



North Coast and Cascades Network Climate Monitoring Report

North Cascades National Park Complex; Water Year 2011

Natural Resource Data Series NPS/NCCN/NRDS—2014/633



ON THE COVER

Ice partially covering Upper Tapto Lake, North Cascades National Park Complex. The photo was taken on August 30, 2011 and is indicative of the cooler than average spring and summer, which resulted in many mountain lakes remaining ice-covered late into the summer.

Photograph by: NPS

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the North Coast and Cascades Network Inventory and Monitoring website (<http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Executive Summary

Climate and weather events are major influences defining ecological characteristics found in national parks and are key to understanding and interpreting changes in natural resources. Everyday park operations including; fire management, search and rescue, maintenance of park infrastructure, and visitor use are influenced by weather. Collecting weather data and maintaining climate records provides essential information needed to support park operations and to monitor park resources.

This report summarizes climate data collected in North Cascades National Park Complex during the 2011 Water Year, and is part of a set of climate summary reports from seven national and historic parks in the North Coast and Cascades Network. Published in the National Park Service's Natural Resource Data Series, annual climate summary reports are intended to provide basic data sets and data summaries in a timely manner, with minimal interpretation and analyses. We intend that the primary audience for this document will be National Park staff, especially decision makers, planners, and interpreters; partners; and interested members of the public.

Temperature and precipitation data are presented from seven weather stations. These stations are distributed on the western and eastern slopes of the North Cascades Range at low and high elevations. Data were recorded using automated instruments operated by the National Park Service and other collaborators, including the National Weather Service (NWS) and the Natural Resources Conservation Service (NRCS). For two stations with long term records, the Newhalem Cooperative Observer (COOP) station on the west side of the Cascade crest and the Stehekin COOP on the drier, east side of the park, monthly average temperatures and monthly total precipitation are reported and compared to the 30-year normal. Monthly snow depth and snow water equivalent are reported for one Snow Telemetry (SNOTEL) site and two NWS COOP stations within the park. Two NPS GLACIER weather stations provide air temperature at high elevations (>6500 feet) in alpine environments. A NWS US Climate Reference Network (USCRN) station located in Marblemount and the Newhalem COOP station represent lowland areas on the west slopes of the North Cascade Range. A series of appendices present daily and monthly air temperature, precipitation and snowpack data from seven park operated weather stations, including comparisons to period of record and highlights of important weather events from each site.

In summary, average annual temperatures were below normal and precipitation was above normal for Water Year 2011. Overall, conditions in fall were warmer and drier than normal, winter was warm and wet at most sites, and in spring there was a shift to cooler and wetter conditions that continued through early summer. Snowpack remained below normal during the warmer, drier winter months only to recover to above normal due to a cooler and wetter spring that persisted into late June. Summer and early fall were drier than normal.

Acknowledgments

North Cascades National Park Complex relies on several cooperating agencies to help support and maintain a long-term climate monitoring program as part of the North Coast and Cascades (NCCN) climate monitoring program. These agencies include:

- National Weather Service – National Weather Service Cooperative Observer Program
- Natural Resources & Conservation Service - National Water and Climate Center, SNOTEL and Snow Survey Program
- US Climate Reference Network, National Oceanic and Atmospheric Administration – National Climate Data Center.
- National Interagency Fire Center – Remote Automated Weather Stations Program

The NPS would also like to thank the Office of the Washington State Climatologist for their regional and statewide weather and climate summaries.

Acronyms

COOP	Cooperative Observer Station
I&M	Inventory and Monitoring
NCCN	North Coast and Cascades Network
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NOCA	North Cascades National Park Service Complex
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PNW	Pacific Northwest
RAWS	Remote Automated Weather Stations
SNOTEL	Snowpack Telemetry
SWE	Snow Water Equivalent
USCRN	United States Climate Reference Network
USDA	United States Department of Agriculture
WRCC	Western Regional Climate Center

Glossary

Climate: Complete and entire ensemble of statistical descriptors of temporal and spatial properties comprising the behavior of the atmosphere. These descriptors include means, variances, frequency distributions, autocorrelations, spatial correlations and other patterns of association, temporal lags, and element-to-element relationships. The descriptors have a physical basis in flows and reservoirs of energy and mass. Climate and weather phenomena shade gradually into each other and are ultimately inseparable (Davey et al. 2006).

Climate Normals: A long-term average value of a meteorological parameter (i.e. temperature) for a certain area. For example, "temperatures are normal for this time of year" means that temperatures are at or near the average climatological value for a given time period. Climate normals are usually taken from data averaged over a 30-year period (e.g., 1971-2000 average), and are concerned with the distribution of data within limits of common occurrence.

Fall: The National Weather Service defines fall as the months of September, October and November.

NWS-COOP: An extensive network of manually operated weather stations overseen by the National Weather Service. Many Cooperative Observer Program weather sites were established in the late 1800's and as such, provide the best long term climate data. At each station, an observer records daily maximum and minimum temperature, as well as total rain and snowfall.

NPS-GLACIER: A network of two weather stations operated by the National Park Service. The stations are located at high elevation sites, adjacent to Silver Glacier and Noisy Creek Glacier, two index glaciers monitored by the NPS. Meteorological parameters measured at each site include temperature, relative humidity, wind speed and direction and net solar radiation.

Period of Record: The total span of time that climate data have been collected at a specific location. The longer the period of record, the more likely the climate data will not be biased by singular weather events or cyclic climate anomalies such as those associated with the Pacific Decadal Oscillation.

RAWS: A network of Remote Automated Weather Stations overseen by the National Interagency Fire Center. RAWS stations provide real-time weather data to assist land management agencies in monitoring wildland fire fuels, rating fire danger and predicting fire behavior. RAWS stations all operate during summer months and many at lower elevations operate on a year round basis

SNOTEL: An automated network of snowpack data collection sites operated by the Natural Resources Conservation Service (NRCS). A standard SNOTEL site consists of a snow pillow, snow depth sensor, a storage type precipitation gage and air temperature sensor. Enhanced sites also measure soil moisture.

Snow Course: A site where trained observers manually measure snow depth, water equivalent and density at a series of points along an established transect. Measurements are taken the last week of each month during winter and early spring. Values are recorded as the first of the month.

Snow Water Equivalent (SWE): A measurement describing the amount of water contained within the seasonal snowpack. It can be thought of as the depth of water that would theoretically result if you melted the entire snowpack instantaneously.

Spring: The National Weather Service defines spring as the months of March, April and May.

Summer: The National Weather Service defines summer as the months of June, July, and August.

USCRN: The U.S. Climate Reference Network (USCRN) is overseen by the National Oceanic and Atmospheric Administration (NOAA) and deploys climate instruments across the continental United States for the express purpose of detecting the national signal of climate change. The stations are located in rural environments, maintained to high standards, and include three independent measurements of temperature and precipitation to ensure continuity of record and collection highly accurate observations.

Water Year: The Water Year (or Hydrologic Year) is most often defined as the period from October 1st to September 30 of the following year. It is called by the calendar year in which it ends. Thus, Water Year 2010 is the 12-month period beginning October 1, 2009 and ending September 30, 2010. The period is chosen so as to encompass a full cycle of precipitation accumulation.

Weather: Instantaneous state of the atmosphere at any given time, mainly with respect to its effects on biological activities. As distinguished from climate, weather consists of the short-term (minutes to days) variations in the atmosphere. Popularly, weather is thought of in terms of temperature, precipitation, humidity, wind, sky condition, visibility, and cloud conditions (Davey et al. 2006).

Winter: The National Weather Service defines winter as the months of December, January and February.

Introduction

Climate is a dominant driver of the physical and ecologic processes of the North Coast and Cascades Inventory and Monitoring Network (NCCN) (Davey et al. 2006). Trends in precipitation and temperature influence how an ecosystem and its organisms function. The quantity and timing of rainfall and snow can influence the productivity and health of forests (Nakawatase and Peterson 2006), the amount of water flowing in streams and rivers (Hamlet et al. 2007) and the growing or shrinking of mountain glaciers (Rasmussen et al. 2000). Likewise, temperature can influence the quantity and timing of plant growth and stream runoff, or the extent and duration of winter snowpack and lake ice. (Thompson et al. 2009). Through direct and indirect methods, climate affects the behavior and reproduction of terrestrial and aquatic animal species (Crozier et al. 2008). Climate influences the frequency and magnitude of disturbance events such as forest fires (Littell and Gwozdz 2011), avalanches, windstorms and floods. These events can have a major impact on park landscapes and their associated ecosystems.

Given the importance of climate, it has been identified as a primary vital sign by all 32 Inventory and Monitoring (I&M) networks within the NPS (Gray 2008). The NCCN monitors climate in order to: understand variations in other park resources being monitored; compare current and historic data to understand long-term trends; and to provide data for modeling impacts to park facilities and resources in the future (Lofgren et al. 2010). Climate data, derived from the NCCN climate network will play an important role in understanding and interpreting the physical and ecological Vital Signs monitored by I&M within NCCN parks.

The NCCN climate monitoring program capitalizes on weather stations operated by partnering agencies. The NCCN climate monitoring program compiles data from over 60 weather stations in and adjacent to the parks, 15 of which are operated by the National Park Service. While a wide variety of climate parameters are measured as part of the NCCN climate program, this report focuses on two key parameters: precipitation and air temperature, while providing supplemental information on snowpack.

This report summarizes climate data collected from seven weather stations located in and adjacent to the North Cascades National Park Complex during the 2011 Water Year, and is part of a set of climate summary reports from seven national and historic parks in the NCCN (Figure 1). Temperature, precipitation, and snow data from the seven weather stations are summarized in the Results section of this report. Additional climate data recorded from each weather station are presented in Appendices A through G.

Annual climate summary reports are intended to provide basic data sets and data summaries in a timely manner, with minimal interpretation and analyses. National Park staff, planners, scientists, interpreters, partners; and interested public are the primary audience.



Figure 1. North Coast and Cascades Network (NCCN).

Methods

Station Locations

This report incorporates data collected from weather stations operated by the NPS (GLACIER), the Natural Resources Conservation Service (SNOTEL), and the National Weather Service (COOP and USCRN) (Table 1 and Figure 2).

Table 1. Weather stations referenced in this report.

Station Name	Station Type	Location	Elevation (ft)	Forest Zone	Period of Record
Marblemount (Darrington 21 NNE)	USCRN	West	407	Forest	2003 to Present
Noisy Creek	GLACIER	West	6590	Alpine	2009 to Present
Newhalem	COOP	West	520	Forest	1959 to Present
Park Creek Ridge	SNOTEL	East	4600	Subalpine	1979 to Present
Ross Dam	COOP	Interior	1240	Forest	1963 to Present
Silver Lake	GLACIER	Interior	7670	Alpine	2009 to Present
Stehekin	COOP	East	1270	Forest	1931 to Present

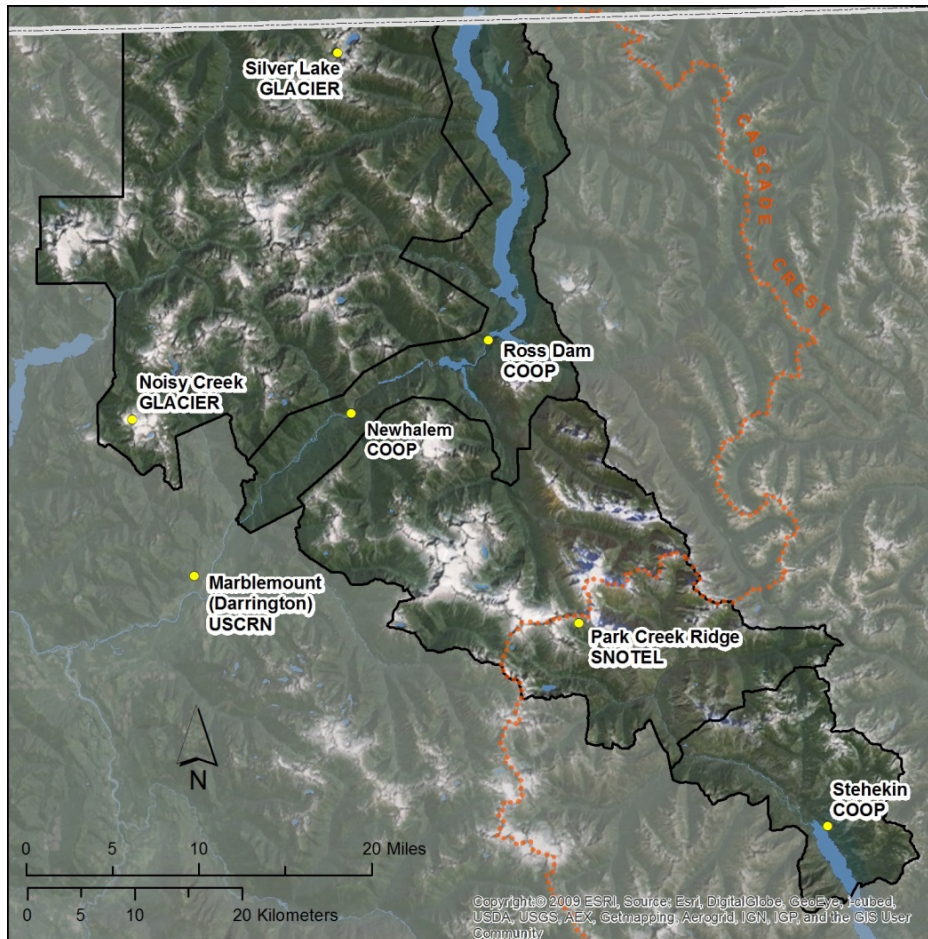


Figure 2. Location of weather stations referenced in this report.

Weather Station Measurements

Weather stations within the NCCN are managed by a variety of different agencies, each with a specific purpose. For this reason, instrumentation, method and period of collection may vary between sites. Table 2 describes the parameters measured at each station, highlights the data which are presented in this report, and indicates which data are available by request from North Cascades National Park Complex.

Table 2. Parameters measured at weather stations included in this report. **X** indicates that the parameter is measured and data are presented in this report; **X** indicates parameter is measured and data are available on request.

Station Name	Managing Agency – Station Type	Air Temp	Rh	Precipitation	Snow Depth	Snowfall	Snow Water Equivalent	Solar Radiation	Wind Speed & Direction	Soil Temperature	Soil Moisture
Marblemount (Darrington 21NNE)	NWS - USCRN ¹	X	X	X				X	X		
Noisy Creek	NPS - GLACIER ²	X	X					X	X		
Newhalem	NWS – COOP ⁴	X		X	X	X					
Park Creek Ridge	NRCS - SNOTEL ³	X	X	X	X		X	X	X	X	X
Ross Dam	NWS - COOP ⁴	X		X	X	X					
Silver Lake	NPS - GLACIER ²	X	X					X	X		
Stehekin	NWS - COOP ⁴	X		X	X	X					

¹ NWS-USCRN has a standard array of automated weather instruments. Parameters are measured every 5 minutes and output as hourly averages.

² NPS-GLACIER station has a standard array of automated weather instruments which are measured at 60 second intervals and output as hourly averages. A single snow water equivalent measurement is taken at these sites as part of the long term glacier monitoring program.

³ NRCS-SNOTEL has a standard array of automated weather instruments in support of water supply forecasting. Parameters are measured every 60 seconds, and output as hourly averages.

⁴ NWS-COOP station has a standard array of manually operated weather instruments. Parameters are measured and recorded daily.

Data Quality Assurance and Control

NWS COOP station and NRCS SNOTEL station data used in this report are acquired directly from the managing agencies. Quality assurance and control is provided by these agencies and is described in the NCCN Climate Monitoring Protocol (Lofgren et al. 2010).

The daily data used in this report from NPS and RAWS stations are derived from hourly data which have been evaluated through automated queries and manual display and graphing. Hourly data flagged or identified as suspect are omitted from daily summaries. If more than two hours of data are missing on a given day, no daily values are presented.

Monthly values are generated and presented for stations where five or fewer daily values are missing. In the case of missing precipitation values, daily quantities may be substituted from another nearby weather station for the purposes of reporting monthly and annual totals. This will only occur when nearby data are available and a known correlation exists between these sites. In these cases where estimates are generated from nearby stations, data are footnoted and a description of the quantity and source of data replacement is given.

Water Year 2011 Data Quality

Due to problems associated with equipment operation and access to these remote sites, data gaps exist at some stations.

Ross Dam is missing two days of precipitation and temperature data for WY 2011. Snow data are missing for ten days in February, nine days in March and 19 days in April. Additional days are also missing in May-September. Of these missing days, only three days had both minimum temperatures below freezing and measurable precipitation. The closest weather station (Diablo Dam COOP) recorded no new snow for the corresponding days.

Improvements to the Noisy Creek GLACIER station tower grounding were performed on October 5, 2010 and the site was brought back online on October 6. As a result, data from the first 5 days in October were not collected.

The Silver Lake GLACIER station was taken offline on September 13, 2011 for equipment upgrades, and remained offline into Water Year 2012. For this report, missing temperature for the Silver Lake GLACIER station has been replaced with data from the Browntop Ridge SNOTEL, which is located approximately five miles to the south.

For the Stehekin COOP weather station, there are three months that have more than five days of missing data. The cause of the missing data is unknown. For this report, missing temperature and precipitation data for the Stehekin COOP have been replaced with data from the adjacent Stehekin RAWS station.

Data Reporting

Data in this report are based on the hydrologic or Water Year (October 1 to September 30) and organized by month and seasons. Ecosystems in the Pacific Northwest are dominated by two distinct hydrological periods, a wet season generally beginning in late October and ending in June, and a

drought season which extends from July to September. While a calendar year divides the wet winter season, the use of a Water Year closely reflects the timing and seasonality of many physical and ecological processes that are driven by climate, such as soil saturation and forest evapotranspiration, onset and breakup of lake ice, glacial accumulation and ablation balances, magnitude and timing of stream flow, emergence and flowering of plants and migratory timing of bird species.

Seasons in this report are distinguished based on National Weather Service (NWS) standards for the Northern Hemisphere. The NWS defines December, January, and February as winter; March, April, and May as spring; June, July, and August as summer; and September, October, and November as fall.

The main report provides monthly averages of daily average temperatures and monthly total precipitation for all stations listed in Table 2. While routinely collected in metric units, the data are presented in Fahrenheit and inches to facilitate use and interpretation by the public and park staff. Two stations with long term records, Newhalem and Stehekin are compared to the 30-year climate normal. Snow water equivalent is reported and compared to the 30-year climate normal for one SNOTEL within the park.

The 2011 weather data for each weather station is reported in a separate appendix. Each appendix includes daily precipitation and temperature data. Maximum and minimum temperatures for each month are reported. Daily or monthly snowfall or snow water equivalent is presented when available. Water Year 2011 is compared with the 30-year climate normal in the main report. The appendices feature a comparison of 2011 with the period of record for that station. Detailed discussion of maintenance issues or data concerns associated with each specific station is also presented.

Results

Temperature

Mean annual temperatures were below normal in Water Year 2011. The annual temperatures ranged from 1.4 °F below normal at Newhalem to 2.1 °F below normal at Stehekin. Fall and winter season temperatures were generally warmer than normal across the park (Table 3 and Figures 3 and 4). However, November, December and February were also punctuated by periods of extreme cold. In late November cold arctic air moved into the area, the coldest temperatures of the year for most sites were recorded at this time. On November 23, the mean daily temperature dipped to -5.6 °F at Silver Lake and 17.2 °F in Marblemount. On November 24, the daily temperature in Stehekin averaged 11.5 °F, with a record low for that day of 5 °F.

Beginning in late February, there was a marked shift to a cooler weather pattern. The cool temperatures continued through July, with daily temperatures averaging 2.6 to 5.3 °F below normal at Newhalem and Stehekin, respectively (Figures 3 and 4). April was unusually cold, as daily temperatures averaged 5.1 and 9.7 °F below normal at the Newhalem and Stehekin COOP stations, respectively (Figures 3 and 4). Daily mean temperatures at the Silver and Noisy GLACIER stations were above freezing only one day during April (32.5 and 34.9 °F, respectively). The maximum temperature in Stehekin on April 6th was 37.0 °F, a record low maximum for that day.

Average temperatures for late summer and early fall were generally warmer than normal. In August temperatures were near normal on the west side of the Cascades and above normal of the east side. Temperatures in September were significantly above average on both sides of the crest. The warmest temperatures of the year were observed during late August and early September as mean daily temperature was 69.3 °F at Silver Lake, 66.4 °F at Marblemount and 79.0 °F at Stehekin.

Table 3. Average monthly air temperatures (°F) from weather stations within or adjacent to North Cascades National Park Complex in Water Year 2011.

Season	Month & Year	Marble-mount USCRN	Noisy Creek GLACIER	Newhalem COOP	Ross Dam COOP	Silver Lake GLACIER	Park Creek Ridge SNOTEL	Stehekin COOP
Fall	October 2010	49.6	36.4	51.6	50.0	42.1	44.0	48.1 ^b
	November 2010	38.3	24.8	38.4	36.6	26.6	29.0	34.4 ^b
Winter	December 2010	37.6	23.3	36.2	33.9	24.4	25.8	29.6
	January 2011	36.0	25.3	35.4	33.6	27.5	29.1	30.3
	February 2011	35.1	19.8	34.8	32.6	20.9	24.8	30.9
	March 2011	40.0	23.3	40.1	38.0	23.9	29.7	33.5 ^b
Spring	April 2011	41.7	24.2	42.5	41.0	25.0	31.5	38.0
	May 2011	50.3	32.5	51.6	49.6	36.3	40.3	48.0
Summer	June 2011	56.3	38.2	57.7	56.9	43.6	47.1	59.5
	July 2011	59.6	42.2	61.3	61.1	47.8	52.0	65.5
	August 2011	61.7	47.5	65.1	66.4	54.3	57.8	71.1
Fall	September 2011	59.0	47.5	62.6	63.2	52.0 ^a	56.2	65.3
Water Year Average		47.1	32.1	48.1	46.9	35.4^a	39.0	46.2^b

^a The Silver Lake GLACIER station was taken offline on September 13, 2011 for equipment upgrades, and remained offline until Water Year 2012. For this report, missing temperature data for the Silver Lake GLACIER has been replaced with data from the nearby Browntop Ridge SNOTEL station.

^b The Stehekin COOP station is missing more than 5 days of data in a month when flagged. For this report, missing temperature data for the Stehekin COOP has been replaced with data from the nearby Stehekin RAWS station.

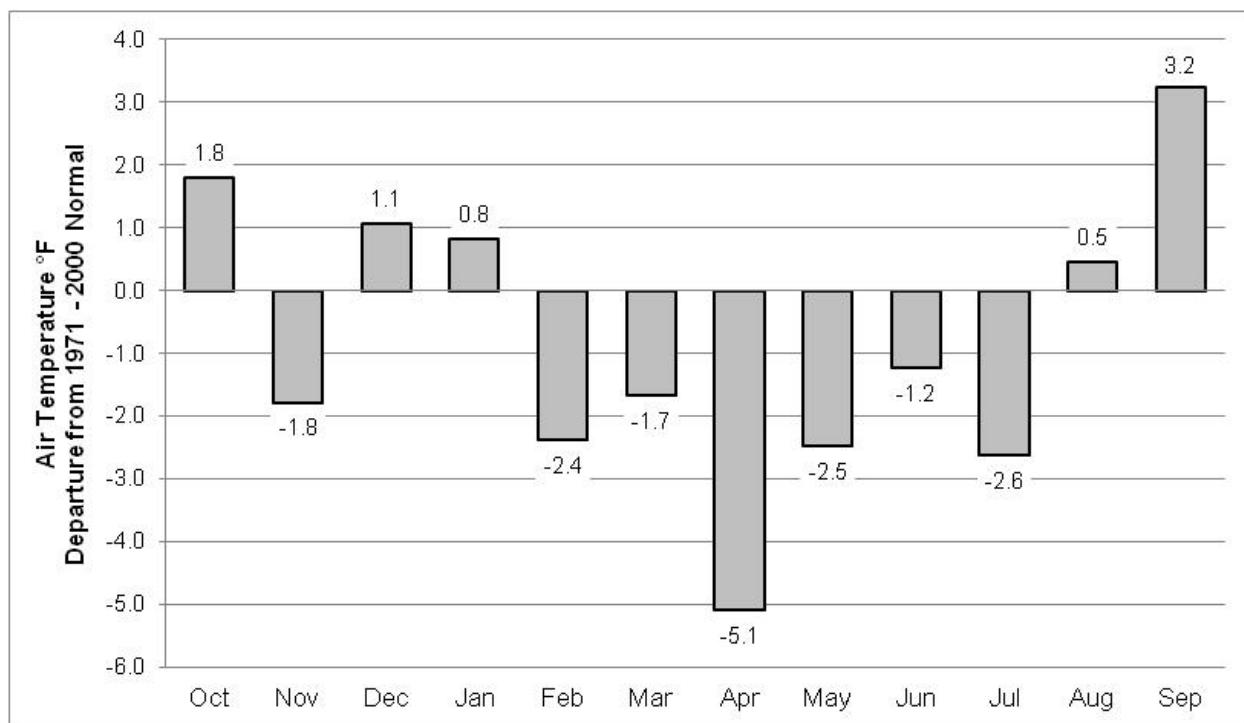


Figure 3. Departure of average monthly temperature (°F) for Newhalem COOP in Water Year 2011 from monthly averages for the climatological normal 1971-2000.

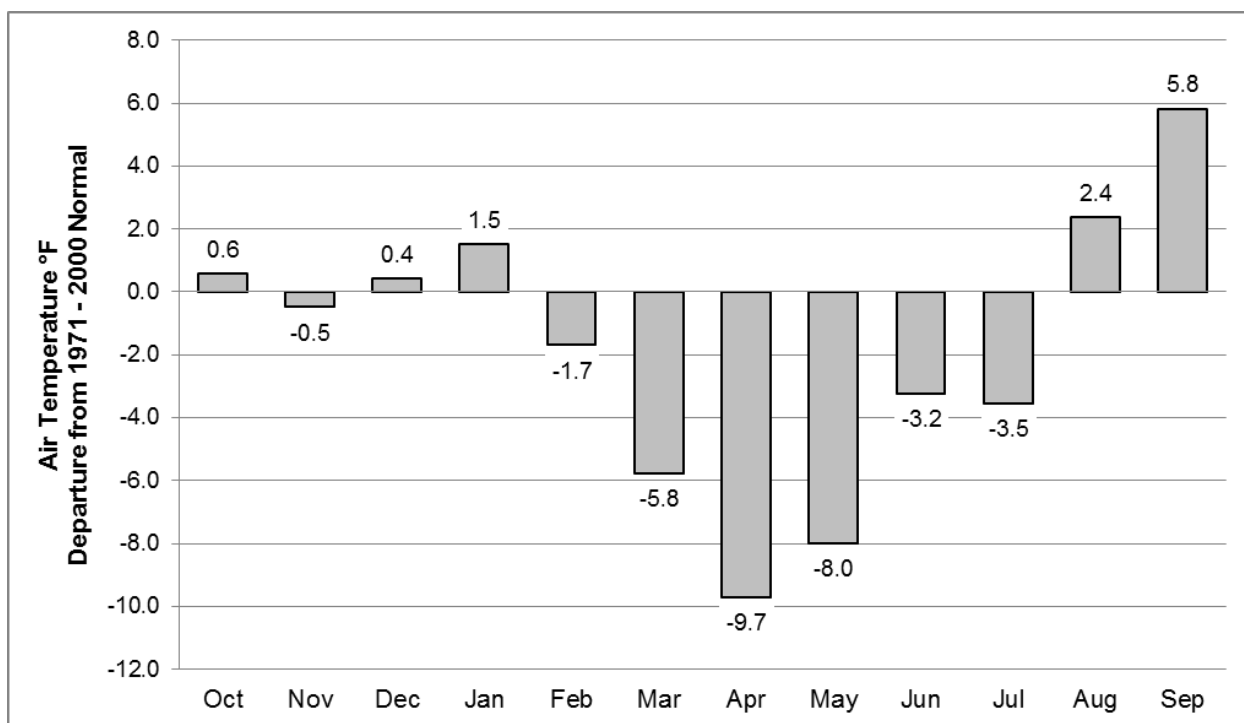


Figure 4. Departure of average monthly temperature (°F) for Stehekin COOP in Water Year 2011 from monthly averages for the climatological normal 1971-2000.

Precipitation

Annual precipitation for WY2011 was 13 percent above normal at Newhalem and 9 percent below normal at Stehekin. Monthly precipitation totals are shown in Table 4. Precipitation in the fall was below normal. November, commonly the wettest month of the year, was 75% of normal at Newhalem and 63% in Stehekin (Figures 5 and 6). A shift in precipitation occurred in the winter months, with above normal precipitation for west side sites and below normal for east side sites. West side precipitation was bolstered by two large storm events in December and January. Between December 7 and 14, over ten inches of rain fell in Marblemount. A second event occurred between January 12 and 17, nearly 11 inches fell in Marblemount. Rainfall was heavy during this event, with single day rainfall totals of four inches in Marblemount (January 16) and 3.8 inches at Park Creek Ridge (January 17); the wettest days of the year at these two sites. For eastside sites, December was relatively dry with only 44 percent of normal precipitation. However this may be partially attributed to missing precipitation data during a storm event on December 12.

Spring was notably wet for all sites, with monthly records established at some stations. In March, Stehekin precipitation was nearly 2.5 times greater than normal with 7.0 inches of rainfall recorded (Figure 6); this was the most precipitation observed in March since 1931. In Newhalem, 13.0 inches was recorded in March (Table 4), 183 percent of normal (Figure 5) and the fourth most since 1959 at this site. Park Creek recorded 11.7 inches, the second most since 1979. A storm event in late March deposited three inches of rain in Newhalem in a single day; making it the wettest day of the year at this site.

Unlike spring, summer and early fall were dry. Rainfall between June and September was 34 percent of normal in Stehekin and 59 percent of normal in Newhalem (Figures 5 and 6). August was the driest month of the season, with less than 0.01 inches of rainfall recorded in Stehekin and Park Creek Ridge and only 0.4 inches recorded in Marblemount and Newhalem (Table 4). For Park Creek Ridge this was only the second August since 1979 when no precipitation was recorded. In Newhalem, August 2011 was the 7th driest since 1959 record. For Stehekin, the dry spell continued in September with three days of measurable precipitation totaling 0.04 inches of rain.

Table 4. Total monthly precipitation (inches) from weather stations within or adjacent to North Cascades National Park Complex in Water Year 2011.

Season	Month & Year	Marblemount USCRN	Newhalem COOP	Park Creek Ridge SNOTEL	Ross Dam COOP	Stehekin COOP
Fall	October 2010	6.2	6.0	5.1	4.7	3.1
	November 2010	11.3	10.0	8.0	7.8	4.5 ^a
Winter	December 2010	12.8	14.3	16.1	12.2	4.0
	January 2011	19.3	18.7	13.0	12.3	6.1
	February 2011	8.0	8.5	7.4	7.0	3.5
Spring	March 2011	14.4	13.0	11.7	8.9	7.0 ^a
	April 2011	7.9	7.9	7.0	5.7	2.2
	May 2011	3.6	3.6	3.3	2.4	1.7
Summer	June 2011	2.5	2.1	1.0	1.3	0.4
	July 2011	2.2	1.6	0.6	1.0	0.4
	August 2011	0.4	0.4	0.0	0.2	0.0
Fall	September 2011	2.5	3.5	2.6	2.7	0.0
Water Year Total		91.0	89.7	75.8	66.1	32.9^a

^a. The Stehekin COOP station is missing more than 5 days of data in a month when flagged. For this report, missing precipitation data for the Stehekin COOP has been replaced with data from the nearby Stehekin RAWs station.

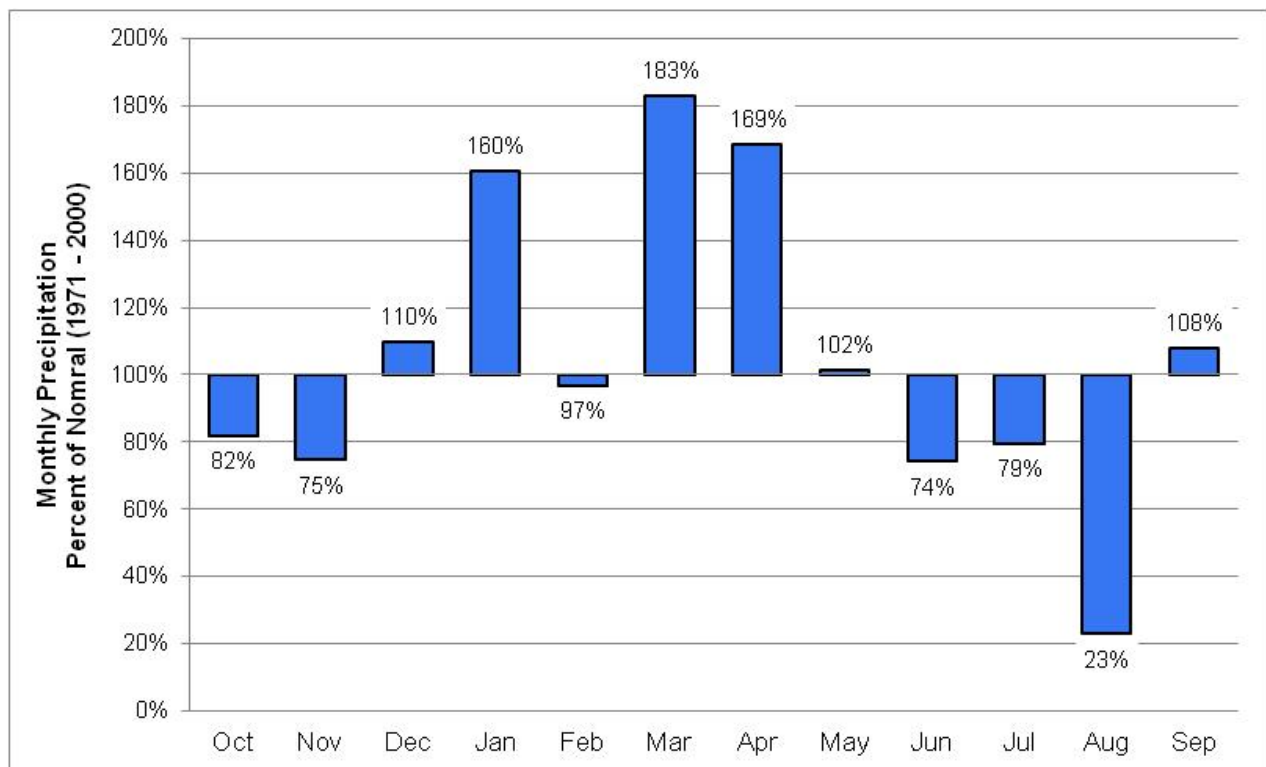


Figure 5. Comparison of total monthly precipitation (inches) at Newhalem COOP in Water Year 2011 against the climatological normal 1971-2000.

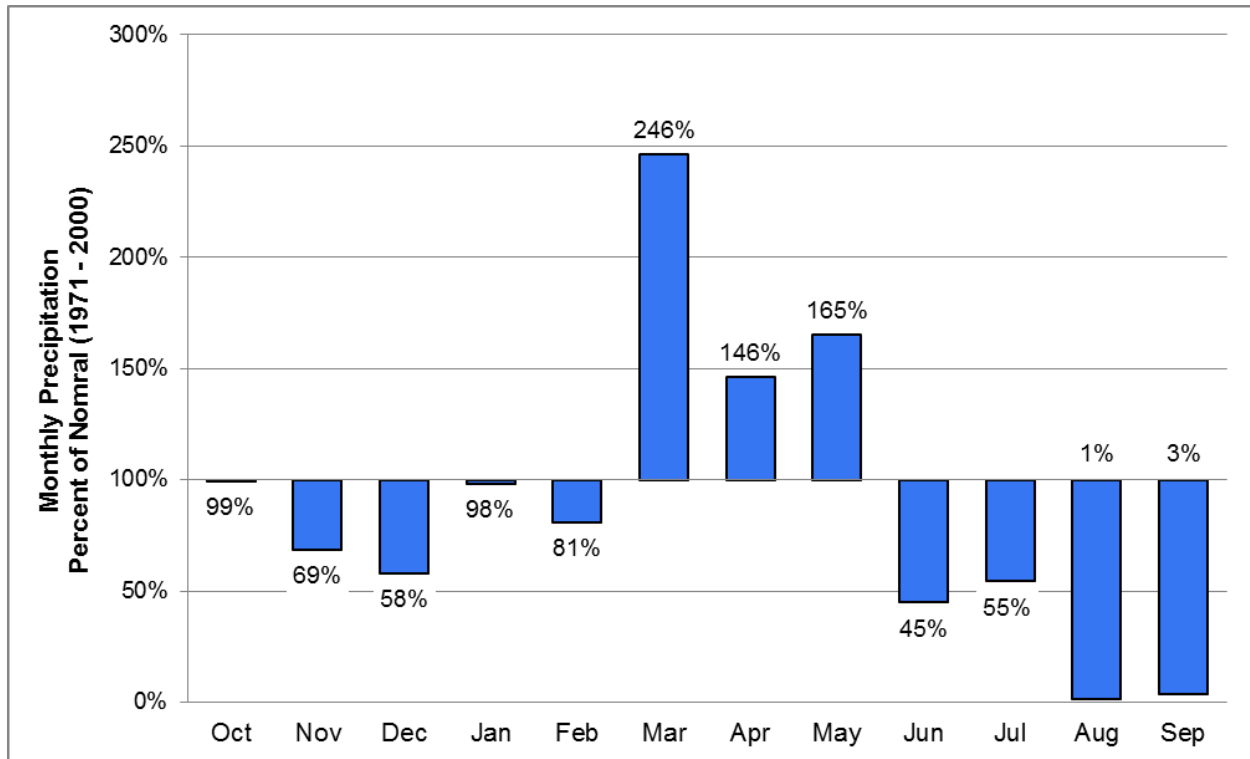


Figure 6. Comparison of total monthly precipitation (inches) at Stehekin COOP in Water Year 2011 against the climatological normal 1971-2000.

Snow

Snow depths from three NOCA locations are shown in Table 5. Warm temperatures and low precipitation in the fall and early winter resulted in a smaller than normal mountain snowpack that persisted into March at the Park Creek Ridge SNOTEL (Figure 7). However a record wet March helped recharge snowpacks to near normal levels by April 1. A cool summer delayed melt and snowpacks persisted late into the summer. Periods of below normal temperatures resulted in several low elevation snow events in late November, mid-December and late February, with snow depths peaking at 10 inches in Newhalem (Figure C-6) and 16 inches at Ross Dam on March 1.

Table 5. Snow depth (inches) measured on the first of the month at SNOTEL and snow courses within NOCA during Water Year 2011.

Month & Year	Ross Dam COOP	Park Creek Ridge SNOTEL	Stehekin COOP
November 1 st 2010	0.0	0.0	0.0
December 1 st 2010	12.0	33.0	14.0
January 1 st 2011	2.0	62.0	24.0
February 1 st 2011	0.0	61.0	18.0
March 1 st 2011	16.0	97.0	34.0
April 1 st 2011	0.0	106.0	6.0
May 1 st 2011	0.0	105.0	0.0
June 1 st 2011	0.0	57.0	0.0
July 1 st 2011	0.0	0.0	0.0

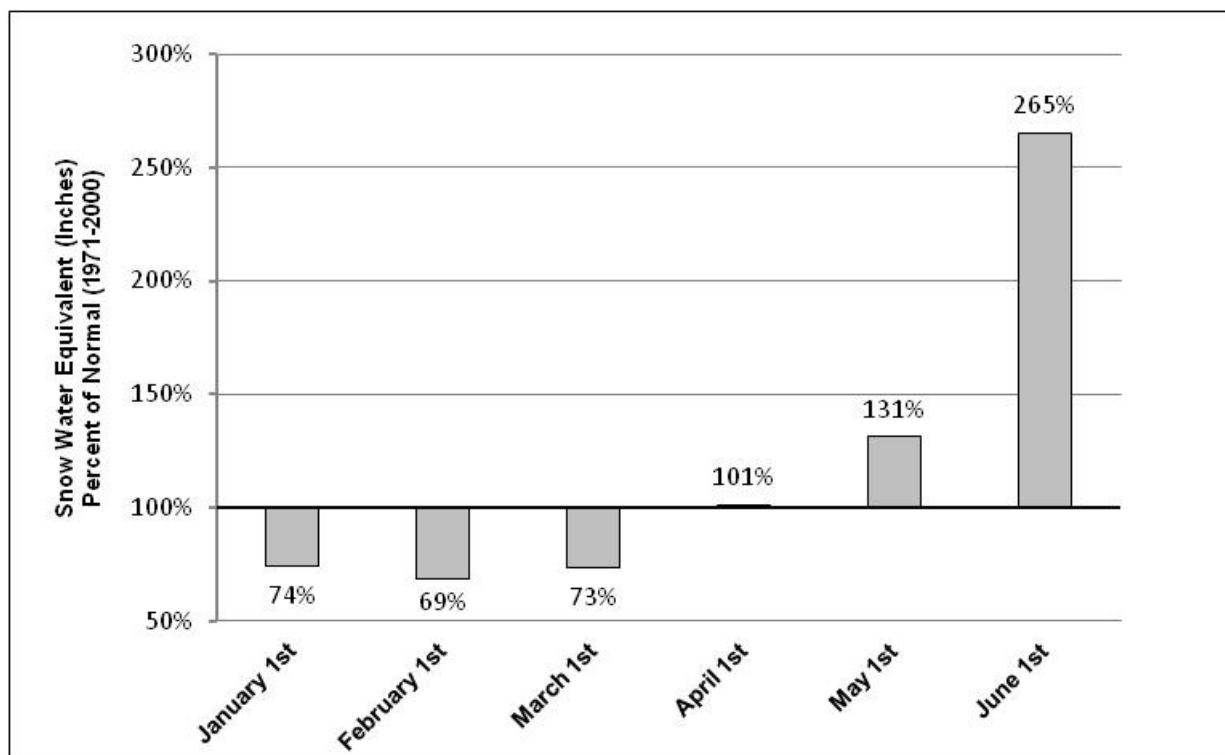


Figure 7. Comparison of snow water equivalent (inches) at the Park Creek Ridge SNOTEL in Water Year 2011 against the climatological normal 1971-2000. Data collected first day of the month.

2011 Water Year in Review

In this section, we highlight significant weather events from the seven NOCA weather stations included in this report and provide a park-wide summary of precipitation for the 2011 water year. Temperature, precipitation, and snow data from the seven stations are detailed in Appendices A-G.

Significant Weather Events and Patterns

In late November cold arctic air moved into the region, setting record lows throughout the state and blanketing most lowland areas with snow. Air temperatures dropped well below normal beginning on November 20 and persisted over five days. The coldest day of the year for most sites in the park occurred on November 24, with daily temperatures averaging single digits in the lowlands and below -19°F at higher elevations.

A series of warm wet systems, often called Pineapple Expresses, occurred in mid-December and mid-January. On December 13 and 14 above freezing temperatures were even recorded at Silver Lake GLACIER station, our highest monitoring site (Figure 2). The warm temperatures combined with heavy rain resulted in some minor flooding of local rivers. Streamflow for the Skagit River (Marblemount, WA) spiked by over four-fold and river stage more than doubled during this event (USGS 2012). A second Pineapple Express arrived on January 14; daily temperatures averaged nearly 40 °F at the Silver Glacier on January 18. The heaviest rain of the year for most monitoring stations occurred during this event, with nearly 11 inches falling over six days in Marblemount, of which 4 inches fell on January 16. The high freezing level and heavy rain result in more flooding, with streamflows spiking again by over four fold (USGS 2012) This mid-January event also created a

widespread and persistent crust in the mountain snowpack. This crust acted as a failure plane as new snow was deposited on top of it, leaving the Park in high avalanche risk for months (Morin 2012).

Beginning in February, a marked shift to a cooler and wetter weather pattern began, and this continued through July. Statewide, this shift was record setting with mean temperatures for April through July the second coldest since 1895 and with March through May being the wettest in the 117-year record for Washington State (NOAA 2011a, b, OWSC 2011).

The cold wet weather helped recharge an otherwise below normal snowpack, more than doubling in depth between mid-February and mid-March. The mountain snowpacks continued to build late into the season and cool temperatures helped preserve the late season snowpack. Many high elevation lakes did not melt out until late summer, while others remained ice covered all year (Figure 8). Beginning in August there was a shift to warmer and drier conditions. No station recorded more than 0.4 inches of rainfall in August, and some east slope locations had no measurable precipitation in the month.

Temperatures climbed in early

September, many stations recording the warmest day of the year during this period. Temperatures of 88 °F and 97 °F were recorded in Marblemount and Stehekin, respectively.

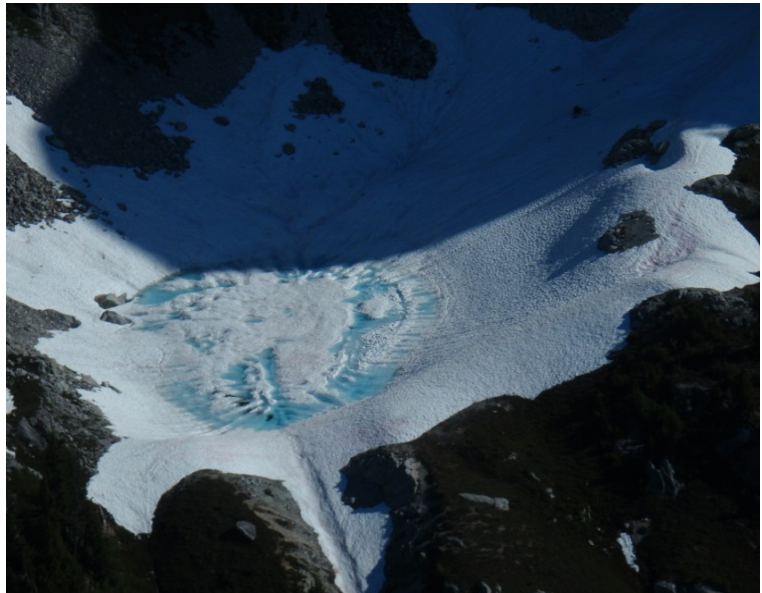


Figure 8. An ice-covered mountain lake (M1501) on September 7, 2011.

Parkwide Precipitation Summary

North Cascades National Park Complex spans the Cascade Crest, which has a strong orographic effect on precipitation. Precipitation varies considerably by geographic area and elevation, with the greatest deposition occurring on the west slopes of the range and at higher elevations. This results in a strong west to east precipitation gradient.

Total precipitation for each of the weather stations in Water Year 2011 is shown graphically in Figure 9. The highest total precipitation occurred in Marblemount, with 91 inches. Approximately ten miles to the east, in Newhalem, total precipitation was 1.3 inches lower. Another ten miles to the east at Ross Dam, precipitation was an additional 24 inches less. At Park Creek Ridge (4,600 ft.), located just east of the Cascade Crest, 76 inches of precipitation was recorded and at Stehekin (1,270 ft.), the most eastern site, 33 inches.

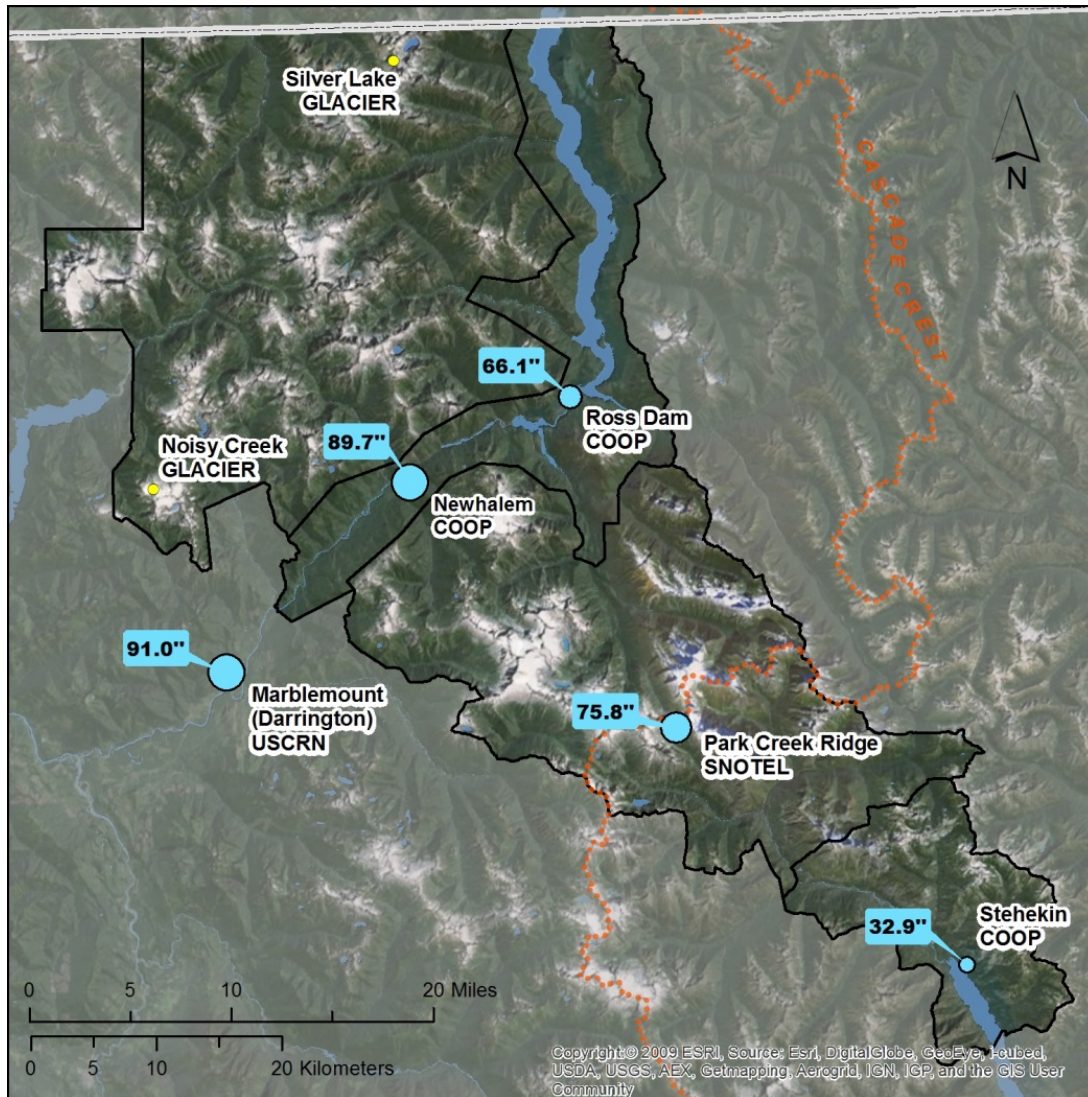


Figure 9. Total precipitation (inches) measured at weather stations located within North Cascades National Park Complex during Water Year 2011. Blue circles are proportional to the total amount of precipitation measured at each site.

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Appendix A: Marblemount (Darrington 21NNE) USCRN - Water Year 2011.

Monthly mean air temperatures and mean daily maximum and minimum air temperatures are shown in Table A-1. Temperatures ranged from an extreme low of 8.4 °F on November 24, 2010 to a high of 88.0 °F on September 11, 2011 (Table A-2). Data from this site reflects the unusually cool spring and summer (Figure A-1). The months of February through August averaged 3.7°F below the period of record mean, with July the most extreme at 5.7 °F below average. The lowest mean daily temperature for the Water Year occurred on November 23 and highest on August 25 (Figure A-2).

Marblemount received a total of 91 inches of precipitation in Water Year 2011 (Table A-1). The winter and early spring (December-April) were much wetter than average. January had the greatest quantity of precipitation at 19.3 inches and April had the greatest departure from average at 204 percent of the period of record mean (Table A-1; Figure A-3). August was significantly drier than average with only 0.4 inches of rain, or 17% of mean rainfall (Figures A-3, A-4). Between July 26 and August 21, no precipitation was recorded at this site. The heaviest period of precipitation was January 12 to 17, a total of 10.8 inches of rain (Figure A-5). The daily extreme occurred on January 16 with 4.0 inches of rain (Figure A-5).

Table A-1. Monthly summary data, Marblemount USCRN, Water Year 2011.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2010	49.6	61.3	41.2	6.2
	November 2010	38.3	50.0	17.2	11.3
Winter	December 2010	37.6	43.2	25.9	12.8
	January 2011	36.0	43.3	27.9	19.3
	February 2011	35.1	42.3	22.3	8.0
Spring	March 2011	40.0	48.9	33.1	14.4
	April 2011	41.7	47.1	36.1	7.9
	May 2011	50.3	57.0	45.0	3.6
Summer	June 2011	56.3	62.4	51.4	2.5
	July 2011	59.6	65.5	53.8	2.2
	August 2011	61.7	66.4	55.9	0.4
Fall	September 2011	59.0	66.0	50.4	2.5
Water Year Average		47.1	66.4	17.2	91.0

Table A-2. Air temperature extremes (°F) at Marblemount USCRN, Water Year 2011.

Date	Max Air Temp °F	Date	Min Air Temp °F
September 11, 2011	88.0	November 24, 2010	8.4
September 7, 2011	87.4	November 23, 2010	9.1
August 20, 2011	85.8	February 26, 2011	13.3
September 8, 2011	85.3	February 25, 2011	15.8
September 10, 2011	85.3	January 1, 2011	20.5

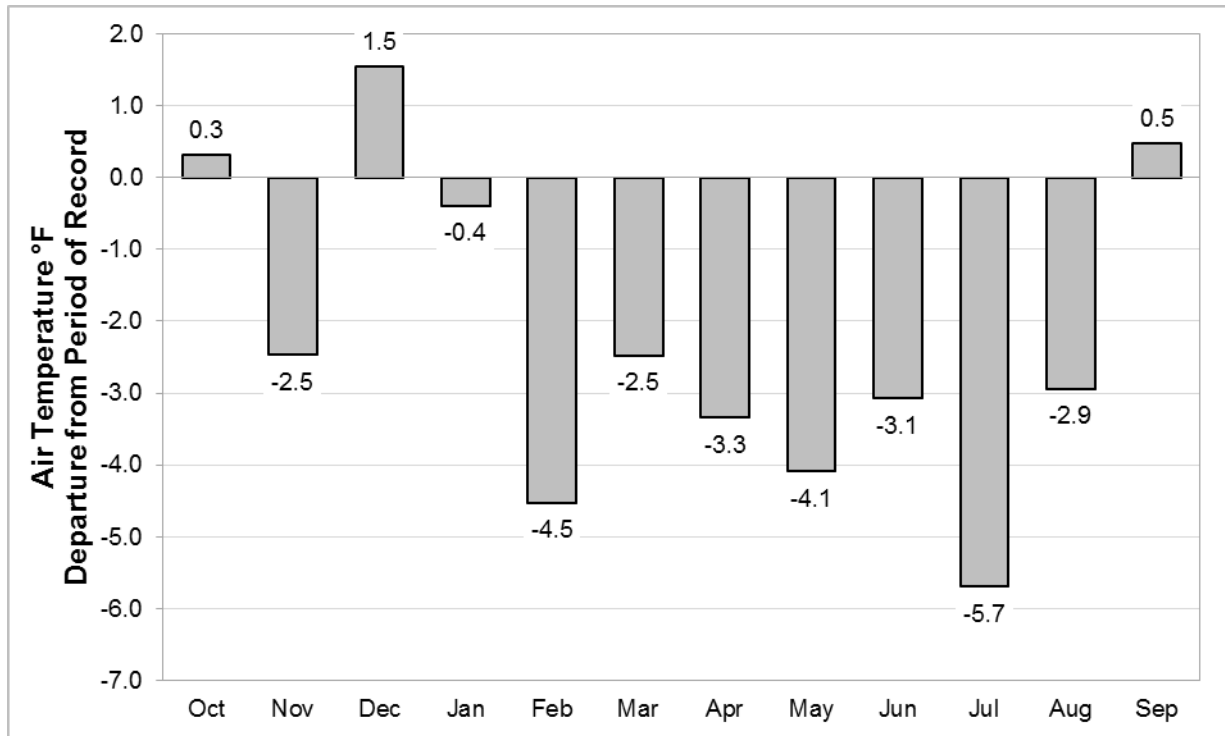


Figure A-1. Comparison of average monthly temperature (°F) at Marblemount USCRN in Water Year 2011 against monthly averages for period of record (2003-2010).

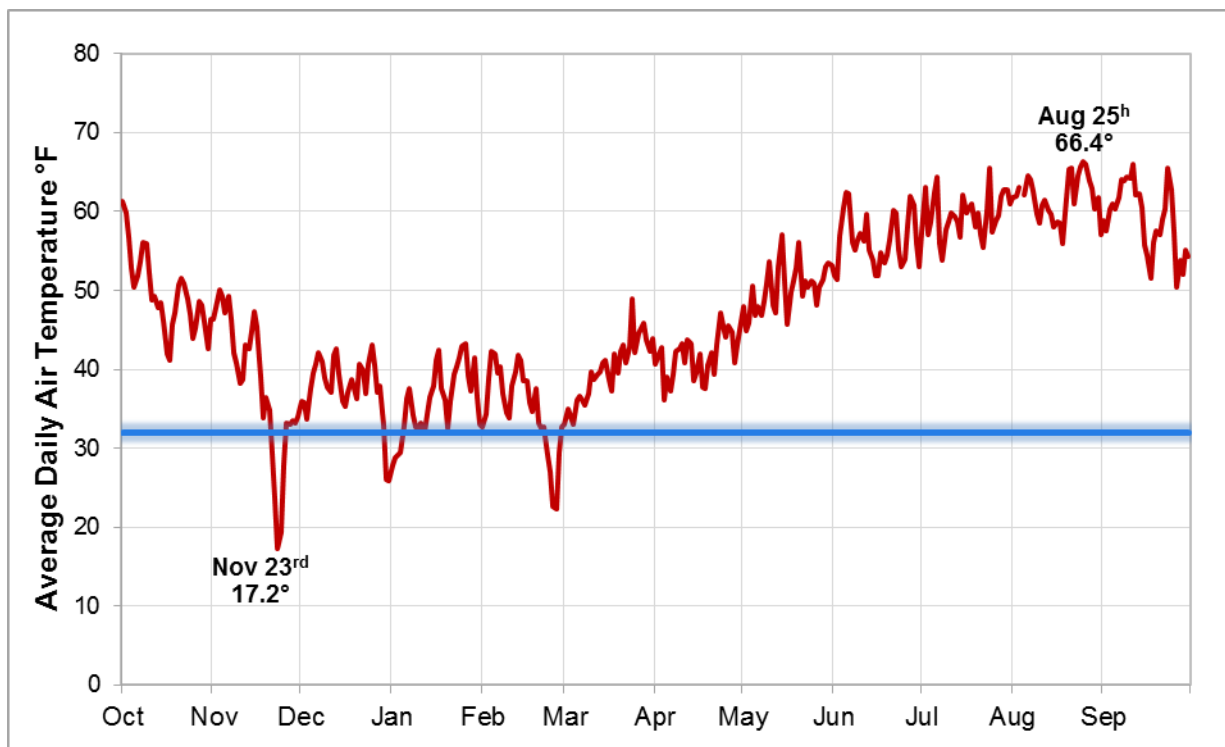


Figure A-2. Daily average air temperature (°F) at Marblemount USCRN, Water Year 2011.

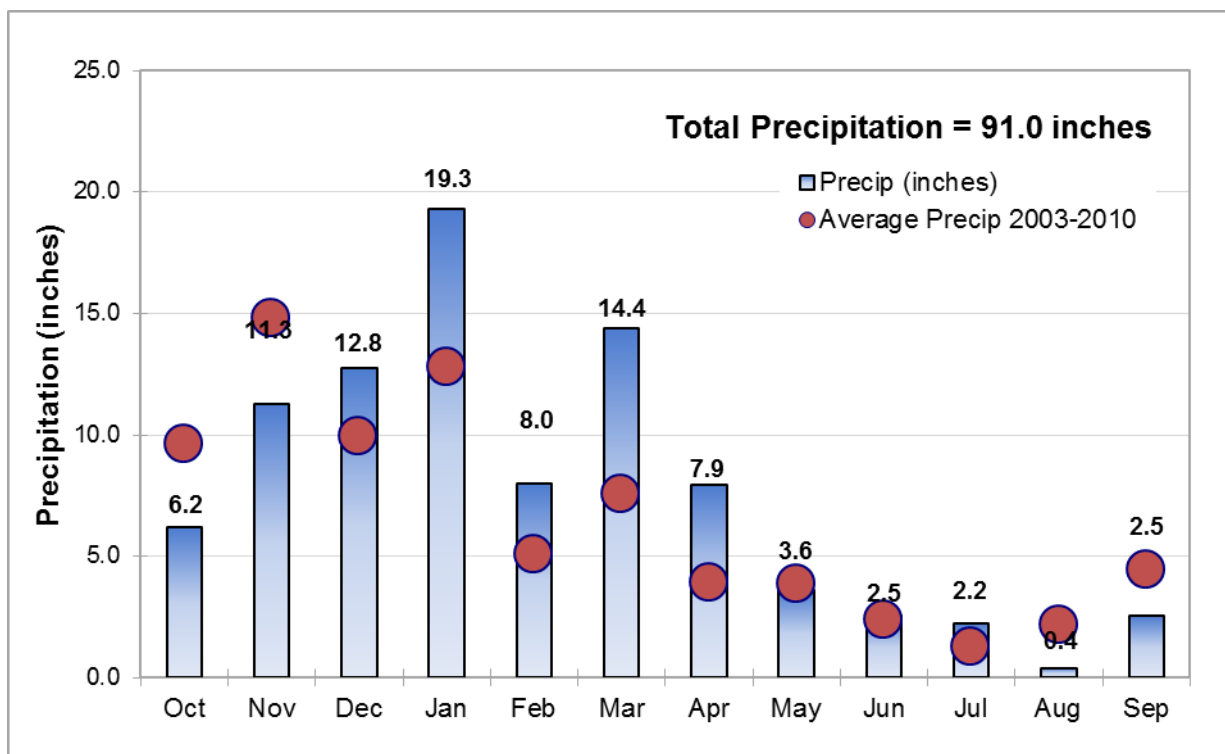


Figure A-3. Monthly precipitation values (inches) at Marblemount USCRN, Water Year 2011 compared to the monthly averages for the period of record (2003-2010).

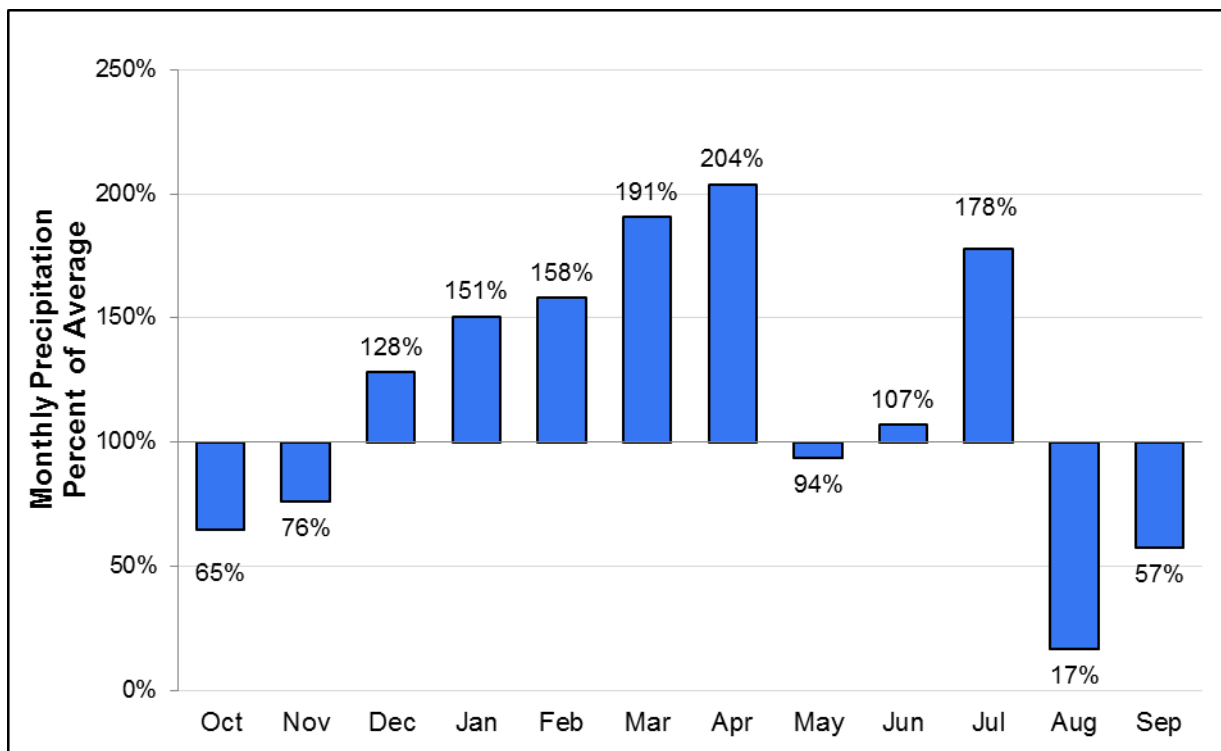


Figure A-4. Percent of average for the period of record (2003-2010) for precipitation at Marblemount USCRN, Water Year 2011.

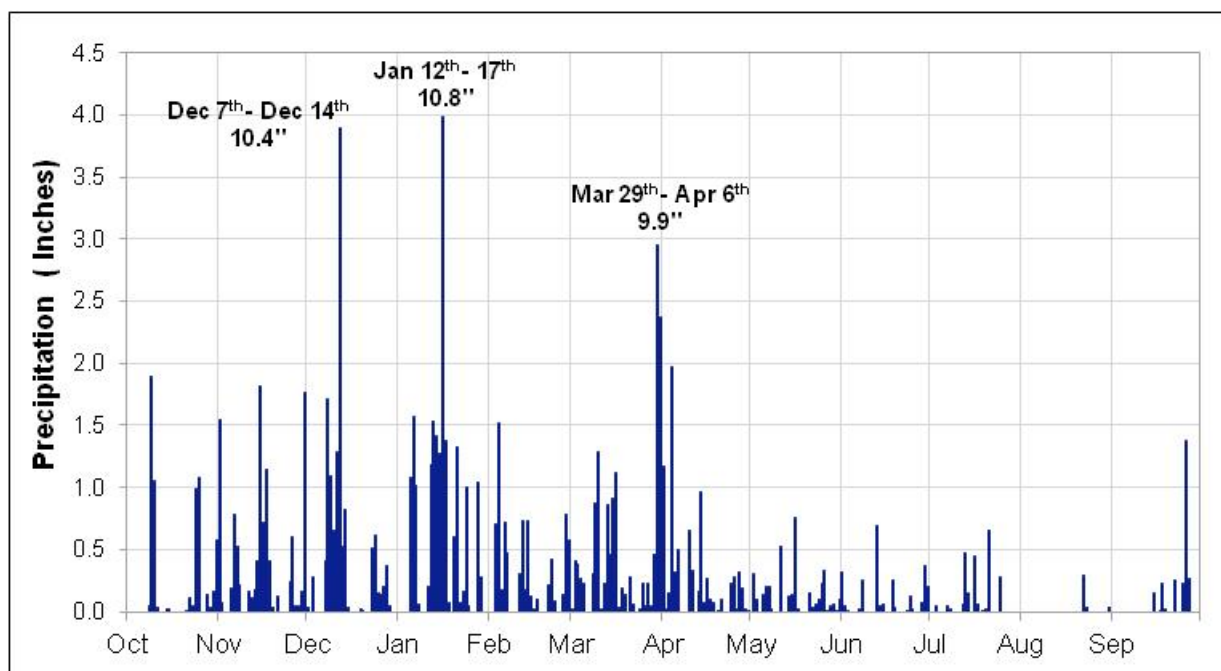


Figure A-5. Daily precipitation (inches) at Marblemount USCRN, Water Year 2011.

Appendix B: Noisy Creek GLACIER - Water Year 2011.

Monthly mean air temperatures and mean daily maximum and minimum air temperatures are shown in Table B-1. February was the coldest month (19.8 °F) and August and September were the warmest months (47.5 °F). Temperatures at Noisy Creek GLACIER station ranged from an extreme low of -13.2 °F in late-November 2010 to a high of 68.4 °F in September 2011 (Table B-2). The lowest mean daily temperature for the Water Year occurred on November 24 and highest on September 11 (Figure B-1). Poor grounding of the equipment that was resulting in data error was resolved in early October; the station began collecting data on October 6, 2010.

Table B-1. Monthly summary data, Noisy Creek GLACIER, Water Year 2011.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F
Fall	October 2010	36.4	53.4	27.0
	November 2010	24.8	48.6	-4.9
Winter	December 2010	23.3	34.5	3.7
	January 2011	25.3	35.6	11.3
	February 2011	19.8	34.7	1.4
Spring	March 2011	23.3	30.0	16.3
	April 2011	24.2	32.5	19.0
	May 2011	32.5	43.9	25.7
Summer	June 2011	38.2	48.2	31.6
	July 2011	42.2	55.2	32.2
	August 2011	47.5	58.3	38.3
Fall	September 2011	47.5	63.7	32.9
Water Year Average		32.1	63.7	-4.9

Table B-2. Air temperature extremes (°F) at Noisy Creek GLACIER, Water Year 2011.

Date	Max Air Temp °F	Date	Min Air Temp °F
September 11, 2011	68.4	November 24, 2010	-13.2
September 12, 2011	68.2	November 23, 2010	-7.8
September 8, 2011	67.6	February 26, 2011	-3.5
September 10, 2011	67.3	February 25, 2011	-2.6
September 9, 2011	66.6	November 25, 2010	-2.4

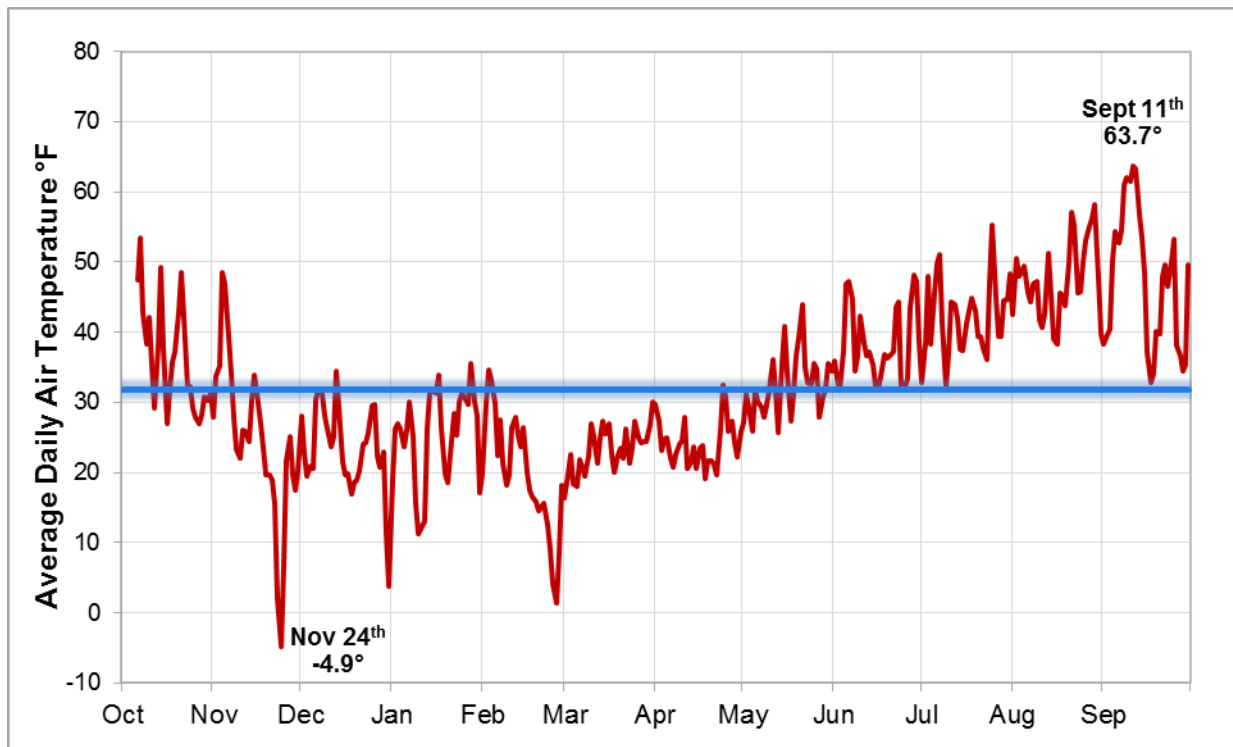


Figure B-1. Daily average air temperature (°F) at Noisy Creek GLACIER, Water Year 2011.

Appendix C: Newhalem COOP - Water Year 2011.

Monthly mean air temperatures and mean daily maximum and minimum air temperatures are shown in Table C-1. Temperatures at Newhalem COOP station ranged from an extreme low of 12 °F in late-November 2010 to a high of 92 °F in September 2011 (Table C-2). The months of February through July averaged 3.3 °F below the period of record mean, with April the most extreme at 5.5 °F below average (Figure C-1). The lowest mean daily temperature for the Water Year occurred on November 24 and highest on August 21 (Figure C-2).

The winter and early spring (December-April) were much wetter than average. January had the greatest quantity of precipitation at 18.7 inches and March had the greatest departure from average at 180 percent of the period of record mean (Figure C-3). August was significantly drier than average with only 0.4 inches of rain, or 21% of mean rainfall (Figures C-3, C-4). The heaviest period of precipitation was January 12 to 17, with 11.0 inches of rain (Figure C-5). The daily extreme occurred on March 31 with 3.0 inches of rain (Figure C-5). Winter snow cover was intermittent, reaching a maximum depth of 10 inches in mid-January (Figure C-6).

Table C-1. Monthly summary data, Newhalem COOP, Water Year 2011.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2010	51.6	63.5	42.0	6.0
	November 2010	38.4	52.1	16.5	10.0
Winter	December 2010	36.2	40.6	25.0	14.3
	January 2011	35.4	42.0	26.0	18.7
	February 2011	34.8	43.0	22.5	8.5
Spring	March 2011	40.1	50.0	32.5	13.0
	April 2011	42.5	52.5	33.6	7.9
	May 2011	51.6	62.1	44.5	3.6
Summer	June 2011	57.7	66.5	51.0	2.1
	July 2011	61.3	72.5	54.1	1.6
	August 2011	65.1	74.0	57.0	0.4
Fall	September 2011	62.6	74.0	53.0	3.5
Water Year Total		48.1	74.0	16.5	89.7

Table C-2. Air temperature extremes (°F) at Newhalem COOP, Water Year 2011.

Date	Max Air Temp °F	Date	Min Air Temp °F
September 8, 2011	92	November 24, 2010	12
September 12, 2011	92	November 23, 2010	13
July 25, 2011	91	February 25, 2011	14
August 21, 2011	91	February 26, 2011	15
September 11, 2011	89	November 25, 2010	15

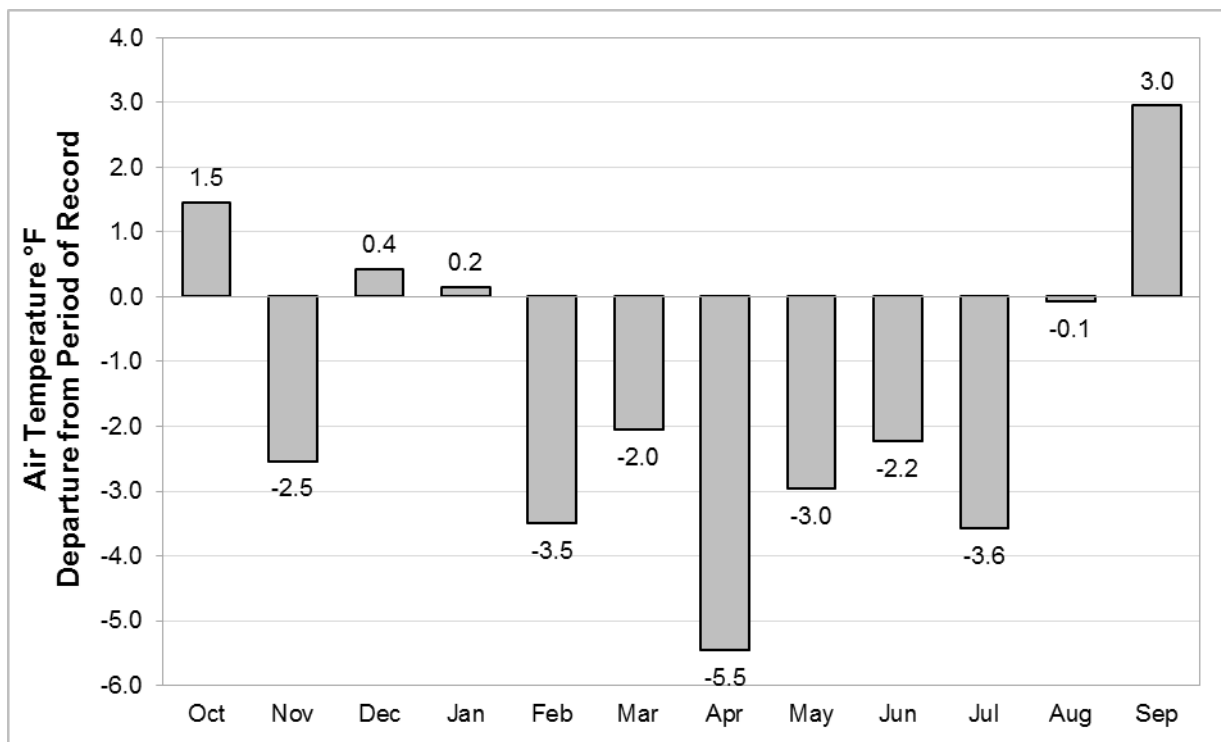


Figure C-1. Comparison of average monthly temperature (°F) for Newhalem COOP in Water Year 2011 against monthly averages for period of record (1959-2010).

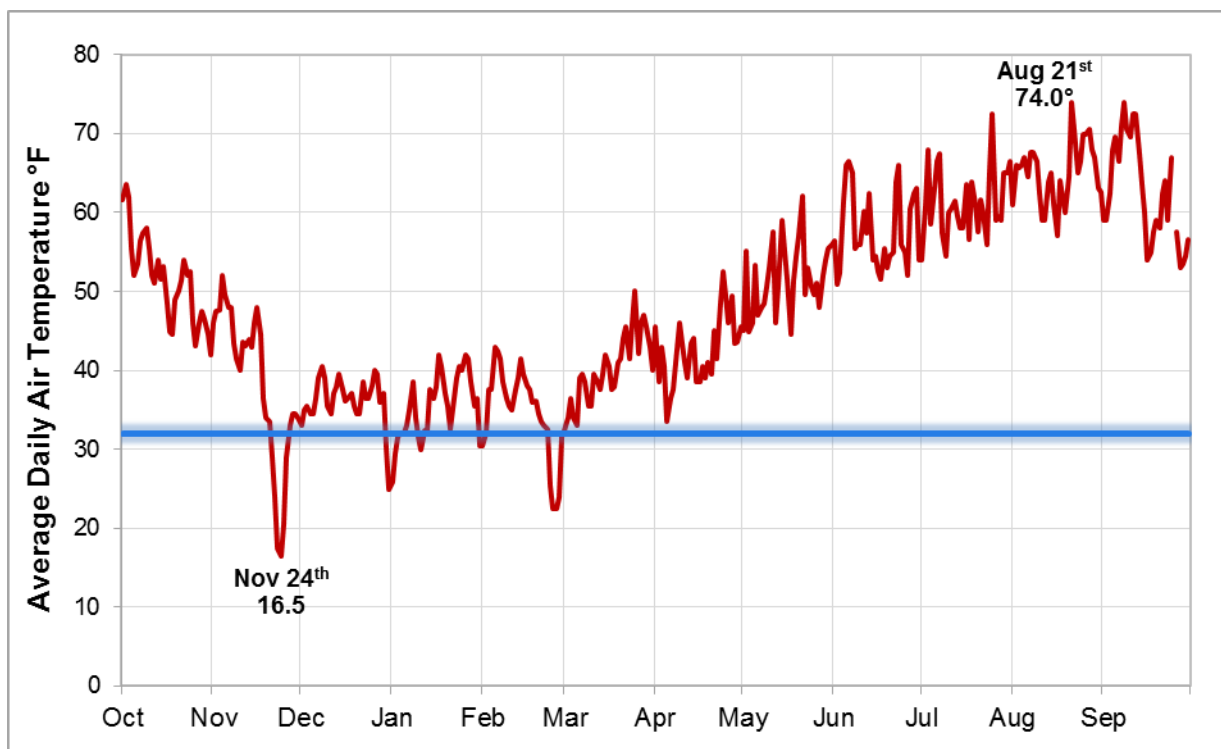


Figure C-2. Daily average air temperature (°F) at Newhalem COOP, Water Year 2011.

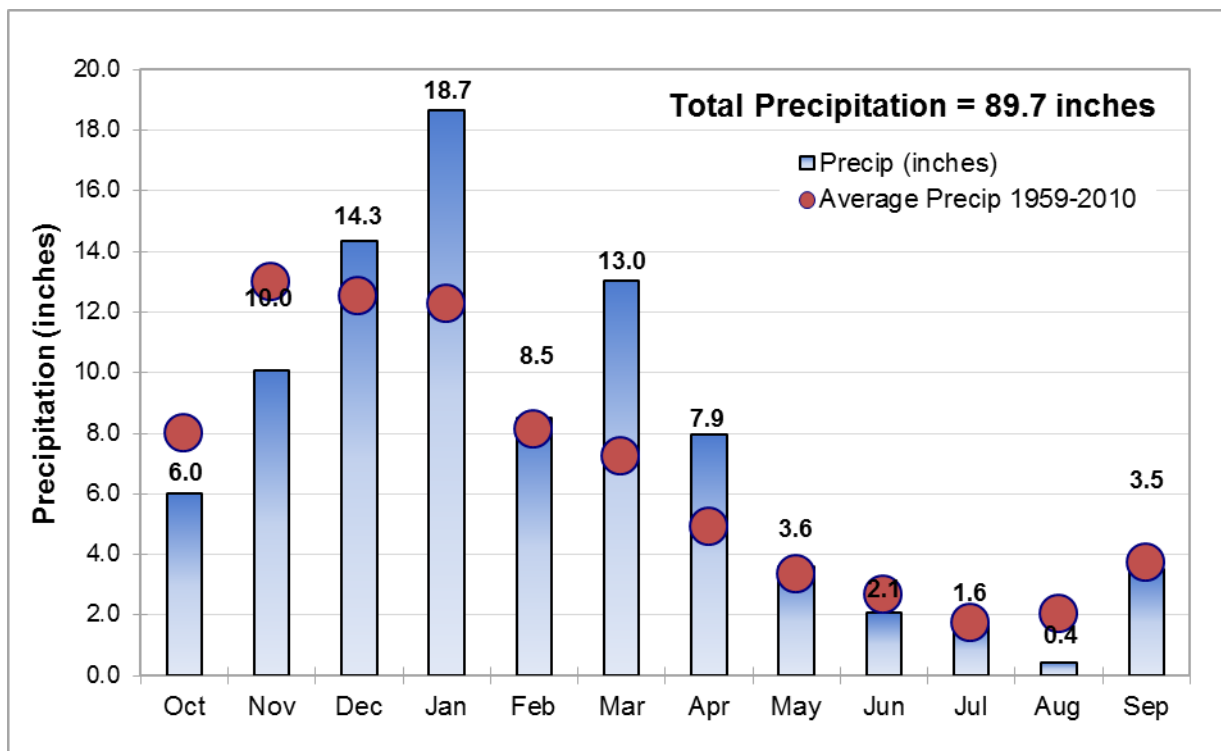


Figure C-3. Monthly precipitation values (inches) at Newhalem COOP, Water Year 2011 compared to the monthly averages for the period of record (1959-2010).

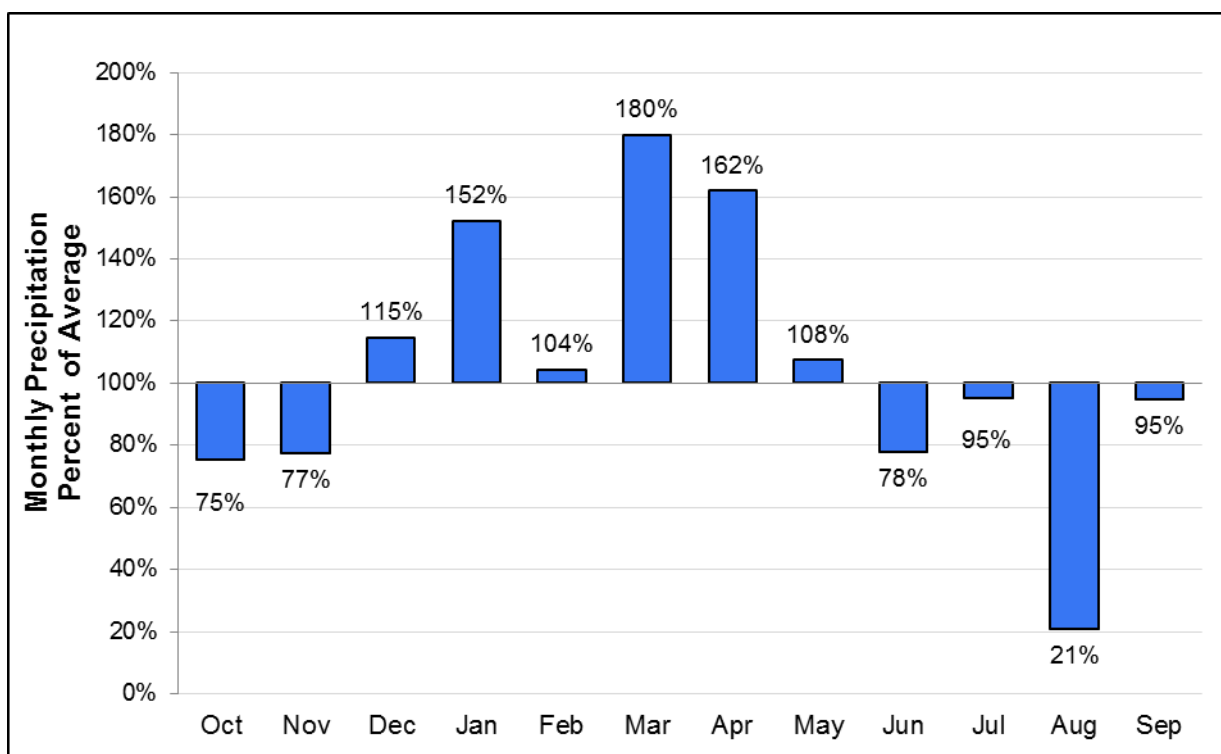


Figure C-4. Percent of average for the period of record (1959-2010) for precipitation at Newhalem COOP in Water Year 2011.

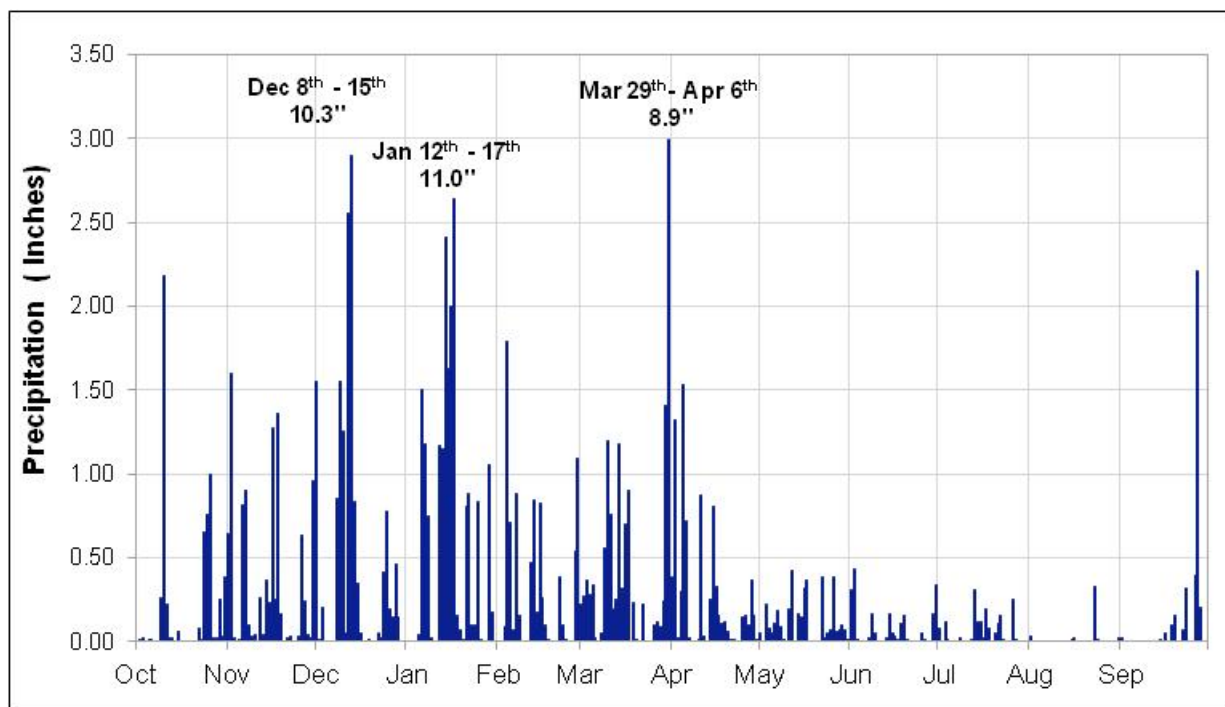


Figure C-5. Daily precipitation (inches) at Newhalem COOP, Water Year 2011.



Figure C-6. Daily snow depth (inches) at Newhalem COOP, Water Year 2011.

Appendix D: Park Creek Ridge SNOTEL - Water Year 2011.

Monthly mean air temperatures and monthly mean daily maximum and minimum air temperatures are shown in Table D-1. Temperatures ranged from an extreme low of -4.4 °F to a high of 85.5 °F (Table D-2). The months of February through July averaged 2.6 °F below the period of record mean, with July the most extreme at 5.2 °F below average (Figure D-1). The largest departure from normal was observed in November with temperature 5.7 °F below normal. January and September were significantly warmer than normal, with a 4.5 °F departure from the period of record in January. The lowest mean daily temperature for the Water Year occurred on November 24 and highest on September 11 (Figure D-2).

The Park Creek Ridge SNOTEL received 75.8 inches of precipitation in Water Year 2011 (Figure D-3). March through May had 170 percent of average precipitation (Figures D-4). The summer months were drier than average, June and July average 60 percent of average and August had no measurable precipitation recorded. The heaviest period of precipitation was January 13 to 22 with 10.6 inches of rain (Figure D-5). The daily extreme occurred on January 17 with 3.7 inches of rain (Figure D-5).

Snowpack at Park Creek Ridge remained below average during the winter months. However, the snowpack was significantly bolstered by a cool wet spring and an above average snowpack remained into the summer, with June 1 snowpack nearly 3 times the average. Snowpack began developing on November 18, 2010 and melted out on June 20, 2011, persisting for 213 days. The maximum snow depth for the year occurred on April 6 with 130 inches of snow (Figure D-6). On April 1 the snowpack was 48.2 inches, 104% of average (Figure D-7 and D-8).

Table D-1. Monthly summary data, Park Creek Ridge SNOTEL, Water Year 2011.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2010	44.0	59.2	34.0	5.1
	November 2010	29.0	42.6	1.9	8.0
Winter	December 2010	25.8	34.9	13.6	16.1
	January 2011	29.1	45.1	9.1	13.0
	February 2011	24.8	36.3	7.5	7.4
	March 2011	29.7	35.2	22.8	11.7
Spring	April 2011	31.5	38.5	26.6	7.0
	May 2011	40.3	51.4	33.6	3.3
	June 2011	47.1	56.5	40.1	1.0
Summer	July 2011	52.0	63.5	41.5	0.6
	August 2011	57.8	67.6	48.9	0.0
Fall	September 2011	56.2	71.4	40.8	2.6
Water Year Average		39.0	71.4	1.9	75.8

Table D-2. Air temperature extremes (°F) at Park Creek Ridge SNOTEL, Water Year 2011.

Date	Max Air Temp °F	Date	Min Air Temp °F
September 11, 2011	85.5	November 24, 2010	-4.4
September 12, 2011	82.9	February 26, 2011	-1.1
August 29, 2011	81.3	November 25, 2010	0.9
September 8, 2011	80.4	November 23, 2010	1.4
September 10, 2011	80.4	January 2, 2011	3.8

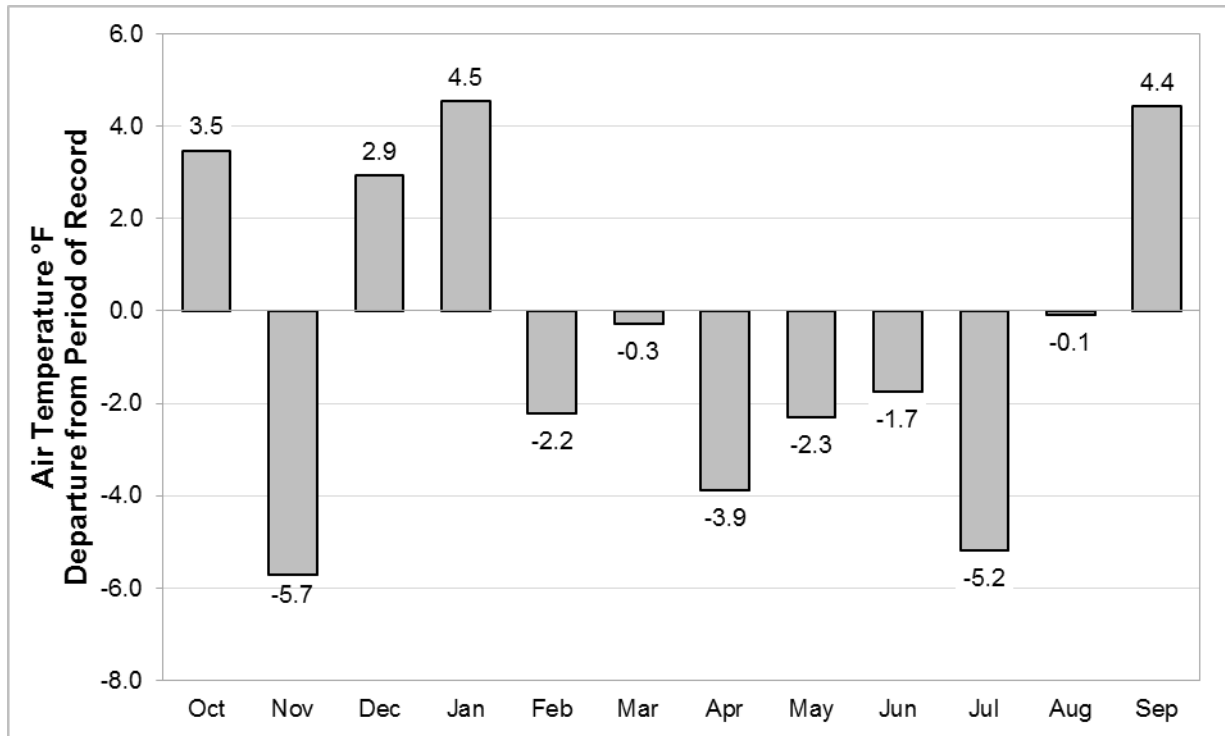


Figure D-1. Comparison of average monthly temperature (°F) for Park Creek Ridge SNOTEL in Water Year 2011 against monthly averages for the period of record (1991-2010).

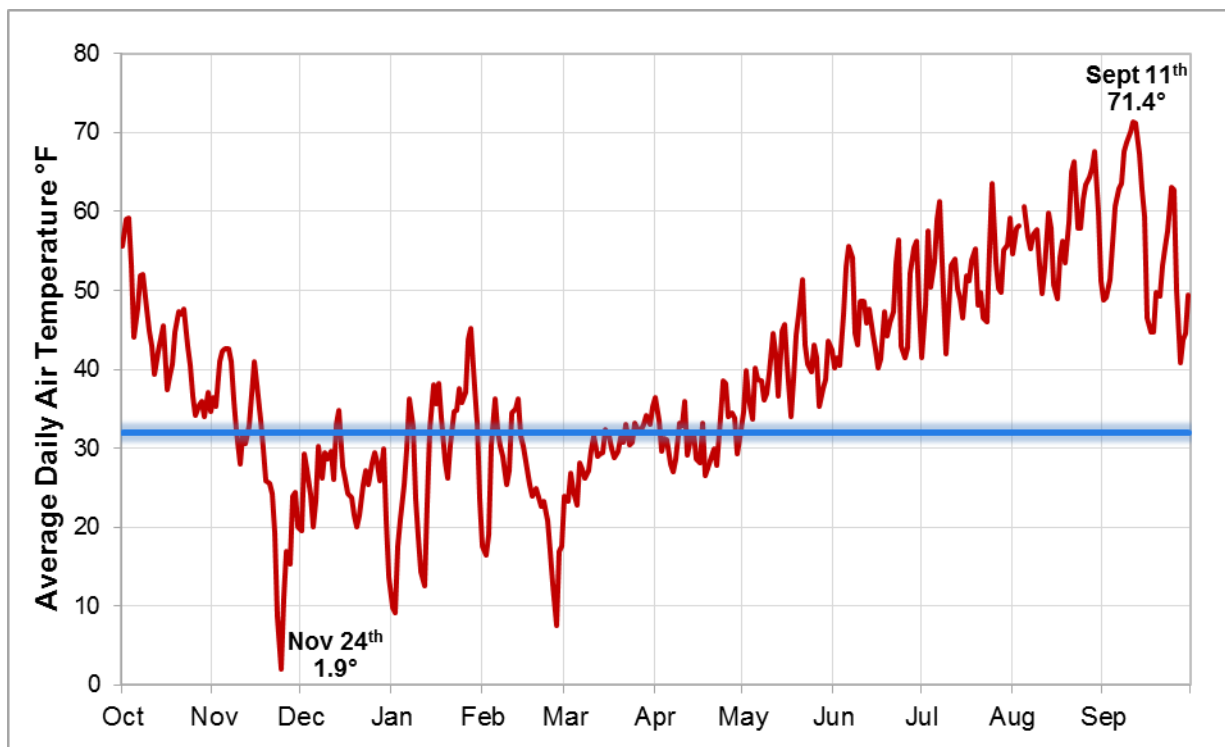


Figure D-2. Daily average air temperature (°F) at Park Creek Ridge SNOTEL, Water Year 2010.

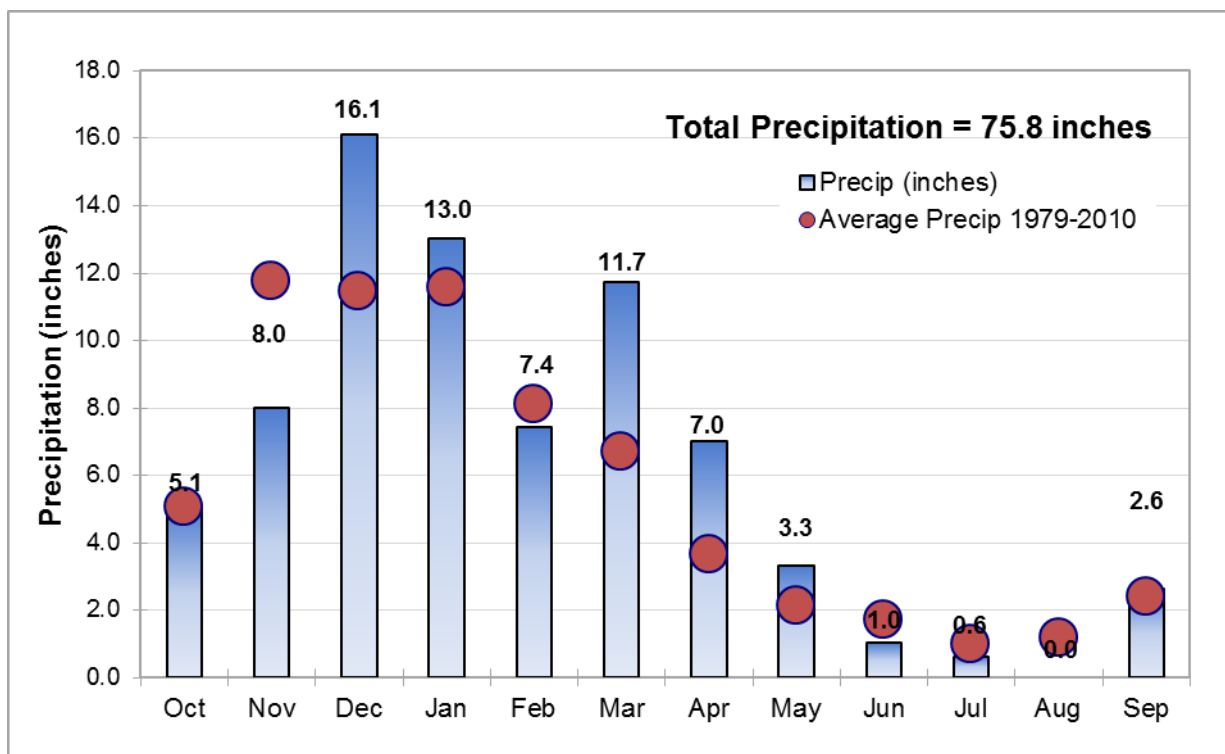


Figure D-3. Monthly precipitation values (inches) at Park Creek Ridge SNOTEL, Water Year 2011 compared to the monthly averages for the period of record (1979-2010).

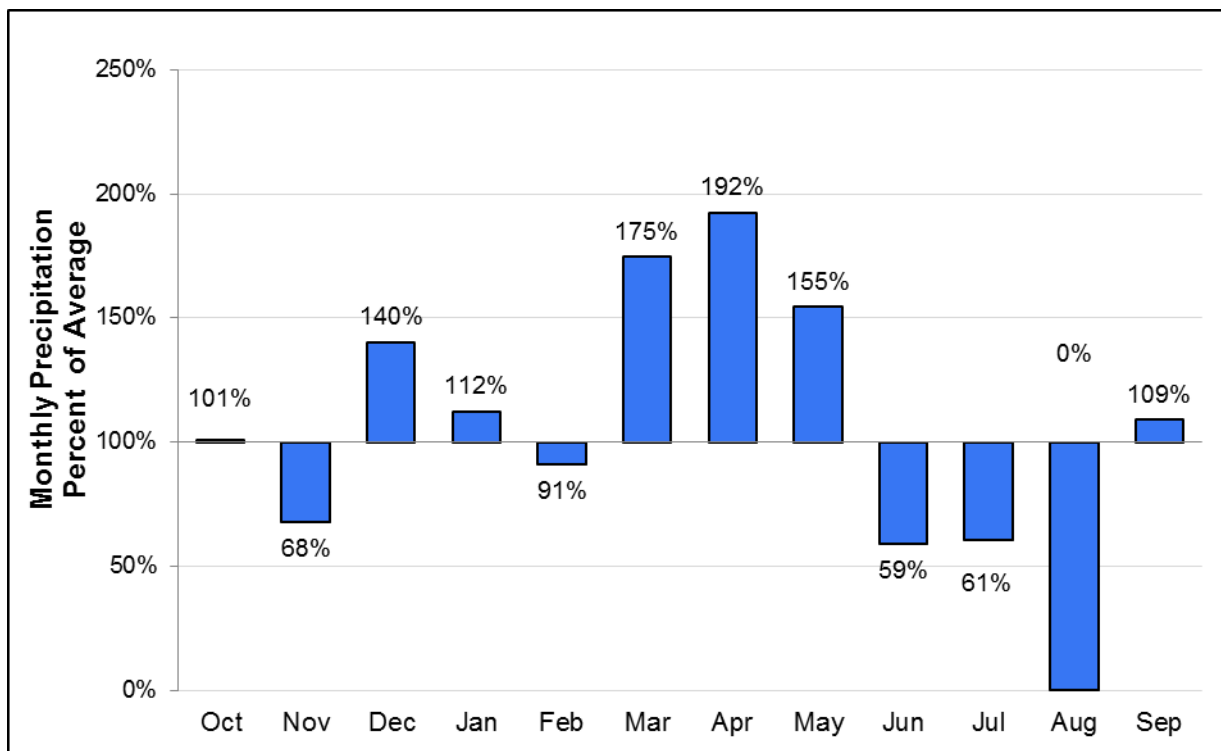


Figure D-4. Percent of average for the period of record (1979-2010) for precipitation at Park Creek Ridge SNOTEL in Water Year 2011.

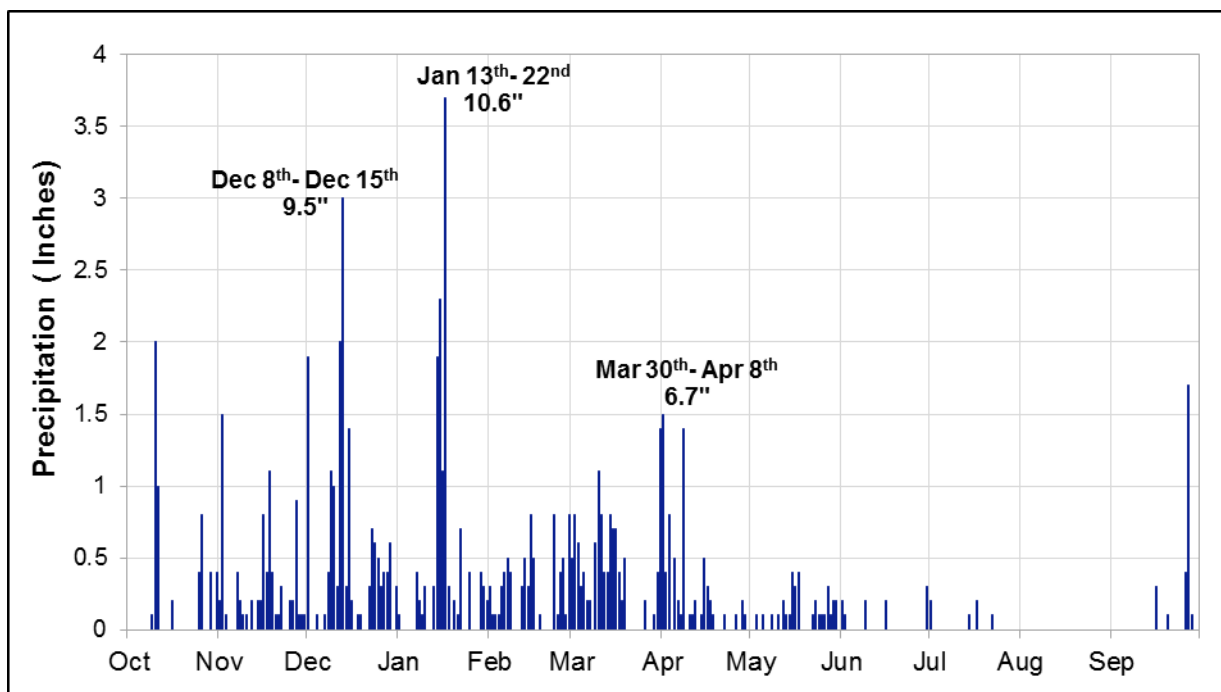


Figure D-5. Daily precipitation (inches) at Park Creek Ridge SNOTEL, Water Year 2010.

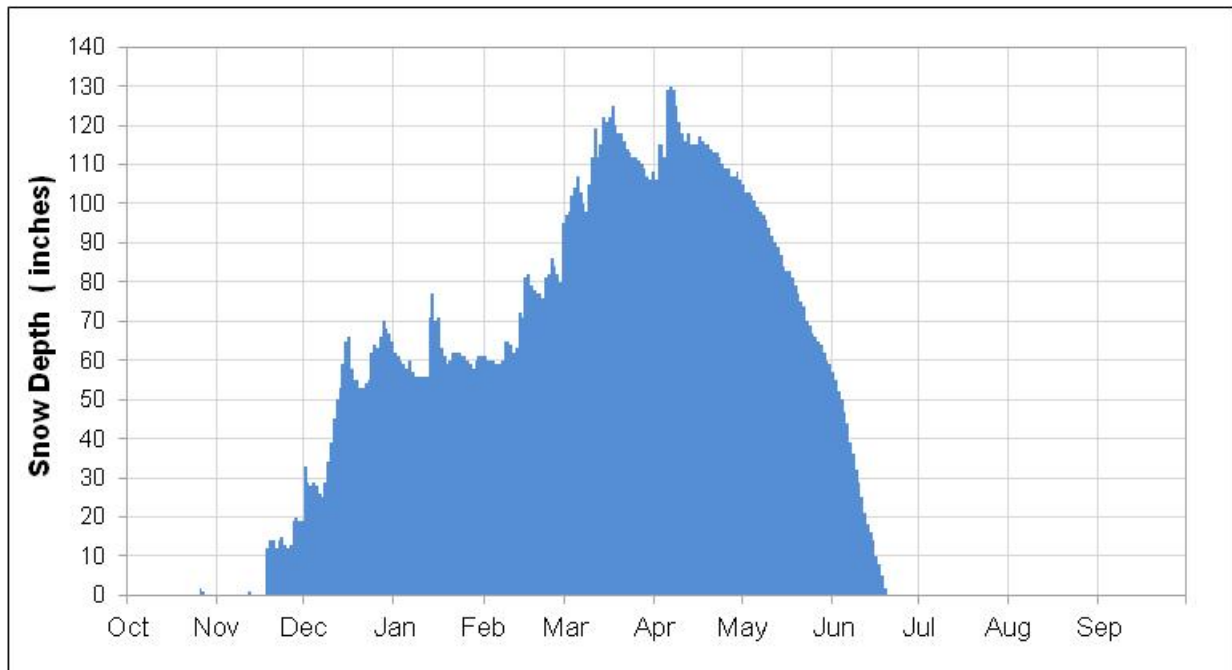


Figure D-6. Daily snow depth (inches) at Park Creek Ridge SNOTEL, Water Year 2011.

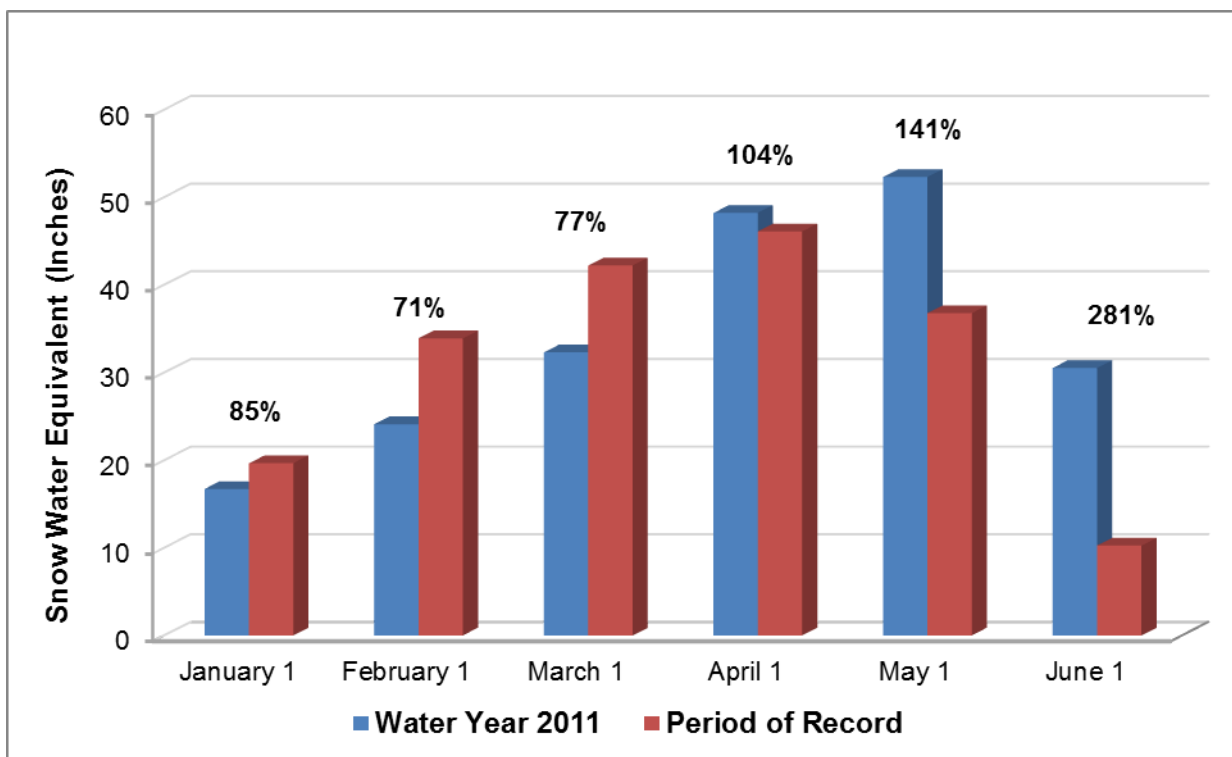


Figure D-7. First of the month snow water equivalent (inches) at Park Creek Ridge SNOTEL in Water Year 2011, compared with the period of record (1928-2010).

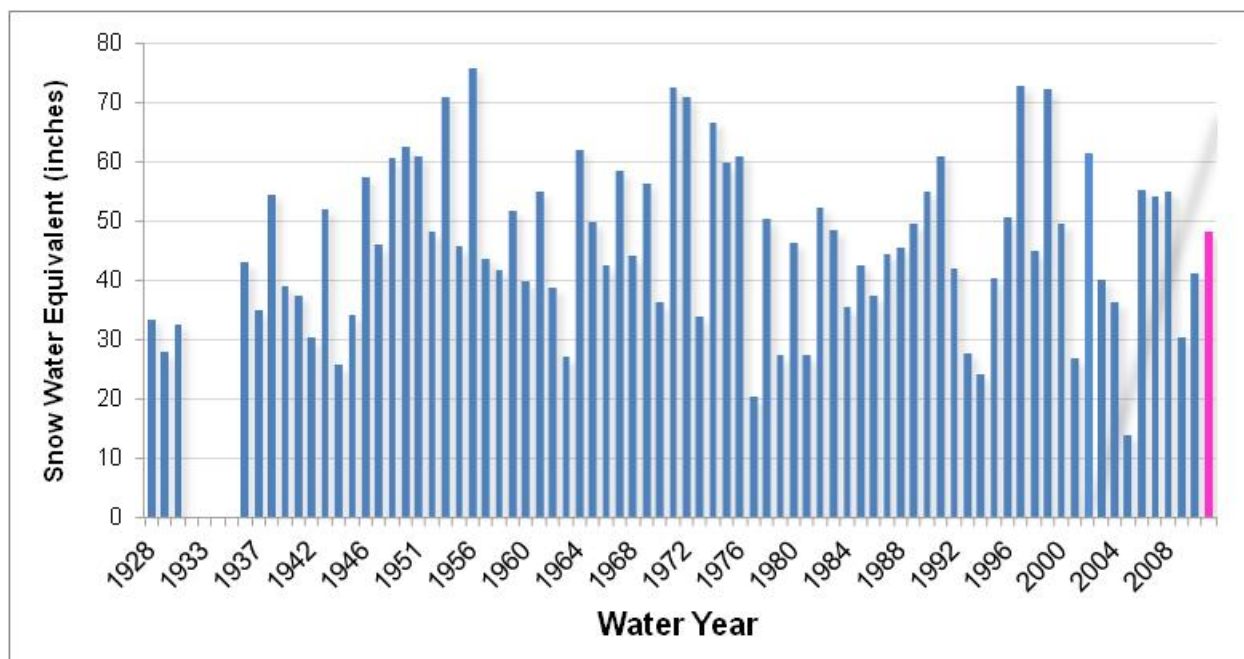


Figure D-8. April 1st snow water equivalent (inches) at Park Creek Ridge SNOTEL for the period of record (1928 -2010). Highlighted column indicates Water 2011. No data were available for Water Years 1932-1935.

Appendix E: Ross Dam COOP - Water Year 2011.

Monthly mean air temperatures and mean daily maximum and minimum air temperatures are shown in Table E-1. Temperatures at Ross Dam ranged from an extreme low of 7 °F in November 2010 to a high of 94 °F in September 2011 (Table E-2). The months of February through July averaged 3.7 °F below the period of record mean, with April the most extreme at 5.3 °F below average (Figure E-1). September was significantly warmer than normal, with a 5.3 °F departure from the period of record. The lowest mean daily temperature for the Water Year occurred on November 24 and highest on September 9 (Figure E-2).

Annual precipitation was 66.1 inches (Figure E-3). Precipitation was 126 percent of average during the winter months (Figure E-4). Spring was significantly wetter than average, March and April was 177 percent of normal. August was significantly drier than normal with 0.2 inches of rain, only 17 percent of the average rainfall. The heaviest period of precipitation was December 8 to 15, a total of 9.3 inches of rain (Figure E-5). The daily extreme occurred on December 13 with 2.8 inches of rain (Figure E-5). Winter snow cover was intermittent, reaching a maximum depth of 16 inches on December 3 and again on March 1 (Figure E-6).

Table E-1. Monthly summary data, Ross Dam COOP, Water Year 2011.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2010	50.0	63.5	41.5	4.7
	November 2010	36.6	49.0	12.0	7.8
Winter	December 2010	33.9	38.5	21.5	12.2
	January 2011	33.6	41.0	20.0	12.3
	February 2011	32.6	43.0	16.5	7.0
Spring	March 2011	38.0	45.5	29.5	8.9
	April 2011	41.0	49.0	34.5	5.7
	May 2011	49.6	61.5	43.0	2.4
Summer	June 2011	56.9	65.0	51.0	1.3
	July 2011	61.1	71.5	51.5	1.0
	August 2011	66.4	74.5	58.0	0.2
Fall	September 2011	63.2	75.5	51.0	2.7
Water Year Average		46.9	75.5	12.0	66.1

Table E-2. Air temperature extremes (°F) at Ross Dam COOP, Water Year 2011.

Date	Max Air Temp °F	Date	Min Air Temp °F
September 12, 2011	94	November 24, 2010	7
September 9, 2011	92	November 23, 2010	8
August 21, 2011	91	February 26, 2011	9
July 25, 2011	90	November 25, 2010	12
August 22, 2011	90	December 31, 2010	15

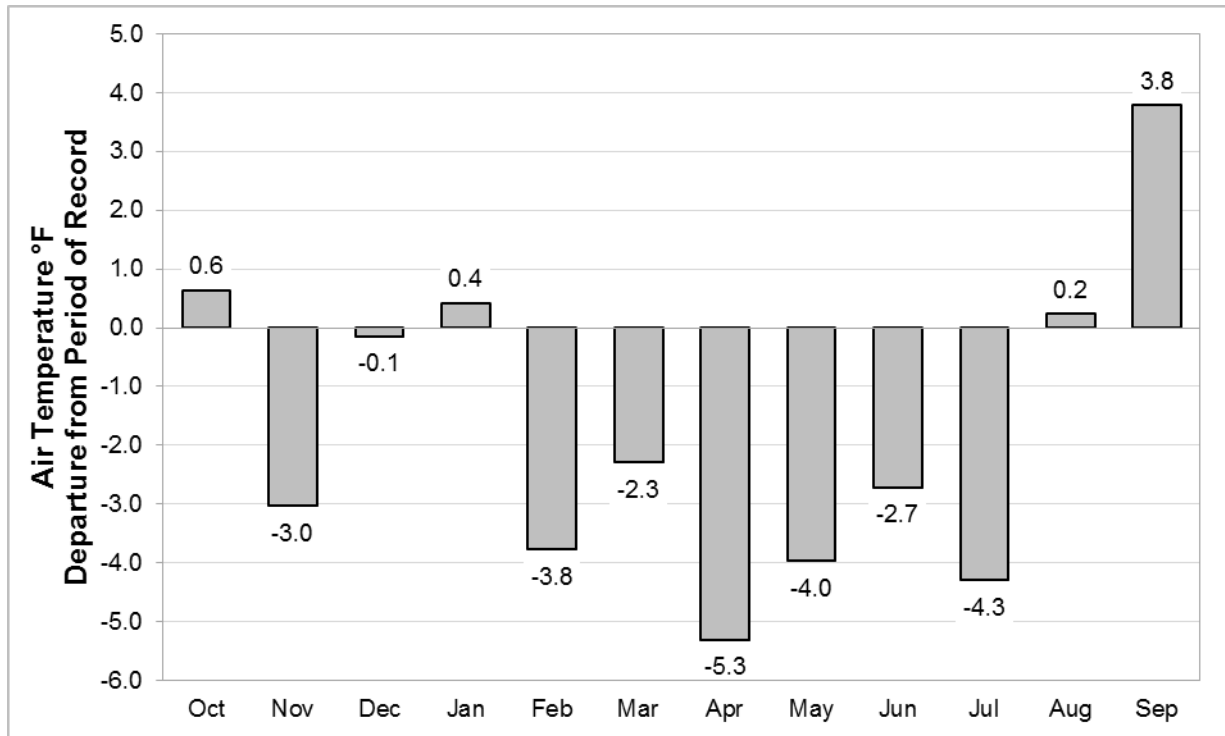


Figure E-1. Comparison of average monthly temperature (°F) for Ross Dam COOP in Water Year 2011 against monthly averages for period of record (1961-2010).

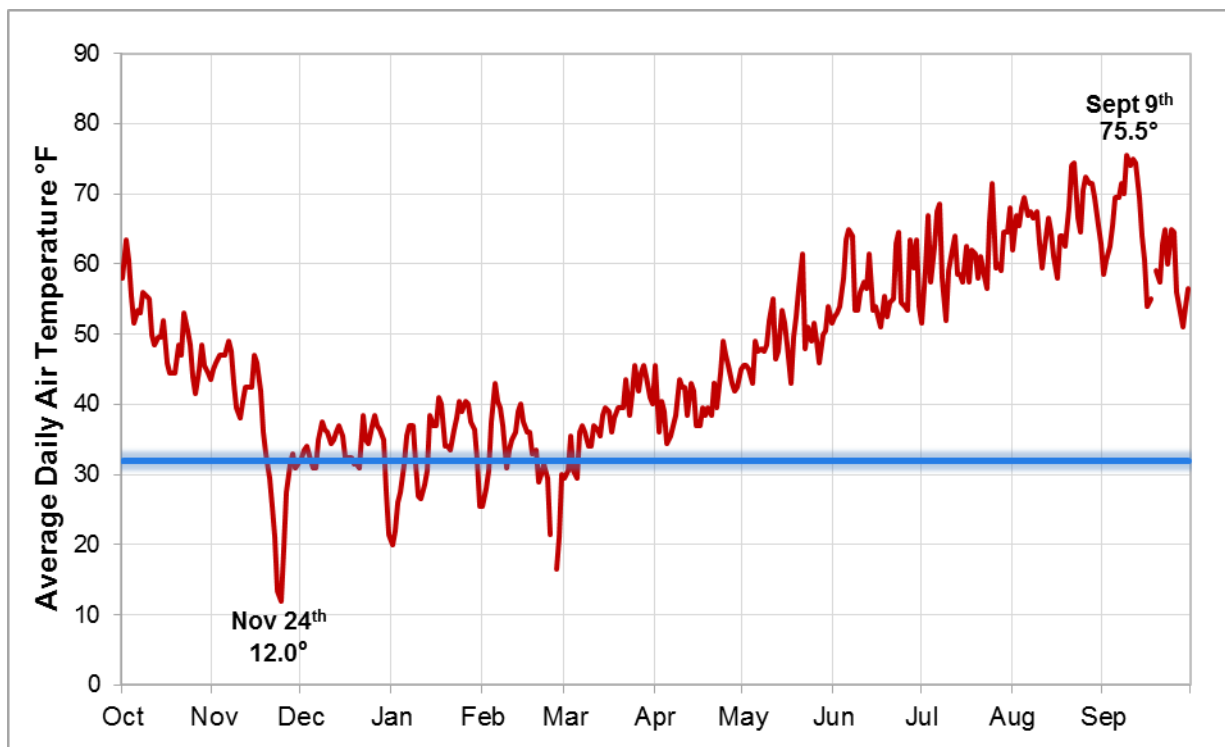


Figure E-2. Daily average air temperature (°F) at Ross Dam COOP, Water Year 2011.

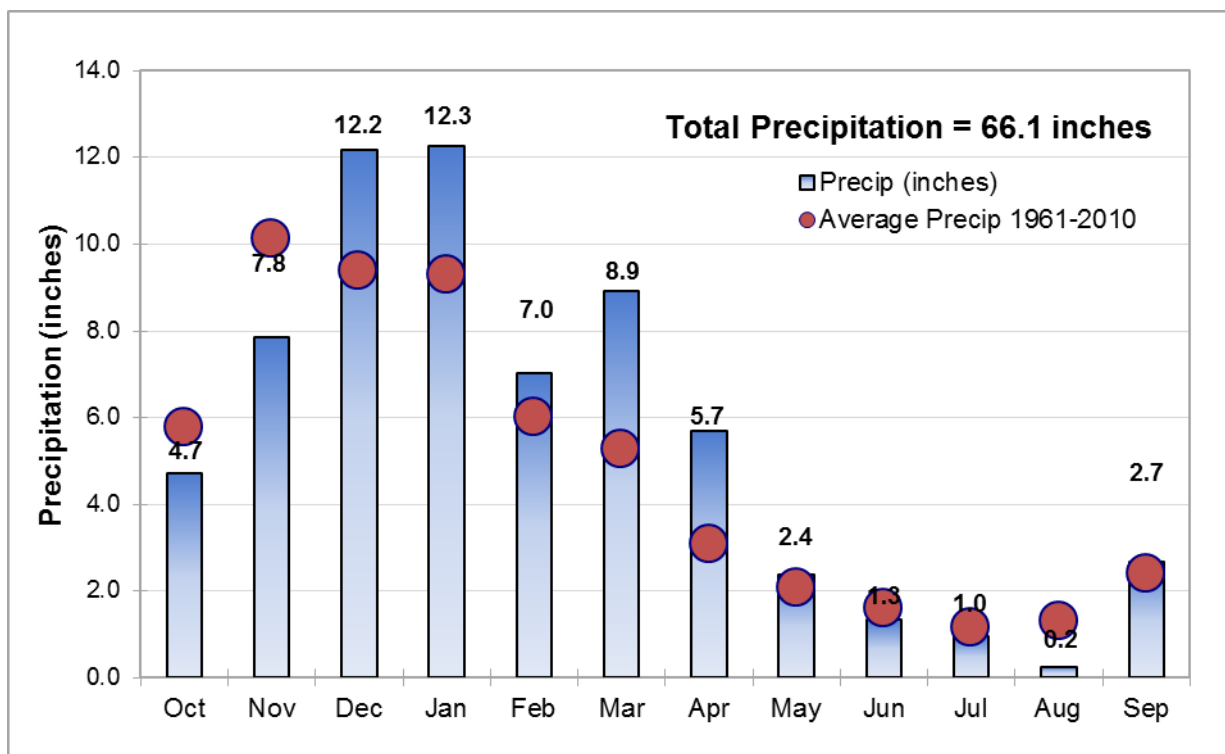


Figure E-3. Monthly precipitation values (inches) at Ross Dam COOP, Water Year 2011 compared to the monthly averages for the period of record (1961-2010).

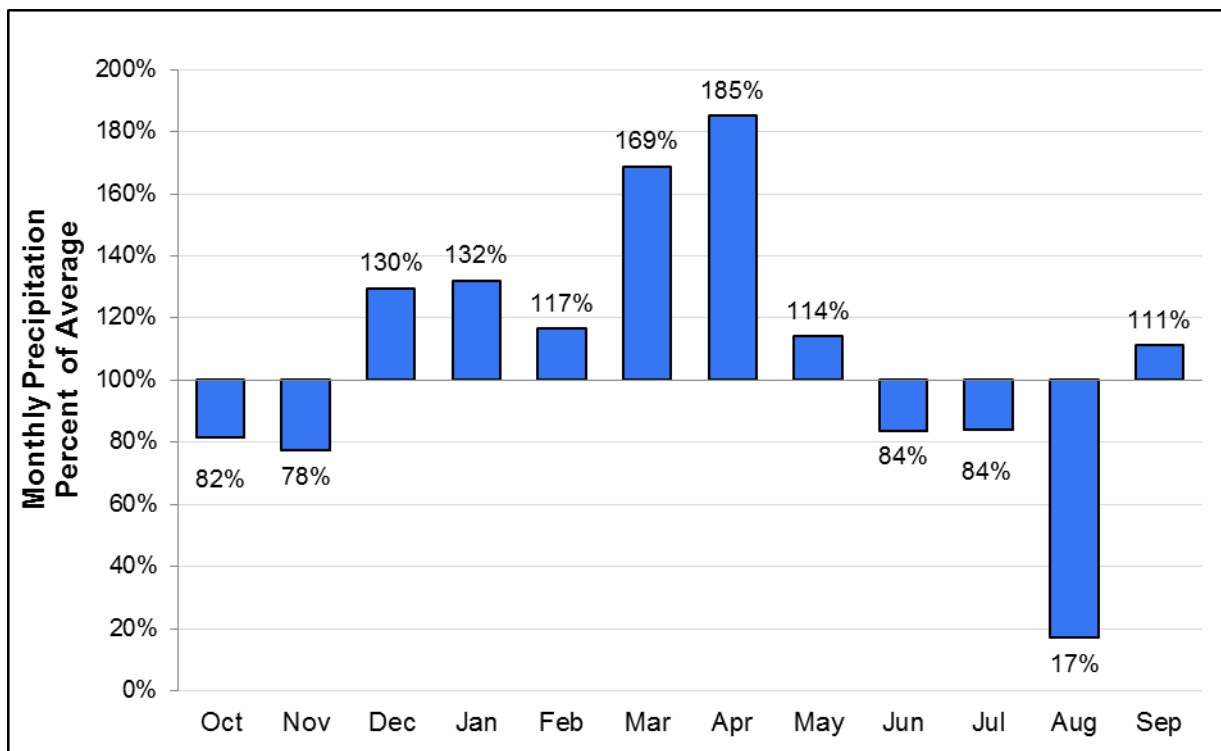


Figure E-4. Percent of average for the period of record (1961-2010) for precipitation at Ross Dam COOP in Water Year 2010.

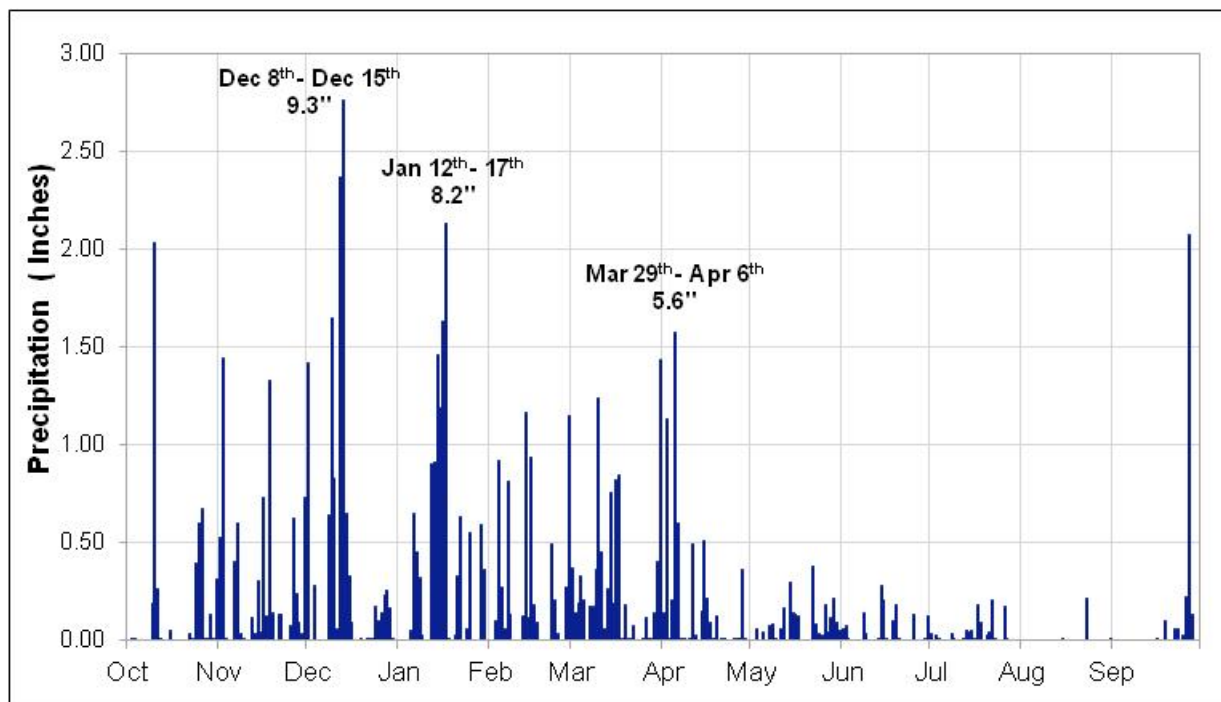


Figure E-5. Daily precipitation (inches) at Ross Dam COOP, Water Year 2010.

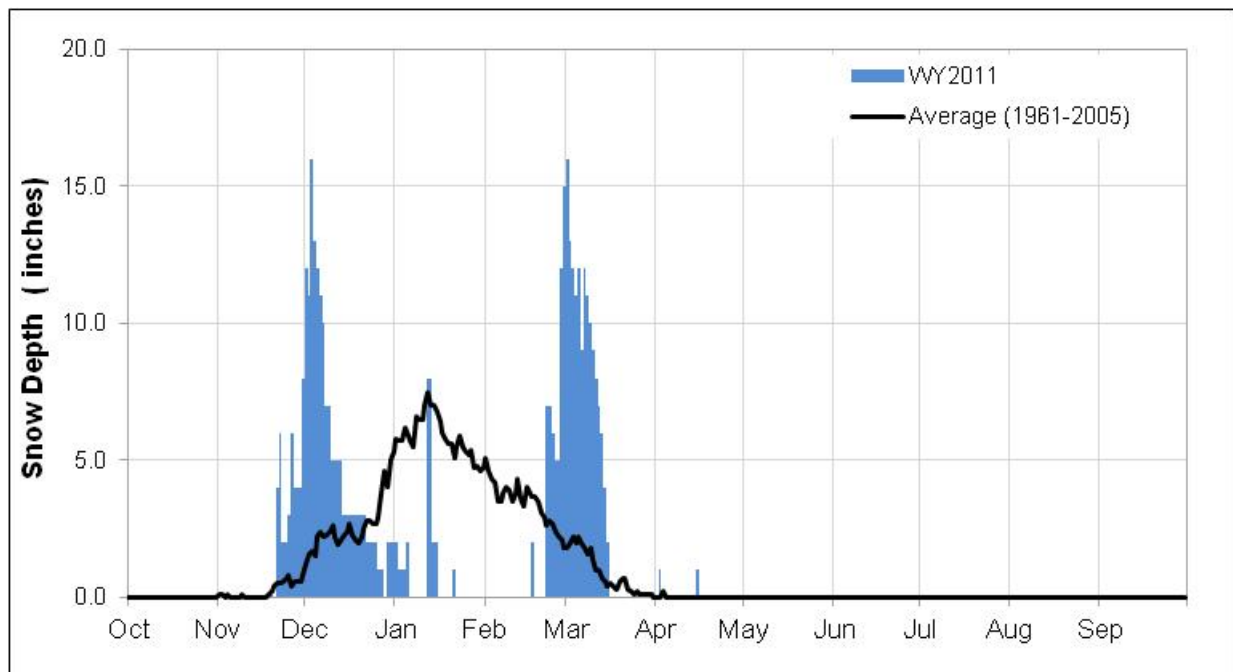


Figure E-6. Daily snow depth (inches) at Ross Dam COOP, Water Year 2011.

Appendix F: Silver Lake GLACIER - Water Year 2011.

Monthly mean air temperatures and monthly mean daily maximum and minimum air temperatures are shown in Table F-1. Temperatures at Silver Lake ranged from an extreme low of -19.1 °F in late November 2010 to a high of 75.6 °F in September 2011 (Table F-2). The Silver Lake GLACIER station was installed in fall 2009. The lowest mean daily temperature for the Water Year occurred on November 23 and highest on September 12 (Figure F-1). Due to the recent installation of this site, no period of record comparisons can be made.

Table F-1. Monthly summary data, Silver Lake GLACIER, Water Year 2011.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F
Fall	October 2010	42.1	62.6	28.0
	November 2010	26.6	54.5	-5.6
Winter	December 2010	24.4	37.4	3.6
	January 2011	27.5	40.3	8.1
	February 2011	20.9	38.1	-2.7
	March 2011	23.9	33.4	14.7
Spring	April 2011	25.0	35.4	19.8
	May 2011	36.3	48.2	27.3
	June 2011	43.6	55.0	36.0
Summer	July 2011	47.8	62.2	36.1
	August 2011	54.3	65.8	41.7
Fall	September 2011	52.0 ^a	69.3 ^a	37.0 ^a
Water Year Average		35.4^a	69.3^a	-5.6^a

^a The Silver Lake GLACIER station was taken offline on September 13, 2011 for equipment upgrades, and remained offline until Water Year 2012. For this report, missing temperature data for the Silver Lake GLACIER has been replaced with data from the nearby Browntop Ridge SNOTEL station.

Table F-2. Air temperature extremes (°F) at Silver Lake GLACIER, Water Year 2011.

Date	Max Air Temp °F	Date	Min Air Temp °F
September 8, 2011	75.6	November 23, 2010	-19.1
September 7, 2011	75.0	November 22, 2010	-12.1
August 28, 2011	74.1	February 24, 2011	-8.3
September 9, 2011	73.8	February 25, 2011	-7.4
September 10, 2011	73.4	December 30, 2010	-0.4

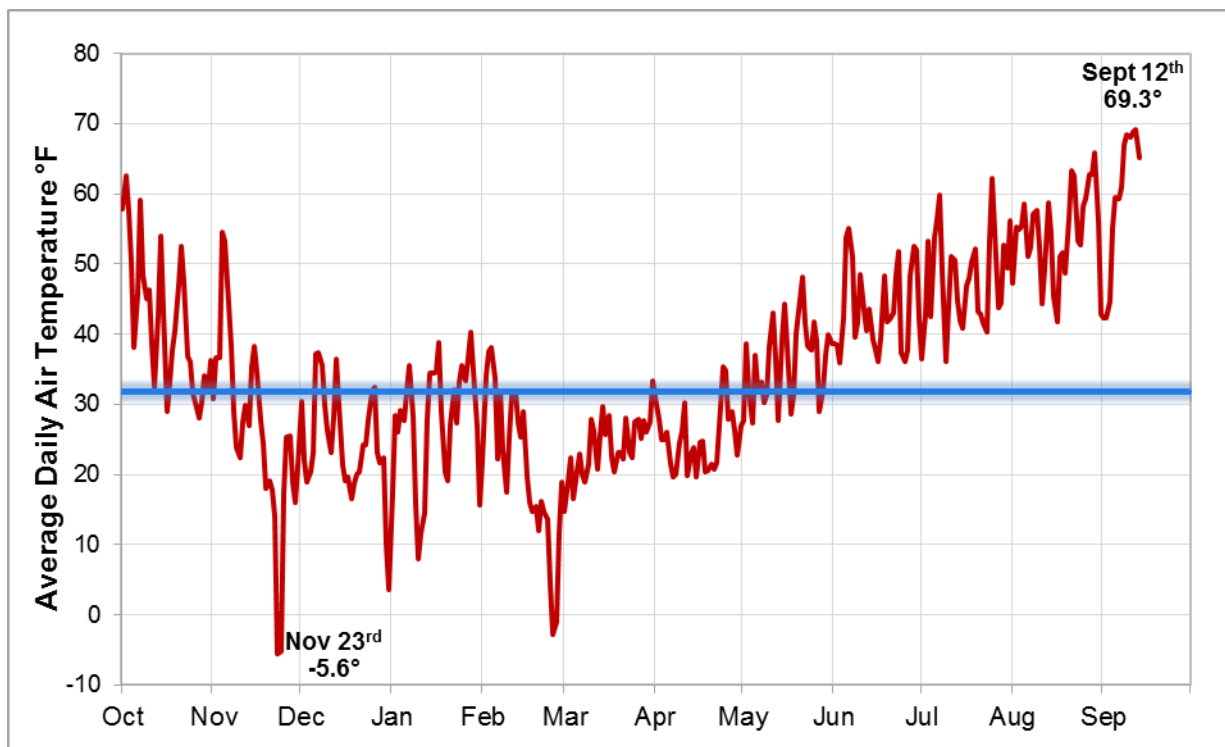


Figure F-1. Daily average air temperature (°F) at Silver Lake GLACIER, Water Year 2011.

Appendix G: Stehekin COOP - Water Year 2011.

Monthly mean air temperatures and mean daily maximum and minimum air temperatures are shown in Table G-1. Temperatures at Stehekin ranged from an extreme low of 5.0 °F on November 5, 2010 to a high of 98.1 °F on August 28, 2011 (Table G-2). The months of February through July averaged 4.6 °F below the period of record mean, with April the most extreme at 9.1 °F below average (Figure G-1). September was significantly warmer than normal, with a 6.7 °F departure from the period of record. The lowest mean daily temperature for the Water Year occurred on November 24 and highest on August 5 (Figure G-2).

Annual precipitation at Stehekin totaled 32.9 inches (Figure G-3). The months of March, April, and May were significantly wetter than average (Figure G-4). In March, Stehekin received 7.0 inches of rain, nearly 2.5 times the average for the period of record. August and September were significantly drier than normal with less than 0.1 inches of rain, or three percent of average rainfall (Figures G-3, G-4). The heaviest period of precipitation was January 12 to 17, a total of 4.4 inches of rain (Figure G-5). The daily extreme occurred on October 10 with 1.7 inches of rain (Figure G-5). Snowpack began developing on November 26, 2010 and melted out on April 1, 2011, persisting for 126 days. The maximum snow depth for the year occurred on January 13 with 39 inches of snow (Figure G-6).

Table G-1. Monthly summary data, Stehekin COOP, Water Year 2011.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2010	48.1 ^a	60.0 ^a	39.5 ^a	3.1
	November 2010	34.4 ^a	51.0 ^a	11.5 ^a	4.5 ^a
Winter	December 2010	29.6	34.0	14.5	4.0
	January 2011	30.3	41.5	15.0	6.1
	February 2011	30.9	42.0	16.5	3.5
Spring	March 2011	33.5 ^a	42.0 ^a	27.0 ^a	7.0 ^a
	April 2011	38.0	48.5	32.5	2.2
	May 2011	48.0	55.5	40.0	1.7
Summer	June 2011	59.5	69.5	45.0	0.4
	July 2011	65.5	77.0	54.0	0.4
	August 2011	71.1	79.0	54.5	0.0
Fall	September 2011	65.3	77.0	51.0	0.0
Water Year Average		46.2	79.0^a	11.5^a	32.9^a

^a The Stehekin COOP station is missing more than 5 days of data in a month when flagged. For this report, missing temperature data for the Stehekin COOP has been replaced with data from the nearby Stehekin RAWS station.

Table G-2. Air temperature extremes (°F) at Stehekin COOP, Water Year 2011.

Date	Max Air Temp °F	Date	Min Air Temp °F
August 28, 2011	98.1	November 24, 2010	5.0
August 27, 2011	97.0	January 4, 2011	7.0
September 13, 2011	97.0	January 3, 2011	7.0
August 26, 2011	96.1	December 31, 2010	8.1
August 29, 2011	96.1	November 25, 2010	10.0

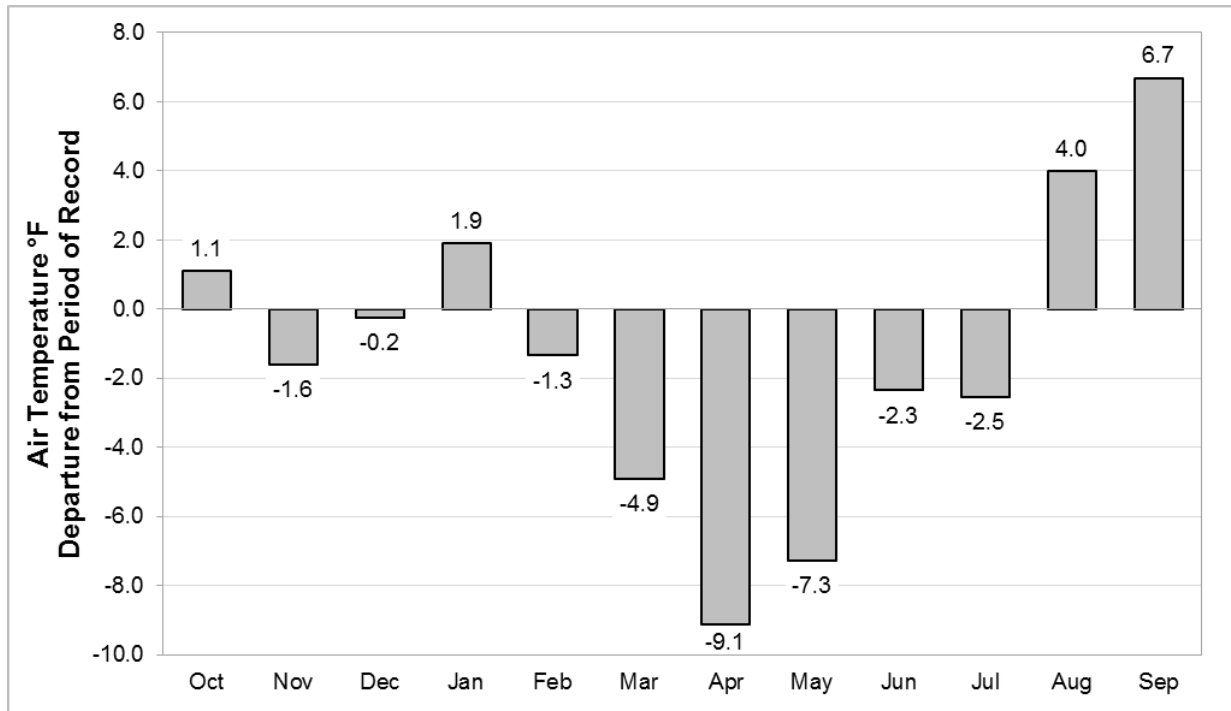


Figure G-1. Comparison of average monthly temperature (°F) for Stehekin COOP in Water Year 2011 against monthly averages for period of record (1931-2010).

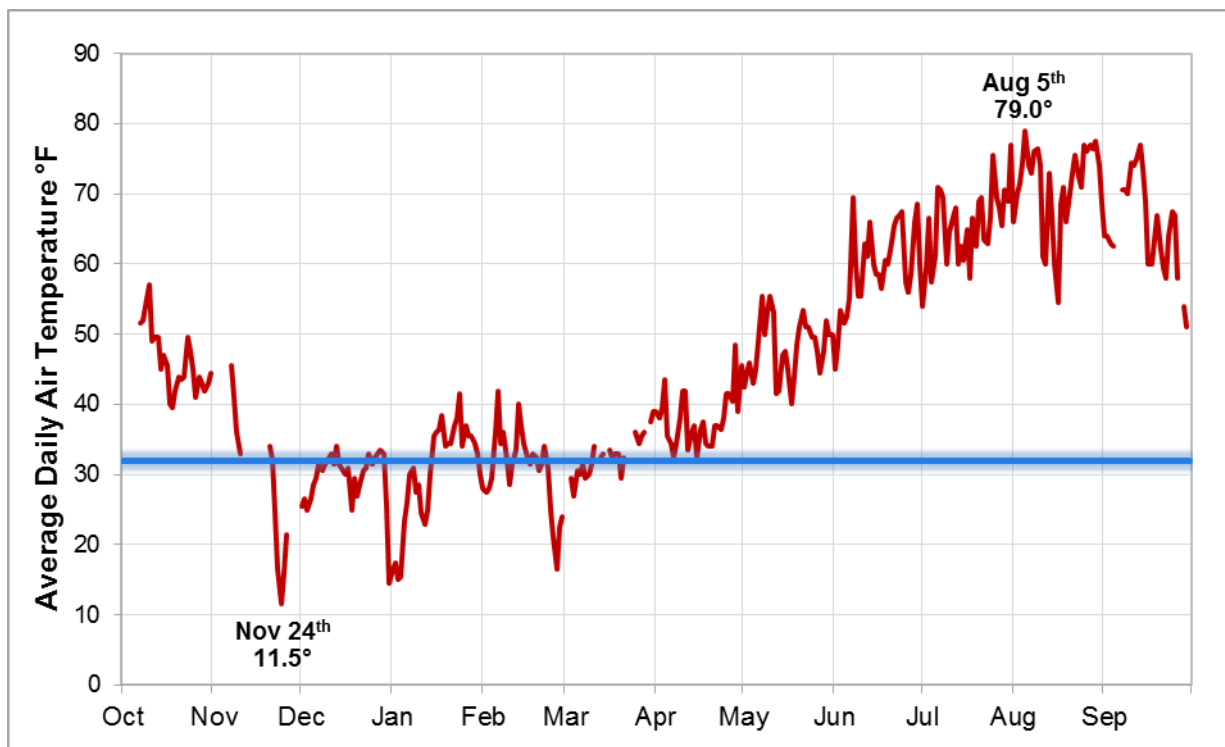


Figure G-2. Daily average air temperature (°F) at Stehekin COOP, Water Year 2011.

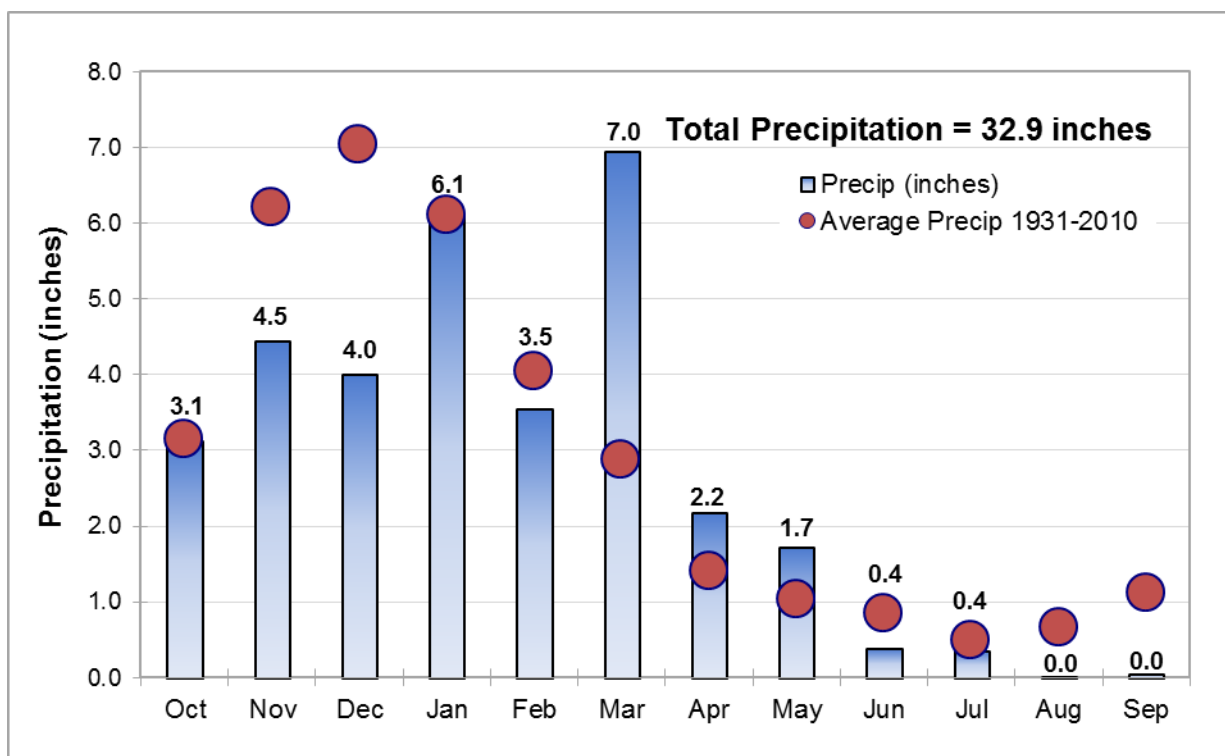


Figure G-3. Monthly precipitation values (inches) at Stehekin COOP, Water Year 2011 compared to the monthly averages for the period of record (1931-2010).

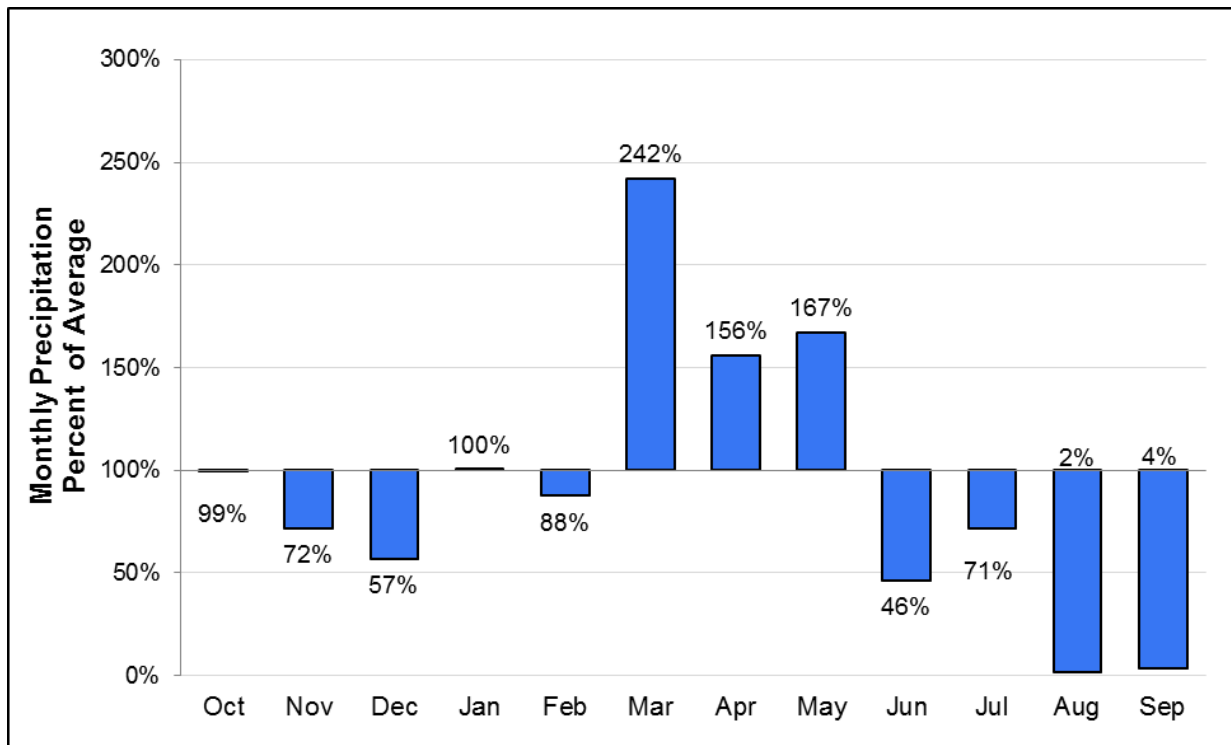


Figure G-4. Percent of average for the period of record (1931-2010) for precipitation at Stehekin COOP, Water Year 2011.

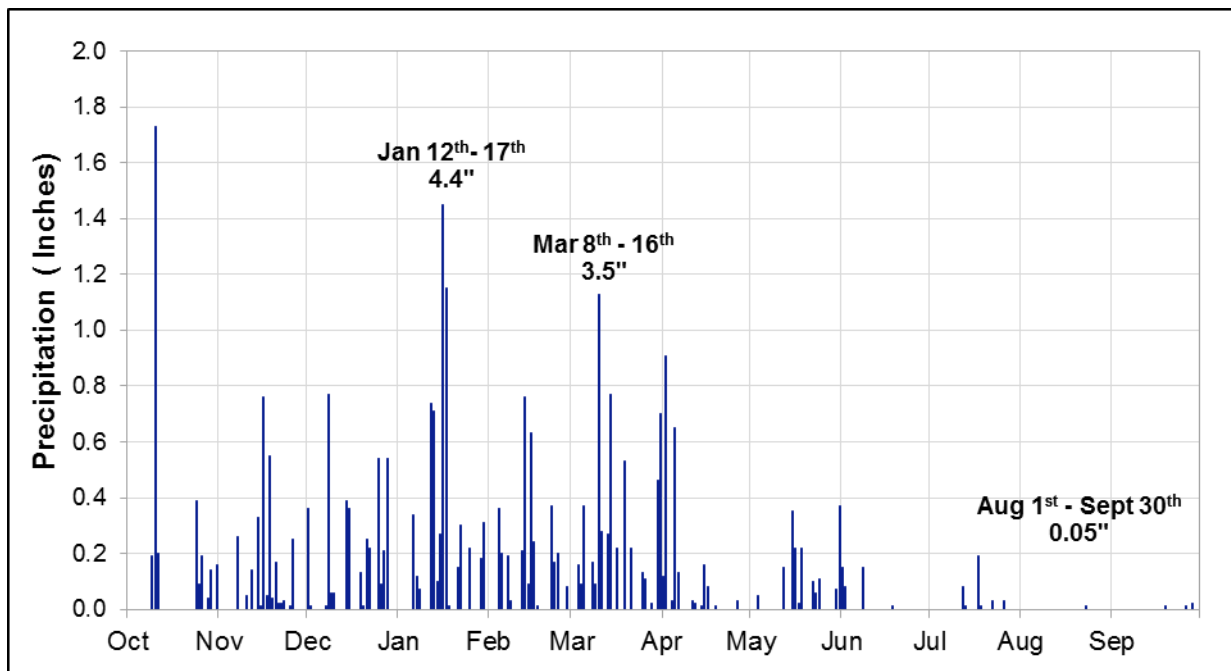


Figure G-5. Daily precipitation (inches) at Stehekin COOP, Water Year 2011.

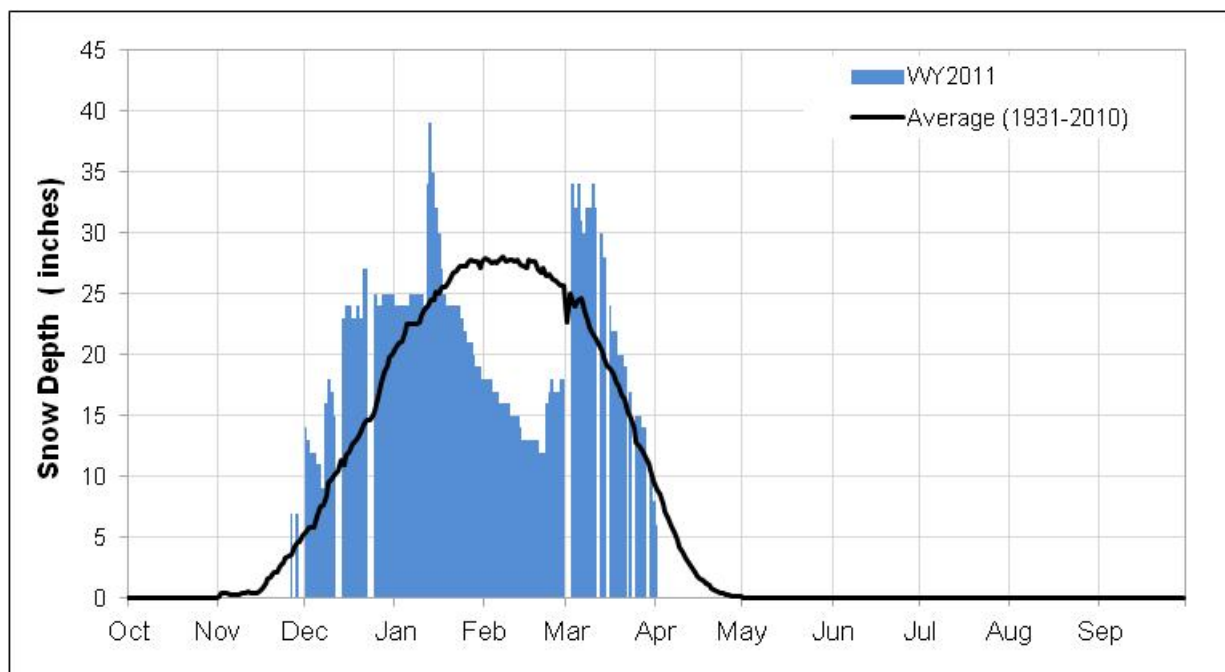


Figure G-6. Daily snow depth (inches) at Stehekin COOP, Water Year 2011.