



Mojave Desert Network Inventory and Monitoring Streams and Lakes Protocol

2016 Monitoring Data

Natural Resource Data Series NPS/NCCN/NRDS—2019/1230



ON THE COVER

Teresa Lake in GRBA, September 2016.

Photograph courtesy of MOJN

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2016 Monitoring Data

Natural Resource Data Series NPS/NCCN/NRDS—2019/1230

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Natural Resource Stewardship and Science
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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.

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Executive Summary

The Mojave Desert Network Inventory and Monitoring Program (MOJN I&M) is a National Park Service (NPS) program that monitors ecological vital signs in eight parks located in Southern California, Nevada, and Arizona. The MOJN I&M Streams and Lakes protocol focuses on monitoring water quality and water quantity in headwater streams and sub-alpine lakes in Great Basin National Park (GRBA), located in eastern Nevada. Pilot testing of the protocol was completed in the summer of 2009, and the protocol was formally approved in 2012. This report presents Streams and Lakes protocol data collected in the 2016 field season.

The report includes water quality and benthic macroinvertebrate assemblage data for GRBA streams and water quality, water level, clarity, and ice-free period data for GRBA lakes. Stream discharge data will be published in a separate report, as the processing, analysis, and review of discharge records can delay their availability for reporting.

The water quality in GRBA streams and lakes is generally excellent, with the measured water quality and chemistry parameters in compliance with regulatory limits. The benthic macroinvertebrate assemblages observed in the streams are consistent with healthy ecosystems.

Annual precipitation was above average in Water Year (WY) 2016; however, the July and August precipitation was unusually low. The April 1st snowpack was below average, but double the snowpack from WY2015. Precipitation events between mid-May and early-June caused brief increases in stream discharge in Lehman Creek. Several small precipitation events in mid-June resulted in a sharp rise in specific conductance in Lower Snake Creek. Relative lake levels were within 0.15m of the previous year in all lakes except Dead Lake, which was dry in WY2015 but had water in WY2016. Summer precipitation caused brief water levels increases of less than 0.15 m in Teresa Lake and Baker Lake. The other lakes did not exhibit a response in level to precipitation events.

Acknowledgments

The data in this report were collected thanks to the efforts of numerous GRBA and MOJN I&M staff. Jonathan Reynolds collected the bulk of the water quality data.

Analytical data were provided by the Cooperative Chemical Laboratory established by Memorandum of Understanding no. PNW-82 between the U.S. Forest Service Pacific Northwest Research Station and the Department of Forest Ecosystems and Society, Oregon State University.

Benthic macroinvertebrate data were provided by the Utah State University National Aquatic Monitoring Center (the BugLab).

The Lehman Creek discharge data were collected, processed, and published by the U.S. Geological Survey.

List of Acronyms

ANC: Acid Neutralization Capacity
BCT: Bonneville Cutthroat Trout (*Oncorhynchus clarki* Utah)
BLM: Bureau of Land Management
BMI: Benthic Macroinvertebrates
CWA: Clean Water Act
DEVA: Death Valley National Park
DO: Dissolved Oxygen
DOC: Dissolved Organic Carbon
EMAP: Environmental Monitoring and Assessment Program
EPT: Ephemeroptera, Plecoptera, and Trichoptera
GRBA: Great Basin National Park
I&M: Inventory and Monitoring Program
JOTR: Joshua Tree National Park
LAKE: Lake Mead National Recreation Area
MANZ: Manzanar National Historic Site
MDL: Method Detection Limit
MOJA: Mojave National Preserve
MOJN: Mojave Desert Network
MQO: Method Quality Objective
NAC: Nevada Administrative Code
NRCS: Natural Resources Conservation Service
NPS: National Park Service
NWS COOP: National Weather Service Cooperative Observers Program
ONRW: Outstanding Natural Resource Water
PARA: Grand Canyon-Parashant National Monument
QAPP: Quality Assurance Project Plan
QA/QC: Quality Assurance and Quality Control
RAWS: Remote Automated Weather Stations program
RL: Reporting Limit
RPD: Relative Percent Difference
SOP: Standard Operating Procedure
TDN: Total Dissolved Nitrogen
TDP: Total Dissolved Phosphorus
TN: Total Nitrogen
TP: Total Phosphorus
US EPA: United States Environmental Protection Agency
USGS: United States Geological Survey

Introduction

The Mojave Desert Network (MOJN) includes nine units of the National Park system: Castle Mountains National Monument (CAMO), Death Valley National Park (DEVA), Great Basin National Park (GRBA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAKE), Manzanar National Historic Site (MANZ), Mojave National Preserve (MOJA), Grand Canyon-Parashant National Monument (PARA), and Tule Springs Fossil Beds National Monument (TUSK). Collectively, these parks comprise 3.3 million hectares or 9.7% of the total land area managed by the NPS.

The MOJN I&M Streams and Lakes protocol (Caudill et al 2012) is focused on monitoring the water quality and quantity at streams and lakes in GRBA. The protocol is only implemented in GRBA because the water bodies in LAKE are monitored by other agencies, and stream and lake habitats are limited or absent in the other parks.

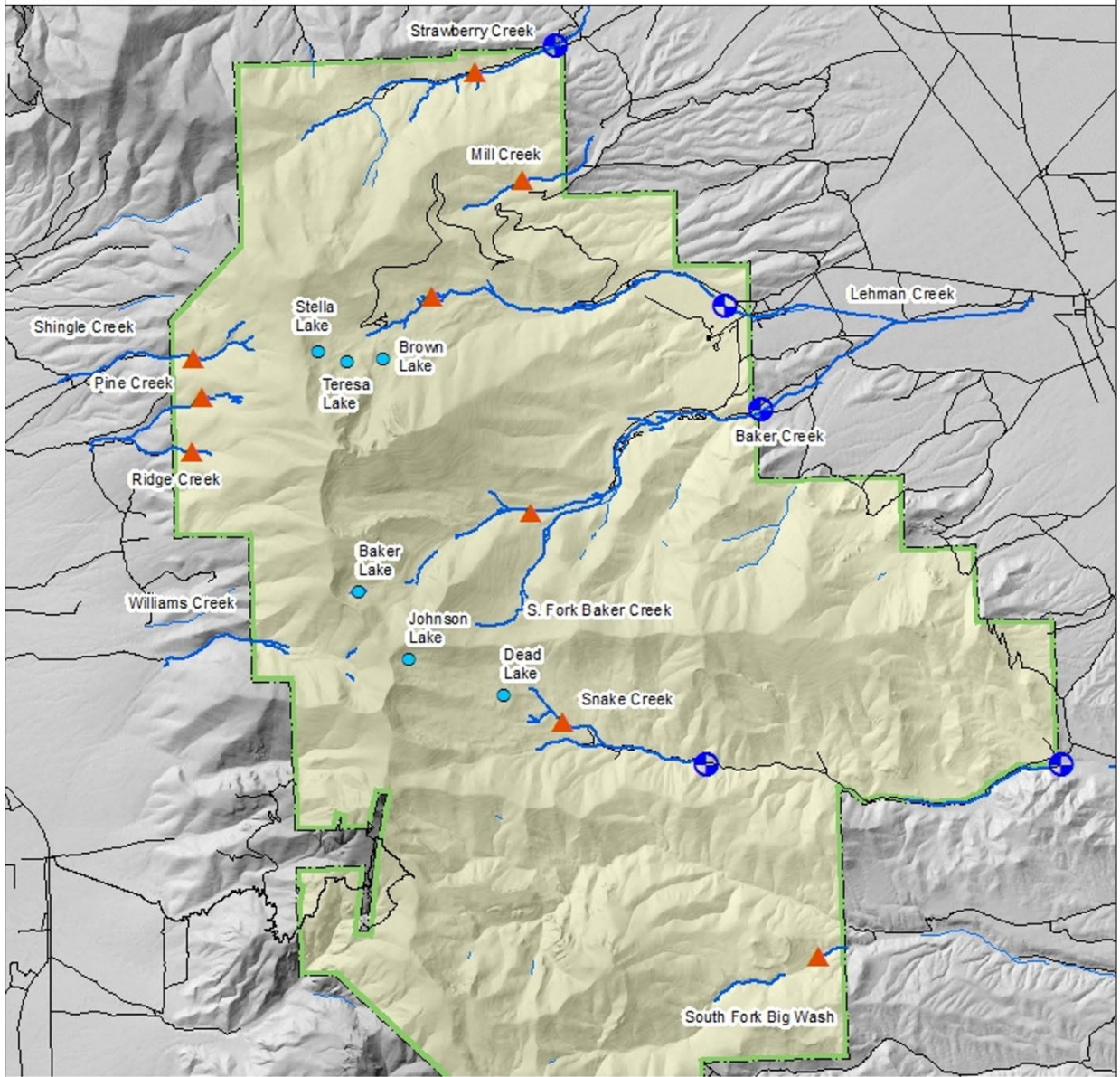
GRBA lies within the South Snake Range of east-central Nevada and receives the most precipitation of the MOJN parks. GRBA contains ten perennial streams and six small subalpine lakes (Figure 1). These streams and lakes are fed primarily by snowmelt, so they are vulnerable to changes in precipitation patterns due to climate change.

Mojave Desert Inventory and Monitoring Network

National Park Service
U.S. Department of the Interior



Monitoring Locations Great Basin National Park



Legend

- Stream gage continuous discharge and WQ monitoring
- Randomly selected stream sample site: annual BMI, water chemistry, and water quality
- Lake: continuous water level monitoring, ice on/ice off, annual water chemistry, WQ depth profile, and clarity
- Permanent streams
- Streams
- Roads
- Lakes
- GRBA park boundary

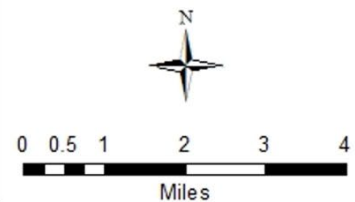


Figure 1. Map of sampling locations in GRBA.

Methods

The methods used to collect the data presented in this report are fully described in the MOJN Streams and Lakes protocol narrative and SOPs (Caudill et al. 2012, Moret et al. 2012). The methods are briefly summarized here.

Streams

The MOJN I&M Streams and Lakes protocol contains four stream monitoring components: stream discharge, continuous water quality monitoring, stream water chemistry, and benthic macroinvertebrate sampling. All monitoring locations are shown on Figure 1.

Stream discharge is continuously monitored by GRBA staff at four gage sites (Strawberry Creek, Baker Creek, upper Snake Creek, and lower Snake Creek) and by the USGS at one gage site (Lehman Creek). Lower snake creek is often dry in the summer, so the upper Snake Creek gage was established to provide perennial discharge data. These sites are shown on Figure 1. No discharge data are included in this report other than USGS data for Lehman Creek, which is included to provide context for the water quality data.

Continuous water quality data are collected from early June to late September at the five sites (Strawberry Creek, Baker Creek, Lehman Creek, upper Snake Creek, and lower Snake Creek) shown on Figure 1. The records are collected using sondes (data-logging instruments deployed in the streams) that are recalibrated approximately every two weeks. The sondes record hourly measurements of temperature, specific conductance, dissolved oxygen (DO), and pH. The data from the two week deployments are processed, graded, and joined using the Aquarius software package. With the exception of the upper Snake Creek site, the water quality sondes are located adjacent to the stream gages.

Stream water chemistry is determined through laboratory analysis of water samples. Annual samples were collected in late summer of 2016 from nine of GRBA's ten perennial streams (the tenth stream, Williams Canyon, was determined to be too inaccessible for annual monitoring) and analyzed for nutrients, major ions, and acid neutralization capacity. A handheld multiprobe water quality instrument was used to measure temperature, dissolved oxygen, specific conductance, and pH at the time of sampling. The water samples were collected from initially randomly-selected sites that are visited each year (Figure 1).

Benthic macroinvertebrate (BMI) samples are collected at the same time and location as the water chemistry samples. Samples are collected using the EPA's Environmental Monitoring and Assessment Program (EMAP) method (Peck et al. 2006), which involves collecting samples from 11 evenly-spaced reaches and compositing them.

Lakes

The MOJN I&M Streams and Lakes protocol contains three lake monitoring components: lake level and ice-free period, lake water chemistry, and lake clarity. All lakes are visited annually in a late-September index period.

Lake level and ice-free period are monitored using data-logging pressure transducers and temperature sensors. At each annual visit, the lake level is compared to the elevation of fixed benchmarks using the line level method (e.g. Hoffman et al. 2005). The lake-bottom pressure transducer record is converted to a lake level record using the measured elevations and an atmospheric pressure record collected using a separate transducer. The lake level record and the temperature record are then used to infer the dates of ice-on and ice-off.

Lake water chemistry is monitored by laboratory analysis of water samples and depth profiles of water quality. Each year, a single water sample is collected by hand-dipping from the deepest area of each lake and analyzed for nutrients, major ions, and acid neutralization capacity. At the same time, a handheld multiprobe water quality instrument is used to measure temperature, dissolved oxygen, specific conductance, and pH at several depths from the lake surface to the lake bed.

Lake clarity is assessed by lowering a Secchi disk until it is no longer visible, then recording the depth. The disk is then raised until it becomes visible, and a second depth is recorded. This process is repeated three times, and the average of the six depths is the Secchi depth. In practice, the lakes of GRBA are shallow and clear, so the disk is often visible on the bottom.

Precipitation, Snowpack, and Discharge

Year-to-year variations in precipitation, snowpack, and stream discharge are expected to cause variations in many of the monitored parameters. This section discusses the precipitation measured at National Weather Service Cooperative Observers Program (NWS COOP) Station Number 263340 (located behind the Lehman Caves Visitor Center), the snowpack measured at Baker Creek Snowcourse # 3 (Natural Resources Conservation Service (NRCS) Station 14L03), and the stream discharge measured at the Lehman Creek gage (USGS site 10243260). These index sites were chosen so that the results in a given year could be compared to the longest possible historical record. The intent of this section is not to provide a comprehensive discussion of the year's precipitation, snowpack, and stream discharge in GRBA, but to provide context for the monitoring data presented in this report.

Water Year 2016 Precipitation

NWS COOP station 263340 recorded 15.21 inches of precipitation in WY2016, which is greater than the 1951-2016 average of 13.43 inches (Figure 2). Precipitation events were distributed throughout the year (Figure 3).

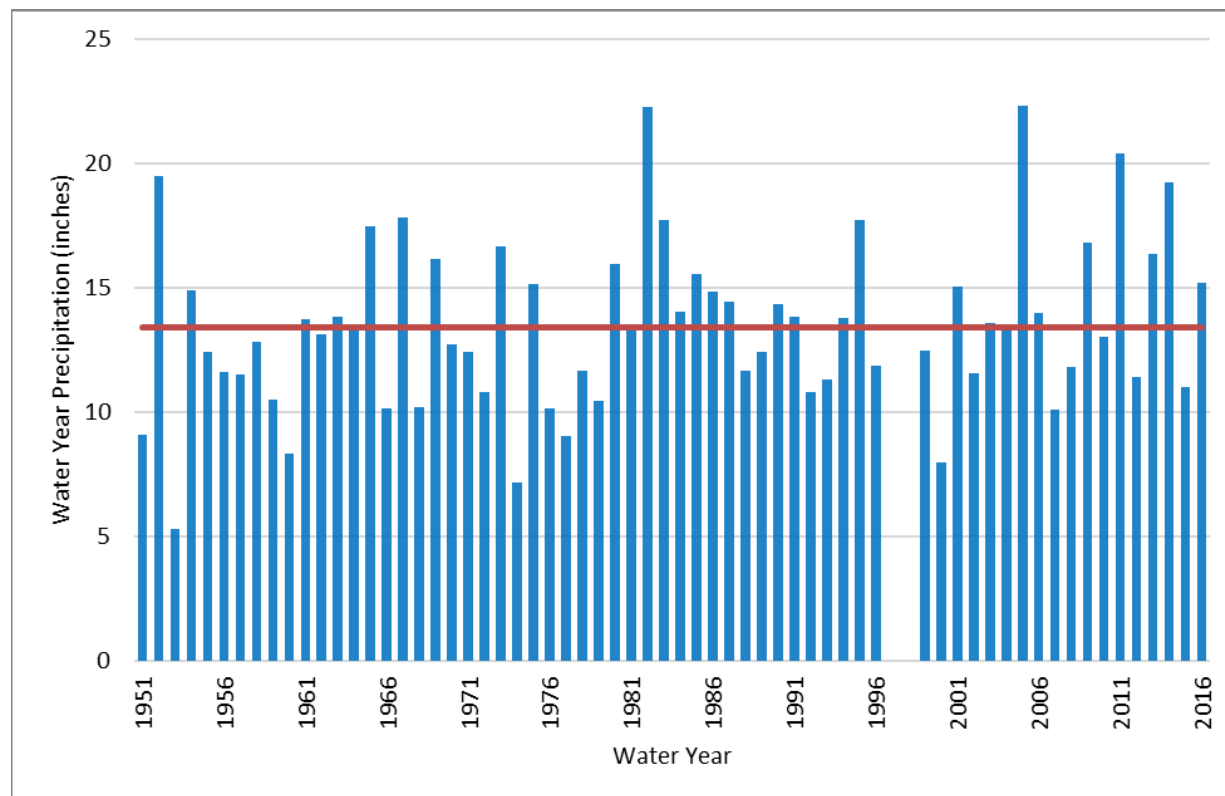


Figure 2. Annual precipitation by water year (October 1 to September 30) recorded at the NWS COOP weather station at Lehman Caves Visitor Center. The average annual precipitation at the site is represented by the horizontal red line.

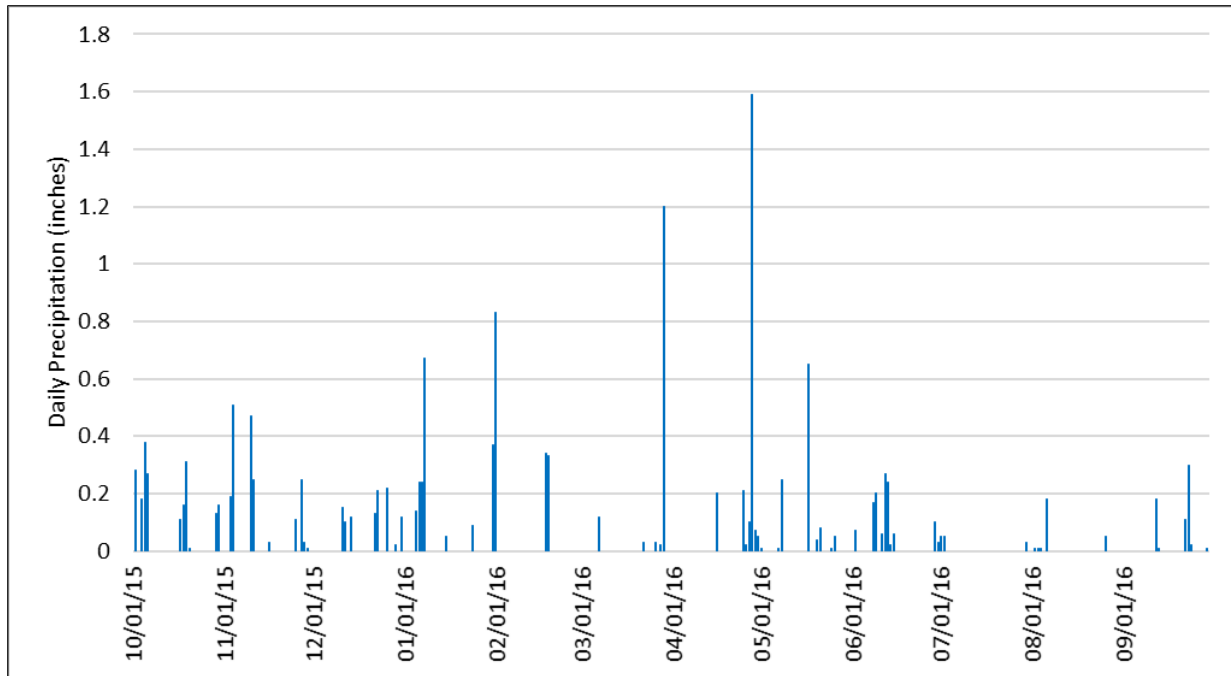


Figure 3. Daily precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center in WY2016.

The total July and August precipitation for 2016 was 0.39 inches, the second lowest in the 1951-2016 record (Figure 4). Monsoonal precipitation, which occurs during July and August in the Southwestern United States, tends to be extremely localized (Barry and Chorley, 2010), so below average precipitation at this weather station is not necessarily indicative of near-record lows across the park.

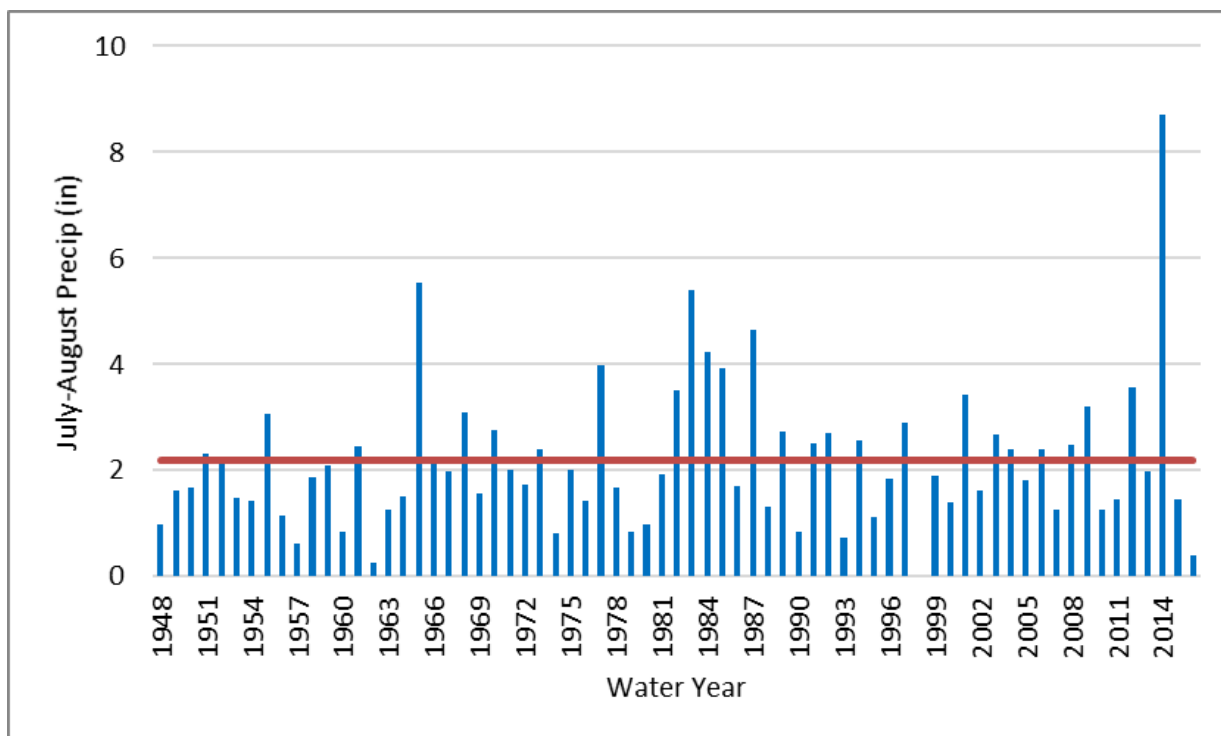


Figure 4. July and August precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center. The average July-August precipitation for the 1948-2016 record is represented by the horizontal red line.

Water Year 2016 Snowpack

The April 1 depth of snowpack at Baker Creek Snowcourse #3 (Measured on March 31, 2016) was 48 inches, which is lower than the 1942-2016 average of 54.57 inches, but double the snowpack from WY2015 (Figure 5).

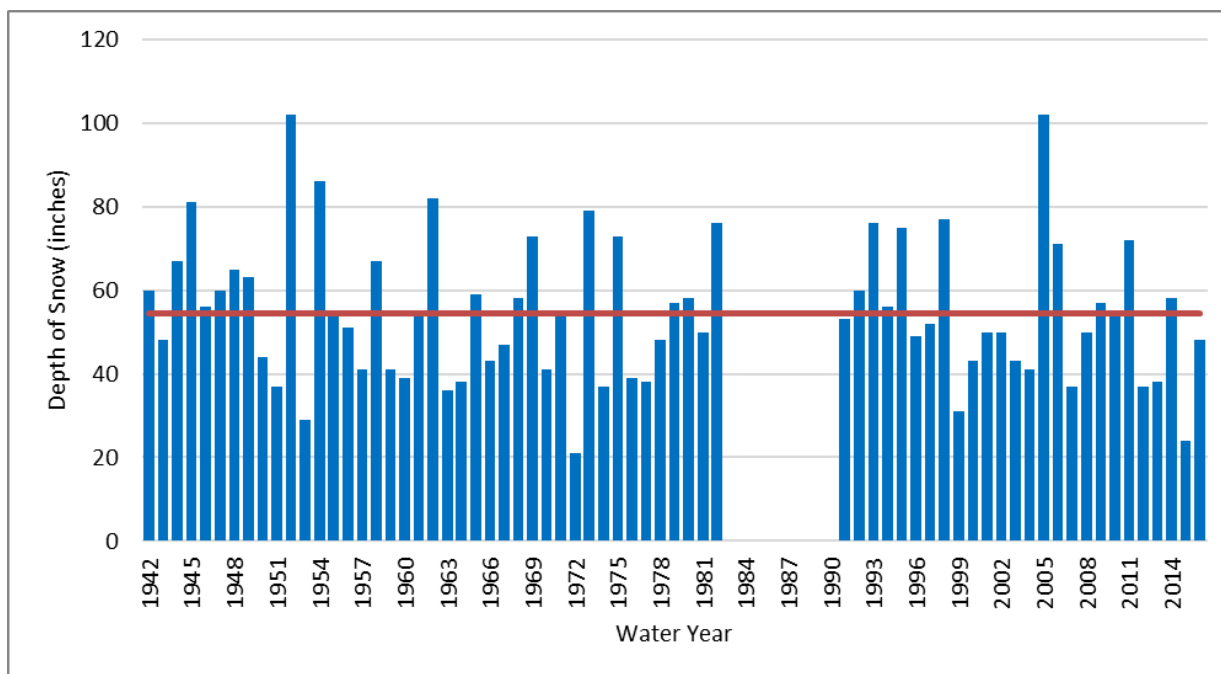


Figure 5. NRDS depth-of-snowpack data collected at Baker Creek Snowcourse #3 near April 1 of each year. The average April 1 snowpack for the site is represented by the horizontal red line.

Water Year 2016 Stream Discharge

The USGS Lehman Creek gage was operational for all of WY2016, and a complete discharge record is available. Discharge remained relatively stable from October through April and peaked on June 11 at 31.0 cfs (Figure 6). The mean annual discharge in WY2016 was 0.53 cfs higher than WY2015 and the peak discharge in WY2016 was nearly double the WY2015 peak discharge (Table 1).

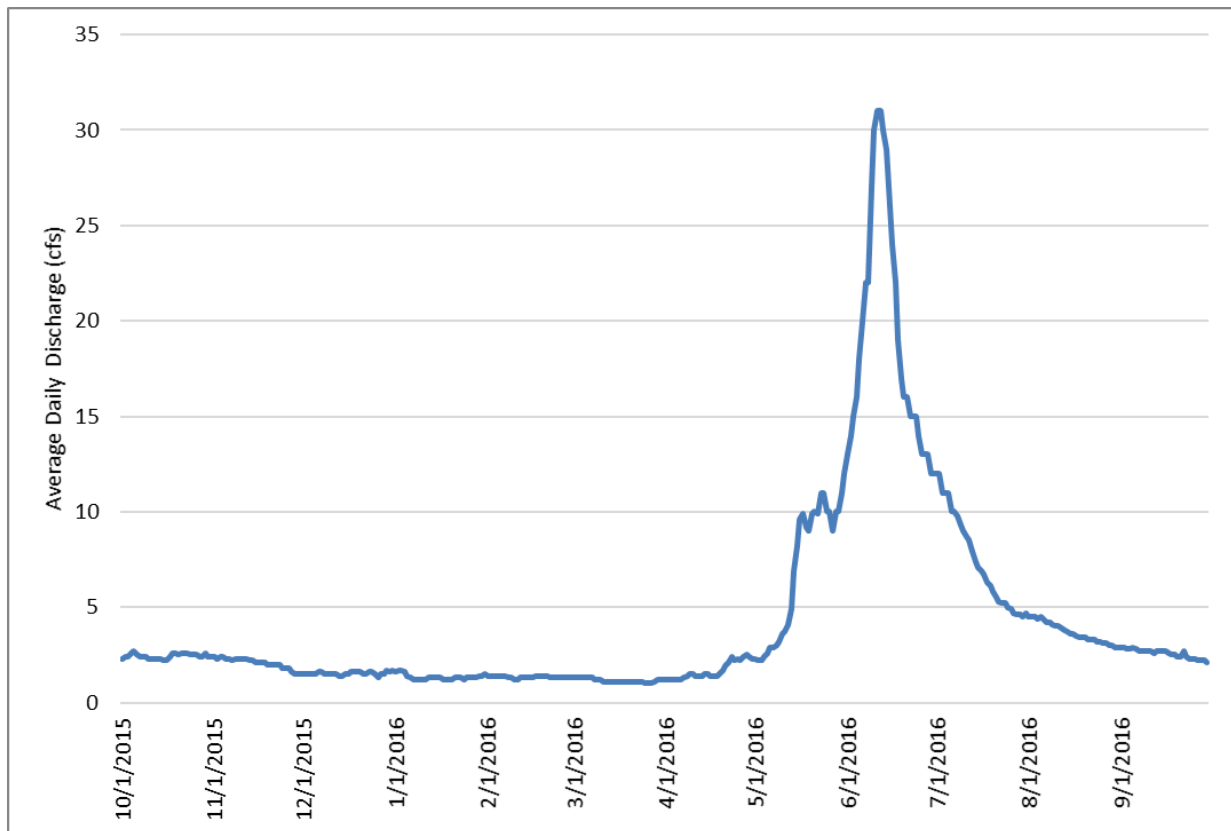


Figure 6. USGS discharge record for Lehman Creek in WY2016.

Table 1. USGS measurements of mean annual discharge, date of peak discharge, and peak discharge value for Lehman Creek gage.

Water Year	Mean Annual Discharge (cfs)	Date of Peak Discharge	Peak Discharge (cfs)
1948	4.31	date not recorded	15
1949	5.98	19-Jun	34
1950	3.67	7-Jun	16
1951	3.90	29-May	16
1952	9.06	2-Jun	45
1953	2.51	25-Jun	7
1954	4.55	22-May	21
1955	5.50	13-Jun	27
1993	5.64	27-May	57
1994	4.17	31-May	24
1995	11.0	29-Jun	80
1996	4.11	15-Jun	15
1997	5.07	24-Jun	24
2003	4.02	30-May	32

Table 1 (continued). USGS measurements of mean annual discharge, date of peak discharge, and peak discharge value for Lehman Creek gage.

Water Year	Mean Annual Discharge (cfs)	Date of Peak Discharge	Peak Discharge (cfs)
2004	3.47	3-Jun	12
2005	13.7	29-May	227
2006	5.70	20-May	30
2007	2.77	22-May	7.5
2008	2.98	21-Jun	12
2009	5.10	21-May	25
2010	4.05	11-Jun	43
2011	8.52	27-Jun	64
2012	3.26	4-Oct*	13*
2013**	—	—	—
2014**	—	—	—
2015	3.76	13-Jun	16
2016	4.29	11-Jun	31

*Spring/Summer peak discharge for 2012 was 5.5 cfs on May 27.

**In 2013, gage was not in operation; in 2014 there were insufficient data.

Monitoring Results from Streams

Continuous water quality results, as well as discrete water chemistry and benthic macroinvertebrate data are summarized below for WY2016. Contact MOJN I&M for more detailed information regarding these data.

Continuous Water Quality

Continuous water quality data were collected near the stream gages on Baker Creek, Lehman Creek, Strawberry Creek, Lower Snake Creek, and Upper Snake Creek (Figure 1).

Baker Creek

A sonde was deployed in Baker Creek from June 9 to September 20, 2016. The average temperature and dissolved oxygen for each of the five index periods are provided in Table 2. There are no pH or specific conductance data in WY2016 due to faulty sensors. Additionally, there are no data available for any parameter between July 26 and August 9 due to instrument malfunction. The daily average, minimum, and maximum of each parameter are plotted in Figure 7.

Table 2. Average water quality parameter values in Baker Creek, 2009-2016.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp. °C	2009	ND	11.7 ^b	ND	ND	ND
	2010	ND	12.5	13.4	13.2	10.5
	2011	ND	9.6	10.3	11.6	10.1
	2012	ND	13.3 ^a	13.9 ^a	13.6	11.6
	2013	13.9	14.7 ^b	ND	13.7	11.7
	2014	13.2	13.7 ^a	12.8	11.1	10.1 ^a
	2015	11.6	11.7	12.4	12.8	11.4
	2016	11.0	13.2 ^c	12.6 ^c	12.2	10.6
Median pH Standard Units	2009	ND	7.47 ^b	ND	ND	ND
	2010	ND	7.70	7.68 ^b	7.59 ^a	7.57
	2011	ND	7.22	7.39	7.40 ^a	ND
	2012	ND	ND	7.52 ^a	7.46	7.41
	2013	7.19	ND	ND	7.29	7.17
	2014	7.56	7.58	7.55	7.47	7.40
	2015	7.20	7.21	7.17	7.24	7.22
	2016	ND	ND	ND	ND	ND

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND – No data collected

Table 2 (continued). Average water quality parameter values in Baker Creek, 2009-2016.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Specific Conductance μS/cm	2009	ND	32 ^b	ND	ND	ND
	2010	ND	40	46 ^a	40 ^a	41
	2011	ND	34	43	49	57
	2012	ND	34 ^a	35 ^a	37	39
	2013	36	ND	ND	42	38
	2014	34	37 ^a	39	39	37 ^a
	2015	31	34	35	38	39
	2016	ND	ND	ND	ND	ND
Mean Dissolved oxygen % Saturation	2009	ND	81.0 ^b	ND	ND	ND
	2010	ND	82.9	80.9 ^a	79.0 ^a	77.9
	2011	ND	79.3	79.3	79.3	79.3
	2012	ND	81.1 ^a	80.6 ^a	80.2	80.3
	2013	78.5	ND	ND	79.2	79.2
	2014	77.8	78.3 ^a	79.2	79.1	79.5 ^a
	2015	79.7 ^b	79.6 ^a	79.1	78.3	77.9 ^b
	2016	79.4	79.9 ^c	79.1 ^c	79.7	79.2

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND – No data collected

Water temperature (Figure 7A) in Baker Creek showed an increasing trend from the beginning of the record until late July, then a decreasing trend from mid-August until the end of the record on September 19, 2016. The minimum temperature recorded in the 2016 field season was 5.8°C on June 13, 2016 and the maximum temperature was 17.0°C on July 22, 2016.

The dissolved oxygen saturation (Figure 7B) ranged from 73.5% to 82%.

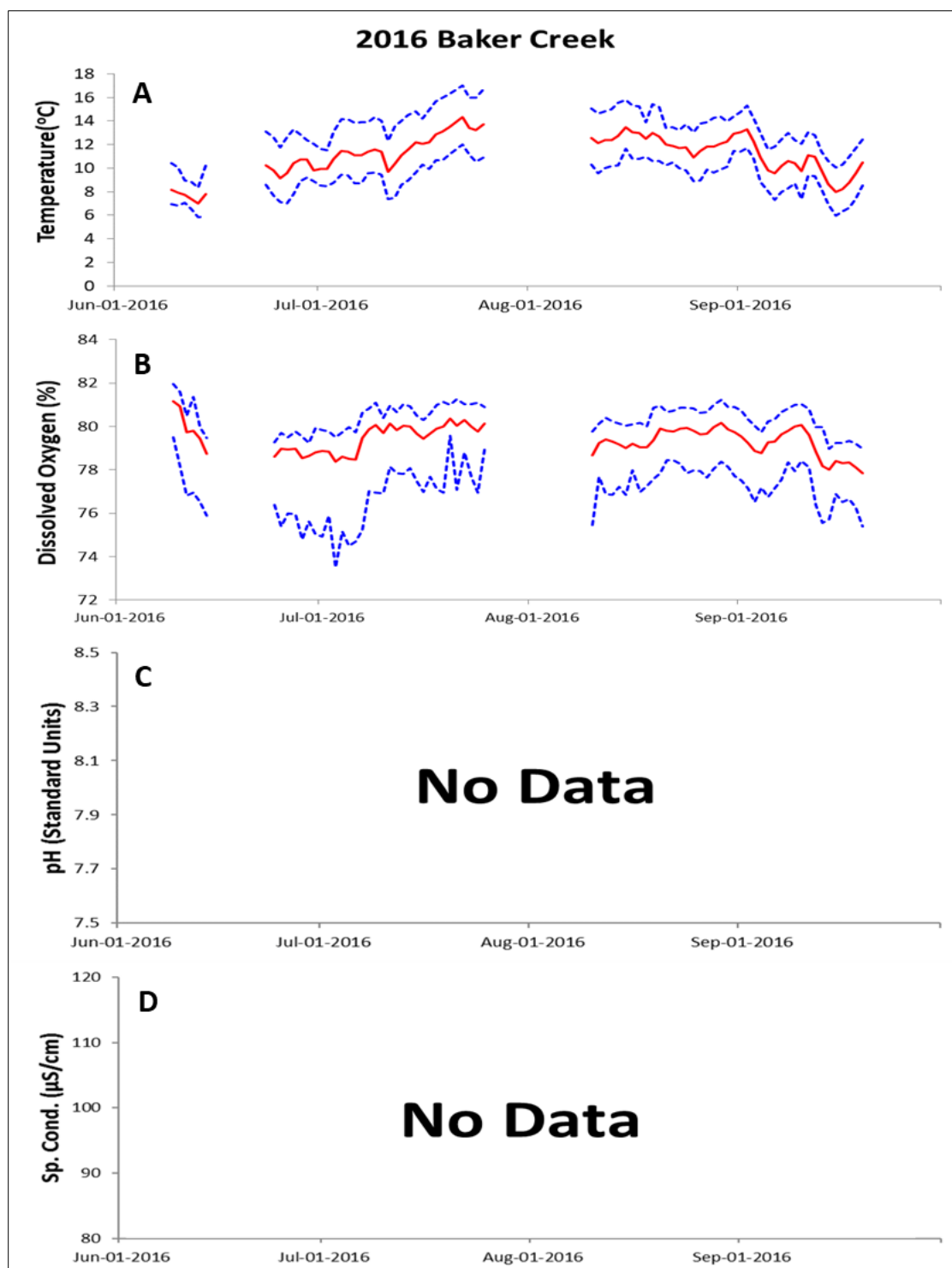


Figure 7. Baker creek water quality data from the 2016 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum and maximum pH values. D. Daily mean, minimum and maximum specific conductance values. In all cases, mean values are denoted by the red line, and minimum and maximum values are denoted by the blue lines.

Lehman Creek

A sonde was deployed in Lehman Creek from June 1 to September 19. The median pH, as well as the average temperature, specific conductance, and dissolved oxygen saturation are provided in Table 3. The daily average (or median for pH), minimum, and maximum values of each parameter are plotted in Figure 8.

Table 3. Average water quality parameter values in Lehman Creek, 2009-2016.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp. °C	2009	ND	ND	ND	10.9 ^a	ND
	2010	ND	ND	ND	11.7 ^a	9.8
	2011	8.9	9.5	9.7	10.6	9.2
	2012	ND	12.7	13.2	12.7	11.2
	2013	ND	ND	13.2	13.2	11.4
	2014	ND	ND	ND	10.1 ^b	9.7
	2015	11.0	11.6	12.5	12.5	11.4
	2016	10.4	12.3	12.2	11.6	10.2
Median pH Standard Units	2009	ND	ND	ND	7.53 ^a	ND
	2010	ND	ND	ND	7.53 ^a	7.55
	2011	ND	ND	7.46 ^a	7.45	7.45
	2012	ND	7.37 ^a	7.44	7.44	7.47
	2013	ND	ND	7.45	7.46	7.33
	2014	ND	ND	ND	7.50 ^b	7.50
	2015	ND	7.21	7.26	7.36	7.32
	2016	7.11	7.13	7.12	7.23	7.20
Mean Specific Conductance µS/cm	2009	ND	ND	ND	35 ^a	ND
	2010	ND	ND	ND	36 ^a	36
	2011	32 ^a	ND	ND	ND	ND
	2012	ND	36	36	37	39
	2013	ND	ND	40 ^a	42	41
	2014	ND	ND	ND	39 ^b	38
	2015	47	47	42	42	43
	2016	37	39 ^c	ND	ND	ND
Mean Dissolved Oxygen % Saturation	2009	ND	ND	ND	79.9 ^a	ND
	2010	ND	ND	ND	79.3 ^a	79.5
	2011	80.8 ^b	ND	80.0 ^a	80.3	80.5
	2012	ND	77.2	77.5	78.0	77.9

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND – No data collected

Table 3 (continued). Average water quality parameter values in Lehman Creek, 2009-2016.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean	2013	ND	ND	79.2	79.5	79.6
Dissolved	2014	ND	ND	ND	80.0 ^b	79.7
Oxygen	2015	81.3	80.8	80.4	80.6	81.5
% Saturation (continued)	2016	78.7	78.6	78.4	78.2	77.8

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND – No data collected

Water temperature (Figure 8A) in Lehman Creek reached a maximum of 16.85°C on July 22 and a minimum of 5.15°C on September 15. The daily average remained relatively stable throughout the record.

The dissolved oxygen saturation (Figure 8B) ranged from a minimum of 76.5% on September 4 to a maximum of 80.9% on June 3.

The pH (Figure 8C) reached a maximum of 7.55 on August 29 and a minimum of 6.82 on June 28.

Data for specific conductance (Figure 8D) are only available from June 1 until July 23. The maximum value during this time period was 45.2 µS/cm and the minimum value was 34.9 µS/cm.

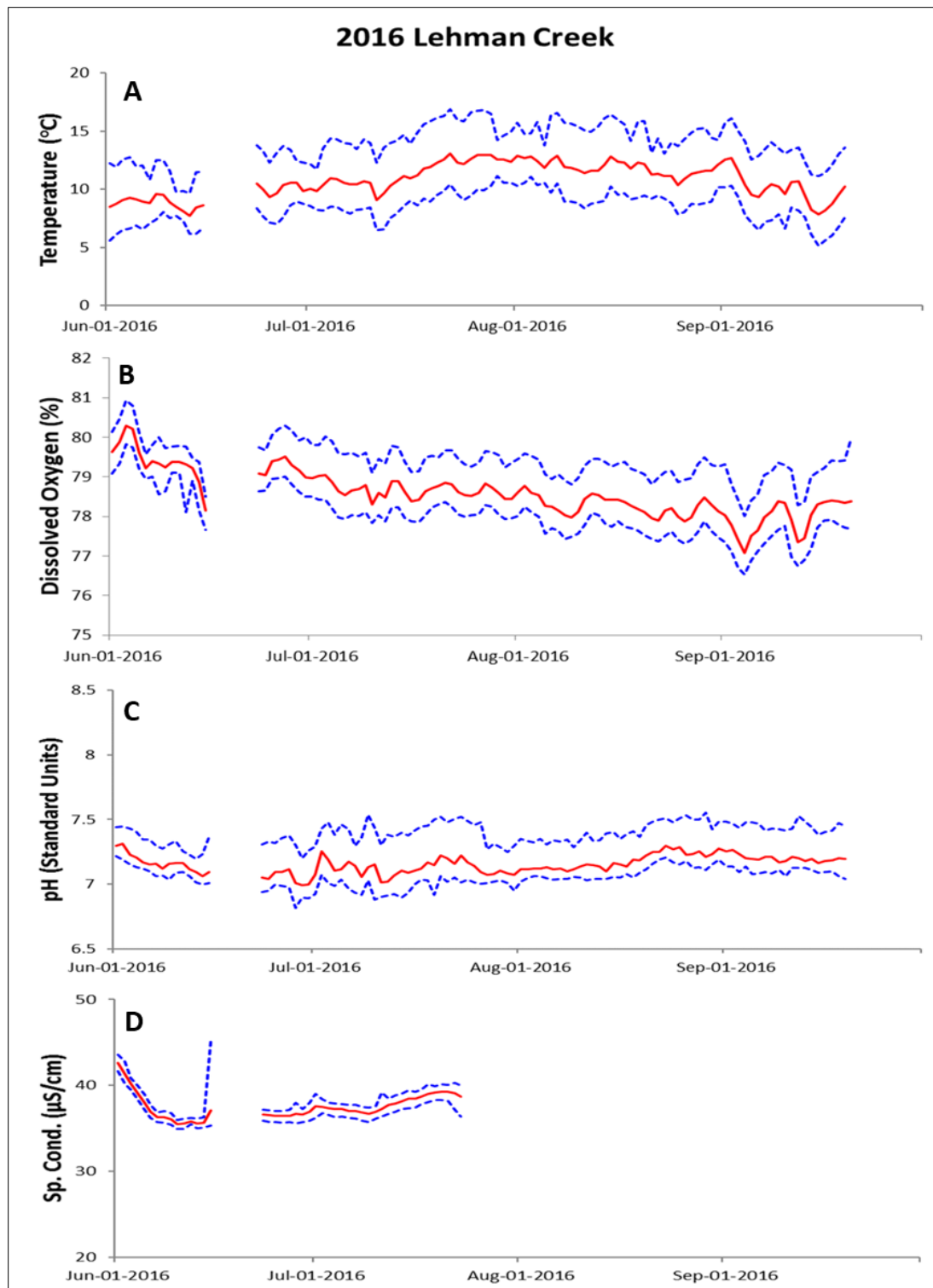


Figure 8. Lehman creek water quality data from the 2016 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum and maximum pH values. D. Daily mean, minimum and maximum specific conductance values. In all cases, mean values are denoted by the red line, and minimum and maximum values are denoted by the blue lines.

Lower Snake Creek

A sonde was deployed at Lower Snake Creek from June 1 to August 13. The median pH, as well as the average temperature, specific conductance, and dissolved oxygen saturation are provided in Table 4. The daily average (or median for pH), minimum, and maximum values of each parameter are plotted in Figure 9. The dissolved oxygen probe was only functional from June 9-16 and from July 20-August 23.

Table 4. Average water quality parameter values in Lower Snake Creek, 2009-2016.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp. °C	2009	11.1	ND	ND	ND	ND
	2010	11.6	13.6	13.5	12.5	10.7
	2011	ND	10.9 ^b	11.5	11.8	10.3
	2012	ND	ND	ND	ND	ND
	2013	14.4	ND	ND	ND	ND
	2014	ND	ND	ND	ND	ND
	2015	12.6	13.3	ND	ND	ND
	2016	11.1	13.2	13.4 ^a	ND	ND
Median pH Standard Units	2009	8.23	ND	ND	ND	ND
	2010	8.36	8.41	8.39	8.35	8.37 ^a
	2011	ND	8.25 ^b	8.24	8.24	8.21
	2012	ND	ND	ND	ND	ND
	2013	8.12	ND	ND	ND	ND
	2014	ND	ND	ND	ND	ND
	2015	8.13	8.11	ND	ND	ND
	2016	7.66	7.84	8.09 ^a	ND	ND
Mean Specific Conductance µS/cm	2009	148	ND	ND	ND	ND
	2010	175	214 ^a	174	186	209 ^a
	2011	ND	156 ^b	176	170	174
	2012	ND	ND	ND	ND	ND
	2013	160 ^b	ND	ND	ND	ND
	2014	ND	ND	ND	ND	ND
	2015	132	147	ND	ND	ND
	2016	140	154	169 ^c	ND	ND

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND – No data collected

Table 4 (continued). Average water quality parameter values in Lower Snake Creek, 2009-2016.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Dissolved Oxygen % Saturation	2009	81.1	ND	ND	ND	ND
	2010	83.1	82.8	82.1	82.9	83.1 ^a
	2011	ND	83.1 ^b	82.6	82.7	82.9
	2012	ND	ND	ND	ND	ND
	2013	77.9	ND	ND	ND	ND
	2014	ND	ND	ND	ND	ND
	2015	79.5	78.7	ND	ND	ND
	2016	ND	81.7 ^b	81.3 ^a	ND	ND

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND – No data collected

Water temperature (Figure 9A) slowly increased throughout June and July, reaching a maximum of 17.3°C on July 27. A minimum temperature of 6.7°C was recorded on June 1.

The dissolved oxygen saturation (Figure 9B) reach a maximum of 82.8% on July 22 and a minimum of 80.1% on August 9.

pH (Figure 9C) reached a maximum value of 8.41 on August 3rd and a minimum of 7.49 on July 11.

Specific conductance (Figure 9D) exhibited a sharp increase on June 19. Following this brief spike, values slowly increased until reaching a maximum value of 179 µS/cm on August 7. The minimum value of 117 µS/cm was recorded on June 2.

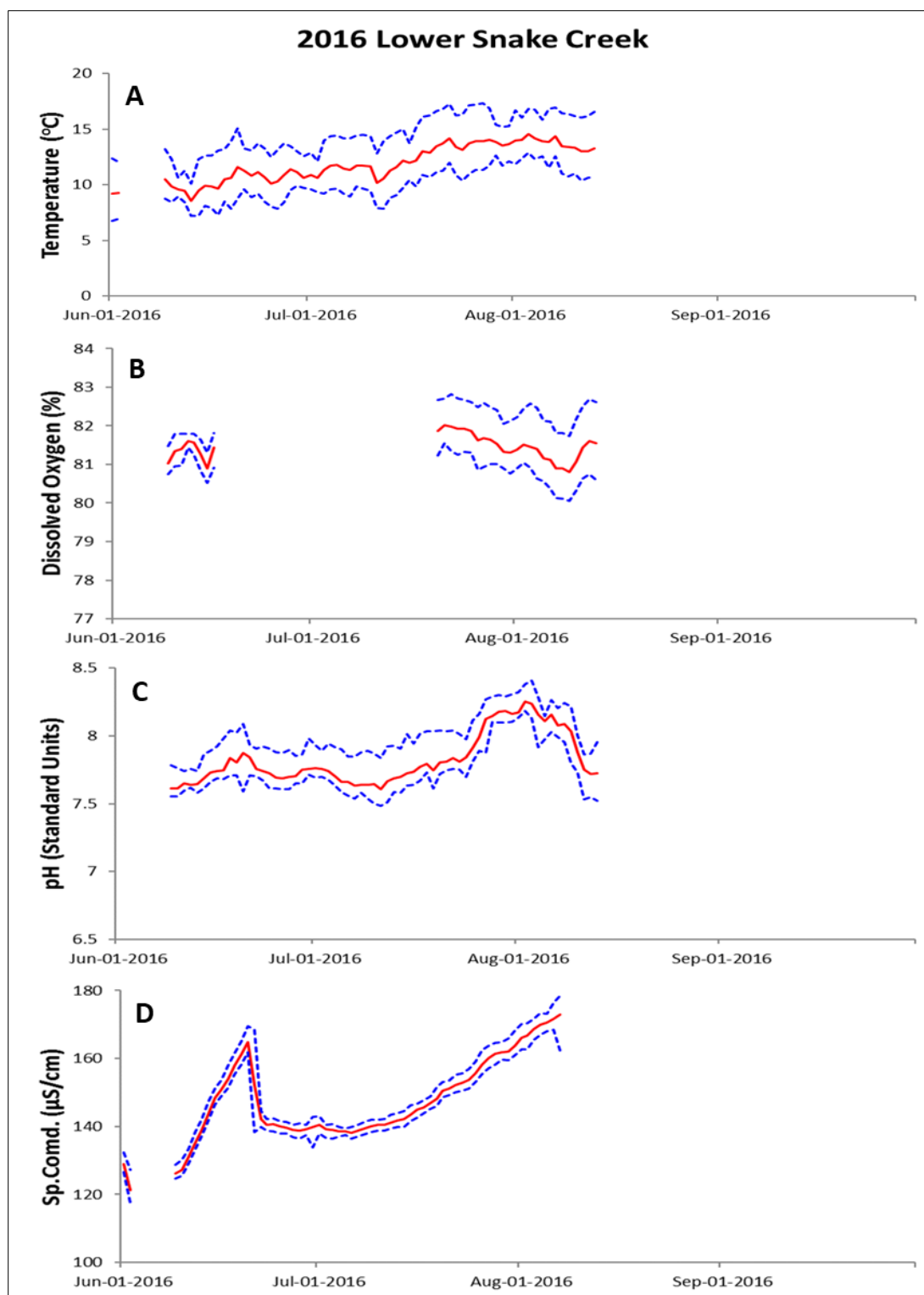


Figure 9. Lower Snake Creek water quality data from the 2016 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum and maximum pH values. D. Daily mean, minimum and maximum specific conductance values. In all cases, mean values are denoted by the red line, and minimum and maximum values are denoted by the blue lines.

Upper Snake Creek

A sonde was deployed in Upper Snake Creek from June 10 to September 22. The median pH, as well as the average temperature, specific conductance, and dissolved oxygen saturation are provided in Table 5. The daily average (or median for pH), minimum, and maximum values of each parameter are plotted in Figure 10.

Table 5. Average water quality parameter values in Upper Snake Creek, 2009-2016

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp. °C	2009	ND	ND	ND	ND	ND
	2010	7.6	9.5	9.5	ND	ND
	2011	ND	ND	ND	ND	ND
	2012	ND	10.7 ^a	11.4 ^a	11.3	9.6
	2013	ND	11.4 ^a	10.4	11.1	10.5
	2014	10.2	10.9 ^a	10.5 ^a	9.7	9.2
	2015	9.1	ND	ND	10.8 ^b	9.3
	2016	8.3	9.9	10.2	10.2	8.2
Median pH Standard Units	2009	ND	ND	ND	ND	ND
	2010	7.57	7.60	7.57	ND	ND
	2011	ND	ND	ND	ND	ND
	2012	ND	ND	8.05	8.08	8.12
	2013	ND	7.90 ^a	7.90	7.87	7.87
	2014	8.01	7.95	8.02	7.93	7.80
	2015	8.09	ND	ND	7.94 ^b	8.02
	2016	7.81	7.85	7.86	7.85	7.89
Mean Specific Conductance µS/cm	2009	ND	ND	ND	ND	ND
	2010	48	47	ND	ND	ND
	2011	ND	112 ^a	111	114	119
	2012	ND	113 ^a	118	119	117
	2013	102	105	110	112	113
	2014	101	107 ^a	110 ^a	111	113
	2015	98	ND	ND	109 ^b	112
	2016	95	102	106	111	112
Mean Dissolved Oxygen % Saturation	2009	ND	ND	ND	ND	ND
	2010	75.8	75.9	73.2	ND	ND
	2011	ND	ND	ND	ND	ND
	2012	ND	ND	76.5 ^a	74.3	74.9

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

ND – No data collected

Table 5 (continued). Average water quality parameter values in Upper Snake Creek, 2009-2016

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean	2013	ND	73.6 ^b	74.8	74.9	75.1
Dissolved Oxygen	2014	74.8	74.9 ^a	74.3 ^a	73.3	73.4
% Saturation	2015	75.0	ND	ND	78.0 ^b	75.6
(continued)	2016	77.6	77.4	77.3	76.0	75.9

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

ND – No data collected

Water temperature (Figure 10A) reached a maximum of 12.7°C on August 7, and a minimum of 4.0°C on September 15.

The dissolved oxygen saturation (Figure 10B) reached a maximum of 78.7% on July 21, and a minimum of 74.3% on September 3.

pH (Figure 10C) reached a maximum value of 8.12 on August 31, and a minimum value of 7.68 on June 16.

Specific conductance (Figure 10D) steadily increased throughout the sampling period. The maximum value, 116 µS/cm, was recorded on September 20 and the minimum value, 81 µS/cm, was recorded on June 11.

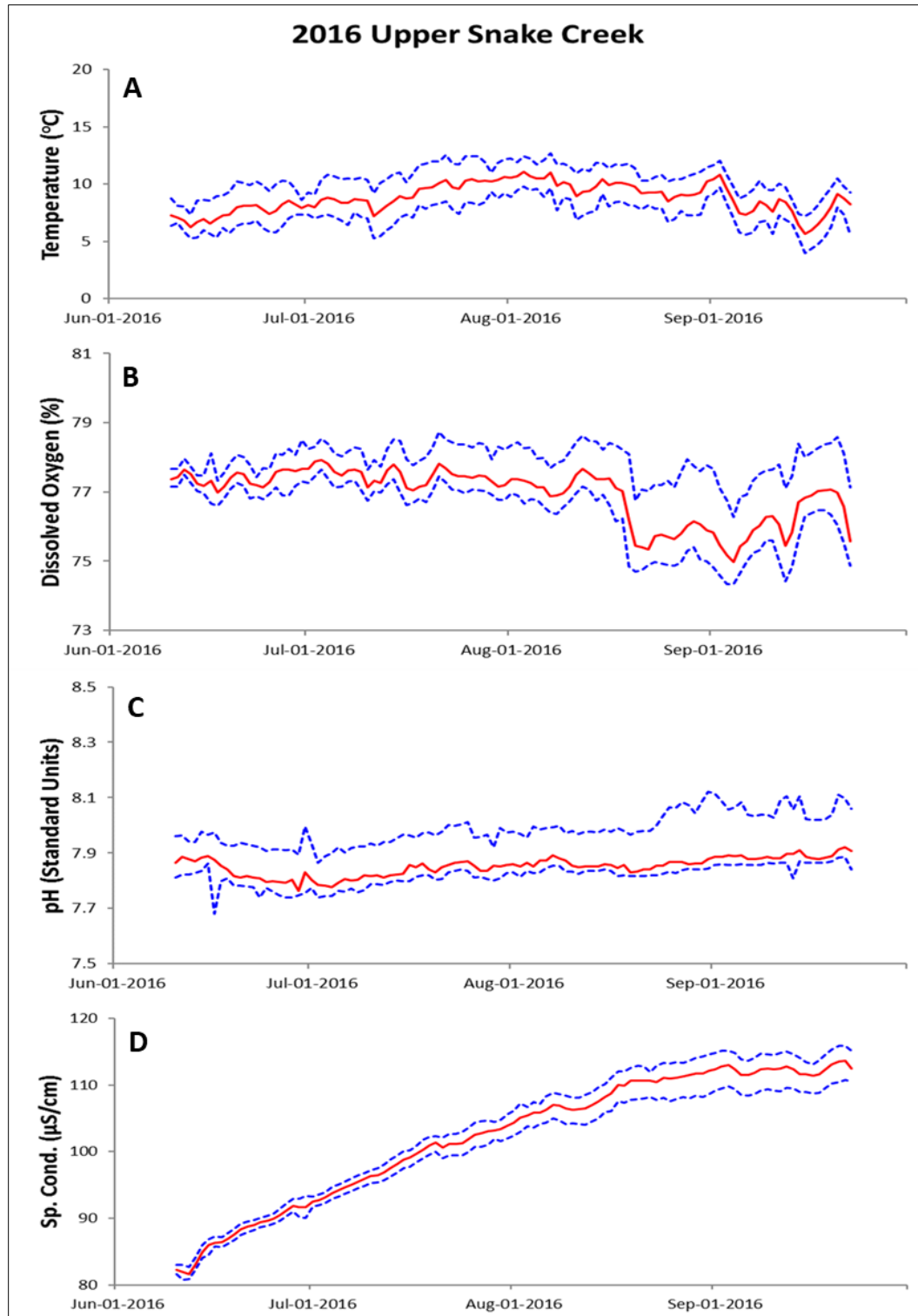


Figure 10. Upper Snake Creek water quality data from the 2016 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum and maximum pH values. D. Daily mean, minimum and maximum specific conductance values. In all cases, mean values are denoted by the red line, and minimum and maximum values are denoted by the blue lines.

Strawberry Creek

A sonde was deployed at Strawberry Creek on June 16. A wildfire destroyed the sonde in early August, and data are only available through August 7. The median pH, as well as the average temperature and specific conductance are provided in Table 6. The DO sensor was not functional during the entire sampling period. The daily average (or median for pH), minimum, and maximum values of each parameter are plotted in Figure 11.

Table 6. Average water quality parameter values in Strawberry Creek, 2009-2016

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp. °C	2009	ND	ND	11.97 ^a	ND	ND
	2010	10.79	13.19	13.02	12.38	10.10 ^a
	2011	9.3	10.6	11.3	12.3	10.2
	2012	ND	14.0 ^a	14.9	14.3	12.2
	2013	15.0	15.5	14.0 ^b	ND	ND
	2014	ND	ND	12.6	11.4	10.6
	2015	ND	ND	ND	ND	11.9 ^b
	2016	12.4	14.3	14.4 ^c	ND	ND
Median pH Standard Units	2009	ND	ND	8.05 ^a	ND	ND
	2010	8.00 ^a	8.02	7.93	8.07	8.06
	2011	ND	8.25 ^b	8.26	8.25	8.26
	2012	ND	7.90 ^a	7.81	7.88	7.88
	2013	7.88	7.96	7.90 ^b	ND	ND
	2014	ND	ND	ND	ND	7.84
	2015	ND	ND	ND	ND	8.00 ^b
	2016	7.85	7.86	7.98 ^c	ND	ND
Mean Specific Conductance µS/cm	2009	ND	ND	120 ^a	ND	ND
	2010	94	108	177	131	124
	2011	73 ^b	93 ^b	ND	114 ^b	122 ^b
	2012	ND	156 ^a	157	157	163
	2013	163	168	176 ^b	ND	ND
	2014	ND	ND	146 ^a	ND	153
	2015	ND	ND	ND	ND	151 ^b
	2016	118	147	153 ^c	ND	ND

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND = No data collected

Table 6 (continued). Average water quality parameter values in Strawberry Creek, 2009-2016

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Dissolved Oxygen % Saturation	2009	ND	ND	78.2 ^a	ND	ND
	2010	79.1 ^b	80.7	78.1	78.9	78.9
	2011	78.8	79.2	78.6	79.2	80.0
	2012	ND	75.7 ^a	78.1	80.5	77.5
	2013	72.4	73.2	73.0 ^b	ND	ND
	2014	ND	ND	ND	ND	ND
	2015	ND	ND	ND	ND	76.4 ^a
	2016	ND	ND	ND	ND	ND

^a. Average calculated with 1-2 days of data missing

^b. Average calculated with 3-5 days of data missing

^c. Average calculated with 6-9 days of data missing

ND = No data collected

Water temperature (Figure 11A) reached a maximum of 17.59°C on July 22, and a minimum of 6.69°C on June 17.

pH (Figure 11C) reached a maximum of 8.26 on July 12, and a minimum of 6.32 on June 19.

Specific conductance (Figure 11D) steadily increased throughout the sampling period, reached a maximum of 165.47 on August 3. A minimum of 80.14 was observed on June 17.

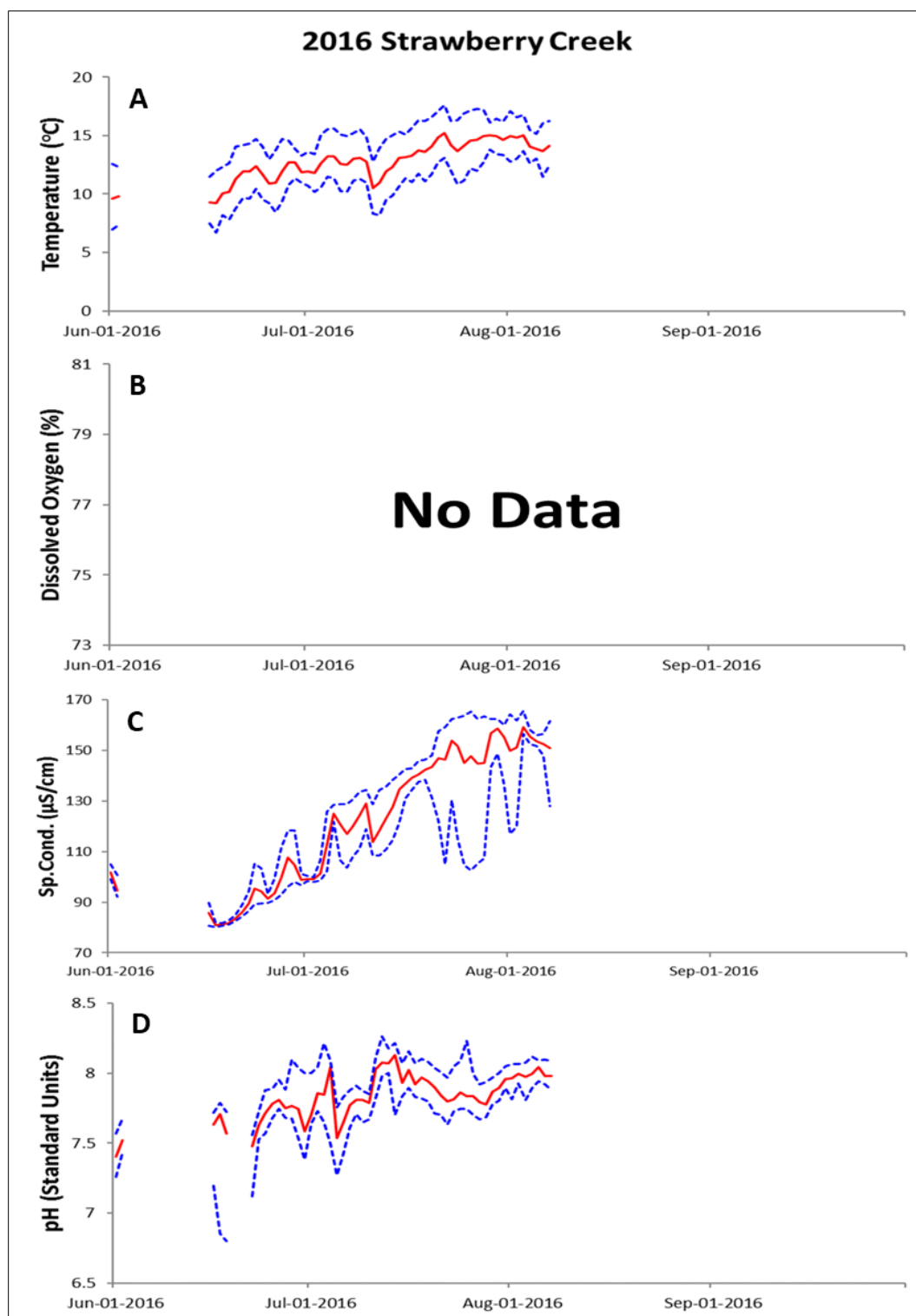


Figure 11. Strawberry Creek water quality data from the 2016 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum and maximum pH values. D. Daily mean, minimum and maximum specific conductance values. In all cases, mean values are denoted by the red line, and minimum and maximum values are denoted by the blue lines.

Stream Water Chemistry

Stream water samples were collected from nine streams at the locations shown in Figure 1. The sites were randomly chosen in 2009 to ensure that the results would be representative of aquatic habitat conditions across the park. Care should be taken in comparing values between streams, as some samples were collected at higher elevations in tributaries while other samples were collected at lower elevations on the main channel (Figure 1).

The water samples were analyzed for basic chemistry and nutrient concentrations at the Cooperative Chemical Analysis Facility (CCAL) in Corvallis, Oregon. The results of these analyses and the water quality data measured at the time of sampling are described in this section.

Water Quality Parameters

Four water quality parameters were measured at each stream: temperature, dissolved oxygen, pH, and specific electrical conductance. In order to assess mixing, these parameters were measured near each bank and at the center of the channel. All of the streams were found to be well mixed each year, with the exception of Strawberry Creek in 2016. Specific conductance values on the right bank (161.9 $\mu\text{S}/\text{cm}$) and in the center (161.3 $\mu\text{S}/\text{cm}$) of Strawberry Creek were twice as high as the left bank (81.2 $\mu\text{S}/\text{cm}$). In a similar pattern, DO decreased across the stream, with a value of 7.35 mg/L near the right bank, 7.03 mg/L in the center, and 6.56 mg/L on the left bank. Temperature and pH remained relatively constant across the stream. The median values of the four core water quality parameters are reported in Table 8.

The state of Nevada has established water quality standards for Class A Waters for pH (between 6.5 and 9.0), DO (greater than or equal to 6.0 mg/L), and temperature (less than or equal to 20°C). There are four GRBA streams listed as Class A waters: Baker Creek, Lehman Creek, Pine Creek, and Ridge Creek. All of the measured values meet the Class A standards (Table 7).

Table 7. Water quality parameters in GRBA streams. Each value is the median of the three measurements.

Stream	Visit Date	Temperature °C	Dissolved Oxygen mg/L	pH	Specific Conductance $\mu\text{S}/\text{cm}$
Snake	8/1/2009	8.3	9.52	8.40	45.5
	9/7/2010	6.8	9.31	8.08	55.0
	8/31/2011	9.8	7.59	7.80	50.5
	8/30/2012	10.1	8.09	8.18	42.2
	8/27/2013	8.9	8.70	7.89	68.1
	8/29/2014	10.2	8.42	ND	63.3
	8/25/2015	9.7	7.68	7.73	60.7
	9/2/2016	11.1	7.32	ND	58.2

ND = No data collected

Table 7 (continued). Water quality parameters in GRBA streams. Each value is the median of the three measurements.

Stream	Visit Date	Temperature °C	Dissolved Oxygen mg/L	pH	Specific Conductance µS/cm
Baker 2	8/31/2010	4.9	9.20	7.59	41.9
	9/2/2016	7.4	8.02	8.72	43.2
Baker 3	9/1/2011	7.2	9.90	7.10	20.5
	8/31/2012	8.4	8.33	7.42	27.4
	8/28/2013	8.5	8.58	7.27	28.0
	8/27/2014	6.2	8.71	7.00	28.1
	8/27/2015	8.1	9.40	7.25	28.8
Lehman	8/30/2010	4.4	8.33	7.92	30.3
	8/30/2011	8.0	8.66	7.90	27.7
	8/31/2012	7.4	8.46	7.79	29.6
	8/29/2013	6.8	9.06	7.49	34.5
	9/3/2014	7.6	8.25	ND	34.6
	8/28/2015	7.5	9.22	7.47	38.5
	9/1/2016	6.9	8.35	8.51	37.8
Pine	8/26/2010	7.9	9.25	7.60	29.8
	9/2/2011	6.7	11.76	7.80	31.2
	9/6/2012	9.5	8.23	7.61	31.6
	8/30/2013	8.7	8.23	7.48	34.1
	8/28/2014	7.5	8.63	7.12	35.8
	8/26/2015	7.7	8.98	7.24	33.4
	8/31/2016	8.0	8.26	7.79	32.2
Ridge	8/26/2010	6.8	9.95	7.57	36.9
	9/2/2011	6.5	9.34	7.60	38.8
	9/6/2012	8.2	8.53	7.73	42.9
	8/30/2013	7.1	8.51	7.50	46.3
	8/28/2014	6.7	9.01	7.30	43.6
	8/26/2015	6.8	8.52	7.29	41.5
	8/31/2016	7.1	8.47	7.24	39.0
South Fork Big Wash	9/2/2010	8.8	9.45	7.99	398.2
	8/31/2011	8.9	8.66	8.00	381.7
	8/29/2012	9.8	8.88	8.14	439.3
	8/28/2013	9.2	7.92	8.10	455.2
	8/26/2014	9.7	8.47	7.84	468.6

ND = No data collected

Table 7 (continued). Water quality parameters in GRBA streams. Each value is the median of the three measurements.

Stream	Visit Date	Temperature °C	Dissolved Oxygen mg/L	pH	Specific Conductance µS/cm
South Fork Big Wash (continued)	8/27/2015	9.9	9.10	8.37	465.4
	8/30/2016	9.8	8.36	7.60	429.5
Mill	9/7/2010	8.3	8.92	7.91	49.7
	9/1/2011	9.0	8.28	7.70	60.6
	8/31/2012	11.8	7.76	8.16	73.3
	8/29/2013	11.4	7.07	7.84	72.5
	9/3/2014	10.8	7.76	ND	59.1
	8/28/2015	10.9	8.00	7.77	55.0
	9/1/2016	12.6	6.91	9.02	49.4
Shingle	8/18/2009	7.0	ND	8.00	66.2
	9/1/2010	6.7	9.71	8.01	70.0
	9/2/2011	6.1	9.01	7.80	74.7
	9/6/2012	9.1	8.20	8.10	80.8
	8/30/2013	11.7	7.37	7.94	80.3
	8/28/2014	10.0	8.42	7.65	79.3
	8/26/2015	10.0	8.40	7.77	72.3
	8/31/2016	8.4	ND	ND	68.3
Strawberry	7/31/2009	12.9	7.08	7.90	103.0
	8/24/2010	12.2	8.58	8.13	112.0
	8/30/2011	11.3	8.40	8.00	123.5
	8/30/2012	14.3	7.31	8.43	152.8
	8/27/2013	13.1	7.76	8.17	166.8
	9/4/2014	9.7	8.98	ND	155.0
	8/25/2015	12.6	8.15	8.19	147.8
	8/30/2016	15.4	7.03	7.83	161.3

ND = No data collected

Nutrients

Nutrient concentrations measured in the stream water samples were all very low (Table 8). The highest Total Nitrogen (TN) and Total Phosphorus (TP) values from 2016 were 0.38 mg/L and 0.058 mg/L, respectively. The state of Nevada has established water quality standards for Class A Waters for TP of less than 0.1mg/L. The four GRBA Class A streams met this standard. Though the other five streams are not listed as Class A waters, they still met this standard.

In 2016, the Total Dissolved Nitrogen (TDN) value in South Fork Big Wash was larger than TN; however, the analytical results fall within the precision limits, so the results are analytically equal. All Total Dissolve Phosphorus (TDP) values were less than or equal to the TP values for all stream samples.

Field crews unintentionally sampled the wrong site in Baker Creek (Baker 2) this year. Baker 2 was used for the first two years of sampling, but the site was abandoned for a more representative location in WY2011. After realizing that they sampled the incorrect location, the crew did not have enough clean sample bottles and filters to sample water chemistry at the correct location (Baker 3). Table 8 separates data from Baker 2 and Baker 3, and data from these sites aren't comparable.

Table 8. Nutrient concentrations in GRBA streams.

Stream	Sampling Date	Total N mg/L	Total Dissolved N mg/L	Nitrate + Nitrite mg/L as N	Total P mg/L	Total Dissolved P mg/L
Snake	9/2/2009	0.05	0.06 ^b	0.002 ^d	0.013	0.011
	9/7/2010	0.05	0.06 ^b	0.003	0.007	0.005
	8/31/2011	0.06	0.04	0.004	0.007	0.004 ^d
	8/30/2012	0.11	0.08	0.008	0.017	0.012
	8/27/2013	0.07	0.07	0.004	0.009	0.006
	8/29/2014	0.07	0.07	0.001 ^d	0.008	0.005 ^d
	8/25/2015	0.06	0.05	0.003	0.006	0.005 ^d
	9/2/2016	0.11	0.04	0.001 ^d	0.013	0.004 ^d
Baker 2	8/27/2009	0.15	0.15	0.051	0.017	0.016
	8/31/2010	0.13	0.15 ^b	0.091	0.008	0.009 ^b
	9/2/2016	0.14	0.12	0.076	0.008	0.001 ^d
Baker 3	9/1/2011	0.22	0.23 ^b	0.173	0.011	0.010
	8/31/2012	0.64	0.48	0.393	0.032	0.011
	8/28/2013	0.53	0.53	0.458	0.016	0.012
	8/27/2014	0.52	0.52	0.415	0.011	0.009
	8/27/2015	0.40	0.38	0.336	0.010	0.009
Lehman	8/27/2009 ^a	0.20	0.24 ^b	0.158	0.020	0.015
	8/30/2010	0.24	0.24	0.191	0.010	0.007
	8/30/2011	0.19	0.18	0.130	0.015	0.007

^a. Sample collected at stream gage or different site; data are not comparable to future years.

^b. TDN (or TDP) value greater than TN (or TP) value with the difference within precision limits, indicating that the samples are analytically equal in concentration.

^c. TDN (or TDP) value greater than TN (or TP) value with the difference outside the expected range of variability, indicating contamination of the sample.

^d. Concentration below the minimum quantitation limit (ML)

ND = No data collected, N = nitrogen, P = phosphorus

Table 8 (continued). Nutrient concentrations in GRBA streams.

Stream	Sampling Date	Total N mg/L	Total Dissolved N mg/L	Nitrate + Nitrite mg/L as N	Total P mg/L	Total Dissolved P mg/L
Lehman (continued)	8/31/2012	0.42	0.40	0.354	0.009	0.006
	8/29/2013	0.54	0.55	0.495	0.010	0.007
	9/3/2014	0.55	0.58 ^b	0.464	0.008	0.010 ^b
	8/28/2015	0.36	0.34	0.284	0.009	0.006
	9/1/2016	0.27	0.25	0.213	0.009	0.008
Pine	8/28/2009	0.12	0.17 ^c	0.092	0.013	0.012
	8/26/2010	0.21	0.19	0.130	0.015	0.012
	9/2/2011	0.17	0.20 ^b	0.111	0.012	0.011
	9/6/2012	0.16	0.11	0.044	0.018	0.010
	8/30/2013	0.16	0.14	0.077	0.012	0.009
	8/28/2014	0.14	0.14	0.061	0.012	0.010
	8/26/2015	0.22	0.18	0.140	0.011	0.009
	8/31/2016	0.28	0.23	0.191	0.014	0.008
Ridge	8/28/2009	0.44	0.33	0.264	0.027	0.019
	8/26/2010	0.31	0.38 ^c	0.248	0.020	0.016
	9/2/2011	0.37	0.29	0.225	0.025	0.017
	9/6/2012	0.37	0.35	0.304	0.018	0.015
	8/30/2013	0.40	0.38	0.350	0.017	0.014
	8/28/2014	0.42	0.42	0.323	0.018	0.016
	8/26/2015	0.39	0.36	0.347	0.014	0.014
	8/31/2016	0.38	0.35	0.324	0.018	0.016
South Fork Big Wash	9/2/2009	0.12	0.13 ^b	0.080	0.005 ^d	0.004 ^d
	9/2/2010	0.10	0.12 ^b	0.070	0.002 ^d	0.003 ^b
	8/31/2011	0.09	0.08	0.059	0.002 ^d	0.001 ^d
	8/29/2012	0.24	0.15	0.106	0.011	0.001 ^d
	8/28/2013	0.14	0.17	0.100	0.003 ^d	0.001 ^d
	8/26/2014	0.17	0.15	0.076	0.005 ^d	0.002 ^d
	8/27/2015	0.15	0.13	0.095	0.010	0.001 ^d
	8/30/2016	0.12	0.13 ^b	0.095	0.000 ^d	0.001 ^d

^a. Sample collected at stream gage or different site; data are not comparable to future years.

^b. TDN (or TDP) value greater than TN (or TP) value with the difference within precision limits, indicating that the samples are analytically equal in concentration.

^c. TDN (or TDP) value greater than TN (or TP) value with the difference outside the expected range of variability, indicating contamination of the sample.

^d. Concentration below the minimum quantitation limit (ML)

ND = No data collected, N = nitrogen, P = phosphorus

Table 8 (continued). Nutrient concentrations in GRBA streams.

Stream	Sampling Date	Total N mg/L	Total Dissolved N mg/L	Nitrate + Nitrite mg/L as N	Total P mg/L	Total Dissolved P mg/L
Mill	7/31/2009	0.45	ND	ND	0.074	ND
	9/7/2010	0.18	0.12	0.003	0.024	0.019
	9/1/2011	0.17	0.14	0.004	0.022	0.015
	8/31/2012	0.25	0.11	0.007	0.036	0.015
	8/29/2013	0.26	0.15	0.006	0.041	0.018
	9/3/2014	0.18	0.13	0.001 ^d	0.027	0.018
	8/28/2015	0.18	0.10	0.002	0.030	0.020
	9/1/2016	0.22	0.10	0.002	0.041	0.023
Shingle	8/18/2009	0.22	ND	ND	0.030	ND
	9/1/2010	0.08	0.11 ^b	0.008	0.010	0.009
	9/2/2011	0.07	0.05	0.015	0.009	0.006
	9/6/2012	0.09	0.06	0.007	0.014	0.009
	8/30/2013	0.10	0.06	0.011	0.013	0.008
	8/28/2014	0.12	0.06	0.006	0.015	0.008
	8/26/2015	0.11	0.06	0.014	0.012	0.008
	8/31/2016	0.12	0.07	0.019	0.009	0.006
Strawberry	9/28/2009	0.16	0.13	0.005	0.031	0.020
	8/24/2010	0.10	0.06	0.004	0.020	0.013
	8/30/2011	0.11	0.11	0.006	0.018	0.014
	8/30/2012	0.06	0.06	0.005	0.008	0.006
	8/27/2013	0.11	0.10	0.008	0.017	0.010
	9/4/2014	0.12	0.08	0.004	0.021	0.012
	8/25/2015	0.15	0.15	0.009	0.027	0.027
	8/30/2016	0.09	0.09	0.004	0.058	0.050

^a. Sample collected at stream gage or different site; data are not comparable to future years.

^b. TDN (or TDP) value greater than TN (or TP) value with the difference within precision limits, indicating that the samples are analytically equal in concentration.

^c. TDN (or TDP) value greater than TN (or TP) value with the difference outside the expected range of variability, indicating contamination of the sample.

^d. Concentration below the minimum quantitation limit (ML)

ND = No data collected, N = nitrogen, P = phosphorus

Major Ions and Acid Neutralization Capacity (ANC)

Water samples were analyzed for sodium, potassium, calcium, magnesium, sulfate, and chloride (Table 9). Systematic changes in the concentrations of these ions over time may be useful in determining changes in the source of water to the streams. In addition, the acid neutralizing capacity (ANC) of each stream was measured. ANC is expressed in microequivalents per liter ($\mu\text{eq/L}$), that is,

the number of micromoles of H ions (acid) that can be neutralized by a liter of the water sample without a change in pH. As ANC decreases, the sensitivity of the stream to acidification increases. A decrease in ANC may be an indication of acid deposition. In WY2016, Lehman Creek and Strawberry Creek both had the highest ANC value out of their respective records.

Table 9. Major ion concentrations and acid neutralization capacity in GRBA streams.

Stream	Sampling Date	Sodium mg/L	Potassium mg/L	Calcium mg/L	Magnesium mg/L	Sulfate mg/L as S	Chloride mg/L	ANC µeq/L
Snake	9/2/2009	3.21	0.52	6.29	0.74	0.66	0.82	485
	9/7/2010	3.32	0.50	6.29	0.75	0.68	0.69	496
	8/31/2011	3.06	0.47	5.74	0.84	0.67	0.67	452
	8/30/2012	6.00	0.84	19.26	4.19	1.49	3.79	1166
	8/27/2013	3.90	0.53	7.08	1.04	0.66	0.74	524
	8/29/2014	3.82	0.54	6.98	1.03	0.71	0.74	551
	8/25/2015	3.58	0.54	6.77	0.94	0.69	0.67	545
	9/2/2016	3.5	0.5	6.54	0.94	0.7	0.67	537
Baker 2	8/27/2009	1.78	0.43	4.42	0.78	0.67	0.71	296
	8/31/2010	2.60	0.41	4.32	0.67	0.52	0.64	362
	9/2/2016	2.57	0.42	4.51	0.8	0.52	0.59	384
Baker 3	9/1/2011	0.82	0.27	2.08	0.47	0.57	0.34	157
	8/31/2012	0.88	0.53	2.79	0.61	0.80	0.65	170
	8/28/2013	0.91	0.36	2.75	0.61	0.75	0.49	161
	8/27/2014	0.87	0.31	2.84	0.61	0.83	0.43	160
	8/27/2015	1.09	0.34	2.96	0.64	0.84	0.45	177
Lehman	8/27/2009 ^a	1.46	0.33	3.96	0.76	0.40	0.60	314
	8/30/2010	1.08	0.27	3.71	0.78	0.36	0.39	268
	8/30/2011	0.97	0.26	3.36	0.66	0.29	0.31	296
	8/31/2012	0.87	0.27	3.51	0.70	0.37	0.39	243
	8/29/2013	0.92	0.28	3.85	0.77	0.42	0.42	247
	9/3/2014	0.94	0.30	3.93	0.74	0.45	0.45	255
	8/28/2015	1.20	0.35	4.43	0.84	0.43	0.44	315

^a. Sample collected at stream gage or different site; data are not comparable to future years.

ND = No data collected, ANC = acid neutralizing capacity

Table 9 (continued). Major ion concentrations and acid neutralization capacity in GRBA streams.

Stream	Sampling Date	Sodium mg/L	Potassium mg/L	Calcium mg/L	Magnesium mg/L	Sulfate mg/L as S	Chloride mg/L	ANC µeq/L
Lehman (continued)	9/1/2016	1.15	0.29	4.49	0.91	0.4	0.43	335
Pine	8/28/2009	1.82	0.22	3.43	0.70	0.49	0.65	270
	8/26/2010	1.16	0.23	3.42	0.74	0.51	0.40	254
	9/2/2011	1.28	0.27	3.66	0.84	0.51	0.52	276
	9/6/2012	1.18	0.23	3.68	0.85	0.46	0.41	291
	8/30/2013	1.19	0.22	3.78	0.87	0.46	0.39	292
	8/28/2014	1.23	0.20	3.98	0.92	0.45	0.42	307
	8/26/2015	1.22	0.20	3.56	0.82	0.46	0.43	278
	8/31/2016	1.13	0.22	3.55	0.84	0.49	0.45	273
Ridge	8/28/2009	1.65	0.43	4.10	0.88	0.61	0.66	124
	8/26/2010	1.33	0.49	4.25	0.95	0.62	0.69	308
	9/2/2011	1.31	0.43	4.37	1.08	0.62	0.54	329
	9/6/2012	1.34	0.45	5.00	1.14	0.67	0.54	346
	8/30/2013	1.32	0.52	5.11	1.17	0.65	0.56	359
	8/28/2014	1.26	0.47	4.78	1.11	0.63	0.48	337
	8/26/2015	1.25	0.43	4.47	1.02	0.61	0.45	325
	8/31/2016	1.15	0.47	4.34	1.02	0.61	0.5	316
South Fork Big Wash	9/2/2009	3.21	0.49	58.70	16.26	2.45	2.93	3771
	9/2/2010	3.08	0.45	62.57	14.55	3.11	2.76	3583
	8/31/2011	3.50	0.48	58.03	14.43	2.90	2.96	2573
	8/29/2012	3.74	0.48	45.36	17.93	3.97	3.61	2863
	8/28/2013	3.48	0.45	64.05	17.37	4.23	3.07	2935

^a. Sample collected at stream gage or different site; data are not comparable to future years.

ND = No data collected, ANC = acid neutralizing capacity

Table 9 (continued). Major ion concentrations and acid neutralization capacity in GRBA streams.

Stream	Sampling Date	Sodium mg/L	Potassium mg/L	Calcium mg/L	Magnesium mg/L	Sulfate mg/L as S	Chloride mg/L	ANC μ eq/L
South Fork Big Wash (continued)	8/26/2014	3.37	0.48	68.27	17.89	4.04	2.96	3256
	8/27/2015	3.42	0.48	75.56	17.56	4.17	2.96	3441
	8/30/2016	3.24	0.46	61.36	16.62	4.01	3.04	2825
Mill	7/31/2009	ND	ND	ND	ND	ND	ND	395
	9/7/2010	2.54	0.50	5.18	1.29	0.73	1.37	416
	9/1/2011	3.18	0.59	6.41	1.87	0.72	1.77	509
	8/31/2012	3.66	0.63	8.33	2.25	0.81	2.24	648
	8/29/2013	3.21	0.66	7.39	2.01	0.74	1.89	557
	9/3/2014	2.72	0.57	6.02	1.66	0.70	1.46	479
	8/28/2015	2.47	0.65	5.52	1.48	0.65	1.34	451
	9/1/2016	2.35	0.49	5.11	1.4	0.64	1.25	425
Shingle	8/18/2009	ND	ND	ND	ND	ND	ND	615
	9/1/2010	2.07	0.32	9.84	1.85	0.66	0.65	657
	9/2/2011	2.01	0.31	10.23	1.83	0.67	0.59	637
	9/6/2012	1.95	0.31	11.39	2.03	0.72	0.59	729
	8/30/2013	1.90	0.32	10.84	1.89	0.66	0.57	606
	8/28/2014	1.90	0.30	10.67	1.85	0.67	0.55	644
	8/26/2015	1.83	0.32	9.28	1.60	0.60	0.51	646
	8/31/2016	1.77	0.28	9.27	1.64	0.61	0.54	665
Strawberry	9/28/2009	4.73	0.77	12.37	3.15	1.19	2.42	963
	8/24/2010	4.44	0.66	15.29	3.33	1.16	2.10	952
	8/30/2011	5.17	0.67	14.82	3.49	1.31	2.65	1011
	8/30/2012	3.65	0.53	6.93	1.03	0.65	0.76	530

^a. Sample collected at stream gage or different site; data are not comparable to future years.

ND = No data collected, ANC = acid neutralizing capacity

Table 9 (continued). Major ion concentrations and acid neutralization capacity in GRBA streams.

Stream	Sampling Date	Sodium mg/L	Potassium mg/L	Calcium mg/L	Magnesium mg/L	Sulfate mg/L as S	Chloride mg/L	ANC μ eq/L
Strawberry (continued)	8/27/2013	6.18	0.82	19.39	4.06	1.55	3.70	1099
	9/4/2014	5.95	0.83	18.49	4.03	1.58	3.69	1188
	8/25/2015	5.59	0.87	18.49	3.65	1.40	3.04	1169
	8/30/2016	5.6	1.28	20.88	4.12	1.43	3.27	1281

^a. Sample collected at stream gage or different site; data are not comparable to future years.

ND = No data collected, ANC = acid neutralizing capacity

Stream Benthic Macroinvertebrates

Benthic macroinvertebrates (BMI) samples were collected from nine streams at the locations shown in Figure 1 at the same time that water samples were collected. The sampled macroinvertebrates were identified and enumerated by the Utah State University National Aquatic Monitoring Center (BugLab) in Logan, Utah. The complete results of the analysis are available from MOJN. Four common population metrics are reported in Table 10.

Abundance (the total number of specimens in each sample), taxa richness (the total number of taxa in each sample), and percent dominant taxon (the percentage of counted specimens in the most abundant taxon) are measures of the diversity of a BMI community. In general, BMI communities in impaired streams are less diverse than those in healthy streams. EPT taxa richness is the number of taxa in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These insects are more sensitive to ecosystem stressors, so EPT taxa richness would be expected to decrease in response to any degradation of water quality.

In WY2016, Snake Creek was treated with rotenone in order to eliminate non-native trout species. A pre-rotenone BMI sample was collected five days prior to the treatment, and a post-rotenone BMI sample was collected sixteen days after the treatment. The resulting population metrics for the pre-rotenone and post-rotenone are each shown in Table 10.

Table 10. Population metrics for BMI samples collected in GRBA streams.

Stream	Sampling Date	Abundance (per m2)	# of Taxa (Richness)	# of EPT Taxa (EPT Richness)	% Dominant Taxon
Snake	9/2/2009	1039	25	14	24
	9/7/2010	858	26	13	12
	8/31/2011	1455	26	13	40
	8/30/2012	2924	29	17	14
	8/27/2013	2938	34	20	12
	8/29/2014	2082	30	15	15
	8/25/2015	2955	32	14	13
	8/11/2016 ^b	2663	22	14	33
	9/2/2016 ^c	1295	18	6	26
Baker	8/27/2009 ^a	820	24	13	24
	8/31/2010 ^a	3563	19	10	38
	9/1/2011	989	19	10	16
	8/31/2012	1727	19	12	13

^a. Sample collected at a different site-not comparable to later data.

^b. WY2016 pre-rotenone BMI results

^c. WY2016 post-rotenone BMI results

BMI = benthic macroinvertebrate, EPT = Ephemeroptera, Plecoptera, Trichoptera

Table 10 (continued). Population metrics for BMI samples collected in GRBA streams.

Stream	Sampling Date	Abundance (per m2)	# of Taxa (Richness)	# of EPT Taxa (EPT Richness)	% Dominant Taxon
Baker (continued)	8/28/2013	2550	24	16	17
	8/27/2014	2125	18	11	15
	8/27/2015	1541	22	14	12
	9/8/2016	2372	21	10	17
Lehman	8/27/2009 ^a	566	30	16	32
	8/30/2010	870	17	11	19
	8/30/2011	802	19	8	15
	8/31/2012	2116	19	12	14
	8/29/2013	4119	19	12	11
	9/3/2014	4222	19	12	18
	8/29/2015	1725	17	11	19
	9/1/2016	662	20	11	17
Pine	8/28/2009	1090	22	10	9
	8/26/2010	1973	22	9	14
	9/2/2011	1762	16	8	23
	9/6/2012	2424	21	10	11
	8/30/2013	3655	25	11	11
	8/28/2014	4817	23	12	13
	8/26/2015	3201	18	9	12
	8/31/2016	2649	23	12	23
Ridge	8/28/2009	1891	19	11	12
	8/26/2010	4840	16	7	16
	9/2/2011	3444	18	10	69
	9/6/2012	11647	15	6	18
	8/30/2013	7975	23	11	9
	8/28/2014	3043	20	10	12
	8/26/2015	5550	21	9	14
	8/31/2016	6180	14	6	78
South Fork Big Wash	9/2/2009	506	14	6	16
	9/2/2010	1467	16	6	19
	9/1/2011	563	16	7	37
	8/29/2012	746	19	9	18

^a. Sample collected at a different site-not comparable to later data.

^b. WY2016 pre-rotenone BMI results

^c. WY2016 post-rotenone BMI results

BMI = benthic macroinvertebrate, EPT = Ephemeroptera, Plecoptera, Trichoptera

Table 10 (continued). Population metrics for BMI samples collected in GRBA streams.

Stream	Sampling Date	Abundance (per m2)	# of Taxa (Richness)	# of EPT Taxa (EPT Richness)	% Dominant Taxon
South Fork Big Wash (continued)	8/28/2013	2802	18	7	28
	8/26/2014	1845	12	6	31
	8/27/2015	891	17	9	42
	8/30/2016	712	17	5	43
Mill	7/31/2009	1252	29	15	27
	9/7/2010	4502	27	15	18
	9/1/2011	1228	20	10	15
	8/31/2012	2446	36	19	9
	8/29/2013	2506	30	17	14
	9/3/2014	1521	34	16	29
	8/28/2015	2425	27	12	11
	9/1/2016	2457	26	13	17
Shingle	8/18/2009	614	25	10	12
	9/1/2010	1062	29	12	11
	9/2/2011	1391	23	10	25
	9/6/2012	1842	29	17	12
	8/30/2013	4836	27	15	11
	8/28/2014	2595	29	18	7
	8/26/2015	2649	28	15	10
	8/31/2016	2550	30	16	22
Strawberry	9/28/2009	311	28	13	12
	8/24/2010	1477	26	12	19
	8/30/2011	967	27	11	17
	8/30/2012	2570	33	16	12
	8/27/2013	3448	29	17	21
	9/4/2014	6648	31	16	27
	8/25/2015	3918	28	15	26
	8/30/2016	683	9	0	47

^a. Sample collected at a different site-not comparable to later data.

^b. WY2016 pre-rotenone BMI results

^c. WY2016 post-rotenone BMI results

BMI = benthic macroinvertebrate, EPT = Ephemeroptera, Plecoptera, Trichoptera

Monitoring Results from Lakes

The six subalpine lakes in GRBA were monitored for lake level and temperature, water quality, water chemistry, and water clarity. The results are summarized below.

Lake Level and Ice-Free Period

The relative water levels measured at the lakes near the end of September each year are given in Table 11. Each lake's water level measurement is reported relative to a lake-specific benchmark (assigned a relative elevation of 100 m), so water levels cannot be compared between lakes.

Table 11 also includes the ice-on dates (the date of the first ice formation as determined from temperature and water level records) and ice-off dates (the date that the ice begins melting as determined from the temperature and water level records). The ice-on dates are relatively imprecise (perhaps ± 5 -7 days). They are difficult to identify because the first ice of the season occurs suddenly and often melts quickly. The ice-off dates are more accurate (perhaps ± 1 day) and easier to identify in the temperature and water level records.

Table 11. Lake level and ice-free period.

Lake	Sampling Date	Relative Lake Level (m) Benchmark = 100 m	Ice-On Date	Ice-Off Date
Stella	8/27/2009 ^a	97.76	ND	ND
	9/21/2010	98.51	11/5/09	ND
	9/27/2011	98.76	ND	ND
	9/25/2012	97.87	ND	4/20/12
	9/24/2013	98.52	10/10/12	5/7/13
	9/30/2014	98.72	10/09/13	5/14/14
	9/23/2015	98.46	10/31/14	5/6/15
	9/20/2016	98.46	10/19/15	5/19/16
Teresa	8/27/2009 ^a	97.25	ND	ND
	9/21/2010	98.10	11/13/09	ND
	9/27/2011	98.67	10/19/10	6/12/11
	9/25/2012	98.64	10/4/11	4/28/12
	9/23/2013	99.18	10/22/12	5/10/13
	9/30/2014	100.17	ND	ND
	2015	98.08	ND	ND
	9/20/2016	98.06	10/27/15	4/20/16

^a. Lake level measured outside of the index period.

ND = No data collected

Table 11 (continued). Lake level and ice-free period.

Lake	Sampling Date	Relative Lake Level (m) Benchmark = 100 m	Ice-On Date	Ice-Off Date
Brown	9/21/2010	99.27	ND	ND
	9/27/2011	99.27	10/4/10	5/5/11
	9/25/2012	99.33	10/5/11	3/31/12
	9/24/2013	99.35	10/12/12	4/30/13
	9/30/2014	99.57	10/9/13	4/18/14
	9/23/2015	99.23	11/9/14	3/27/15
	9/20/2016	99.08	12/13/15	4/9/16
Baker	9/25/2009	98.98	ND	ND
	9/22/2010	99.37	11/13/09	6/2/10
	9/29/2011	99.08	10/4/10	6/11/11
	9/27/2012	99.06	ND	ND
	9/25/2013	99.36	10/11/12	5/15/13
	10/1/2014	99.46	10/05/13	5/21/14
	9/22/2015	99.05	11/1/14	5/31/15
	9/21/2016	98.92	10/27/15	6/4/16
Johnson	9/24/2009	98.81	ND	ND
	9/23/2010	98.98	11/13/09	5/31/10
	9/28/2011	99.09	ND	ND
	9/26/2012	99.06	ND	ND
	2013	ND	10/6/12	4/28/13
	10/2/2014	99.10	10/3/13	4/9/14
	9/23/2015	99.03	11/16/14	3/29/15
	9/28/2016	98.98	10/27/15	6/2/16
Dead	9/23/2010	99.02	ND	ND
	9/28/2011	101.33	ND	ND
	9/26/2012	98.10	ND	ND
	2013	ND	10/12/12	5/1/13
	10/2/2014	97.76	ND	4/23/14
	9/24/2015	Dry	11/10/14	5/1/15
	9/28/2016	97.96	ND	4/21/16

^a. Lake level measured outside of the index period.

ND = No data collected

Stella Lake

The pressure transducer from Stella Lake was recovered outside of the water in September 2016 (Figure 12). It appears to have been moved out of the lake in early June.

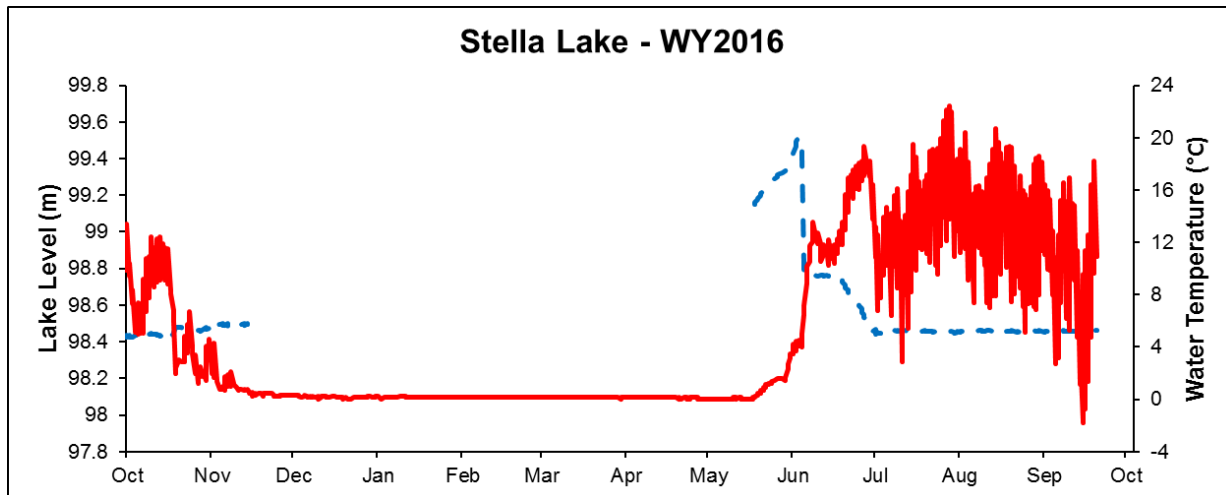


Figure 12. WY2016 water level record (blue line) and temperature record (red line) for Stella Lake.

Teresa Lake

Teresa Lake's relative water level gradually increased for one month after the ice-off date and then sharply increased from 98.58 m on May 30 to 101.51 m on June 10, 2016, a 2.93 m increase over a period of eleven days (Figure 13). Two smaller peaks in lake level occurred on June 24 and July 3, 2016 and caused a 0.07 m and 0.14 m increase in water level over three days, respectively. Summer monsoons most likely caused these increases in lake level.

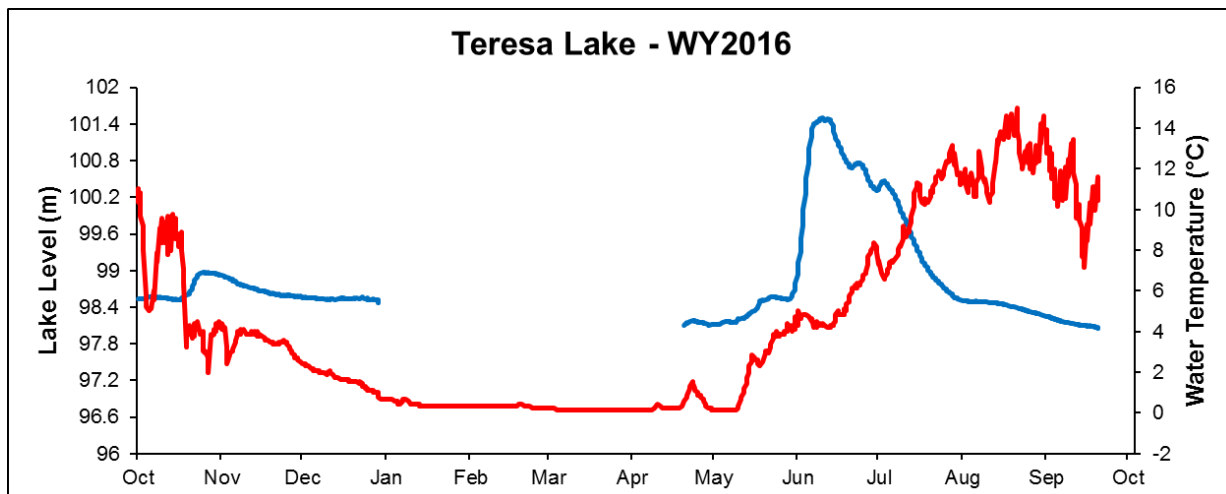


Figure 13. WY2016 water level record (blue line) and temperature record (red line) for Teresa Lake.

Brown Lake

Brown Lake's relative water level steadily increased for two months after the ice-off date, peaking at 99.87 m on June 13, 2016 (Figure 14). The total increase in lake level during this time period was 0.79 m. Levels gradually decreased from mid-June through the end of WY2016.

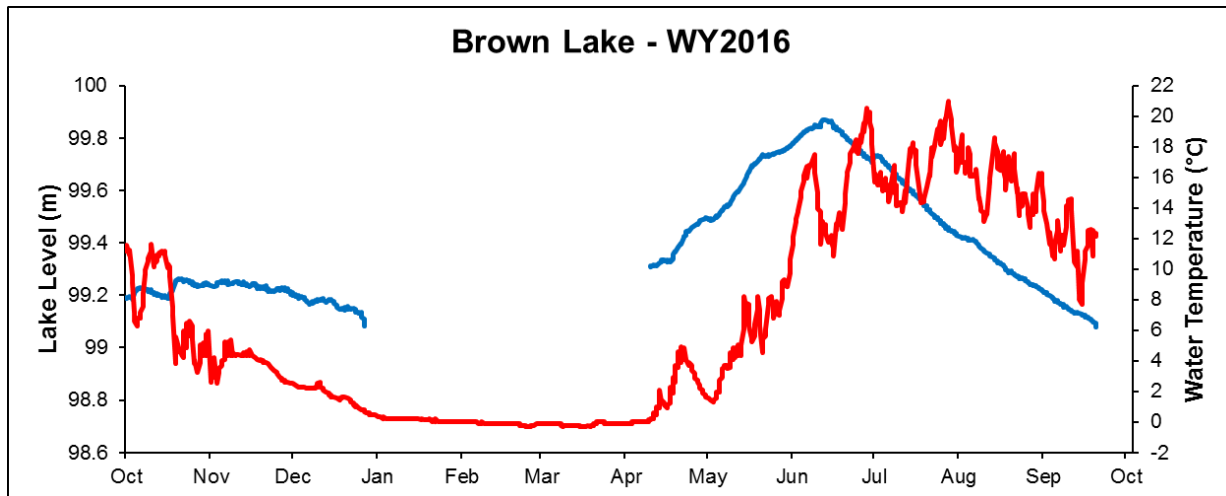


Figure 14. WY2016 water level record (blue line) and temperature record (red line) for Brown Lake.

Baker Lake

The pressure transducer in Baker Lake recorded several erroneous spikes in pressure between November 28, 2015 and February 24, 2016 (Figure 15). Those data were deemed to be outliers and were not reported here. The lake reached its maximum relative water level on June 14, 2016, gradually decreased through the beginning of August, and then remained mostly stable through the end of the water year. A brief rise in lake level of 0.12 m was observed in mid-September, and was likely due to a precipitation event.

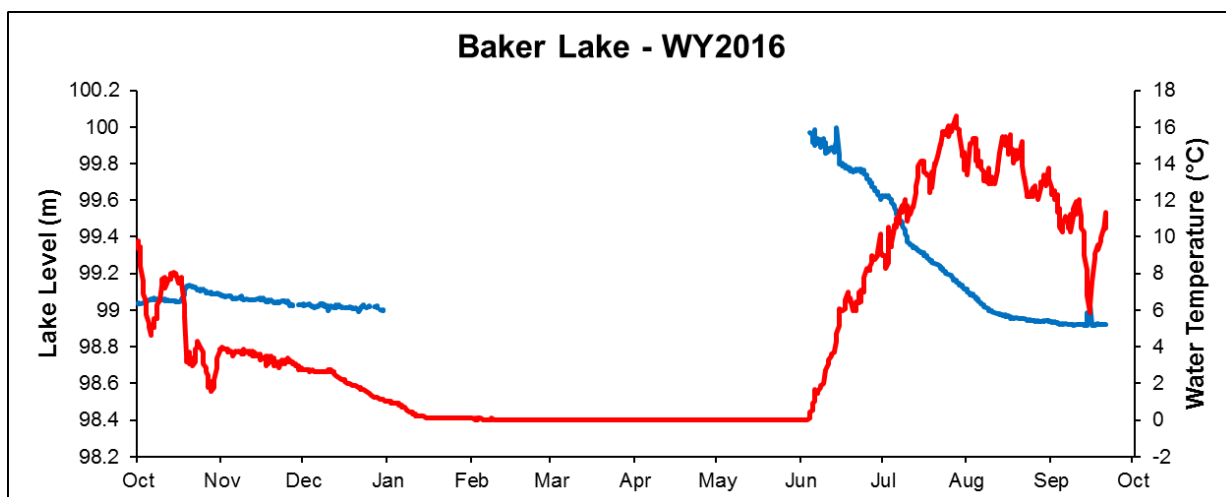


Figure 15. WY2016 water level record (blue line) and temperature record (red line) for Baker Lake.

Johnson Lake

The relative water level in Johnson Lake reached a maximum of 99.40 m on June 6, 2016, gradually decreased through early September, and then remained fairly stable through the end of the water year (Figure 16).

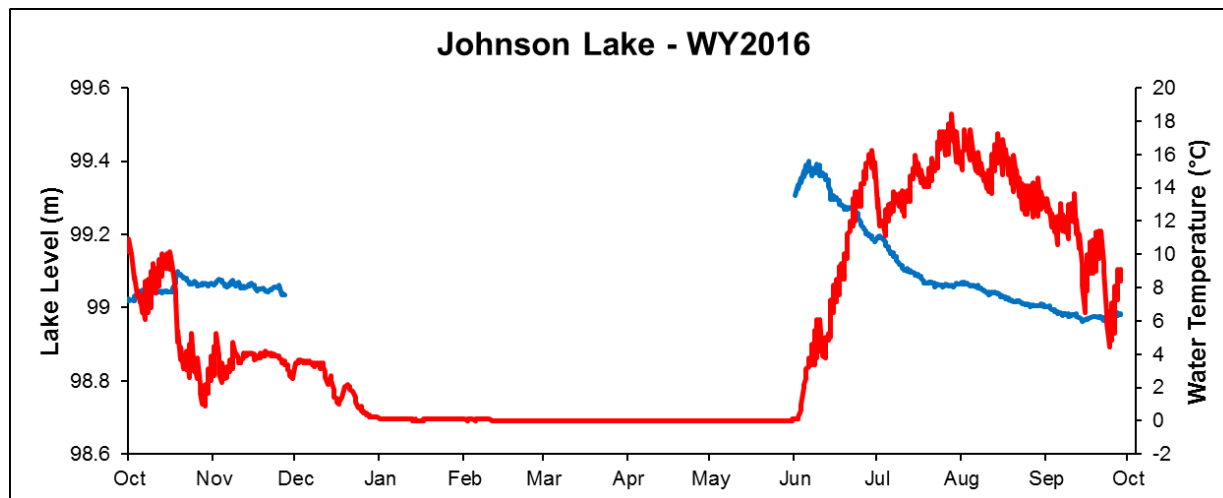


Figure 16. WY2016 water level record (blue line) and temperature record (red line) for Johnson Lake.

Dead Lake

Dead Lake was dry when the pressure transducer was deployed at the beginning of WY2016 (Figure 17). The temperature record began to stabilize in late December, and remained stable through mid-April, most likely because the transducer was covered in snow (Figure 17). The ice-off date for Dead Lake listed in Table 12 is actually the date the snow melted, as indicated by an increase in temperature and lake level.

The relative water level in Dead Lake increased 1.09 m from late April until late May, reaching a maximum of 101.22 m on May 23, 2016. The lake level remained stable through early July and then steadily decreased through the end of the water year.

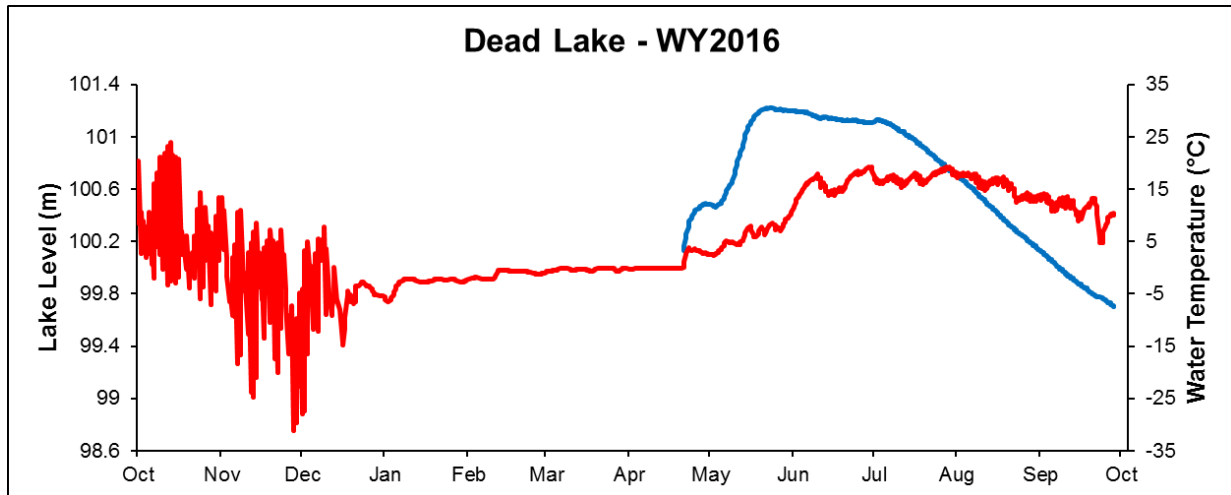


Figure 17. WY2016 water level record (blue line) and temperature record (red line) for Dead Lake.

Lake Water Clarity

Lake water clarity was assessed in the field by measuring Secchi depth (Table 12). The disk was visible on the bottom in all lakes in 2016. While GRBA lakes are likely too shallow to detect small changes in water clarity using this method, these data allow any major decrease in water clarity (i.e. the 2011 and 2012 algae blooms in Dead Lake) to be documented.

Table 12. Secchi depth in GRBA lakes.

Lake	Visit Date	Secchi Depth
Stella	8/27/2009 ^a	visible on bottom (0.9 m)
	9/21/2010	visible on bottom (0.7 m)
	9/27/2011	visible on bottom (1.0 m)
	9/25/2012	visible on bottom (0.7 m)
	9/24/2013	visible on bottom (0.8 m)
	9/30/2014	visible on bottom (1.0 m)
	9/23/2015	visible on bottom (0.7 m)
	9/20/2016	visible on bottom (0.6m)
Teresa	8/27/2009 ^a	visible on bottom (1.3 m)
	9/21/2010	visible on bottom (0.8 m)
	9/27/2011	visible on bottom (1.5 m)
	9/25/2012	visible on bottom (1.4 m)
	9/23/2013	visible on bottom (1.9 m)
	9/30/2014	visible on bottom (2.4 m)
	9/23/2015	visible on bottom (0.8 m)
	9/20/2016	visible on bottom (0.8m)

^a. Lake monitored outside of index period

ND = No data collected

Table 12 (continued). Secchi depth in GRBA lakes.

Lake	Visit Date	Secchi Depth
Brown	9/21/2010	visible on bottom (0.5 m)
	9/27/2011	visible on bottom (0.9 m)
	9/25/2012	visible on bottom (0.5 m)
	9/24/2013	visible on bottom (0.7 m)
	9/30/2014	visible on bottom (0.9 m)
	9/23/2015	visible on bottom (0.5 m)
	9/20/2016	visible on bottom (0.3m)
Baker	9/25/2009	visible on bottom (2.1 m)
	9/22/2010	visible on bottom (2.0 m)
	9/29/2011	visible on bottom (2.2 m)
	9/27/2012	visible on bottom (2.1 m)
	9/25/2013	visible on bottom (2.3 m)
	10/7/2014	visible on bottom (2.3 m)
	9/22/2015	visible on bottom (1.9 m)
	9/21/2016	visible on bottom (2.0m)
Johnson	9/24/2009	visible on bottom (4.4 m)
	9/23/2010	visible on bottom (4.2 m)
	9/28/2011	visible on bottom (4.9 m)
	9/26/2012	visible on bottom (3.4 m)
	2013	ND
	10/2/2014	visible on bottom (4.0 m)
	9/24/2015	visible on bottom (4.0 m)
	9/28/2016	visible on bottom (4.4m)
Dead	9/23/2010	visible on bottom (1.4 m)
	9/28/2011	bottom not visible (3.7 m)
	9/26/2012	bottom not visible (0.3 m)
	2013	ND
	10/2/2014	visible on bottom (0.2 m)
	9/24/2015	dry
	9/28/2016	visible on bottom (0.3m)

^a. Lake monitored outside of index period

ND = No data collected

Lake Water Chemistry

Lake water samples were collected near the deepest point in each lake using the hand-dipping method. These samples were analyzed for basic chemistry and nutrient concentrations at the

Cooperative Chemical Analysis Facility (CCAL) in Corvallis, Oregon. This section describes the results of these analyses and the water quality data measured at the time of sampling.

Lake Water Quality

A water quality depth profile was taken near the deepest point of each lake (Table 13). Measurements were evenly spaced from the water surface to the lake bottom. The parameters measured were temperature, dissolved oxygen, pH, and specific conductance. A pH meter was not available during the Johnson and Dead lakes monitoring.

Table 13. Water quality depth profiles measured in 2016 in GRBA lakes.

Lake and Sampling Date	Depth (m)	pH	Dissolved Oxygen (mg/L)	Specific Conductance (µs/cm)	Temperature (°C)
Stella 9/20/2016	0.00	7.41	7.90	40.00	9.88
	0.30	7.30	7.62	38.00	9.85
	0.64	7.29	7.42	38.00	9.92
Teresa 9/20/2016	0.00	6.62	6.83	25.00	12.07
	0.30	6.67	6.79	24.00	11.42
	0.79	6.66	6.83	24.00	11.29
Brown 9/20/2016	0.00	7.37	6.26	52.00	13.59
	0.34	7.25	6.21	52.00	13.44
Baker 9/21/2016	0.00	8.18	7.70	18.00	10.94
	0.61	7.92	7.59	18.00	10.91
	1.22	7.87	7.55	18.00	10.75
	1.83	7.76	7.75	18.00	10.43
	1.95	7.70	7.60	18.00	10.38
Johnson 9/28/2016	0.00	ND	5.2	45.7	8.60
	0.61	ND	6.02	43.9	8.4
	1.22	ND	6.11	43.8	8.3
	1.83	ND	6.14	43.8	7.8
	2.44	ND	6.08	44	7.3
	3.05 ^a	ND	6.16	43.7	6.9
Dead Lake 9/28/2016	0.00	ND	6.62	30.9	13.2
	0.27	ND	2.97	29.4	12

^a. Extent of the cable, not the actual bottom measurement

ND – No data collected

Nutrients

Nutrient concentrations in GRBA lakes were very low and comparable to previous years, with the exception of Dead Lake (Table 14). Excluding Dead Lake, the highest total nitrogen (TN) value was

0.95 mg/L, observed in Brown Lake. The highest total phosphorus (TP) value was 0.024 mg/L, observed in both Baker Lake and Teresa Lake.

All nutrients measured in Dead Lake, with the exception of nitrate + nitrite, were higher than previous years. TN concentrations were particularly high, with values that were five to ten times higher in WY2016 than in previous years. CCAL noted that black particulates were found in the filtered sample, and corrections were applied to the results from these samples.

Table 14. Nutrient concentrations in GRBA lakes.

Lake	Sampling Date	Total N mg/L	Total Dissolved N mg/L	Nitrate + Nitrite mg/L as N	Total P mg/L	Total Dissolved P mg/L
Stella	8/27/2009 ^a	0.25	0.25	0.002 ^d	0.012	0.007
	9/21/2010	0.27	0.26	0.001 ^d	0.011	0.007
	9/27/2011	0.28	0.28	0.002 ^d	0.016	0.009
	9/25/2012	0.43	0.31	0.005	0.019	0.007
	9/24/2013	0.45	0.35	0.001 ^d	0.011	0.007
	9/30/2014	0.22	0.24 ^b	0.009	0.008	0.005 ^d
	9/25/2015	0.32	0.27	0.001 ^d	0.009	0.005 ^d
	9/20/2016	0.34	0.26	0.001 ^d	0.019	0.005 ^d
Teresa	8/27/2009 ^a	0.21	0.39 ^c	0.252 ^c	0.012	0.010
	9/21/2010	0.68	0.64	0.014	0.054	0.035
	9/27/2011	0.48	0.47	0.360	0.012	0.010
	9/25/2012	0.77	0.69	0.599	0.012	0.006
	9/23/2013	0.89	0.84	0.789	0.010	0.006
	9/30/2014	0.79	0.81 ^b	0.724	0.014	0.015 ^b
	9/25/2015	0.49	0.34	0.010	0.040	0.018
	9/20/2016	0.37	0.29	0.003	0.024	0.016
Brown	2009	ND	ND	ND	ND	ND
	9/21/2010	0.69	0.63	0.025	0.015	0.009
	9/27/2011	0.49	0.46	0.011	0.016	0.008
	9/25/2012	0.57	0.52	0.076	0.009	0.004 ^d
	9/24/2013	0.41	0.35	0.011	0.009	0.004 ^d

^a. Lake sampled outside of index period.

^b. TDN (or TDP) value greater than TN (or TP) value with the difference within precision limits, indicating that the samples are analytically equal in concentration.

^c. TDN (or TDP) value greater than TN (or TP) value with the difference outside the expected range of variability, indicating contamination of the sample.

^d. Concentration below the minimum quantitation limit (ML)

ND = No data collected, N = nitrogen, P = phosphorus

Table 14 (continued). Nutrient concentrations in GRBA lakes.

Lake	Sampling Date	Total N mg/L	Total Dissolved N mg/L	Nitrate + Nitrite mg/L as N	Total P mg/L	Total Dissolved P mg/L
Brown (continued)	9/30/2014	0.33	0.34 ^b	0.040	0.008	0.006
	9/25/2015	0.87	0.46	0.008	0.025	0.006
	9/20/2016	0.95	0.83	0.006	0.019	0.008
Baker	9/25/2009	0.26	0.24	0.052	0.025	0.019
	9/22/2010	0.28	0.29 ^b	0.068	0.033	0.026
	9/29/2011	0.27	0.37 ^c	0.107	0.020	0.013
	9/27/2012	0.43	0.42	0.307	0.017	0.010
	9/25/2013	0.52	0.48	0.403	0.014	0.005 ^d
	10/7/2014	0.54	0.46	0.384	0.015	0.009
	9/22/2015	0.45	0.40	0.234	0.026	0.023
	9/21/2016	0.23	0.19	0.045	0.024	0.015
Johnson	9/24/2009	0.20	0.21	0.004	0.008	0.006
	9/23/2010	0.21	0.23 ^b	0.004	0.009	0.008
	9/28/2011	0.14	0.13	0.003	0.006	0.005 ^d
	9/26/2012	0.16	0.14	0.011	0.006	0.003 ^d
	2013	ND	ND	ND	ND	ND
	10/2/2014	0.19	0.19	0.024	0.009	0.009
	9/24/2015	0.28	0.21	0.001 ^d	0.010	0.008
	9/28/2016	0.30	0.19	0.005	0.009	0.005 ^d
Dead	2009	ND	ND	ND	ND	ND
	9/23/2010	0.82	0.95 ^c	0.001 ^d	0.051	0.039
	9/28/2011	0.54	0.45	0.001 ^d	0.029	0.018
	9/26/2012	1.08	0.88	0.001 ^d	0.218	0.044
	2013	ND	ND	ND	ND	ND
	10/2/2014	0.81	0.77	0.002 ^d	0.160	0.029
	2015	Dry	Dry	Dry	Dry	Dry
	9/28/2016	5.53	1.84	0.000 ^d	0.525	0.086

^a. Lake sampled outside of index period.

^b. TDN (or TDP) value greater than TN (or TP) value with the difference within precision limits, indicating that the samples are analytically equal in concentration.

^c. TDN (or TDP) value greater than TN (or TP) value with the difference outside the expected range of variability, indicating contamination of the sample.

^d. Concentration below the minimum quantitation limit (ML)

ND = No data collected, N = nitrogen, P = phosphorus

Major Ions and Acid Neutralization Capacity

Water samples were analyzed for sodium, potassium, calcium, magnesium, sulfate, and chloride (Table 15). Systematic changes in the concentration of these ions over time may be useful in determining whether the lake is being affected by atmospheric deposition. The relatively minor year-to-year variations of these concentrations suggest that any future changes will be detectable.

The acid neutralizing capacity (ANC) is used to determine a water body's sensitivity to acidification. Lakes with ANC values of less than 100 $\mu\text{eq/L}$ are considered to be sensitive to acidification (Campbell et al. 2004, Stoddard et al. 2008, Burns et al. 2011). In WY2016, all GRBA lakes had the highest ANC values out of the 2009-2016 record, and all ANC values were greater than 100 $\mu\text{eq/L}$.

Table 15. Major ion concentrations and acid neutralization capacity in GRBA lakes.

Lake	Sampling Date	Sodium mg/L	Potassium mg/L	Calcium mg/L	Magnesium mg/L	Sulfate mg/L as S	Chloride mg/L	ANC µeq/L
Stella	8/27/2009 ^a	1.25	0.51	3.87	0.71	0.19	0.50	241
	9/21/2010	1.62	0.57	4.35	0.84	0.23	0.62	335
	9/27/2011	1.21	0.60	3.64	0.61	0.20	0.46	283
	9/25/2012	1.35	0.69	4.03	0.75	0.19	0.60	320
	9/24/2013	1.39	0.43	3.85	0.68	0.15	0.61	300
	9/30/2014	1.19	0.52	4.47	0.72	0.16	0.48	312
	9/25/2015	1.49	0.38	4.97	0.81	0.08	0.54	377
	9/20/2016	1.63	0.65	4.9	0.87	0.07	0.67	384
Teresa	8/27/2009 ^a	0.69	0.34	1.96	0.43	0.34	0.45	92
	9/21/2010	0.87	0.59	2.44	0.64	0.36	0.67	192
	9/27/2011	0.55	0.28	1.80	0.46	0.33	0.32	129
	9/25/2012	0.58	0.33	2.01	0.52	0.40	0.45	127
	9/23/2013	0.74	0.32	2.35	0.58	0.44	0.53	135
	9/30/2014	0.67	0.37	2.32	0.57	0.41	0.48	117
	9/25/2015	0.88	0.39	2.46	0.62	0.37	0.45	207
	9/20/2016	0.83	0.50	2.92	0.74	0.39	0.51	237
Brown	2009	ND	ND	ND	ND	ND	ND	ND
	9/21/2010	2.05	1.19	4.08	1.13	0.57	1.76	306
	9/27/2011	0.98	0.63	1.95	0.55	0.25	0.67	168
	9/25/2012	1.19	0.78	2.12	0.66	0.56	1.12	176
	9/24/2013	0.96	0.56	1.88	0.57	0.60	0.72	161
	9/30/2014	0.85	0.46	1.97	0.53	0.40	0.65	137

^a. Lake sampled outside of index period.

ND = No data collected, ANC = acid neutralizing capacity.

Table 15 (continued). Major ion concentrations and acid neutralization capacity in GRBA lakes.

Lake	Sampling Date	Sodium mg/L	Potassium mg/L	Calcium mg/L	Magnesium mg/L	Sulfate mg/L as S	Chloride mg/L	ANC µeq/L
Brown (continued)	9/25/2015	1.93	1.06	3.94	1.07	0.56	1.46	304
	9/20/2016	2.87	1.57	5.06	1.43	0.55	2.68	392
Baker	9/25/2009	0.73	0.33	1.94	0.37	0.41	0.55	144
	9/22/2010	0.70	0.40	1.77	0.43	0.43	0.44	140
	9/29/2011	0.72	0.36	1.63	0.37	0.39	0.57	129
	9/27/2012	0.53	0.27	1.77	0.39	0.41	0.37	121
	9/25/2013	0.62	0.26	1.80	0.39	0.39	0.37	118
	10/7/2014	0.53	0.25	1.83	0.39	0.41	0.32	103
	9/22/2015	0.65	0.38	2.24	0.47	0.55	0.37	152
	9/21/2016	0.73	0.30	2.03	0.44	0.51	0.39	159
Johnson	9/24/2009	1.06	0.29	5.76	0.38	1.15	0.42	293
	9/23/2010	0.96	0.30	5.30	0.40	1.12	0.24	258
	9/28/2011	0.79	0.21	4.16	0.30	0.91	0.18	238
	9/26/2012	0.55	0.06	6.08	0.36	1.18	0.10	301
	2013	ND	ND	ND	ND	ND	ND	ND
	10/2/2014	0.65	0.13	5.69	0.34	1.08	0.14	264
	9/24/2015	1.13	0.37	6.35	0.43	1.20	0.44	333
	9/28/2016	1.06	0.33	6.27	0.41	1.30	0.32	339
Dead	2009	ND	ND	ND	ND	ND	ND	ND
	9/23/2010	1.52	0.89	1.80	0.41	0.34	1.04	152
	9/28/2011	1.25	0.73	2.50	0.52	0.27	0.58	214
	9/26/2012	1.62	0.52	1.61	0.39	0.24	0.92	154
	2013	ND	ND	ND	ND	ND	ND	ND

^a. Lake sampled outside of index period.

ND = No data collected, ANC = acid neutralizing capacity.

Table 15 (continued). Major ion concentrations and acid neutralization capacity in GRBA lakes.

Lake	Sampling Date	Sodium mg/L	Potassium mg/L	Calcium mg/L	Magnesium mg/L	Sulfate mg/L as S	Chloride mg/L	ANC µeq/L
Dead (continued)	10/2/2014	1.75	1.02	3.24	0.73	1.85	0.65	137
	2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	9/28/2016	2.25	0.86	3.05	0.63	0.66	0.99	247

^a. Lake sampled outside of index period.

ND = No data collected, ANC = acid neutralizing capacity.

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) are discussed in Appendix A. Most of the QA/QC issues encountered with WY2016 data were missing continuous water quality data. This is primarily the result of malfunctioning water quality probes. Additional details are provided in Appendix A. MOJN is in the process of upgrading its sondes to newer models to help prevent these issues in the future. In the future, MOJN should also provide a more comprehensive water quality training for both GRBA and MOJN staff, with an emphasis on preventing and identifying equipment malfunction. MOJN will work to establish a timely line of communication between GRBA and MOJN throughout the field season in order to address equipment problems and other data quality issues as they occur. Many of the missing data are due to faulty probes that were faulty throughout the entire season. Data loss could have been minimized if new probes were ordered and placed on the instruments as soon as errors were detected.

Discussion

Water year 2016 had above average annual precipitation; however, snowpack and monsoonal precipitation in July and August were below average. The largest summer storms resulted in brief periods of high stream discharge, but no major changes to stream chemistry were observed. Baker and Teresa Lakes exhibited water level increases of less than 0.15 m in response to summer storms. Dead Lake exhibited higher Total Nitrogen (TN), Total Dissolved Nitrogen (TDN), and Total Phosphorus (TP) in WY2016 than in previous years. No major changes in water chemistry were observed in any of the other lakes.

The overall water quality of the streams and lakes in GRBA is high. Both the streams and the lakes have low nutrient concentrations, circumneutral to slightly basic pH, low temperatures, and high levels of oxygen saturation. The four Class A streams met the water quality standards set forth by the state of Nevada. The observed BMI communities in the streams are consistent with unimpaired water quality.

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Appendix A: QA/QC Measurements

This appendix contains the results of all QA/QC measurements made in the field and the laboratory during the 2016 field season.

Instrument Testing

QA/QC testing of the instruments was performed at the beginning of the field season in accordance with the protocol SOPs (Moret et al. 2012). The instruments included in the pre-season testing are listed in Table A-1.

Table A-1. Instruments included in QA/QC testing

Instrument	Stream	Owner	Type	Parameters	Manufacturer	Model
A	Upper Snake Creek	GRBA	Sonde	All 4	YSI	6920 V2
B	Strawberry Creek	MOJN	Sonde	All 4	YSI	6920 V2
C	Lehman Creek	MOJN	Sonde	All 4	YSI	6920 V2
D	Baker Creek	MOJN	Sonde	All 4	YSI	6920 V2
E	Lower Snake Creek	MOJN	Sonde	All 4	YSI	6920

Temperature Sensor Comparison

Temperature sensors are calibrated by the manufacturer, not by field personnel. To ensure that temperature sensors are functioning properly they are tested against each other in water baths of three different relative temperatures. First, all sondes were placed in a large cooler containing ice water. The sondes collected data every minute for approximately ten minutes. This process was repeated in a cooler containing room-temperature water, and then hot water. Table A-2 shows the average of ten temperature readings in each bath. Temperature readings across instruments should be within 0.2°C of each other in their respective water baths. The ice bath was the most successful, and all temperature sensors met the 0.2°C standard. In the room-temperature water bath, all sondes were within the acceptable range except for sonde A, which ranged from 0.53 - 0.70°C higher than the other sondes. The hot water bath was the least successful, with values varying by 1.97°C. The only two sondes that were within the acceptable limits were C and E. In the future, a NIST-certified thermistor will be used to check the accuracy of the individual temperature sensors.

Table A-2. Temperature sensor comparison results.

Instrument	Ice Bath	Room-Temperature Bath	Hot Bath
A	9.12	21.75 ^a	40.71 ^a
B	9.10	21.05	40.05 ^a
C	9.26	21.07	39.79
D	9.06	21.22	41.70 ^a
E	9.23	21.15	39.73

^a. failed temperature values

AMS+ Results

Alternative Measurement Sensitivity Plus (AMS+) is used to determine measurement sensitivity of an instrument in a well-mixed stream. To assess AMS+, instruments were placed side-by-side in Lehman Creek and seven measurements were taken. AMS+ was calculated using the equation below. AMS+ values should meet the sensitivity measurement quality objectives (MQOs) listed in the protocol.

$$AMS+ = t \times s$$

where

$t = 3.708$, the 99% confidence middle (two-sided) t-value for a sample size of 7, and

s = sample standard deviation of 7 in-situ measurement values

The pH probe on sonde B did not meet the sensitivity standards. Additionally, the specific conductance and pH probes on sonde D did not meet the sensitivity standards. DO data are not available for sondes B and C due to probe malfunction. All other probes met the standards (Table A-3).

Table A-3. AMS+ results.

Sonde	Temp	Specific Conductance	pH	Dissolved Oxygen
A	0.03	1.98	0.01	0.04
B	0.04	0.00	0.55 ^a	ND
C	0.03	1.81	0.04	ND
D	0.03	10.24 ^a	1.09 ^a	0.04
E	0.03	1.40	0.27	0.21
Sensitivity MQO	0.30	5.00	0.30	0.40

^a. Outside of acceptable standards

ND = No data collected

Laboratory QA/QC

The discussion below summarizes QA/QC checks and procedures for laboratory analytical data collected during 2016. All analyses were performed by the Cooperative Chemical Analytical Laboratory (CCAL).

Laboratory Detection Limits and Quantitation Limits

CCAL met the MQOs for detection limits. In seven instances, analytes were detected but the values were below the minimum level of quantitation (ML). These data have been flagged and careful consideration should be taken prior to using these data in trend analyses.

Dissolved Concentrations Exceeding Total Concentrations

The South Fork Big Wash sample had a total dissolved nitrogen value that exceeded the total nitrogen value; however, these values were within precision limits and are considered analytically equal.

Duplicate Analyses

In 2016, CCAL performed 25 duplicate analyses and 1 triplicate analysis on 15 samples and 1 field blank. At least one duplicate analysis was performed for each of the measured parameters.

The analytical results for the duplicate samples are compared using Relative Percent Difference (RPD). The RPD for each pair of measurements is calculated as:

$$RPD = \left[\frac{S_1 - S_2}{(S_1 + S_2) / 2} \right] \times 100$$

where:

S_1 = the larger test result values, and

S_2 = the smaller test result value

The results of the duplicate analyses and RPD calculations are given in Table A-4. All RPD values were less than the laboratory precision MQO of 30%, with the exception of the field blank. The field blank RPD was far beyond the 30% MQO limit, indicating potential bias.

Table A-4. 2016 duplicate laboratory analyses and relative percent difference (RPD) values.

Sample	Analysis	Original Result	Duplicate Result	Triplicate Result	RPD
Baker Creek	Na (mg/L)	2.57	2.62	—	2%
Baker Creek	K (mg/L)	0.42	0.42	—	0%
Baker Creek	Ca (mg/L)	4.51	4.46	—	1%
Baker Creek	Mg (mg/L)	0.8	0.76	—	5%
Baker Lake	Alk CaCO ₃	7.96	7.94	—	0%
Baker Lake	NO ₃ + NO ₂ -N (mg/L)	0.045	0.046	—	2%
Brown Lake	Cl (mg/L)	2.68	2.69	—	0%
Brown Lake	SO ₄ -S (mg/L)	0.55	0.56	—	2%
Field Blank	TDN (mg N/L)	0.02	0.00	—	200%
Field Blank	TDP (mg P/L)	0.000	0.000	—	0%
Johnson Lake	TN (mg N/L)	0.3	0.3	—	0%
Lehman Creek	pH	7.7	7.7	—	0%
Lehman Creek	Alk CaCO ₃	16.74	16.74	—	0%
Lehman Creek	Conductivity	36.2	36.7	—	1%

Table A-4 (continued). 2016 duplicate laboratory analyses and relative percent difference (RPD) values.

Sample	Analysis	Original Result	Duplicate Result	Triplicate Result	RPD
Lehman Creek	Cl (mg/L)	0.43	0.43	–	0%
Lehman Creek	SO ₄ -S (mg/L)	0.40	0.41	–	2%
Pine Creek	Alk CaCO ₃	13.67	13.4	–	2%
Pine Creek	Alk CaCO ₃	13.67	–	13.3	3%
Pine Creek	TDP (mg P/L)	0.008	0.008	–	0%
Pine Creek	TDN (mg N/L)	0.23	0.23	–	0%
Snake Creek	NO ₃ + NO ₂ -N (mg/L)	0.001	0.001	–	0%
Stella Lake	TP (mg P/L)	0.019	0.023	–	19%
Stella Lake	Na (mg/L)	1.63	1.64	–	1%
Stella Lake	K (mg/L)	0.65	0.64	–	2%
Stella Lake	Ca (mg/L)	4.90	4.88	–	0%
Stella Lake	Mg (mg/L)	0.87	0.85	–	2%

Effectiveness and Completeness

Effectiveness, E, is calculated as:

$$E = \left(\frac{U}{N} \right) \times 100$$

where:

U = number of useable parameter values, and

N = number of parameter values collected, including low-quality data that cannot be used in future analyses

Completeness, C, is calculated as:

$$C = \left(\frac{U}{P} \right) \times 100$$

where:

P = number of potential parameter values that would have been collected had the field season proceeded as envisioned in the sampling plan

Annual Stream Visits

All of the streams were visited in 2016 and all of the chemistry data are useable. As a result, both the effectiveness and completeness were 100%.

Annual Lake Visits

All of the lakes were visited in 2016 and all of the chemistry data are useable. As a result, both the completeness and effectiveness were 100%.

Lake Level Records

All lakes except Stella Lake had a 100% effectiveness and completeness. Stella Lake's pressure transducer was found out of the water at the annual visit. The pressure transducer record suggests that the instrument was moved out of the water around June 5, 2016. The effectiveness and completeness for Stella Lake were each 70.25%.

Continuous Water Quality

The effectiveness and completeness statistics for the continuous water quality monitoring are summarized in Table A-5. Continuous water quality monitoring in Upper Snake Creek was the most successful of all locations (C = 100%, E = 100%). Periods of missing data were due to probe malfunction. In the future, faulty probes will be replaced as soon as possible to reduce the length of missing data. Instruments will also be sent off for maintenance prior to the start of the field season to detect and fix potential errors.

Table A-5. Effectiveness and completeness of continuous water quality monitoring for the 77-day index period in 2016.

Stream	Parameter*	Days of Data (N)	Days of Usable Data (U)	% Effectiveness (E)	% Completeness (C), P=77
Baker	Temperature	64	62	97	81
	DO	64	62	97	81
	pH	0	0	0	0
	SpCond	64	0	0	0
	Average	48	31	48	40
Lehman	Temperature	77	77	100	100
	DO	77	77	100	100
	pH	77	77	100	100
	SpCond	23	23	100	30
	Average	64	64	100	82
Upper Snake	Temperature	77	77	100	100
	DO	77	77	100	100
	pH	77	77	100	100
	SpCond	77	77	100	100
	Average	77	77	100	100
Lower Snake	Temperature	44	44	100	57
	DO	25	25	100	32
	pH	44	44	100	57

* SpCond = specific conductance

Table A-5 (continued). Effectiveness and completeness of continuous water quality monitoring for the 77-day index period in 2016.

Stream	Parameter*	Days of Data (N)	Days of Usable Data (U)	% Effectiveness (E)	% Completeness (C), P=77
Lower Snake (continued)	SpCond	38	38	100	49
	Average	38	38	100	49
Strawberry	Temperature	38	38	100	49
	DO	0	0	0	0
	pH	38	38	100	49
	SpCond	38	38	100	49
	Average	29	29	75	37

* SpCond = specific conductance

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