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MEMORANDUM

To:	Darwin Green and Maria Egerton, Constantine North
From:	Alice Conovitz, Integral Consulting Inc.
Date:	April 30, 2018
Subject:	Klehini River and Glacier Creek Hydrologic Data Summary—Spring 2018 Update
Project No.:	C708

The Palmer exploration project is located in southeastern Alaska near the town of Haines. In 2006, Constantine North Inc. (Constantine), a wholly owned U.S. subsidiary of Constantine Metal Resources Ltd., began exploratory drilling to delineate resource extent and quality. The exploration drill program is seasonal, with helicopter-supported drill activity typically extending from late May until early October in each calendar year. Constantine intends to continue exploration and strives to understand hydrologic conditions within the project area to support potential future site activities.

Glacier Creek and its tributaries provide the primary drainage within the Palmer project boundary, ultimately flowing into the Klehini River (Figure 1). Streamflow measurements taken along Glacier Creek and its tributaries provide the basis for characterizing streamflow conditions within the Palmer site. These data were used with stream gage data from the Chilkat and Klehini rivers collected by the U.S. Geological Survey (USGS) to characterize surface water hydrology within and near the Palmer project property.

This memorandum updates the hydrology information presented in two previous memoranda prepared by Integral Consulting Inc. (Integral): *Klehini River and Glacier Creek Hydrologic Data Summary—Fall 2016 Update* (Integral 2016a) and *Klehini River and Glacier Creek Hydrologic Data Summary* (Integral 2016b).

HYDROLOGIC DATA SUMMARY

This section summarizes available local hydrologic data for Glacier Creek and tributaries in the vicinity of the Palmer project property (Figure 1). Regional hydrologic data from the Klehini and Chilkat rivers, as well as regional and local climate data, are also included.

Streamflow measurement locations are shown on Figures 1 and 2. The Palmer project is centered within the Glacier Creek watershed that drains into the Klehini River. The Klehini River in turn flows into the Chilkat River approximately 14 miles downstream of the Glacier Creek and Klehini River confluence. The Klehini River follows a large braided channel that runs from west to east along the northern property boundary. From north to south within the Palmer property, the names of the stream systems are Jarvis Creek, Little Jarvis Creek, Sarah Creek, and Glacier Creek. Flow measurements have been made on tributaries to Glacier Creek, including Oxide Creek, Argillite Creek, Christmas Creek, Hangover Creek, Waterfall Creek, and unnamed streams and seeps. An additional discharge measurement location is on the Klehini River approximately 10 miles downstream of the project area at the Klehini River Bridge near Haines Highway milepost 26 and Porcupine Creek. A summary of hydrologic data available for each water body, as well as meteorological data, is provided in Table 1.

The drainage area for each watershed that contributes to the Klehini River near the Palmer property is shown as purple outlines on Figure 1 (regional scale) and Figure 2 (Palmer property zoom scale). These drainage areas were determined based on USGS hydrologic unit code (HUC) boundaries. Within the Glacier Creek watershed, smaller drainage catchments are shown as orange outlines. The Glacier Creek sub-basins were delineated manually based on topography and aerial imagery, as well as previous delineations by Teitzel (2017). The total surface area associated with each of the watersheds and catchments, as well as discharge measured within these areas, is summarized in Table 2. Figure 3 presents a watershed and catchment key to accompany Table 2

Previous hydrographic evaluations (Teitzel 2017; Integral 2016a,b) found that peak flows are expected in spring and early summer during snowmelt. Highest precipitation occurs in the fall (September and October), which may cause a short secondary flow peak during wet years. In this memorandum, references to periods of expected high flow conditions are for the months of May through September, and references to expected low flow conditions are for the months of October through April. These are simplistic groupings used for purposes of discussion and graphical presentation; the actual high flow and low flow periods vary each year, particularly during the decreasing flows in the fall months and increasing flows during the spring. A more detailed discussion of the annual hydrograph, based on quantitative observations, is presented in this memorandum.

Chilkat River

The Chilkat River basin is characterized by widespread glaciers, rugged mountains with steep-gradient streams, and braided rivers and alluvial fans in valley (Bugliosi 1985). The Chilkat River flows south from a glacier source in British Columbia, Canada, to the ocean at Chilkat Inlet near Haines, Alaska. USGS gage 15056500 is located on the Chilkat River near the town of Klukwan, upstream of the confluences of the Klehini and Tsirku rivers, the two largest tributaries to the Chilkat. This gage captures a drainage area of approximately 760 square miles. Historical daily discharge data are available for USGS gage 15056500 from 1959 to 1961 and from 2013 to 2015. Discharge data are also available in 15-minute intervals from 2013 to March 2018. Figure 4 (upper plot) presents recent discharge data for the Chilkat River USGS gage. Monthly average discharge data is summarized in Table 3.

Tsirku River

The Tsirku River originates at the Tsirku Glacier and runs approximately 25 river miles to its confluence with the Chilkat River near the town of Klukwan, Alaska, approximately 14 miles downstream of the Palmer project area. Limited Tsirku River discharge data were found in an internet search by Integral. Bugliosi (1985) presents monthly average discharge data recorded from October 1981 to September 1982. These data are summarized in Table 3.

Klehini River

The Klehini River originates in British Columbia and flows southeast toward the Chilkat River, where they join at the town of Klukwan. USGS gage 15056560 was located at the Klehini River Bridge at the Porcupine Creek crossing near Haines Highway milepost 26, approximately 10 miles downstream from the Palmer project (Figure 1). This gage measured streamflow from a drainage area of approximately 290 square miles. Historical daily discharge data from this gage are available for the 12-year period from 1981 to 1993. Figure 4 (lower plot) presents all available daily discharge data for USGS gage 15056560. Streamflow discharge data from this gage are summarized in Tables 1 and 3.

A stilling well and water level logger were installed at the Klehini River Bridge on November 4, 2014, by R2 Resources Consultants (2015). The stilling well gage was located on the bridge abutment in the middle of the river and a backup pressure transducer was located approximately 100 ft downstream of the bridge in front of a boulder. Water level[1]

[1] Water level measurements are provided in units of feet and are relative to local benchmarks installed on November 4, 2014. The water levels measured in the stilling well and backup transducer reference

measurements taken at 15-minute intervals are available for the stilling well gage from November 2014 through June 2016. These water levels are shown with Chilkat River discharge on Figure 4. In July 2016, the bridge stilling well gage was removed prior to construction of a new bridge.[2]

Manual discharge measurements were taken approximately 300 ft upstream of the bridge on November 6, 2014, and at the bridge on June 4, 2015. Due to unsafe high flows, river depths and velocity measurements over the entire channel could not be completed in 2015. Individual discharge measurements for the Klehini River are shown on Figure 5a and summarized in Tables 1 and 2.

Glacier Creek

Glacier Creek discharge was measured at upstream, midstream, and downstream locations (Figure 2) during five flow measurement events from 2015 to 2018 using a velocity meter over a cross section of the stream. Individual discharge measurements for Glacier Creek are shown in the bar chart on Figure 5b and the upper time series plot on Figure 6, and are summarized in Tables 1 and 4. Glacier Creek streamflow measurements collected to date are as follows:

- Upstream station P1 was measured three times, all during low flow conditions.[3] Upstream Glacier Creek flows ranged from 4 cfs to 21 cfs.

Benchmark 1 (BM1), which is set at an arbitrary elevation of 100.00 ft. The levels do not relate to mean sea level, nor do they indicate the depth of water in the river.

[2] Alaska Department of Transportation and Public Facilities (DOT & PF) initiated the Klehini River Bridge replacement project in July 2016. A web site posting dated November 23, 2016, for construction management service proHNS indicated that the bridge replacement project was underway (http://prohns.com/portfolio/klehini-river-bridge-transfer-%E2%80%A2-haines-ak-%E2%80%A2-2016-2017/). According to an e-mail from Hilary Lindh, the Regional Environmental Manager for DOT & PF Southcoast, the project involves construction of a new bridge followed by demolition of the existing bridge. Additional information is available at the project web site: http://dot.alaska.gov/sereg/projects/haines_klehini_bridge/index.shtml. Bridge reconstruction is likely to alter the river cross section. Following the bridge replacement project, if the stilling well is replaced on the new bridge, additional discharge and cross-sectional data would be required to determine a water level/flow rating curve.

[3] Due to the steep stream gradient, it has not been possible to safely measure streamflow at station P1 during higher flow conditions. Constantine contractors attempted additional discharge measurements at Glacier Creek upstream stations multiple times in 2015 and 2016, however, high flow conditions prevented manual measurement by wading or use of an acoustic Doppler velocimeter (ADV). Similarly, due to high flow conditions, ADV measurements at mid-channel location GC could not be collected in June 2015; an alternate float method was employed at station GC to obtain an estimated discharge value.

- Midstream station P27 was measured twice, both during low flow conditions, ranging from 7 cfs to 17 cfs. Midstream station GC was measured once, during high flow conditions, using a semi-quantitative float method that may have overestimated the flow. The high flow measurement was 470 cfs.
- Downstream station P6 was measured five times, across a range of flow conditions. Downstream station LG was measured once, during high flow conditions. The low flow measurements for lower Glacier Creek ranged from 31 cfs to 41 cfs. High flow measurements ranged from 141 cfs to 272 cfs. Due to the braided nature of the channel, for some events the LG and P6 station discharge measurements were calculated as a sum of the main Glacier Creek channel and braided side channels.

Streamflows measured at tributaries to Glacier Creek are discussed below.

Tributaries to Glacier Creek

Several tributaries flow into Glacier Creek within the Palmer project area (Figure 2). Tributary discharge measurements were taken from eight waterways (creeks or springs) from 2015 to 2018, as listed in Tables 1 and 4. Bar charts of streamflow data for tributaries flowing into Glacier Creek from the east are shown on Figure 5c, while tributaries flowing into Glacier Creek from the west are shown on Figure 5d. Tributary flow data are also shown on the middle and lower time series plot on Figure 6. Measurements have been collected during both low flow and high flow conditions. Streamflow measurements collected to date for the three Glacier Creek tributaries with the largest flow volume are as follows:

- Waterfall Creek (P25) was measured once under low flow conditions and three times during high flow conditions. The low flow measurement was 0.9 cfs. Waterfall Creek flows ranged from 26 cfs to 52 cfs during the high flow season. R2 measured Waterfall Creek flow at station HT1 on June 2, 2015. The flow was estimated to be between 14–15 cfs; field notes indicate that this may be an underestimate of the actual flow.
- Christmas Creek (P5 and CC) was measured three times during low flow conditions and six times during high flow conditions. The low flow measurements ranged from 0.7 cfs to 6 cfs. High flow measurements ranged from 3.5 cfs to 39 cfs.
- Hangover Creek (P26) was measured once under low flow conditions and twice during high flow conditions. The low flow measurement was 0.4 cfs. Hangover Creek flows ranged from 7.1 cfs to 9.4 cfs during the high flow season.

Discharge results for all tributary streams are summarized in Tables 2 and 4.

Meteorological Data

Climate data including rainfall and air temperature are available from the onsite Palmer meteorological station and a regional station located at Pleasant Camp, British Columbia, on the border between the U.S. and Canada. The Palmer meteorological station records continuous 15-minute climate data beginning in October 2014. Thirty-year (1981 to 2010) monthly normal climate data are available for the Pleasant Camp meteorological station. Onsite precipitation and temperature data available through February 2018 are shown on Figure 7; long-term regional data for the Pleasant Camp station are shown on Figure 8. Average daily temperature is typically above freezing for the months of April through October. Total precipitation is lowest from April through July. Precipitation begins to increase in August as rainfall. Peak rainfall occurs in September and October, followed by precipitation primarily as snowfall from November through March.

SEASONAL AND DIURNAL HYDROLOGIC VARIATIONS

Integral evaluated Klehini River and Glacier Creek surface water hydrology patterns based on stream discharge and meteorological data. Surface water in the region exhibits seasonal and diurnal patterns due to the influences of snowmelt, rainfall events, and ambient air temperature.

Klehini River Seasonal Patterns

A hydrograph showing daily Klehini River discharge for a 14-year period from 1981 to 1993 is shown in Figure 4 (lower panel). Table 3 presents monthly average discharge for the Klehini River at the Porcupine Creek Bridge approximately 10 miles downstream of the Palmer property. The sustained high discharge volumes for the Klehini River occur in the summer months (June, July, and August) with monthly average discharge up to 4,151 cfs. The maximum daily discharge recorded at the Klehini River station from 1981 to 1993 was 9,000 cfs on October 15, 1981.[4] Lowest flows for the Klehini River occur through winter and early spring (December through March), with the minimum monthly average discharge of 222 cfs in March. The minimum daily discharge recorded at the Klehini River station from 1981 to 1993 was 109 cfs, recorded on March 29, 1985. Based on monthly average discharge, Klehini River wintertime base flow is over 90 percent less than the summer peak flows.

[4] A total of 1 inch of precipitation was recorded at the Haines, Alaska, PAHN weather station on October 14 and 15, 1981 (https://www.wunderground.com/history/airport/PAHN/1981/10/14/DailyHistory.html?req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo).

Upon careful examination of the streamflow hydrograph (Figure 4), two seasonal patterns emerge. The first pattern illustrates the dominant character of the Klehini River watershed, whereby snowmelt runoff drives annual peak stream discharge in the spring. The onset of peak flow (the rising limb) occurs quickly in the late spring to early summer months, generally late April through June. Peak flows occur when average daily air temperatures routinely exceed freezing and when total monthly rainfall is lowest (Figures 7 and 8), indicating that snowmelt drives the hydrographic peak. During the period following peak flow (the falling limb), beginning in the late summer months until early fall, stream discharge gradually declines as the snow pack recedes and average daily air temperatures approach freezing. Klehini River discharge remains near base flow throughout the winter and early spring months, typically from November to April. During this time, individual precipitation events produce short-lived increases in stream discharge above base flow.

A second pattern can be seen in the Klehini River hydrograph for most years, when river discharge shows a secondary peak in late fall, as seen in Figure 4. The late fall peak discharge events occur when total monthly precipitation begins to increase and before average daily temperatures dip below freezing. The increase, and subsequent decline in late fall discharge, occur over a much shorter period of time than the summertime peak discharge cycle because individual precipitation events, rather than snowmelt runoff, provide runoff for the late fall peak flow.

Glacier Creek Seasonal Patterns

Stream discharge measurements taken at Glacier Creek midstream stations (P27 and GC) and downstream stations (P6 and LG) show seasonal patterns similar to the Klehini River hydrograph. Lower flows were observed at the midstream and downstream stations during events conducted in October[5], January, and February relative to flow measurements made during the warmer months of June and August. The higher discharge measured at Glacier Creek stations in summer months corresponds to periods of peak flows driven by snowmelt, but little rainfall. The relatively lower discharge measured in October 2016 corresponds to the falling limb of the Klehini River hydrograph as temperatures cool, snowpack is diminished, and the influence of snowmelt decreases. Base flow was captured in the February 2017 and January 2018 measurements; streamflows measured in January and February indicate that wintertime base flow is approximately 90 percent less than the summer peak flows for middle and lower portions of Glacier Creek.

[5] The October measurement was taken during a dry period; precipitation measured onsite during September and October 2016 was below average with only 2 inches of rainfall in August, 4.2 inches in September, and 1.5 inches in October.

Klehini River Diurnal Patterns

During the warmer spring, summer, and fall months, when average air temperature remains above freezing, diurnal discharge patterns are apparent for the Klehini River. Figure 9 (lower plot) shows hourly Klehini River stage and ambient air temperature measured from May 20–27, 2015, during a period of peak stage and when there was no measurable precipitation. During this period, daily maximum air temperatures occurred in the late afternoon, while daily maximum stage was observed from late night to early morning. This diurnal pattern suggests gradually increasing rates of snowmelt runoff through the daylight hours in response to increasing air temperature followed by a lag in the peak stage. Peak stage and streamflow discharge lag behind peak temperature because of increased travel times required for runoff to move through tributaries upstream from the Klehini River gage station.

Average daily temperatures are below freezing from December through March (Figure 8). Clear diurnal patterns for the Klehini River are not apparent during these colder winter months, as shown in the example meteorological data set from January 1–8, 2015, in Figure 9 (upper plot).

The discrete streamflow measurements available for the Glacier Creek system do not support evaluation of diurnal patterns.

HYDROLOGIC SYSTEM EVALUATION

Integral evaluated regional (Chilkat River and Klehini River) and localized (Glacier Creek and tributaries) surface water hydrology patterns in the context of drainage basin area and stream discharge data.

Regional Hydrology

The Klehini River flows into the Chilkat River approximately 14 miles downstream of the Palmer project area and the Glacier Creek and Klehini River confluence. Comparison of the Chilkat River and Klehini River discharge measurements at USGS gages 15056500 and 15056560, respectively, provides a basis for evaluating discharge contributions from each river at their confluence near the town of Klukwan. On the Chilkat River, USGS gage 15056500 measures discharge from a drainage area of 760 square miles and is located immediately upstream of the confluence of the Klehini and Tsirku rivers. Monthly average discharge ranged from 300 cfs to 9,200 cfs, and the annual average discharge is 3,400 cfs. The Klehini River USGS gage 15056560 measures discharge from a drainage area of 290 square miles and is located approximately 2 miles upstream of the confluence with the

Chilkat River. Monthly average discharge at the Klehini River gage ranged from 220 cfs to 4,100 cfs, with an annual average discharge of 1,500 cfs. Table 3 summarizes average monthly flows recorded at the Chilkat River and Klehini River USGS gages for the available periods of record.

The drainage area to the Chilkat River measured at USGS gage 15056500 is 2.6 times larger than the Klehini River drainage area measured at USGS gage 15056560. The relative drainage area sizes were considered with respect to available discharge measurements. From May to September, the period of relatively higher discharge supported primarily by snowmelt, the Klehini River and Chilkat River discharge measured at the USGS gages averaged 2,900 cfs and 7,000 cfs, respectively. Based on these averages, the discharge recorded for the upper portion of the Chilkat River was approximately 2.4 times larger than the average discharge recorded for the Klehini River; these relative discharge volumes are generally consistent with the relative total drainage areas. However, during the lower-flow months of November through April, the Chilkat River discharge was only 60 percent larger than the Klehini River discharge, on average. These data suggest that the complex influences of snowmelt, precipitation, groundwater, and air temperature preclude a simple estimate of flows based on drainage area alone.

Glacier Creek Hydrology

The relative drainage area sizes of the Klehini River at USGS gage 15056560 and Glacier Creek were also evaluated to estimate expected Glacier Creek discharge for the higher-flow spring/summer period. The Glacier Creek drainage area, at 15 square miles, is approximately 5 percent of the total Klehini River drainage area measured at USGS gage 15056560. Average discharge for the Klehini River for the May to September period was 2,900 cfs. Based on the relative size of the Klehini River and Glacier Creek drainage areas, typical flows in Glacier Creek during the summer months may be estimated as 5 percent of the Klehini River flows, yielding approximately 150 cfs. This estimate is consistent on an order-of-magnitude level with the individual daily flow measurements made on the downstream portion of Glacier Creek during summer months in 2015, 2016, and 2017, which ranged from 141 cfs to 272 cfs (Table 4). During winter base flow (December through March), Klehini River streamflow averaged 280 cfs. The Klehini River winter discharge is approximately 90 percent greater than the Glacier Creek downstream flow of 31 cfs measured in January 2018, which is consistent with the relative drainage basin areas.

Increases in Glacier Creek flows from upstream to downstream are generally observed in the measurements, and are likely due to cumulative inflow from tributaries and groundwater. Comparison of individual flow measurements collected at Glacier Creek upstream (P1) and midstream (P27 and GC) stations during February 2017 and January

2018 shows similar flows at these locations, ranging from 4 cfs to 17 cfs. During the January 2018 event, flow measured at downstream station P6 was 31 cfs, approximately double the flow of 17 cfs measured at the upstream and midstream stations. Glacier Creek flow was also measured at the upstream (P1) and downstream (P6) stations on October 6, 2016. This was a period of low flow with little precipitation during the preceding weeks and limited influence of snowmelt expected due to cooler temperatures and reduced snowpack. The discharge of 21 cfs measured at upstream station P1 nearly doubled to 41 cfs at downstream station P6.

The largest surface water flow contributions to Glacier Creek are from the Waterfall Creek, Christmas Creek, and Hangover Creek catchments (Table 4). Based on available flow measurements, surface water flows entering Glacier Creek from the eastside tributaries are up to 12 times greater than flows entering from the westside tributaries; this is clearly apparent when viewing the different y-axis scales on Figures 5c and 5d. Based on the available data for the Glacier Creek upstream station, Glacier Creek flow approximately doubles from the upstream station P1 to downstream station P6, over a distance of approximately 4 miles. Surface water flows from all measured tributaries contribute up to approximately one-third to one-half of the increased discharge measured at the Glacier Creek downstream station. Additional inflows to Glacier Creek are expected to be from groundwater and unmeasured surface water sources.

SUMMARY

This memorandum summarizes hydrology data for the Palmer project area and surrounding region. The discharge data collected from 2015 through 2018 at Glacier Creek locations and at inflowing tributaries, paired with historical and recent discharge data from the Klehini and Chilkat rivers, provides a quantitative basis for understanding local and regional hydrology in the vicinity of the Palmer exploration project. The streamflow data collection efforts conducted to date yielded individual point-in-time flow measurements, as well as valuable on-the-ground experience with the practical challenges of collecting accurate discharge data in this extremely dynamic and rugged hydrologic system.

Evaluation of stream discharge and meteorological data indicates seasonal and diurnal discharge patterns. Flow in Klehini River varies seasonally; average monthly flows measured downstream of the Palmer property from 1983 to 1991 ranged from 222 cfs in winter months (December through March) to over 4,100 cfs in the summer (June through August). Flows increase in the late spring to early summer months, generally late April through June, as average daily air temperatures above freezing melt snowpack. During these warmer months, diurnal flow fluctuations are observed.

Glacier Creek and its tributaries provide the primary drainage within the Palmer project boundary, ultimately flowing into the Klehini River. Individual flow measurements on Glacier Creek from 2015 to 2018 ranged from 4 cfs to 471 cfs, roughly 10 percent of the Klehini River discharge volume. Similar to the regional patterns observed in the Klehini River hydrograph, the highest discharge measurements in the Glacier Creek drainage were collected in the month of June, while the lowest discharge was measured in February.

Ongoing streamflow data collection across seasons will add to the developing understanding of Glacier Creek flow ranges and variability, and can be used to support Palmer project exploration planning, site infrastructure design, environmental chemical loading estimates, and permit applications.

REFERENCES

Bugliosi, E.F. 1985. Hydrologic reconnaissance of the Chilkat River Basin, Southeast Alaska, with special reference to the Bald Eagle Critical Habitat at the Tsirku River alluvial fan. USGS Open-File Report 84-618. U.S. Geological Survey, Anchorage, AK.

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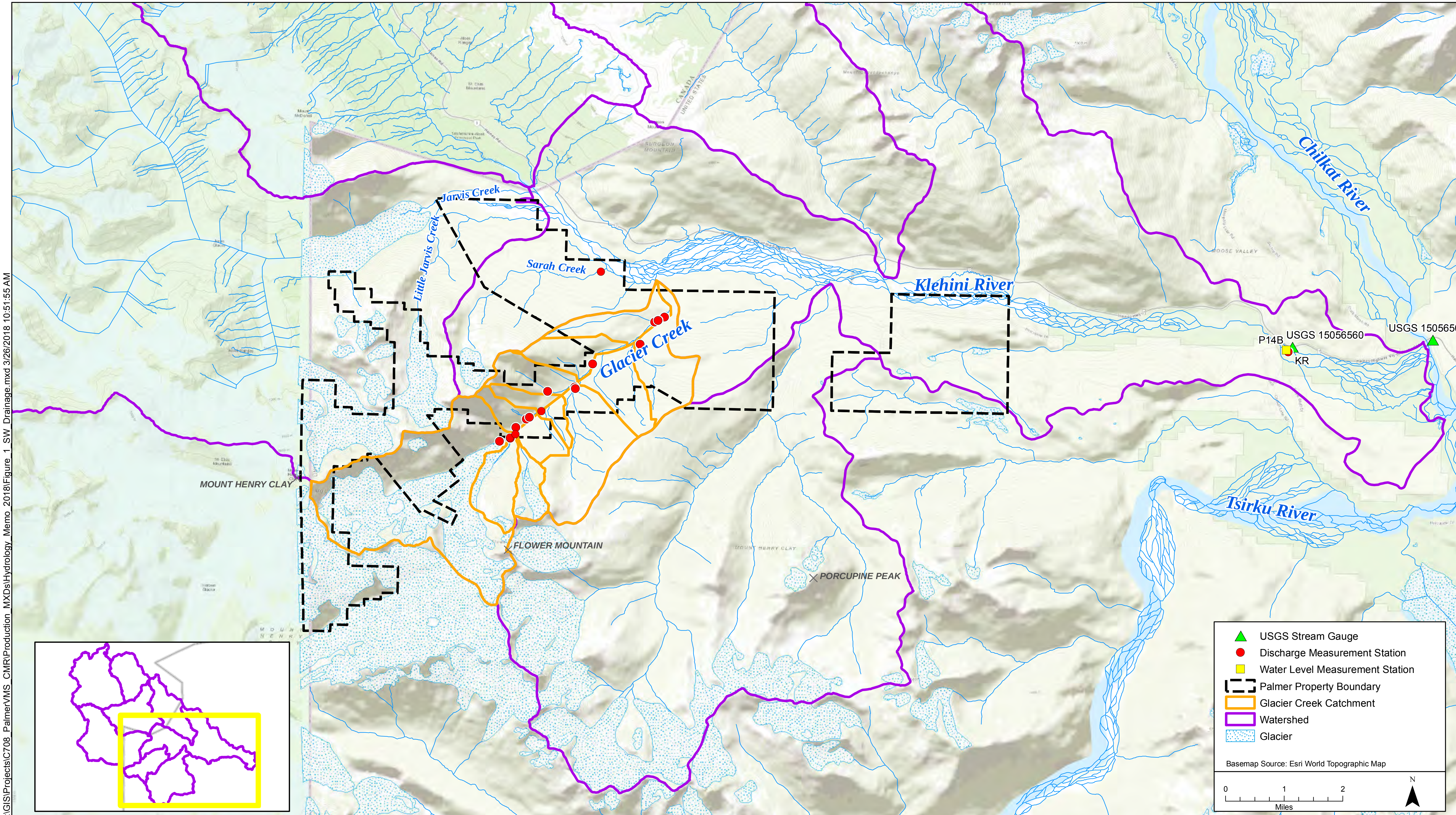
FIGURES



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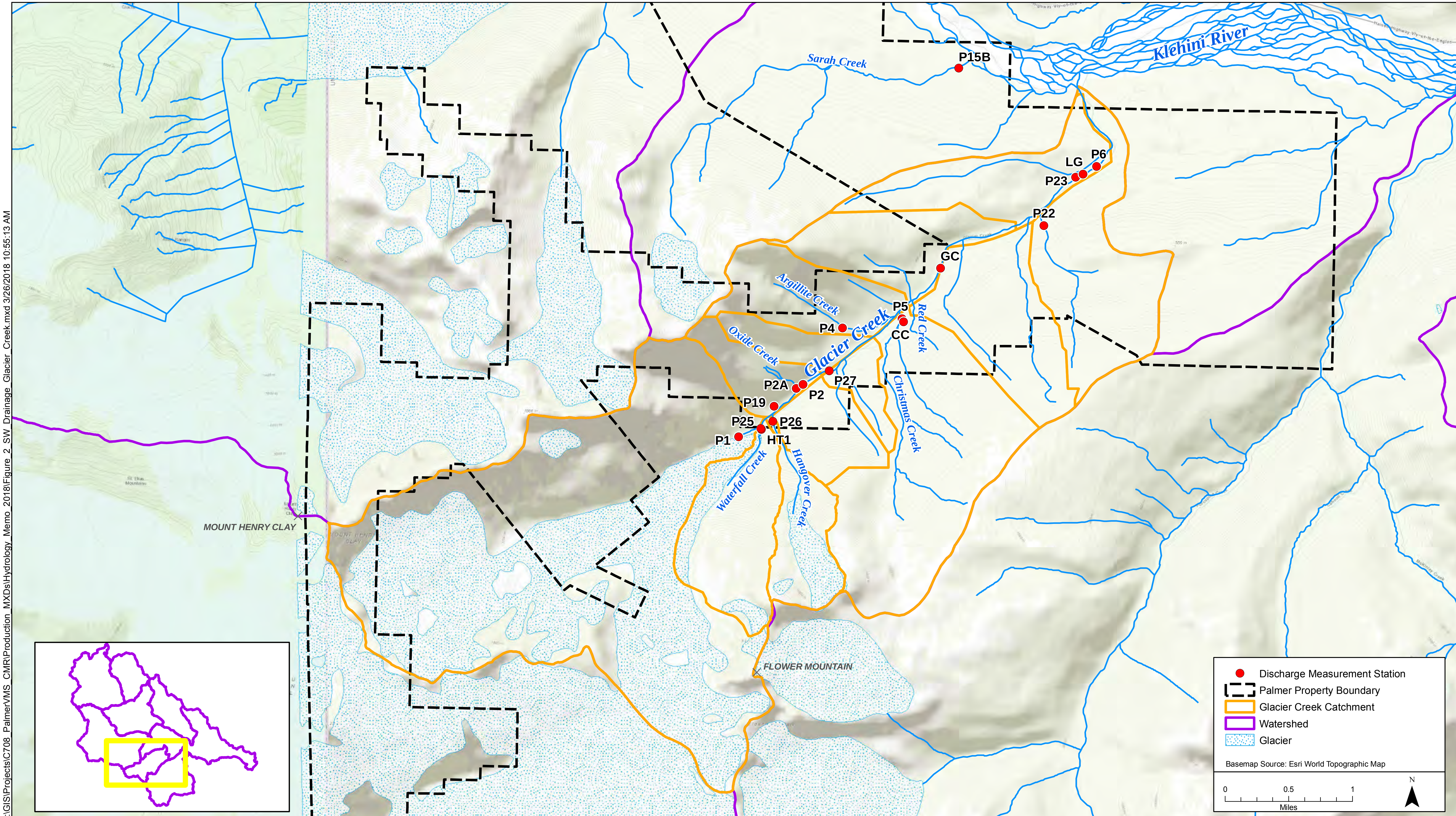
Hydrography Source: USGS National Hydrography Dataset and Constantine North 2016

Figure 1.
Palmer Exploration Project
Surface Water Discharge Measurement Locations and Drainage Areas – Regional View



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Hydrography Source: USGS National Hydrography Dataset and Constantine North (2016)

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Figure 2.
Palmer Exploration Project
Surface Water Discharge Measurement Locations and Drainage Areas – Glacier Creek View

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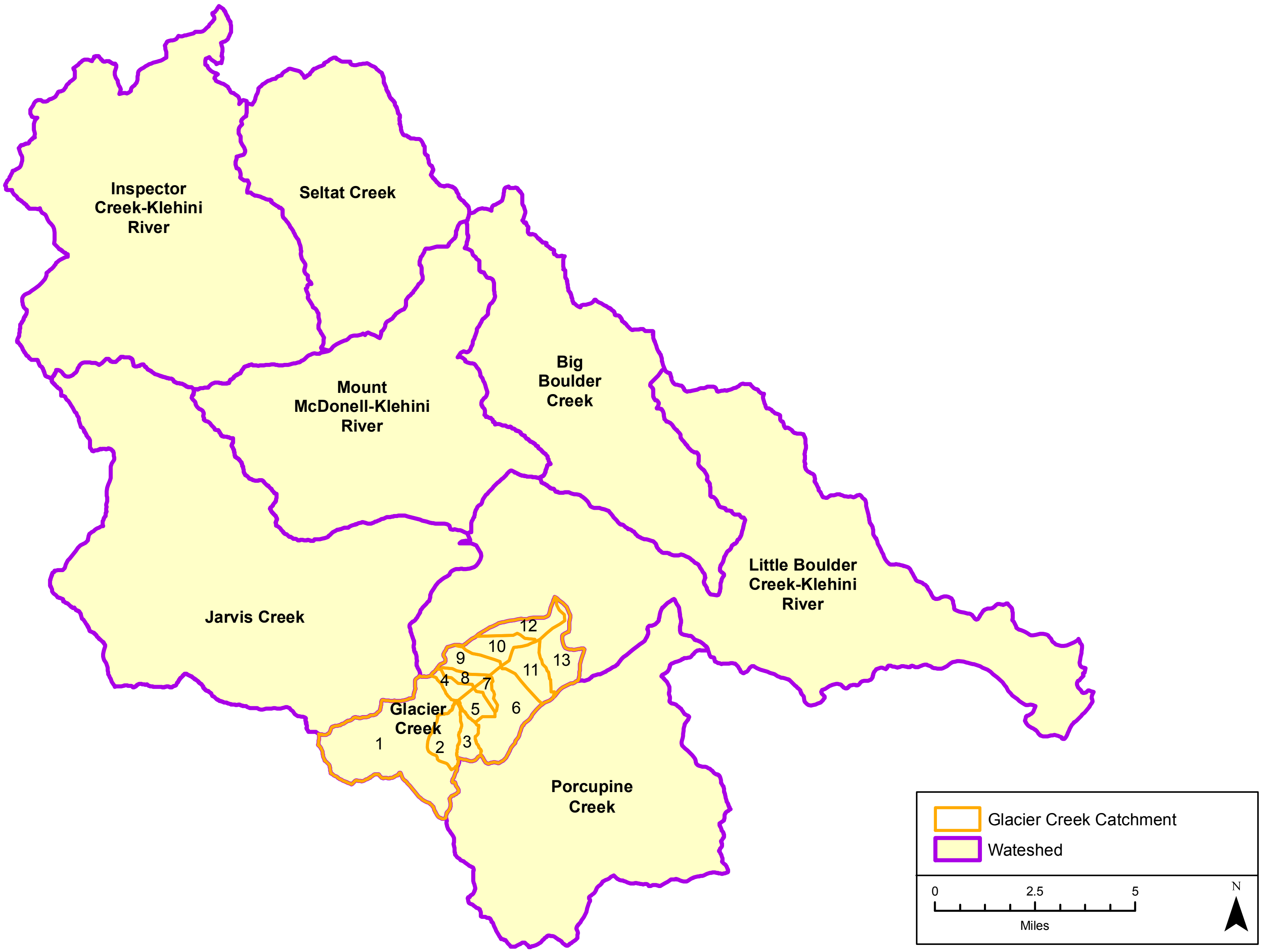

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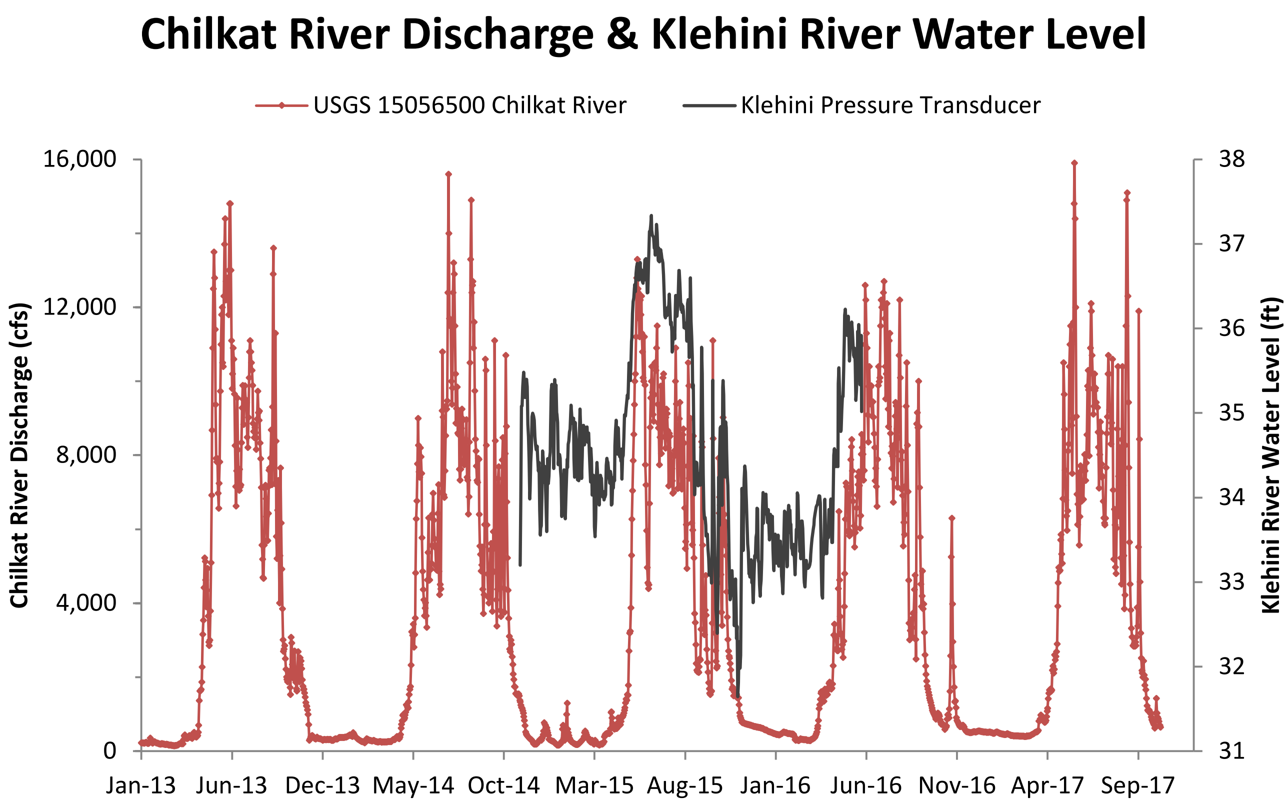
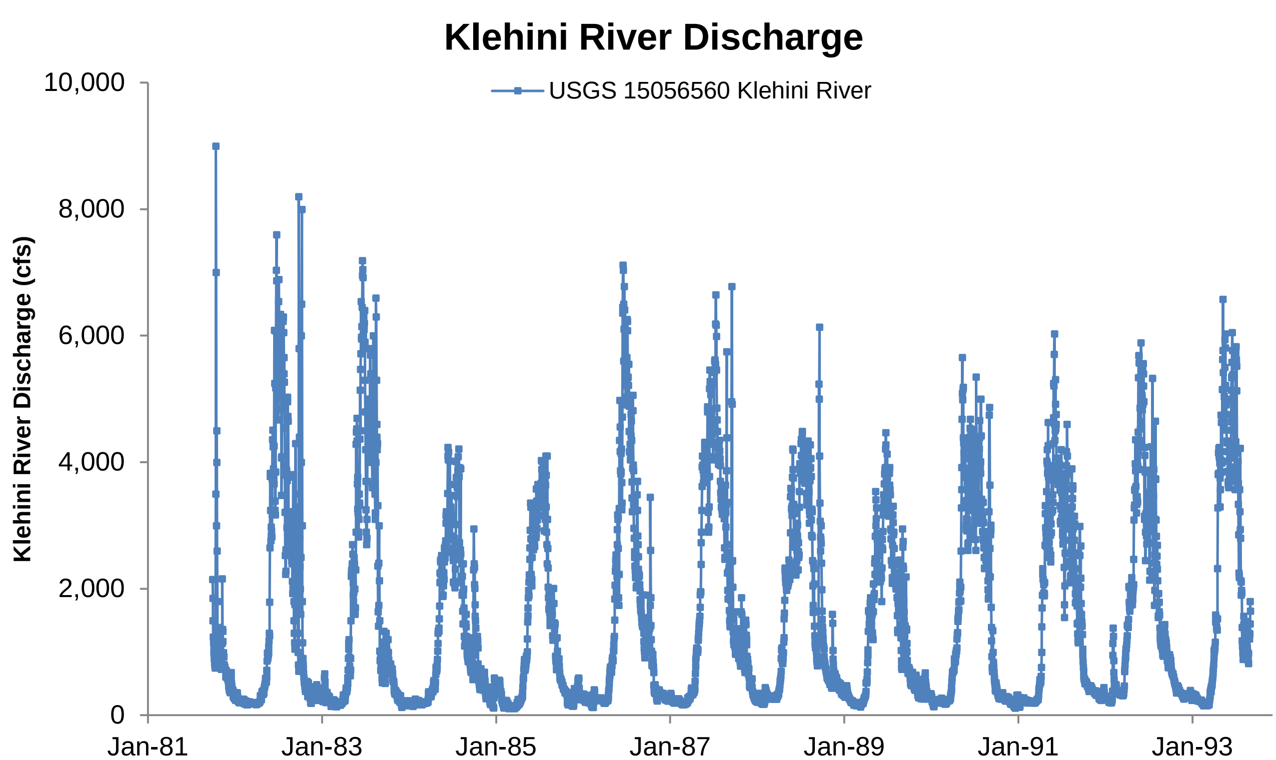
Figure 3.
Palmer Exploration Project
Klehini River and Glacier Creek Drainage Areas
Overview Map





cfs = cubic feet per second
USGS = U.S. Geological Survey
Klehini River water levels are relative to local benchmarks and do not relate to mean sea level or indicate the depth of the water.

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Figure 4.
Chilkat and Klehini River Discharge at USGS Gages with Klehini River Bridge Water Levels
Palmer Project

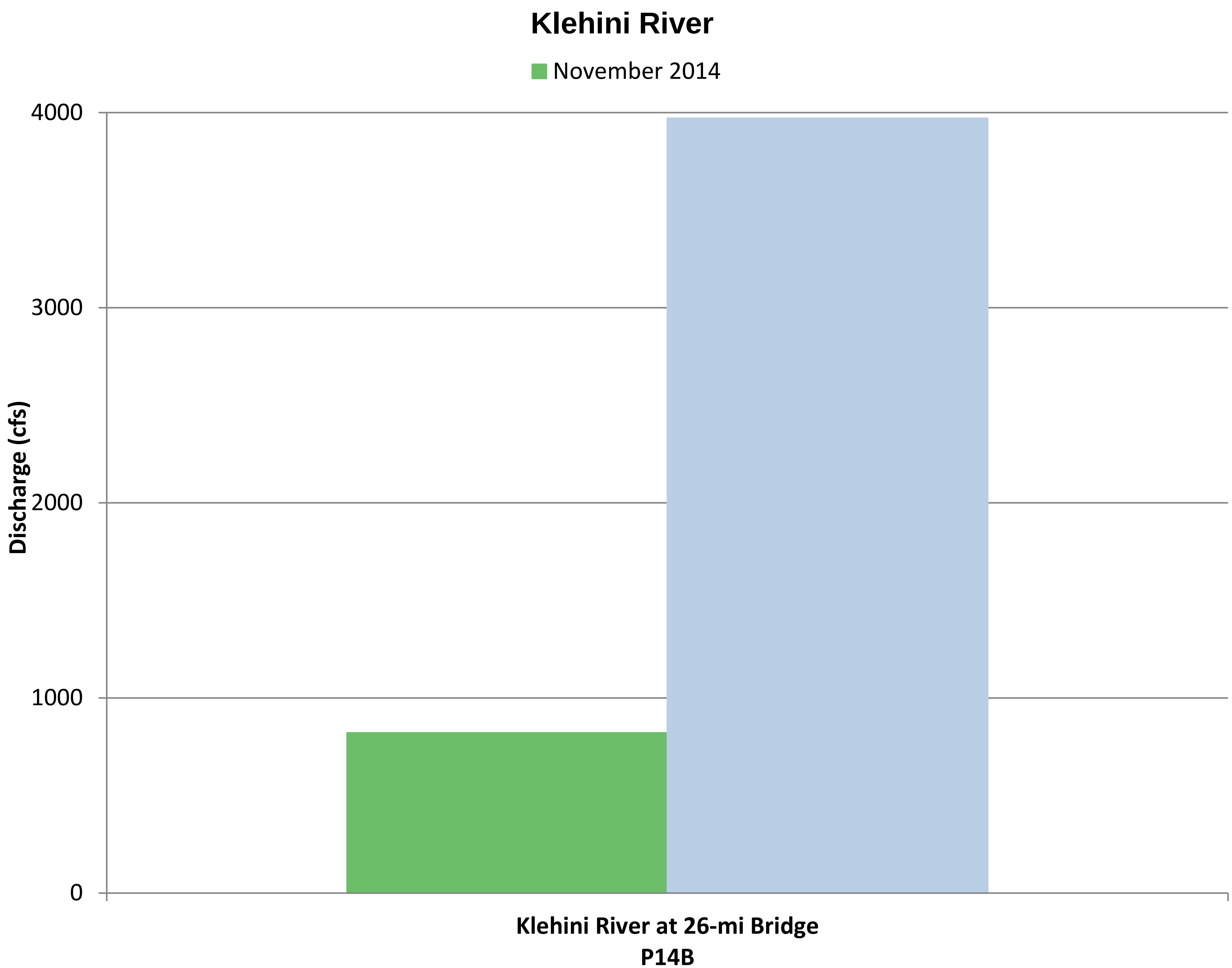

Figure 5a.
Klehini River Manual Discharge Measurements
Palmer Project

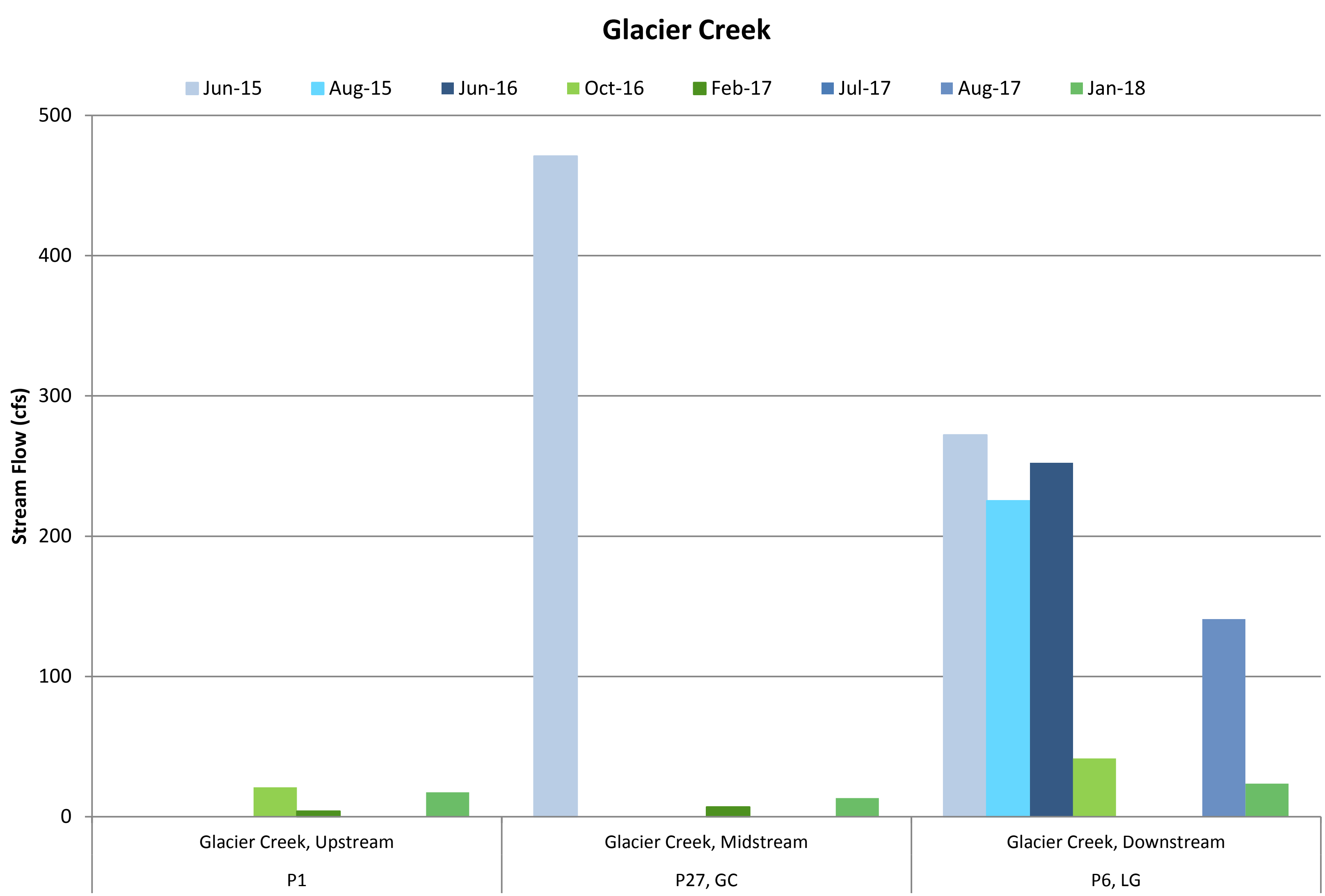

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Figure 5b.
Glacier Creek Discharge Measurements
Palmer Project

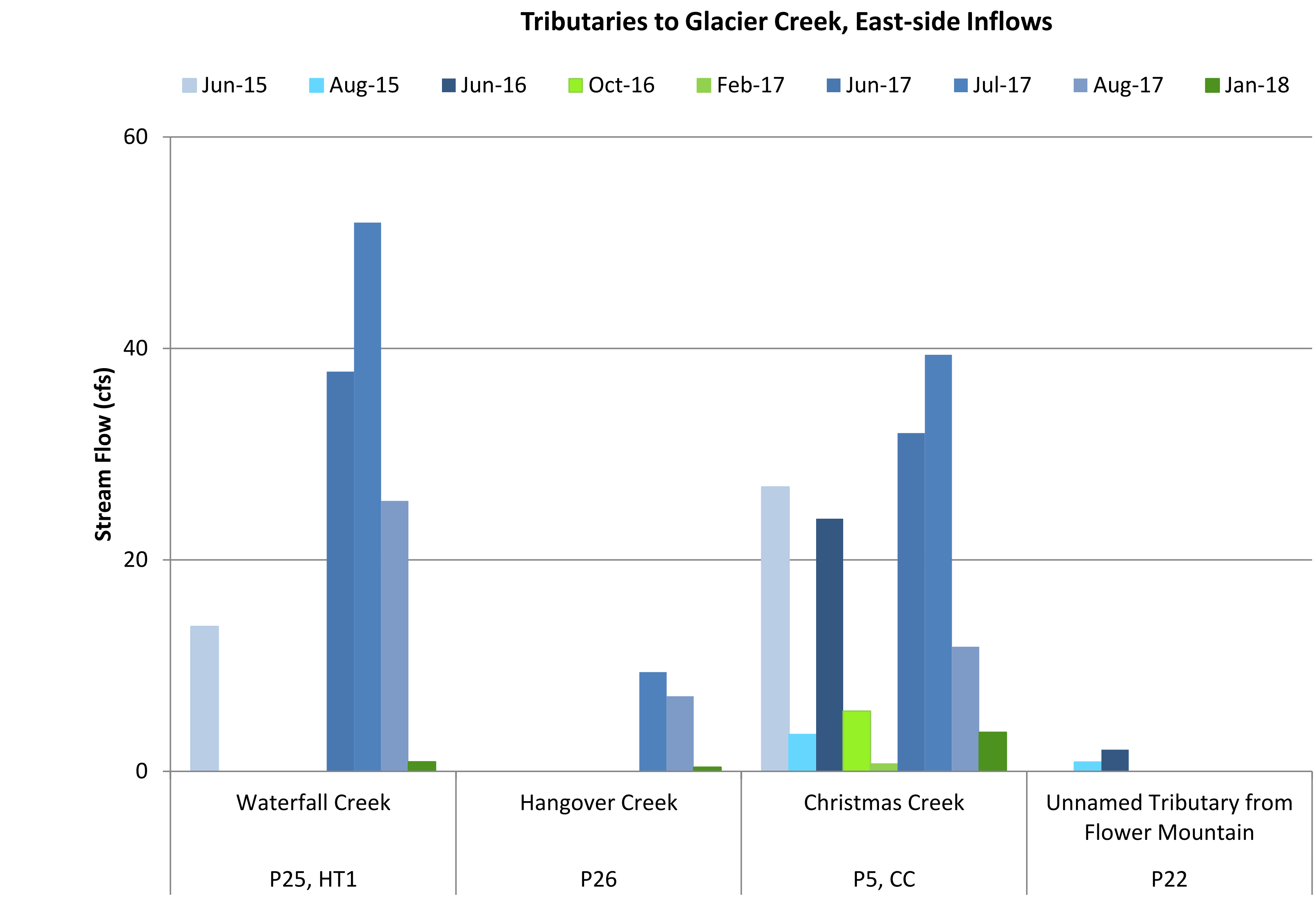

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Figure 5c.
Tributaries to Glacier Creek, East-side Inflows Discharge Measurements
Palmer Project

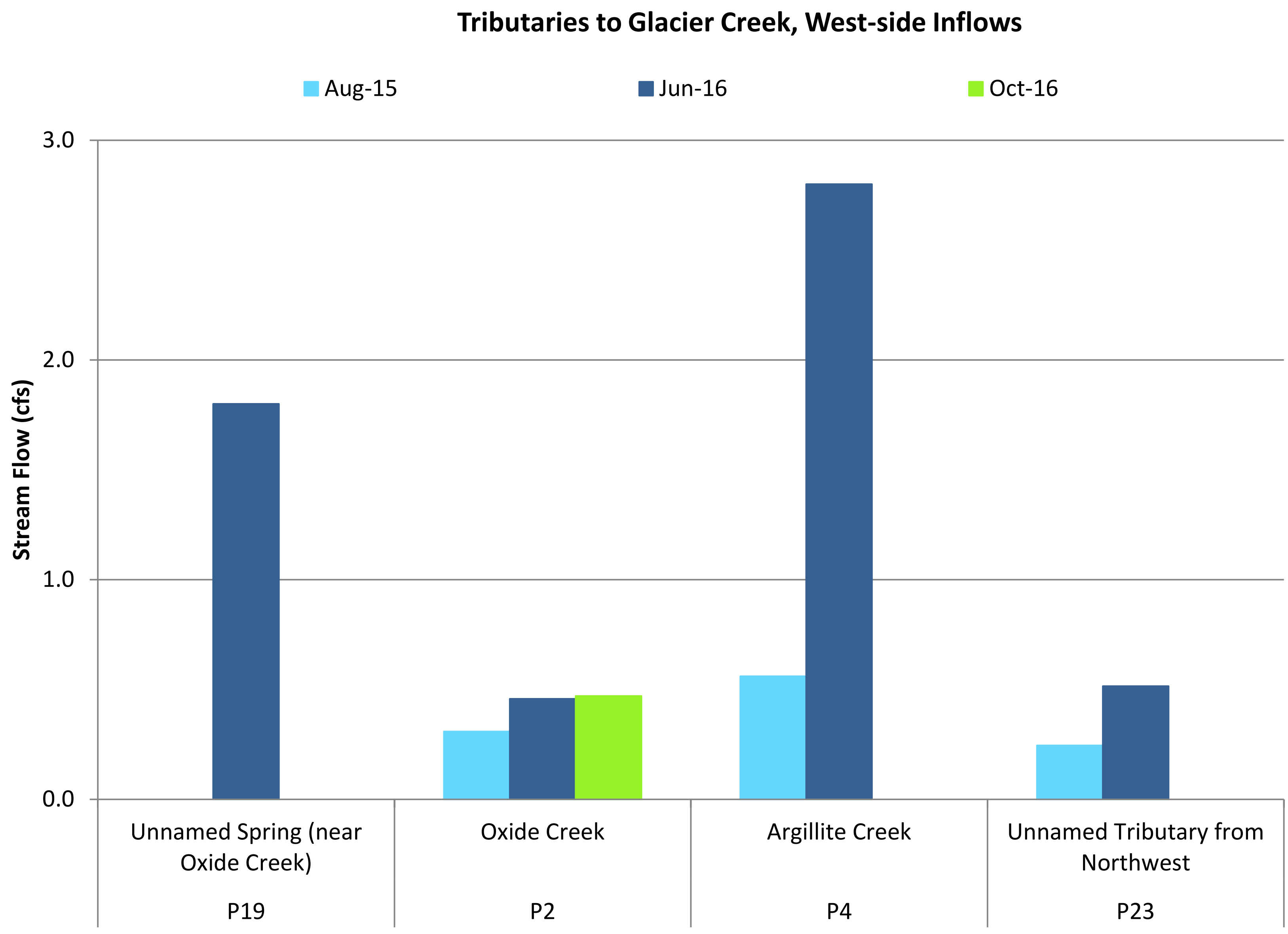

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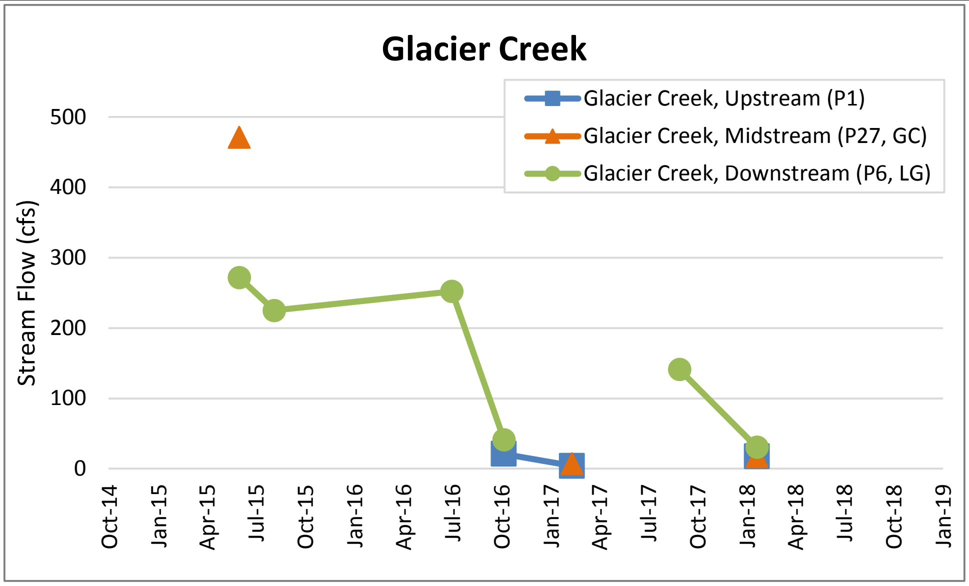
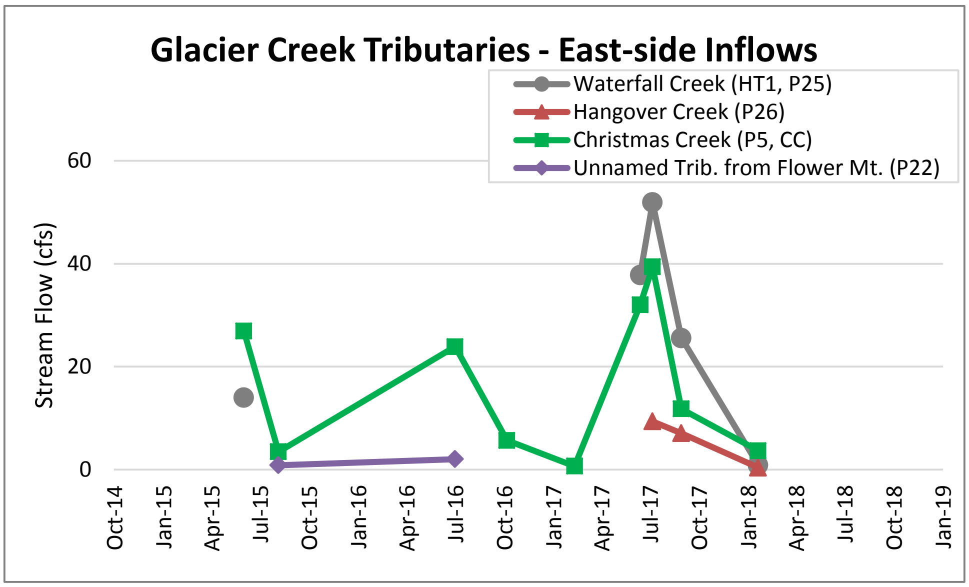
Figure 5d.
Tributaries to Glacier Creek, West-side Inflows Discharge Measurements
Palmer Project





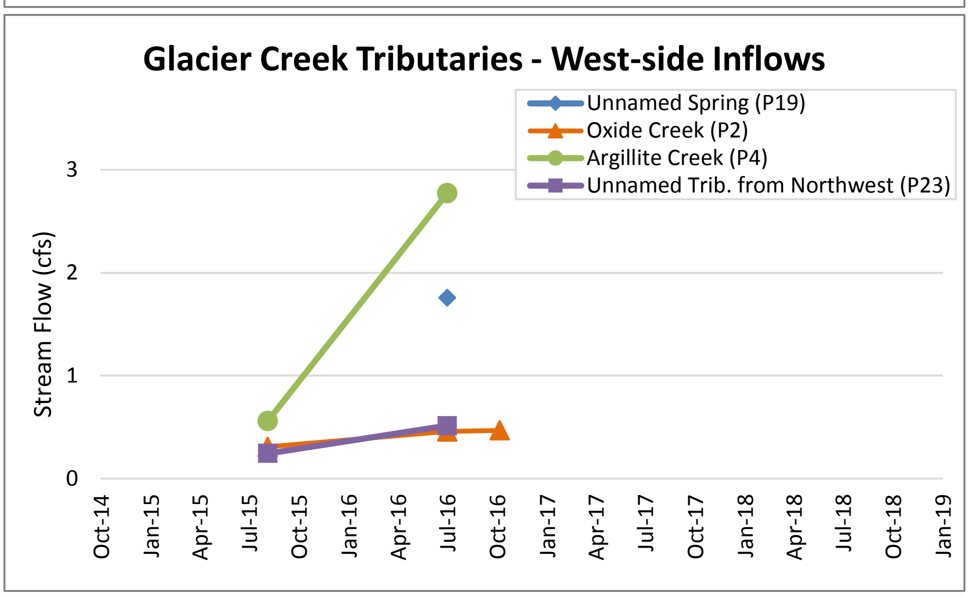


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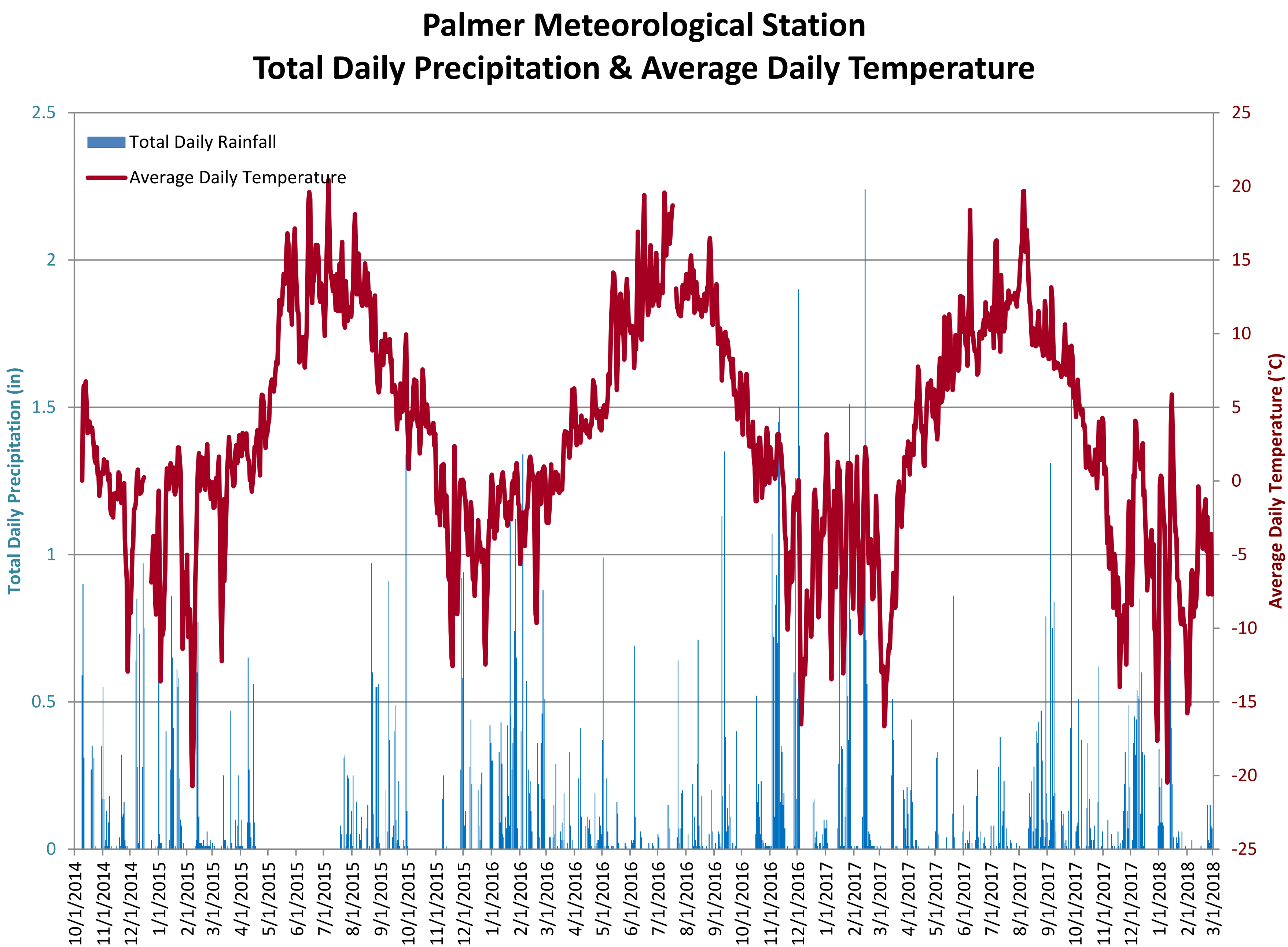
Figure 6.
Time Series Plots of Glacier Creek and
Tributary Discharge Measurements
Palmer Project



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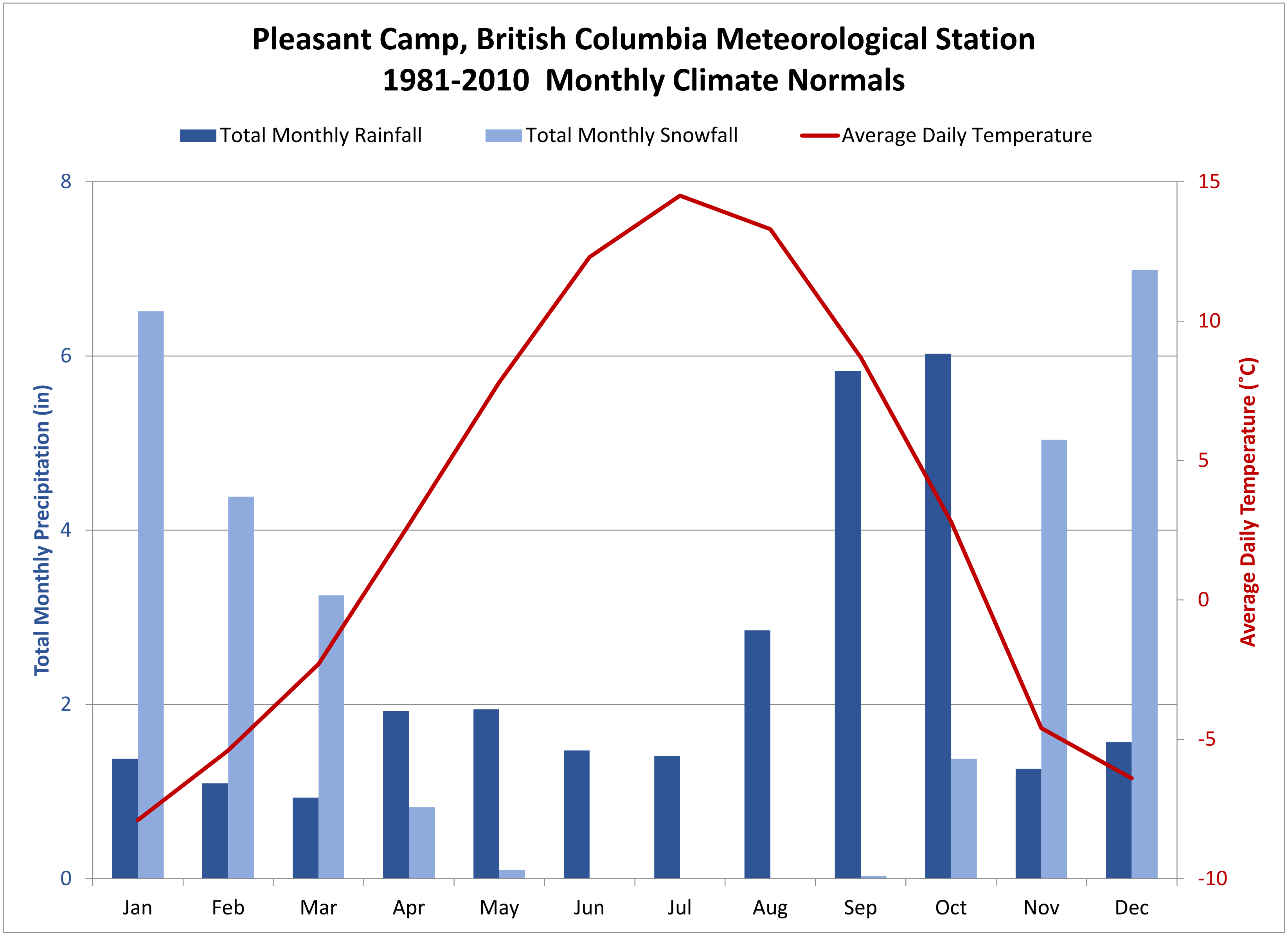
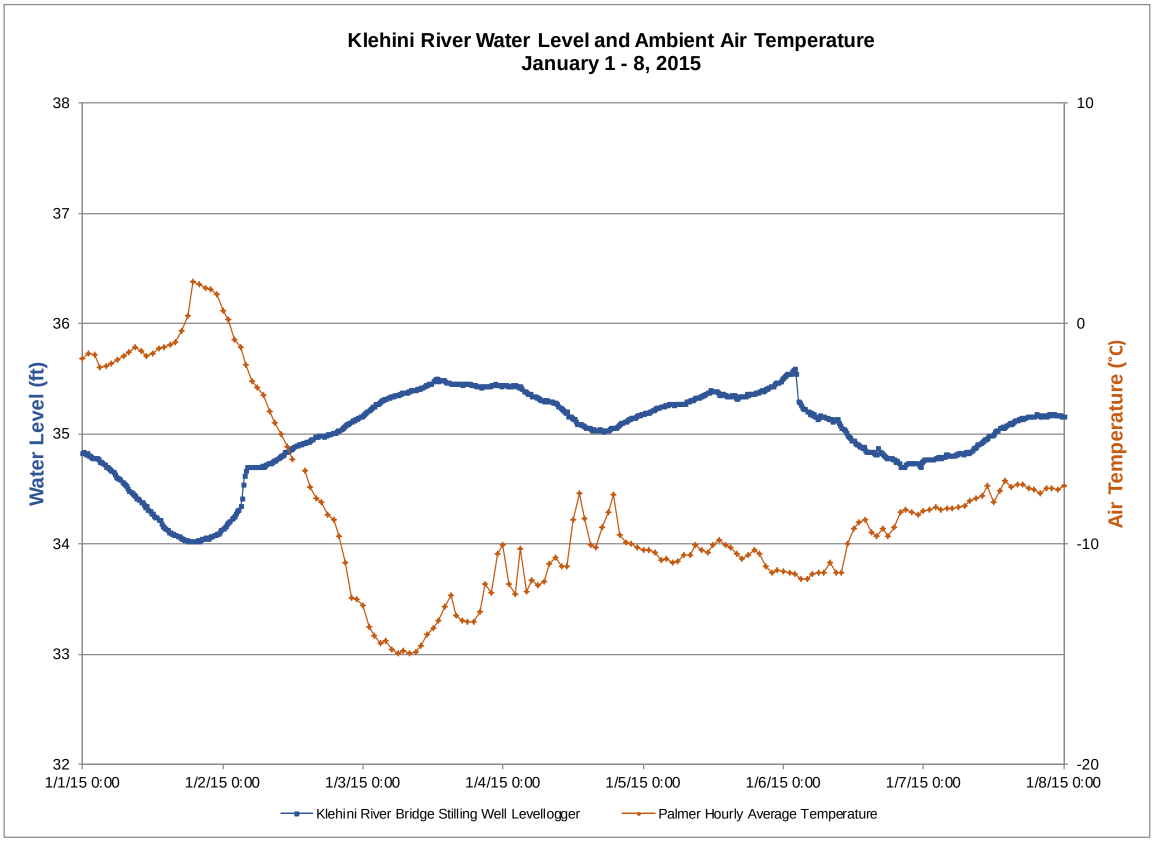
Note:
Rainfall data is not available from 4/20/2015 to 7/15/2015 due to an instrument malfunction.

Figure 7.
Rainfall and Temperature for the Palmer Project Area
Palmer Project



integral consulting inc.

Figure 8.
Regional 30-year Precipitation and Temperature
Palmer Project



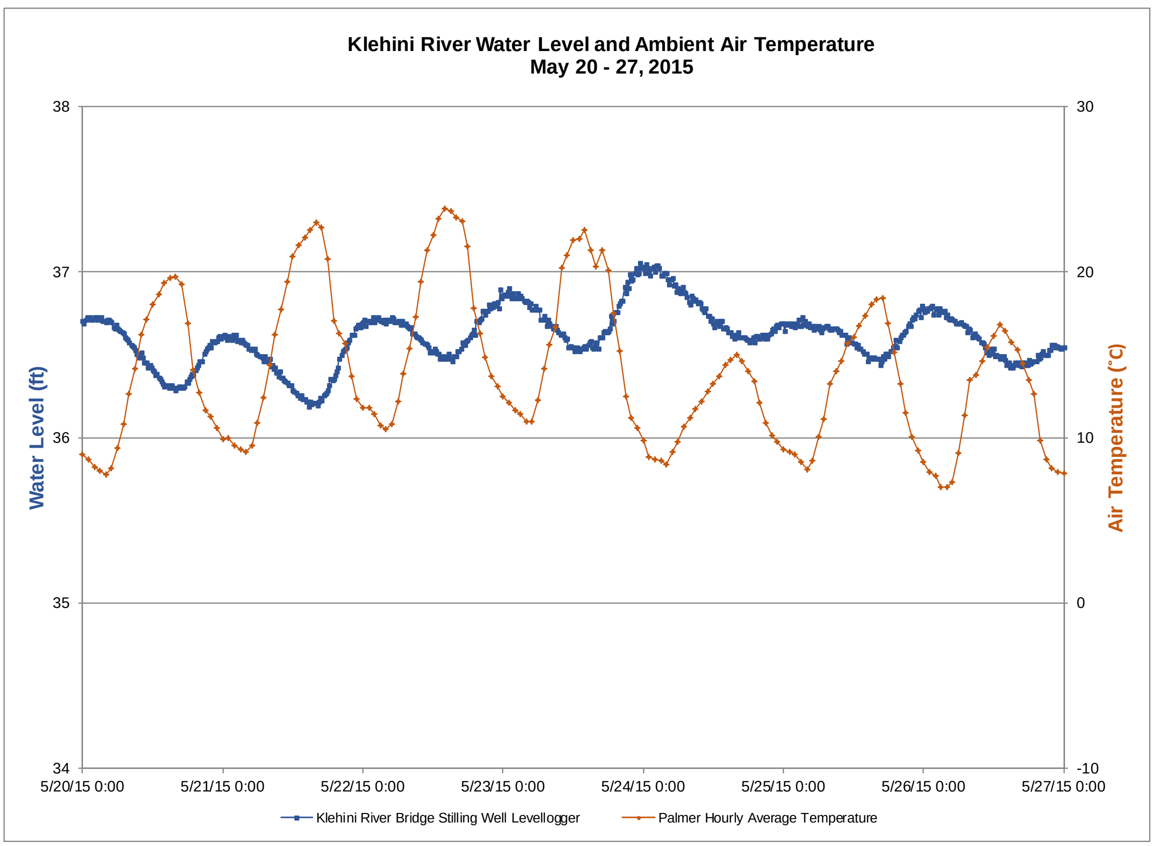


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Figure 9.
Examples of Diurnal Cycles: Klehini River Water Level and Ambient Air Temperature
Palmer Project

TABLES

Table 1. Summary of Hydrological and Meteorological Data for the Klehini River, Glacier Creek, and Surrounding Areas

				GPS Coordinates		Data Records					Records Not Available		
Location Description	Station ID	Collector	Instrument	(NAD27, UTM08 Alaska)		Start Date	End Date	Type	Interval	Number of Records	Start Date	End Date	Notes
Stream Flow - Klehini River and Chilkat River													
Chilkat River near Klukwan, Alaska	15056500	USGS	--	447261 E	6586455 N	4/8/2013	3/14/2018	Discharge	15 minutes	119,671	11/15/2017	3/14/2018	Record not available due to ice at gauging station, USGS will estimate flows during this period and release data at later date.
			--			7/1/1959	3/14/2018	Discharge	Daily Mean	2,582 (1,759 after 2013)	10/1/1961 11/15/2018	1/10/2013 3/14/2018	Records not available due to ice at gauging station from 11/5/2017 - Present Date, USGS will estimate flows during this period and release data at later date.
Klehini River near Klukwan, Alaska	15056560	USGS	--	443410 E	6586264 N	10/1/1981	9/30/1993	Discharge	Daily	4,383	--	--	
Klehini River at Porcupine Crossing (26-mile) Bridge (300 ft. upstream of bridge)	--	R2	Price AA R2R2	-- --	-- --	11/6/2014	11/6/2014	Discharge	Instantaneous	1	--	--	
Klehini River at Porcupine Crossing (26-mile) Bridge	KR	R2	FlowTracker	443242 E	6586172 N	6/4/2015	6/4/2015	Discharge	Instantaneous	1 (sum of main channel and 1 side channel)	--	--	Discharge may be underestimated due to ~90 ft. in middle of stream unmeasured, of ~250 ft. total channel width.
	P14B	R2, Integral	Levelogger #34764	443242 E	6586172 N	11/4/2014	7/1/2016	Height	15 minutes	56,179	--	--	River stage height and water temperature data.
Tsirku River near Klukwan, Alaska	Tsirku River	USGS (Bugliosi 1985[a])	--	59 E	136 N	10/1/1981	9/30/1982	Discharge	Monthly Mean	12	--	--	Monthly mean flow
Stream Flow - Glacier Creek													
Glacier Creek, upstream	P1	Constantine	Hach FH950 Flow Meter	421637 E	6583666 N	10/6/2016	10/6/2016	Discharge	Instantaneous	1	--	--	Flow measurement taken by AC of Constantine
						2/10/2017	2/10/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM), David Korobanik (casual CEM), Darsie Culbeck (independent)
		Integral				1/20/2018	1/20/2018	Discharge	Instantaneous	1	--	--	
Glacier Creek, Midstream	P27	Constantine	Hach FH950 Flow Meter	422758 E	6584654 N	2/11/2017	2/11/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM), David Korobanik (casual CEM), Darsie Culbeck (independent)
		Integral				1/22/2018	1/22/2018	Discharge	Instantaneous	1	--	--	
Glacier Creek, mid-channel (near laydown area)	GC	R2	Float	424187 E	6585796 N	6/2/2015	6/2/2015	Discharge	Instantaneous	1 (sum of 4 sections)	--	--	Estimated from surface float velocity measurements. Appears to be overestimated in comparison to R2 Glacier Creek lower measurement and Integral Glacier Creek downstream location P6.
Glacier Creek, downstream	P6	Integral	Swoffer Current Meter	426162 E	6587082 N	8/9/2015	8/9/2015	Discharge	Instantaneous	1 (sum of 4 sections)	--	--	
						7/1/2016	7/1/2016	Discharge	Instantaneous	1 (sum of 4 sections)	--	--	Flow measurement taken just upstream of the old bridge
		Constantine	Hach FH950 Flow Meter			10/6/2016	10/6/2016	Discharge	Instantaneous	1	--	--	Flow measurement taken by AC of Constantine, immediately downstream of the old bridge
						9/3/2017	9/3/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM) & D.C.
		Integral				1/22/2018	1/22/2018	Discharge	Instantaneous	1	--	--	
Glacier Creek, lower (500 ft. upstream of the old bridge crossing)	LG	R2	FlowTracker	425990 E	6586986 N	6/2/2015	6/2/2015	Discharge	Instantaneous	1 (sum of 4 sections)	--	--	Discharge may be underestimated as ~5 ft. in middle of stream unmeasured, of ~17 ft. total channel width.
Stream Flow - Tributaries to Glacier Creek													
Unnamed Glacier Creek headwater tributary	HT1	R2	FlowTracker	421927 E	6583758 N	6/2/2015	6/2/2015	Discharge	Instantaneous	1	--	--	Cascading creek, discharge may be underestimated.
Unnamed Spring (near Oxide Creek)	P19	Integral	Swoffer Current Meter	422066 E	6584042 N	6/30/2016	6/30/2016	Discharge	Instantaneous	1	--	--	
Oxide Creek	P2A	Integral	Swoffer Current Meter	422354 E	6584357 N	8/7/2015	8/7/2015	Discharge	Instantaneous	1 (sum of 2 sections)	--	--	
						6/30/2016	6/30/2016	Discharge	Instantaneous	1 (sum of 2 sections)	--	--	
	P2	Constantine	Hach FH950 Flow Meter	422546 E	6584357 N	8/5/2015	8/5/2015	Discharge	Instantaneous	1			
						7/1/2016	7/1/2016	Discharge	Instantaneous	1			
						10/5/2016	10/5/2016	Discharge	Instantaneous	1	--	--	Flow measurement taken by AC of Constantine, upstream of P2 before channel split. Appeared to be spring fed source, not connected by surface water
Argillite Creek	P4	Integral	Swoffer Current Meter	422949 E	6585050 N	8/7/2015	8/7/2015	Discharge	Instantaneous	1	--	--	
						6/30/2016	6/30/2016	Discharge	Instantaneous	1	--	--	

Table 1. Summary of Hydrological and Meteorological Data for the Klehini River, Glacier Creek, and Surrounding Areas

Location Description	Station ID	Collector	Instrument	GPS Coordinates (NAD27, UTM08 Alaska)		Data Records: Start Date	End Date	Type	Interval	Number of Records	Records Not Available: Start Date	End Date	Notes
Christmas Creek	CC	R2	FlowTracker	423720 E	6585117 N	6/2/2015	6/2/2015	Discharge	Instantaneous	1	--	--	
	P5	Integral	Swoffer Current Meter	423662 E	6585204 N	8/7/2015	8/7/2015	Discharge	Instantaneous	1	--	--	
						7/1/2016	7/1/2016	Discharge	Instantaneous	1	--	--	
		Constantine	Hach FH950 Flow Meter			10/6/2016	10/6/2016	Discharge	Instantaneous	1	--	--	Flow measurement taken by AC of Constantine, just upstream of confluence with Glacier Creek
						2/12/2017	2/12/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM), David Korobanik (casual CEM), Darsie Culbeck (independent)
						6/13/2017	6/13/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM)
						7/6/2017	7/6/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM)
						8/29/2017	8/29/2017	Discharge	Instantaneous	1	--	--	Field crew: D.C.
		Integral				1/22/2018	1/22/2018	Discharge	Instantaneous	1	--	--	
Unnamed tributary from Flower Mountain	P22	Integral	Swoffer Current Meter	425497 E	6586334 N	8/7/2015	8/7/2015	Discharge	Instantaneous	1	--	--	
						6/29/2016	6/29/2016	Discharge	Instantaneous	1	--	--	
Unnamed tributary from northwest	P23	Integral	Hach FH950 Flow Meter	425980 E	6587002 N	8/7/2015	8/7/2015	Discharge	Instantaneous	1	--	--	
						7/1/2016	7/1/2016	Discharge	Instantaneous	1	--	--	
Waterfall Creek	P25	Constantine	Hach FH950 Flow Meter	421920 E	6583797 N	6/13/2017	6/13/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM)
						7/6/2017	7/6/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM)
						8/29/2017	8/29/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM)
		Integral				1/20/2018	1/20/2018	Discharge	Instantaneous	1	--	--	
Hangover Creek	P26	Constantine	Hach FH950 Flow Meter	422075 E	6584048 N	7/6/2017	7/6/2017	Discharge	Instantaneous	1	--	--	
						8/29/2017	8/29/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM)
		Integral				1/21/2018	1/21/2018	Discharge	Instantaneous	1	--	--	
Stream Flow - Sarah Creek													
Sarah Creek	P15B	Integral	Hach FH950 Flow Meter	424500 E	6588380 N	7/10/2017	7/10/2017	Discharge	Instantaneous	1	--	--	Allegra Cairns (CEM)
						8/29/2017	8/29/2017	Discharge	Instantaneous	1	--	--	Field crew: D.C.
	--	Takshanuk Watershed Council/Alaska Sustainable Salmon Fund	--	-- --	-- --	--	--		--	--	--	--	Alaska Sustainable Salmon Fund January 2013 Completion Report (https://s3-us-west-1.amazonaws.com/akssfapm/APM_Uploads/2008/45976/.pdf/CR_1_2013.pdf) indicates that monthly discharge measurements were taken on Sarah Creek with a data logger during 2011 and 2012. These discharge data have not been published to the Takshanuk Watershed Council website as of March 2018.
Meteorological Data													
Palmer Meteorological Station	--	Constantine	--	-- --	-- --	10/8/2014	10/31/2016		15 minutes	33,364 temperature 25,405 rainfall	4/18/2015	7/16/2015	
			--	-- --	-- --	10/8/2014	10/31/2016		1 hour	8,420 temperature 6,357 rainfall	4/18/2015	7/16/2015	
Pleasant Camp, British Columbia	1206197	Government of Canada	--	-- --	-- --	1/1/1981	12/31/2007		Monthly normals	9,295 temperature 9,067 precipitation	Unknown	Unknown	

Notes:
-- = not available or not applicable
Constantine = Constantine North
GPS = global positioning system
Integral = Integral Consulting Inc.
NAD27 = North American Datum of 1927
R2 = R2 Resource Consultants, Inc.
USGS = U.S. Geological Survey
UTM08 = Universal Transverse Mercator #08
[a] Source: Bugliosi, E.F. 1985. Hydrologic reconnaissance of the Chilkat River Basin, Southeast Alaska, with special reference to the Bald Eagle Critical Habitat at the Tsirku River alluvial fan. USGS Open-File Report 84-618. U.S. Geological Survey, Anchorage, AK.

Table 2. Klehini River Watershed, Glacier Creek Catchment Drainage Areas, and Summary of Discharge Measurements

Drainage Area Description	Map Code (Figure 3)	Total Drainage Area (Square Miles)	Station ID	No. of Measurements	Discharge (cfs) Minimum	Maximum	Average	Median
Klehini River								
Klehini River	--	290	KR	1	3,972	3,972	--	--
			14B	1	820	820	--	--
			15056560	4,383	109	9000	1,507	700
Klehini River Watersheds								
Inspector Creek / Klehini River	--	47	--	--	--	--	--	--
Seltat Creek	--	24	--	--	--	--	--	--
Big Boulder Creek	--	29	--	--	--	--	--	--
Mount McDonnel / Klehini River	--	34	--	--	--	--	--	--
Jarvis Creek	--	52	--	--	--	--	--	--
Glacier Creek	--	15	GC	1	471	471	--	--
			P27	2	7	17	12	12
			LG	1	272	272	--	--
			P6	5	31	272	160	183
Little Boulder Creek–Klehini River	--	56	P15B	2	32	38	35	35
Porcupine Creek	--	33	--	--	--	--	--	--
Glacier Creek Catchments								
Glacier Creek headwaters (dominated by permanent glacier)	1	6.1	P1	3	4	21	14	17
Waterfall Creek	2	0.9	HT1, P25	5	0.9	52	26	26
Hangover Creek	3	0.5	P26	3	0.4	9	5.6	7.1
Oxide Creek	4	0.3	P2, P2A	3	0.3	0.5	0.4	0.5
Concrete Creek	5	0.4	--	--	--	--	--	--
Christmas Creek	6	2.1	CC, P5	9	0.7	39	16	12
Red Creek	7	0.2	--	--	--	--	--	--
Unnamed drainage (between Oxide and Argillite Creeks, west side)	8	0.3	--	--	--	--	--	--
Argillite Creek	9	0.7	P4	2	0.6	2.8	1.7	1.7
Unnamed drainage to Glacier Creek (middle, west side)	10	0.7	--	--	--	--	--	--
Unnamed drainage to Glacier Creek (middle, east side)	11	1.0	--	--	--	--	--	--
Unnamed drainage to Glacier Creek (lower, east side)	12	0.8	P23	2	0.2	0.5	0.4	0.4
Unnamed drainage to Glacier Creek (lower, east side)	13	1.3	P22	2	0.9	2.1	1.5	1.5

Notes:
-- = not available or not applicable
cfs = cubic feet per second

Table 3. Monthly Average Discharge for the Chilkat, Klehini and Tsirku Rivers

Month	USGS 15056500 Chilkat River 760 mi^2 (1959–1961; 2013–Mar. 2018)	USGS 15056560 Klehini River 290 mi^2 (1981–1993)	Bugliosi 1985[a] Tsirku River 230 mi^2 (1981–1982)
January	424	285	185
February	316	243	155
March	306	222	143
April	884	390	177
May	4,963	1,782	780
June	8,604	3,730	6,200
July	9,210	4,151	8,600
August	7,684	3,204	4,600
September	4,545	1,763	2,950
October	2,398	1,323	2,500
November	989	518	900
December	590	375	345

Notes:

All discharge values in units of cubic feet per second (cfs).
mi^2: square miles

USGS = U.S. Geological Survey

[a] Source: Bugliosi, E.F. 1985. Hydrologic reconnaissance of the Chilkat River Basin, Southeast Alaska, with special reference to the Bald Eagle Critical Habitat at the Tsirku River alluvial fan. USGS Open-File Report 84-618. U.S. Geological Survey, Anchorage, AK.

Table 4. Palmer Project Area Stream Flow Measurements, 2014–2018

			Flow (cfs)									
			Low Flow or Transitional Seasons				High Flow Season					
Area	Station	Description	Nov-14	Oct-16	Feb-17	Jan-18	Jun-15	Aug-15	Jul-16	Jun-17	Jul-17	Aug-17
Klehini River	P14B	Klehini River at 26-mi Bridge	820	--	--	--	3972	--	--	--	--	--
Sarah Creek	P15B	Sarah Creek	--	--	--	--	--	--	--	--	38	32
Glacier Creek	P1	Glacier Creek, Upstream	--	21	4.0	17	--	--	--	--	--	--
	P27, GC	Glacier Creek, Midstream	--	--	7.0	17	471	--	--	--	--	--
	P6, LG	Glacier Creek, Downstream	--	41	--	31	272	225	252	--	--	141
Tributaries to Glacier Creek, East-side Inflows	HT1, P25	Waterfall Creek	--	--	--	0.9	14	--	--	38	52	26
	P26	Hangover Creek	--	--	--	0.4	--	--	--	--	9.4	7.1
	P5, CC	Christmas Creek	--	5.7	0.7	3.7	27	3.5	24	32	39	12
	P22	Unnamed Tributary from Flower Mountain	--	--	--	--	--	0.88	2.1	--	--	--
Tributaries to Glacier Creek, West-side Inflows	P19	Unnamed Spring (near Oxide Creek)	--	--	--	--	--	--	1.8	--	--	--
	P2	Oxide Creek	--	0.47	--	--	--	0.31	0.46	--	--	--
	P4	Argillite Creek	--	--	--	--	--	0.56	2.8	--	--	--
	P23	Unnamed Tributary from Northwest	--	--	--	--	--	0.25	0.52	--	--	--
All Glacier Creek Tributaries		Cumulative Glacier Creek Upstream (P1) and Tributary Flow[a]	--	27	5	22	41	5	31	70	101	44
		Percentage of Glacier Creek Downstream Flow	--	66%	--	73%	15%	2%	12%	--	--	32%

Notes:
Low flow and transitional seasons refers to the months of October through April. This includes expected periods of fall decreasing, early spring increasing, and winter low flows for the area.
High flow season refers to the months of May through September. This encompasses expected periods of spring increasing flows and summer peak flows for the area.

-- = flow not measured
[a] The Glacier Creek upstream station has not been measured during high flow events; therefore, the cumulative Glacier Creek upstream and tributary flow for high flow events is an underestimate of the true cumulative flow.