	530485.43	100.62
5 RB	6468405.63	529177.71	17.22	19 RB	6469640.12	530479.01	83.07
6 LB	6468489.75	529221.35	28.44	20 LB	6469667.34	530487.25	87.17
6 RB	6468484.43	529190.52	30.25	20 RB	6469666.62	530489.52	100.85
7 LB	6468525.75	529186.07	29.86	21 LB	6469695.98	530483.82	92.62
7 RB	6468527.72	529214.71	22.97	21 RB	6469697.16	530486.28	102.85
7.5 LB	6468549.27	529231.58	28.87	22 LB	6469731.91	530476.08	94.29
7.5 RB	6468572.39	529215.11	32.61	22 RB	6469732.51	530479.11	103.48
8.5 LB	6468585.55	529288.09	28.87	23 LB	6469764.23	530470.70	98.65
8.5 RB	6468615.79	529270.68	29.20	23 RB	6469764.77	530473.41	104.99
9 LB	6468640.83	529401.10	23.95	24 LB	6469829.12	530476.70	104.30
9 RB	6468688.96	529378.23	32.58	24 RB	6469835.56	530451.42	106.36
10 LB	6468735.98	529604.05	40.26	25 LB	6469859.17	530502.07	102.76
10 RB	6468794.53	529579.52	36.84	25 RB	6469875.72	530455.26	103.22
11 LB	6468861.92	529692.64	44.95	26 LB	6469878.54	530506.41	104.72
11 RB	6468791.42	529722.45	25.72	26 RB	6469906.50	530455.79	115.65
12 LB	6468834.73	529874.10	41.44	27 LB	6469883.97	530508.22	103.84
12 RB	6468911.41	529854.57	41.96	27 RB	6469908.14	530504.33	105.58
13 LB	6468893.09	530092.69	46.82	28 LB	6469887.37	530511.71	102.62
13 RB	6468984.57	530072.63	54.46	28 RB	6469909.73	530509.47	104.63
13.5 LB	6468927.47	530178.65	48.06	29 LB	6469922.66	530517.18	102.13
13.5 RB	6468998.15	530151.29	57.58	29 RB	6469880.24	530563.61	108.20
14 LB	6468996.83	530301.23	57.22	30 LB	6469906.15	530578.37	98.49
14 RB	6469066.20	530229.75	71.23	30 RB	6469940.82	530530.60	102.30
14.5 LB	6469120.32	530394.17	57.38	31 LB	6469955.16	530595.03	108.73
14.5 RB	6469181.15	530333.03	65.55	31 RB	6469996.61	530578.44	105.05
15 LB	6469176.22	530439.10	64.67				
15 RB	6469212.08	530385.70	63.22				