



Mojave Desert Network Inventory and Monitoring Streams and Lakes Protocol

2011-2013 Monitoring Data

Natural Resource Data Series NPS/MOJN/NRDS—2015/817



ON THE COVER

GRBA staff deploy a water quality sonde in June 2012.

Photograph courtesy of MOJN

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Natural Resource Data Series NPS/MOJN/NRDS—2015/817

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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.

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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.

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.

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Contents

	Page
Figures.....	v
Tables.....	vii
Executive Summary	ix
Acknowledgments.....	x
List of Acronyms	xi
Introduction.....	1
Methods.....	3
Streams	3
Lakes	3
Precipitation, Snowpack, and Discharge.....	5
Water Year 2011.....	7
Water Year 2012.....	8
Water Year 2013.....	9
Monitoring Results from Streams	11
Continuous Water Quality	11
Baker Creek.....	11
Lehman Creek	17
Lower Snake Creek	22
Upper Snake Creek.....	27
Strawberry Creek.....	31
Stream Water Chemistry	36
Water Quality Parameters.....	36
Nutrients	37
Major Ions and Acid Neutralization Capacity.....	39
Stream Benthic Macroinvertebrates	40
Monitoring Results from Lakes	42
Lake Level and Ice-Free Period	42
Stella Lake	43

Contents (continued)

	Page
Teresa Lake	44
Brown Lake	45
Baker Lake.....	46
Johnson Lake	46
Dead Lake.....	47
Lake Water Clarity	48
Lake Water Chemistry.....	48
Water Quality Parameters.....	48
Nutrients	51
Major Ions and Acid Neutralization Capacity.....	52
Quality Assurance and Quality Control	54
Discussion	55
Literature Cited	56
Appendix A: QA/QC Measurements	57

Figures

	Page
Figure 1. Map of sampling locations in GRBA.	2
Figure 2. Annual precipitation by water year (October 1 to September 30) recorded at the NWS COOP weather station at Lehman Caves Visitor Center.	5
Figure 3. NRDS depth-of-snowpack data collected at Baker Creek Snowcourse #3 near April 1 of each year.....	6
Figure 4. Daily precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center in WY2011.	7
Figure 5. USGS discharge record for Lehman Creek in WY2011.	8
Figure 6. Daily precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center in WY2012.	8
Figure 7. USGS discharge record for Lehman Creek in WY2012.	9
Figure 8. Daily precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center in WY2013.	10
Figure 9. Baker Creek water quality data from the 2011 field season.	14
Figure 10. Baker Creek water quality data from the 2012 field season.	15
Figure 11. Baker Creek water quality data from the 2013 field season.	16
Figure 12. Lehman Creek water quality data from the 2011 field season.	19
Figure 13. Lehman Creek water quality data from the 2012 field season.	20
Figure 14. Lehman Creek water quality data from the 2013 field season.	21
Figure 15. Lower Snake Creek water quality data from the 2011 field season.	24
Figure 16. Lower Snake Creek water quality data from the 2012 field season.	25
Figure 17. Lower Snake Creek water quality data from the 2013 field season.	26
Figure 18. Upper Snake Creek water quality data from the 2012 field season.....	29
Figure 19. Upper Snake Creek water quality data from the 2013 field season.....	30
Figure 20. Strawberry Creek water quality data from the 2011 field season.....	33
Figure 21. Strawberry Creek water quality data from the 2012 field season.....	34
Figure 22. Strawberry Creek water quality data from the 2013 field season.....	35
Figure 23. Water level records and temperature records for Stella Lake.....	43
Figure 24. Water level records and temperature records for Teresa Lake.	44
Figure 25. Water level records and temperature records for Brown Lake.....	45

Figures (continued)

	Page
Figure 26. Water level records and temperature records for Baker Lake.	46
Figure 27. Water level record, water level record not tied to a lake level reading, and temperature record for Johnson Lake.....	47
Figure 28. Water level record, water level record not tied to a lake level reading, and temperature record for Dead Lake.	47

Tables

	Page
Table 1. USGS measurements of mean annual discharge, date of peak discharge, and peak discharge for Lehman Creek gage.....	6
Table 2. UTM coordinates (NAD 83, Zone 11S) for continuous water quality monitoring locations.	11
Table 3. Average water quality parameter values in Baker Creek, 2009-2013.....	12
Table 4. Average water quality parameter values in Lehman Creek, 2009-2013.	17
Table 5. Average water quality parameter values in Lower Snake Creek, 2009-2013.	22
Table 6. Average water quality parameter values in Upper Snake Creek, 2009-2013.	27
Table 7. Average water quality parameter values in Strawberry Creek, 2009-2013.	31
Table 8. Water quality parameters in GRBA streams.	36
Table 9. Nutrient concentrations in GRBA streams.....	37
Table 10. Major ion concentrations and acid neutralization capacity in GRBA streams.....	39
Table 11. Population metrics for BMI samples collected in GRBA streams.....	40
Table 12. Measured water levels in GRBA lakes.	42
Table 13. Secchi depth in GRBA lakes.....	48
Table 14. Water quality depth profiles for 2011 collected in GRBA lakes.	49
Table 15. Water quality depth profiles for 2012 collected in GRBA lakes.	50
Table 16. Water quality depth profiles for 2013 collected in GRBA lakes.	51
Table 17. Nutrient concentrations in GRBA lakes.....	51
Table 18. Major ion concentrations and acid neutralization capacity in GRBA lakes.....	53
Table A-1. Instruments included in QA/QC testing.....	57
Table A-2. Temperature sensor comparison results.....	57
Table A-3. Head-to-head comparison of water quality measurements made using different instruments.	58
Table A-4. AMS+ values for water quality instruments used during the field season.....	59
Table A-5. 2011 stream cross-section data for selected water quality parameters.	60
Table A-6. 2012 stream cross-section data for selected water quality parameters.	60
Table A-7. 2013 stream cross-section data for selected water quality parameters.	60
Table A-8. Summary of 2011 laboratory analyses with TDN > TN.....	61

Tables (continued)

	Page
Table A-9. Summary of 2013 laboratory analyses with TDN > TN.....	61
Table A-10. 2011 duplicate laboratory analyses and relative percent difference (RPD) values.	62
Table A-11. 2012 duplicate laboratory analyses and relative percent difference (RPD) values.	63
Table A-12. 2013 duplicate laboratory analyses and relative percent difference (RPD) values.	64
Table A-13. 2012 nutrient and major ion concentrations for field filtration blank.	65
Table A-14. Effectiveness and completeness of continuous water quality monitoring for 77-day index period in 2011.	66
Table A-15. Effectiveness and completeness of continuous water quality monitoring for 77-day index period in 2012.	67
Table A-16. Effectiveness and completeness of continuous water quality monitoring for 77-day index period in 2013.	67

Executive Summary

The Mojave Desert Network Inventory and Monitoring Program (MOJN I&M) is a National Park Service 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 presents data collected in the 2011, 2012, and 2013 field seasons, and serves as the Annual Reports for those years.

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.

The first five years of monitoring have provided valuable baseline data on the health of the aquatic ecosystems in GRBA and provided information on how they respond to wet years and dry years. MOJN I&M will prepare synthesis reports incorporating these data following the publication of the stream discharge records and the 2014 annual report.

Acknowledgments

The data in this report was collected thanks to the efforts of numerous GRBA and MOJN I&M staff. In particular, Mark Pepper and Jonathan Reynolds collected the bulk of the water quality and discharge 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.

Helpful reviews were provided by Ben Roberts and Jonathan Reynolds of GRBA and Gary Karst of the NPS Water Resources Division.

List of Acronyms

AMS+: Alternative Measurement Sensitivity Plus
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

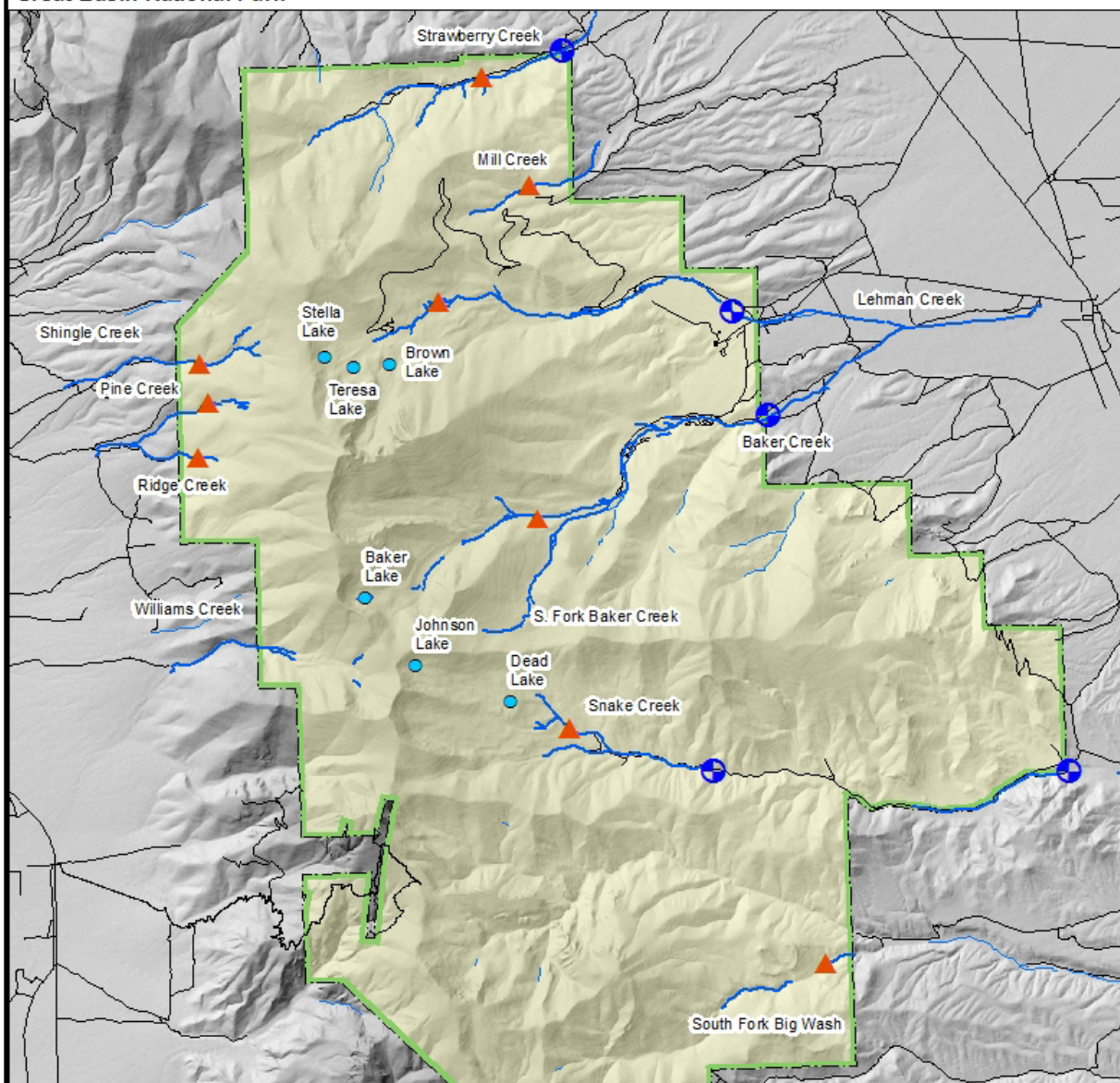
The Mojave Desert Network (MOJN) includes eight units of the National Park system: Death Valley National Park (DEVA), Great Basin National Park (GRBA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAKE), Manzanar National Historic Site (MANZ), Mojave National Preserve (MOJA), 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 is only concerned with 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. 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. This 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.



**Monitoring Locations
Great Basin National Park**



Legend

- Stream Gage Continuous Discharge and WQ Monitoring
- Randomly Selected Stream Sample Site: Annual BMI Sample, Water Sample, and Water Quality Samples
- Lake: Continuous Water Level Monitoring, Ice out and Ice Over Monitoring, Annual Water Sample, WQ, Depth Profile, and Clarity Measurements
- Permanent Streams
- Streams
- Roads
- Lakes
- GRBA Park Boundary

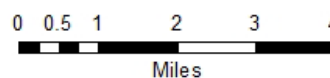


Figure 1. Map of sampling locations in GRBA.

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 monitored by GRBA staff at four gages (Strawberry Creek, Baker Creek, upper Snake Creek, and lower Snake Creek) and by the USGS at one gage (Lehman Creek). These sites are shown on Figure 1. No discharge data is 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, and pH. The data from the two week deployments are processed, graded, and joined using the Aquarius software package. In accordance with the MOJN Streams and Lakes protocol and standard practices (e.g., Wagner et al. 2006), unusable data are not included in the published data set, although copies of the raw data and records of all edits are archived. 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 from nine of GRBA's ten permanent 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 multimeter was used to measure temperature, dissolved oxygen, specific conductance, and pH at the time of sampling. The water samples were collected from randomly-selected sites that will be visited each year (Figure 1).

Benthic macroinvertebrate (BMI) samples are collected at the same time and location as the water 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. In 2013, only four lakes (Stella, Teresa, Brown, and Baker) were visited due to adverse weather conditions and the government shutdown.

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-over and ice-out.

Lake water chemistry is monitored by laboratory analysis of water samples and depth profiles of water chemistry. 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 multimeter 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 (Figures 2 and 3, Table 1). The intent of this section is not to provide a complete discussion of the year's precipitation, snowpack, and stream discharge in GRBA, but to provide context for the monitoring data presented in this report.

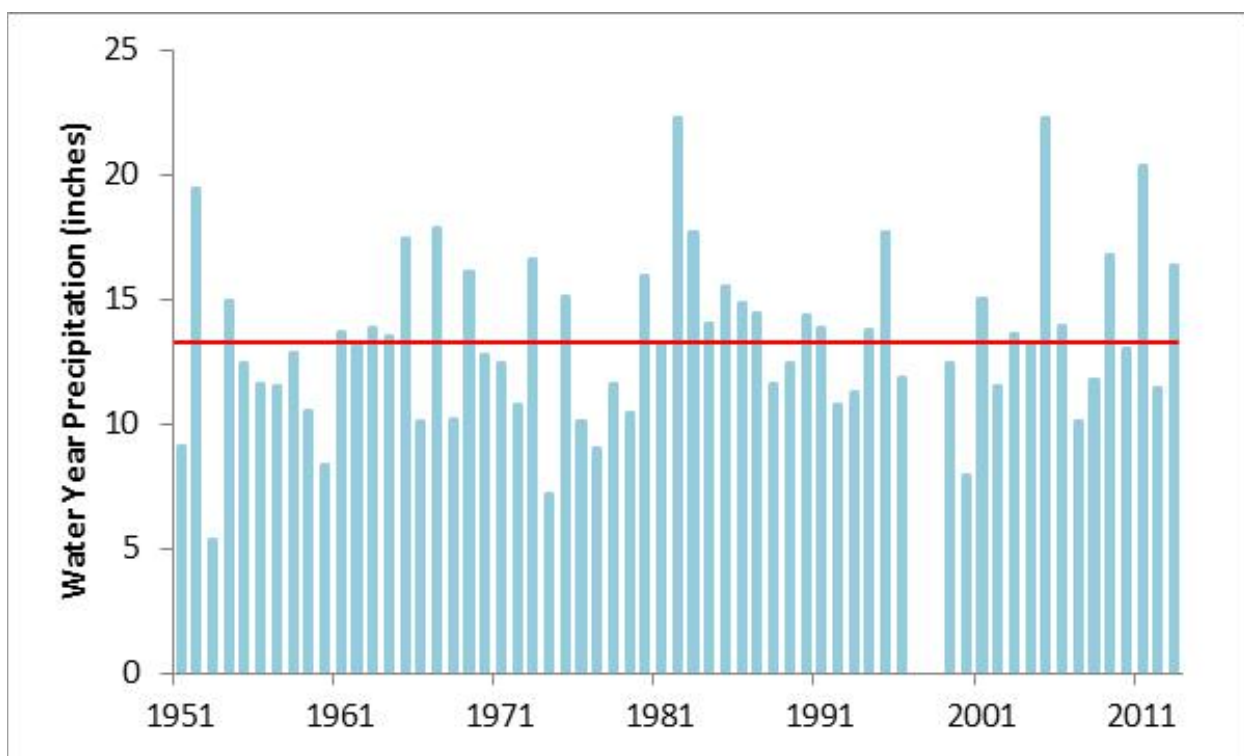


Figure 2. Annual precipitation by water year (October 1 to September 30) recorded at the NWS COOP weather station at Lehman Caves Visitor Center. The red line represents the 1951-2013 average of 13.20 inches.

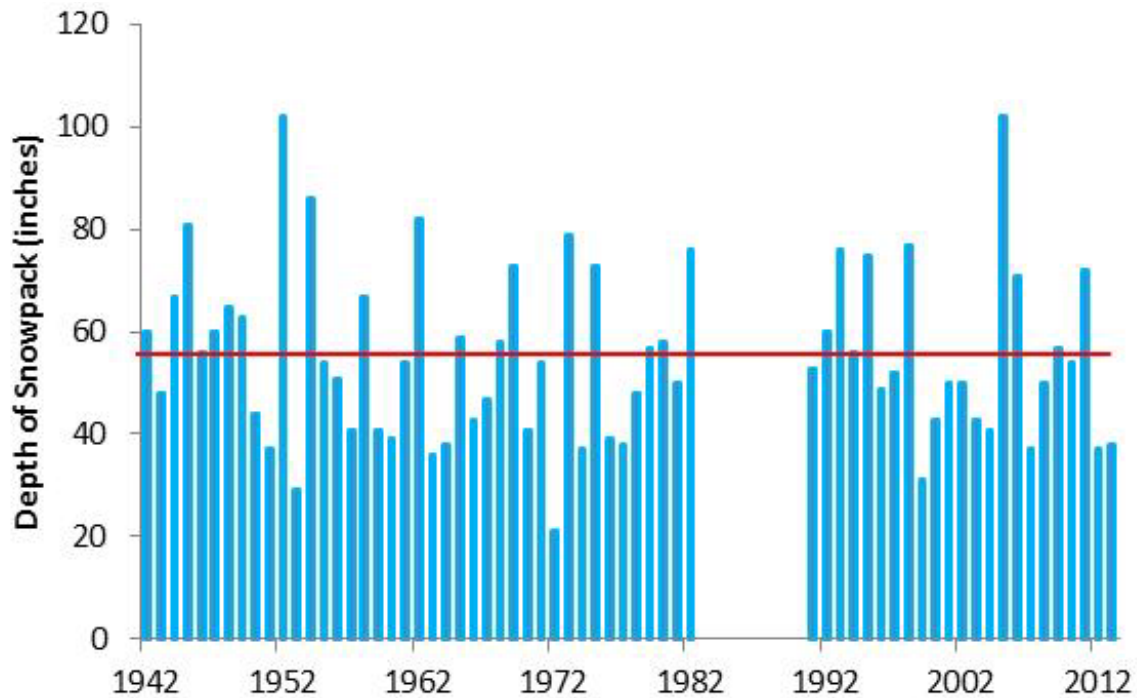


Figure 3. NRDS depth-of-snowpack data collected at Baker Creek Snowcourse #3 near April 1 of each year. The red line represents the 1942-2013 average of 55.2 inches.

Table 1. USGS measurements of mean annual discharge, date of peak discharge, and peak discharge 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
2004	3.47	3-Jun	12
2005	13.7	29-May	227

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

Water Year	Mean Annual Discharge (cfs)	Date of Peak Discharge	Peak Discharge (cfs)
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	----gage not in operation----		
Average	5.35	7-Jun	36.8

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

Water Year 2011

NWS Coop Station 263340 recorded 20.40 inches of precipitation in WY2011 (Figure 2), which was greater than the 1951-2013 average of 13.20 inches. Precipitation events were distributed throughout the year, with the highest total monthly precipitation (4.23 inches) occurring in December 2010 (Figure 4).

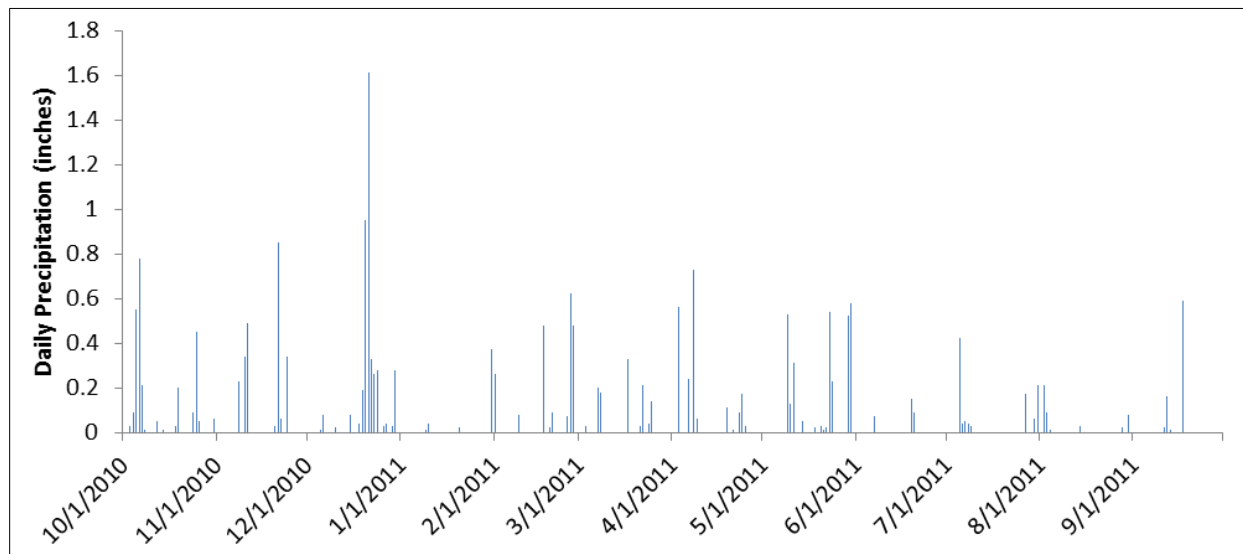


Figure 4. Daily precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center in WY2011.

The April 1 depth of the snowpack at the snow course site for 2011 (actually measured on March 31) was 72 inches (Figure 3), which was greater than the 1942-2013 average of 55.2 inches.

Lehman Creek reached its peak discharge for WY2011 on June 27 at 64 cfs, which was greater than the long-term average peak discharge of 36.8 cfs (Table 1). The average annual discharge was 8.52 cfs, which was greater than the long-term average of 5.35 cfs.

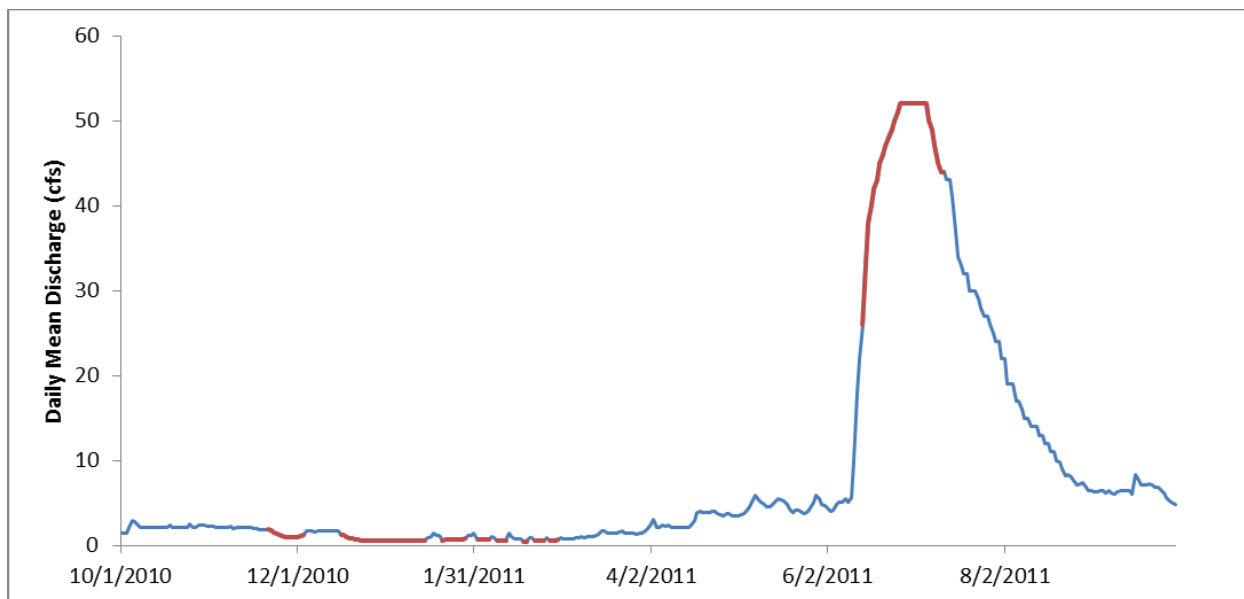


Figure 5. USGS discharge record for Lehman Creek in WY2011. The thick red line segments represent estimated data.

Water Year 2012

NWS Coop Station 263340 recorded 11.42 inches of precipitation in WY2012 (Figure 2), which was slightly less than the 1951-2013 average of 13.20 inches. Precipitation events were distributed throughout the year, with the highest total monthly precipitation (2.01 inches) occurring in July 2012 (Figure 6).

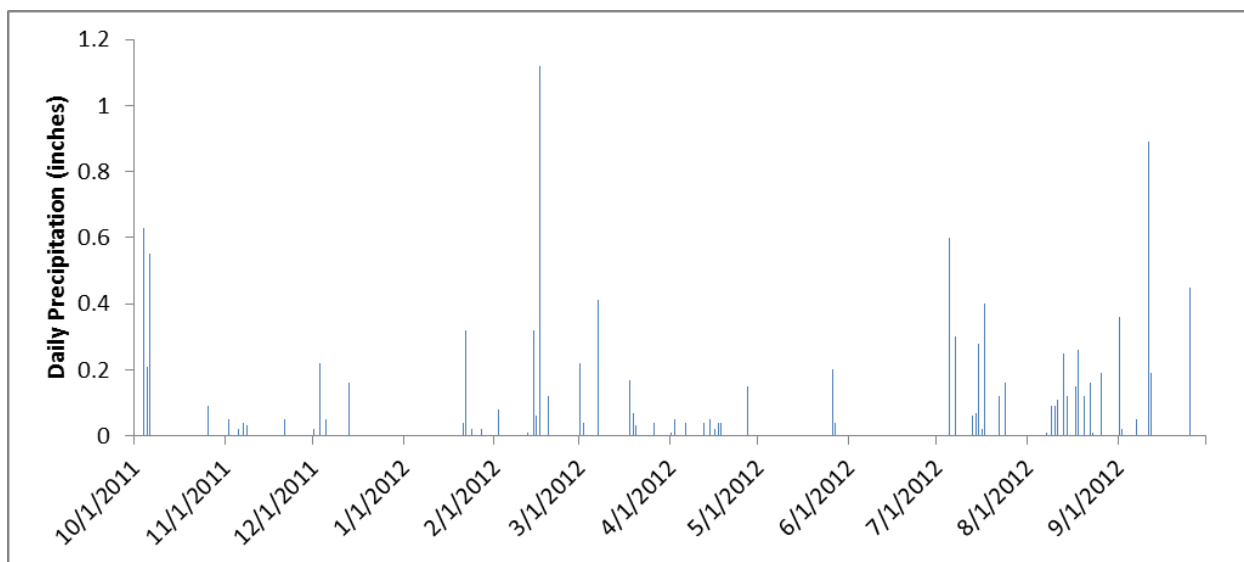


Figure 6. Daily precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center in WY2012.

The April 1 depth of the snowpack at the snow course site for 2012 (actually measured on March 30) was 37 inches (Figure 3), which was less than the 1942-2013 average of 55.2 inches, and among the lowest April 1 measurements recorded at the site.

The WY2012 discharge record for Lehman Creek (Figure 7) does not exhibit the usual pattern for a snowmelt-fed stream. The October and November 2011 mean monthly discharges were the highest recorded for those months over the period of record (U.S. Geological Survey 2013), due to the extended runoff from the WY2011 snowmelt pulse (Figure 5) and rainstorms in October 2011 (Figure 6). In contrast, the spring/summer runoff peak occurred on May 27 at 5.5 cfs, the lowest recorded for the gage over the period of record and far below the mean annual maximum discharge 36.8 cfs. The actual maximum discharge for Lehman Creek in WY2012 occurred during a rainstorm on October 4, when the creek's flow reached 13 cfs.

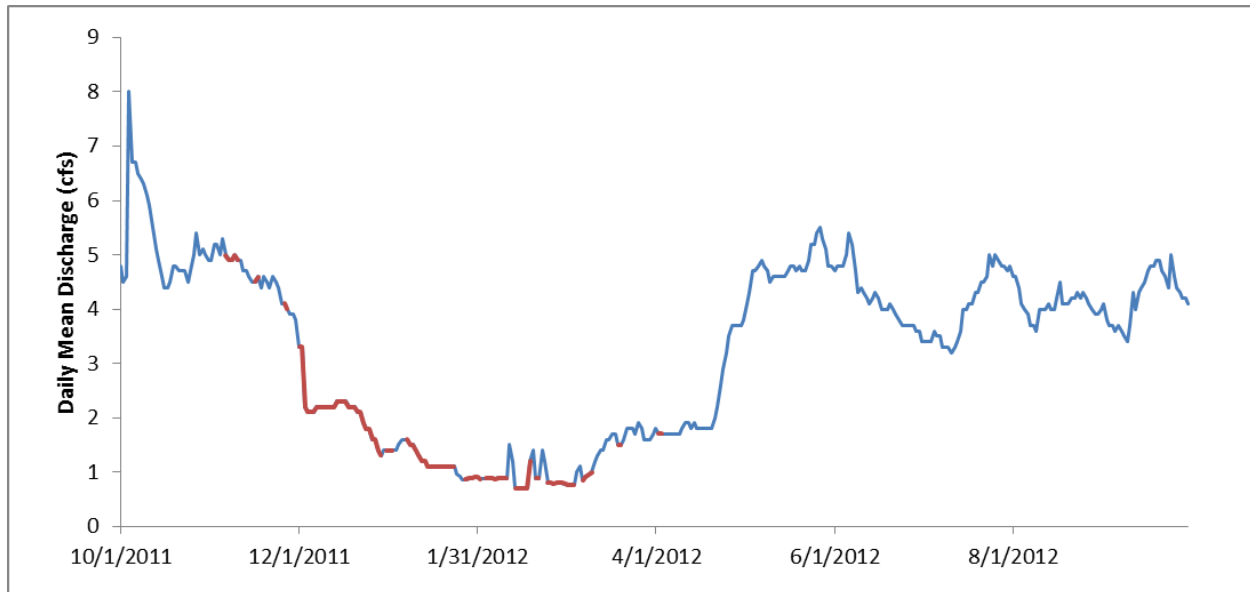


Figure 7. USGS discharge record for Lehman Creek in WY2012. The thick red line segments represent estimated data.

Water Year 2013

NWS Coop Station 263340 recorded 16.35 inches of precipitation in WY2013 (Figure 2), which was greater than the 1951-2013 average of 13.20 inches. Precipitation events were distributed throughout the year, with the highest total monthly precipitation (4.12 inches) occurring in September 2013 (Figure 8).

The April 1 depth of the snowpack at the snow course site for 2013 was 38 inches (Figure 3), which was less than the 1942-2013 average of 55.2 inches, and among the lowest April 1 measurements recorded at the site.

The USGS gage at Lehman Creek was not in operation during WY2013 due to a lack of funding. Operations were restored in the summer of 2014.

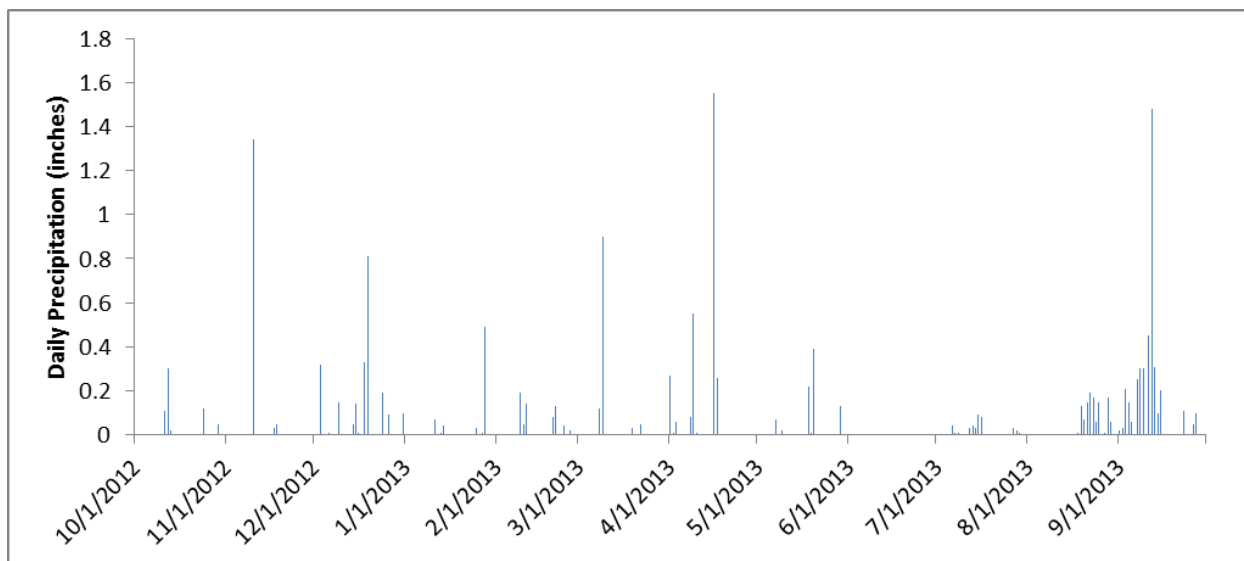


Figure 8. Daily precipitation recorded at the NWS COOP weather station at Lehman Caves Visitor Center in WY2013.

Monitoring Results from Streams

The results of stream continuous water quality monitoring, stream water chemistry monitoring, and benthic macroinvertebrate sampling activities are summarized below. More detailed information regarding these data may be obtained by contacting the Mojave Desert Network.

Continuous Water Quality

Continuous water quality data were collected near the stream-gages on the four second-order streams in GRBA, with sondes deployed in both the upper and lower portions of Snake Creek (gage locations are shown in Figure 1 and given in Table 2).

Table 2. UTM coordinates (NAD 83, Zone 11S) for continuous water quality monitoring locations.

Gaged Stream	Easting (m)	Northing (m)
Baker Creek	742,027	4,319,535
Lehman Creek	741,152	4,321,829
Lower Snake Creek	748,657	4,311,656
Upper Snake Creek	740,625	4,311,740
Strawberry Creek	733,483	4,327,499

Baker Creek

In 2011, water quality data was collected in Baker Creek from July 16 to September 21.

In 2012, water quality data was collected from June 20 to September 19, with gaps in early July and early August for sonde testing and maintenance. The pH and DO sensors malfunctioned early in the season, resulting in incomplete records. The sonde was retrieved on September 19.

In 2013, a sonde was deployed from June 7 to September 19. The sonde had battery problems in late July and early August, resulting in incomplete records.

The average values of each parameter in five index periods are presented in Table 3. The daily average, minimum, and maximum values of each parameter are plotted in Figures 9 to 11.

Table 3. Average water quality parameter values in Baker Creek, 2009-2013.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp °C	2009	-	11.7 ^b	-	-	-
	2010	-	12.5	13.4	13.2	10.5
	2011	-	9.6	10.3	11.6	10.1
	2012	-	13.3 ^a	13.9 ^a	13.6	11.6
	2013	13.9	14.7 ^b	-	13.7	11.7
Median pH Standard Units	2009	-	7.47 ^b	-	-	-
	2010	-	7.70	7.68 ^b	7.59 ^a	7.57
	2011	-	7.22	7.39	7.40 ^a	-
	2012	-	-	7.52 ^a	7.46	7.41
Mean SpCond µS/cm	2013	7.19	-	-	7.29	7.17
	2009	-	32 ^b	-	-	-
	2010	-	40	46 ^a	40 ^a	41
	2011	-	34	43	49	57
	2012	-	34 ^a	35 ^a	37	39
Mean DO % Saturation	2013	36	-	-	42	38
	2009	-	81.0 ^b	-	-	-
	2010	-	82.9	80.9 ^a	79.0 ^a	77.9
	2011	-	79.3	79.3	79.3	79.3
	2012	-	81.1 ^a	80.6 ^a	80.2	80.3
	2013	78.5	-	-	79.2	79.2

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

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

2011

Water temperature (Figure 9A) in Baker Creek increased from 8.2°C in mid-July to its high of 12.2°C on August 26 and then began to decrease until the end of September.

The dissolved oxygen saturation (Figure 9B) remained steady over the period of deployment, with values fluctuating between 80.7% and 82.0%.

The pH (Figure 9C) increased throughout July and early August from a low of 7.18 on July 16. It remained steady over late August and September, with values fluctuating between 7.32 and 7.49.

The specific conductance (Figure 9D) continuously increased from 32 µS/cm in mid-July to 60 µS/cm in late September.

2012

Water temperature (Figure 10A) in Baker Creek increased from late June to its high of 14.9°C on July 9. It began to decrease in late August and reached a low of 9.2°C on September 13.

The dissolved oxygen saturation (Figure 10B) increased rapidly during mid-July to a high of 81.4%. It decreased throughout August to a low of 79.9% on September 4.

The pH (Figure 10C) decreased over the period of deployment from a high of 7.70 in early August to a low 7.35 in late September.

The specific conductance (Figure 10D) increased from mid-June to early July and then decreased to a low of 33 $\mu\text{S}/\text{cm}$ on July 29. It increased again throughout August and September. The sharp peak of 43 $\mu\text{S}/\text{cm}$ on September 11 occurred shortly after a rain event.

2013

Water temperature (Figure 11A) in Baker Creek increased rapidly in late June from a low of 8.5°C. It remained steady throughout July and August, with values fluctuating between 12.5°C and 15°C. It began to decline in early September to a new low of 7.3°C.

The dissolved oxygen saturation (Figure 11B) decreased from a high of 80.2% in early June to a low of 77.5% on July 22. After the gap in the record due to battery problems, the saturation was again 80.2% on August 9 and then gradually decreased over late August until becoming steady around 79% in September.

The pH (Figure 11C) was relatively steady in June and July, with values fluctuating between 7.00 and 7.20. It increased rapidly from 7.05 on August 15 to a high of 7.41 on August 18. It then gradually decreased until the end of September.

The specific conductance (Figure 11D) increased continuously from 29.2 $\mu\text{S}/\text{cm}$ in early July to 41.1 $\mu\text{S}/\text{cm}$ on July 22. It remained steady throughout August and began to decrease in early September. The sharp peak of 43.1 $\mu\text{S}/\text{cm}$ on September 12 corresponds to a rain event.

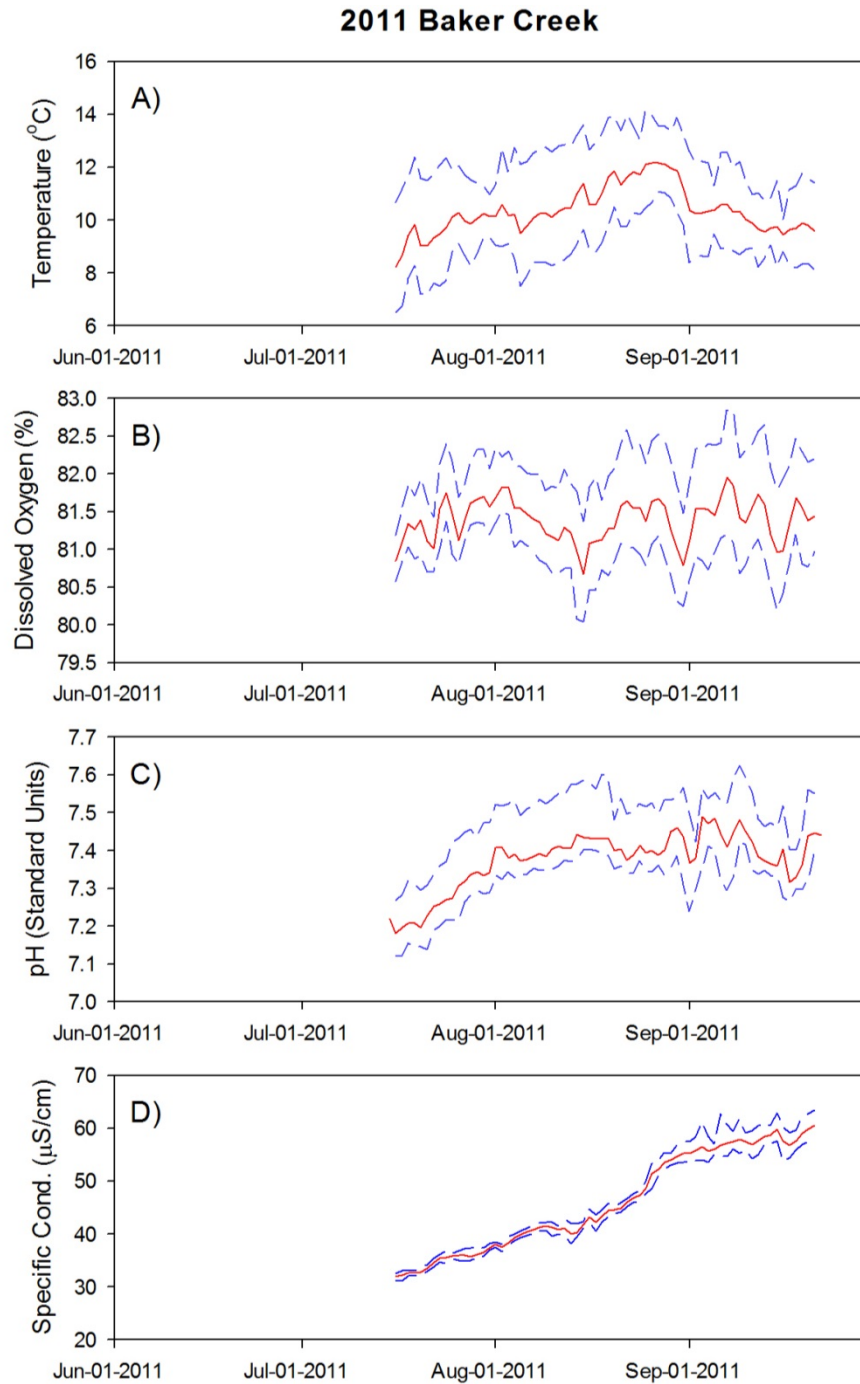


Figure 9. Baker Creek water quality data from the 2011 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

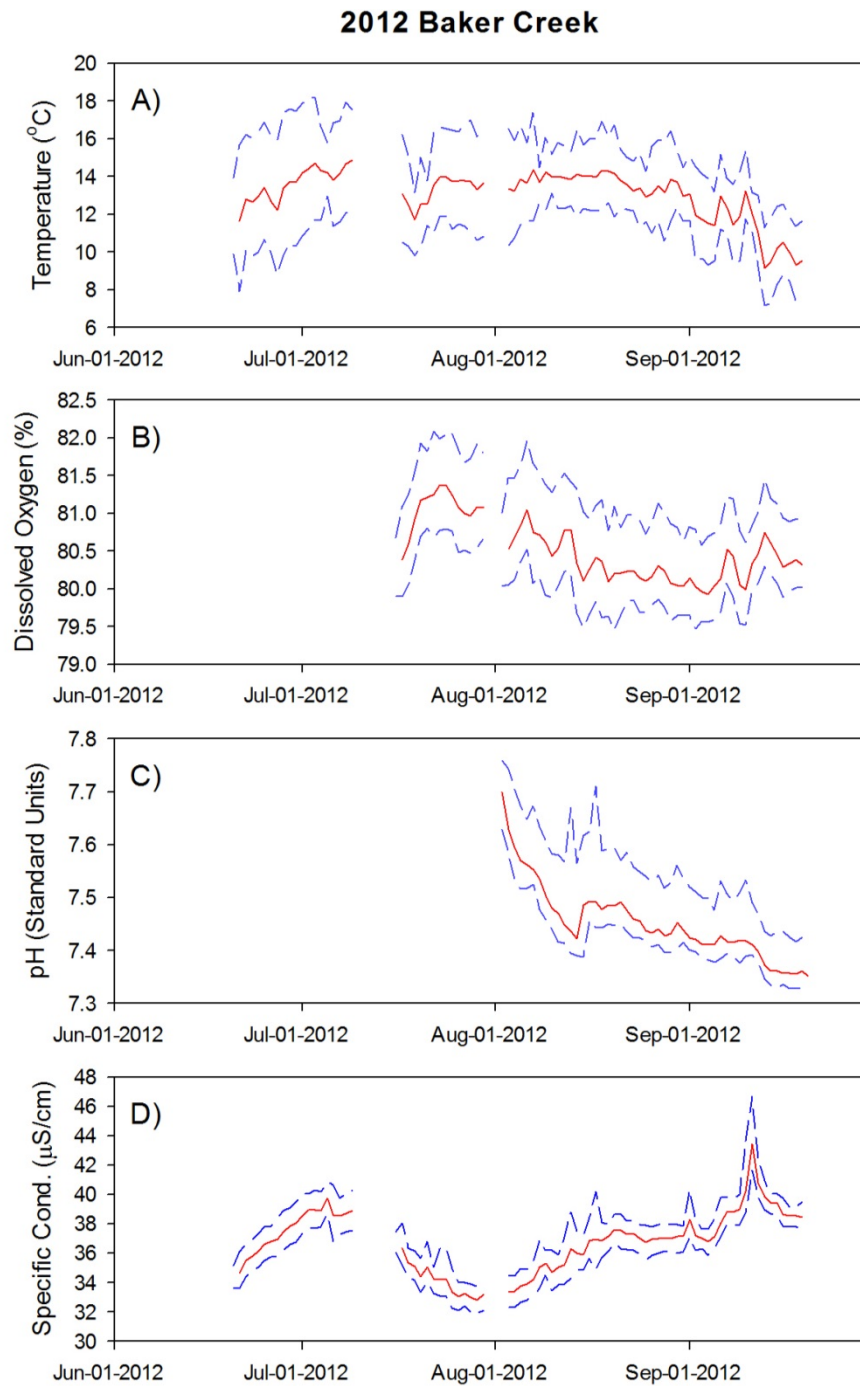


Figure 10. Baker Creek water quality data from the 2012 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

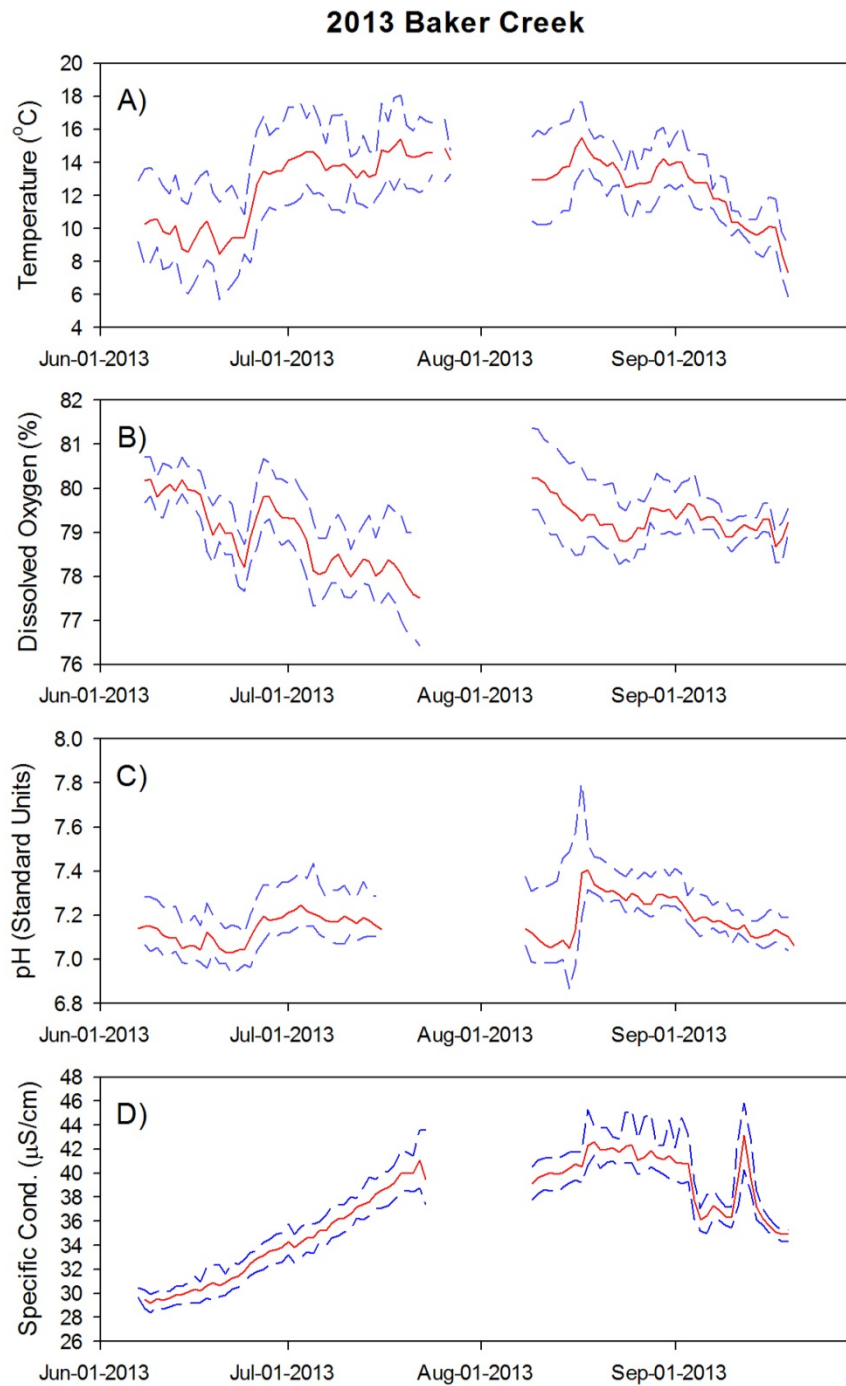


Figure 11. Baker Creek water quality data from the 2013 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

Lehman Creek

In 2011, a sonde was deployed in Lehman Creek from July 1 to September 21. The pH meter had instrument problems throughout July. Large swings and poor quality data in the middle of the dissolved oxygen and specific conductivity records were deleted.

In 2012, a sonde was deployed from June 14 to September 19. The sonde was taken back to the lab from July 7 to July 16 to replace the dissolved oxygen membrane.

In 2013, a sonde was deployed from June 7 to September 19. The sonde had a battery problem from mid-June until late July.

The average values of each parameter in five index periods are presented in Table 4. The daily average, minimum, and maximum values of each parameter are plotted in Figures 12 to 14.

Table 4. Average water quality parameter values in Lehman Creek, 2009-2013.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp °C	2009	-	-	-	10.9 ^a	-
	2010	-	-	-	11.7 ^a	9.8
	2011	8.9	9.5	9.7	10.6	9.2
	2012	-	12.7	13.2	12.7	11.2
	2013	-	-	13.2	13.2	11.4
Median pH Standard Units	2009	-	-	-	7.53 ^a	-
	2010	-	-	-	7.53 ^a	7.55
	2011	-	-	7.46 ^a	7.45	7.45
	2012	-	7.37 ^a	7.44	7.44	7.47
	2013	-	-	7.45	7.46	7.33
Mean SpCond µS/cm	2009	-	-	-	35 ^a	-
	2010	-	-	-	36 ^a	36
	2011	32 ^a	-	-	-	-
	2012	-	36	36	37	39
	2013	-	-	40 ^a	42	41
Mean DO % Saturation	2009	-	-	-	79.9 ^a	-
	2010	-	-	-	79.3 ^a	79.5
	2011	80.8 ^b	-	80.0 ^a	80.3	80.5
	2012	-	77.2	77.5	78.0	77.9
	2013	-	-	79.2	79.5	79.6

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

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

2011

Water temperature (Figure 12A) in Lehman Creek increased continuously from 8.7°C in early July to a high of 11.4°C on August 27. It decreased rapidly in late August and then decreased gradually throughout September.

The dissolved oxygen saturation (Figure 12B) decreased from a high of 81.1% in early July to a low of 79.8% on August 15. It then increased throughout August with a dip to 79.7% on August 31. The saturation became relatively steady in September, with values fluctuating between 80.0% and 80.9%.

The pH (Figure 12C) remained steady over the period of deployment, with values fluctuating between 7.43 and 7.48.

The specific conductance (Figure 12D) record is sparse. The measured low was 31 $\mu\text{S}/\text{cm}$ on July 7. The high was a peak of 36 $\mu\text{S}/\text{cm}$ on September 17, corresponding to moderate rain events during the middle of the month.

2012

Water temperature (Figure 13A) in Lehman Creek remained steady from mid-June to late August, with values fluctuating between 11.0°C and 14.2°C. It decreased in September to a low of 8.9°C on September 13.

The dissolved oxygen saturation (Figure 13B) decreased from a high of 81.0% on June 16 to a low of 76.8% on July 17. It increased gradually to 78.3% at the end of September.

The pH (Figure 13C) was steady throughout June, with a high of 7.60 on July 5. It decreased during July to a low of 7.35 on July 29, perhaps due to rainfall. The slight increase at the very end of July may have been a response to conditions becoming more drier. The pH continued to increase gradually until the end of September.

The specific conductance (Figure 13D) was steady at about 39 $\mu\text{S}/\text{cm}$ throughout June and early July. It decreased in mid-July to a low of 35 $\mu\text{S}/\text{cm}$ on July 20 and then increased continuously until the end of September. The sharp peak of 42 $\mu\text{S}/\text{cm}$ on September 11 corresponds to a rain event.

2013

Water temperature (Figure 14A) in Lehman Creek varied between 9.5°C and 12.0°C in June. After the gap in the record, it remained steady from late July to mid-August, reaching a peak of 14.8°C on August 17. It then decreased to a low of 7.5°C on September 19.

The dissolved oxygen saturation (Figure 14B) was between 79% and 80% in mid-June. It reached a low of 78.3% on July 28 and then increased gradually until the end of September. The peak of 80.5% on September 12 occurred during a large rain event.

The pH (Figure 14C) was steady from late July to mid-August, with a high of 7.54 on August 17. It then decreased continuously until mid-September, reaching a low of 7.28 on September 16.

The specific conductance (Figure 14D) varied between 36 $\mu\text{S}/\text{cm}$ and 39 $\mu\text{S}/\text{cm}$ in June. After the gap in the record, it remained relatively steady, with values fluctuating between 39 $\mu\text{S}/\text{cm}$ and 42 $\mu\text{S}/\text{cm}$. The peak of 47 $\mu\text{S}/\text{cm}$ on September 12 occurred during a large rain event, and the jump to 44 $\mu\text{S}/\text{cm}$ in mid-August occurred during a smaller rain event.

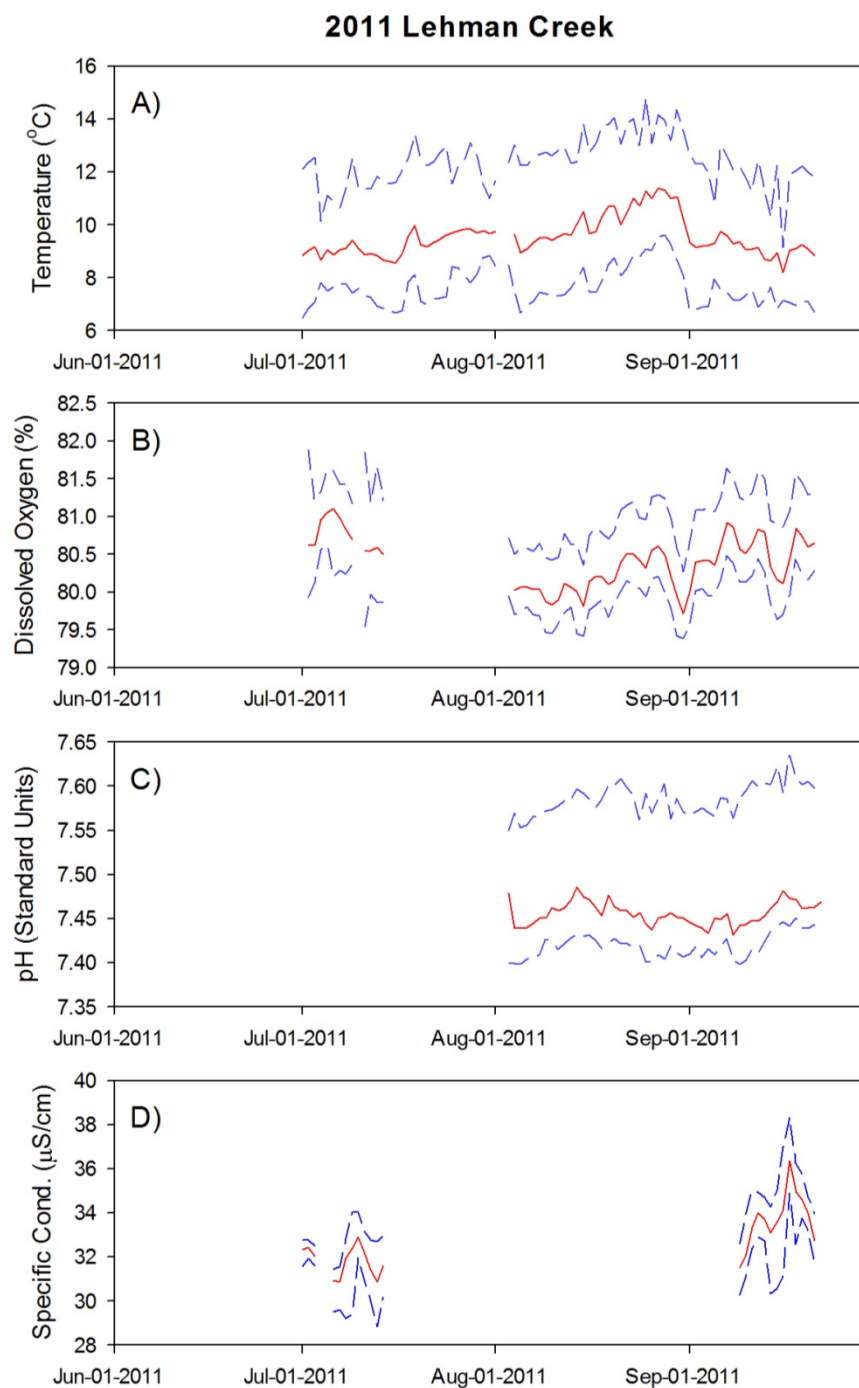


Figure 12. Lehman Creek water quality data from the 2011 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

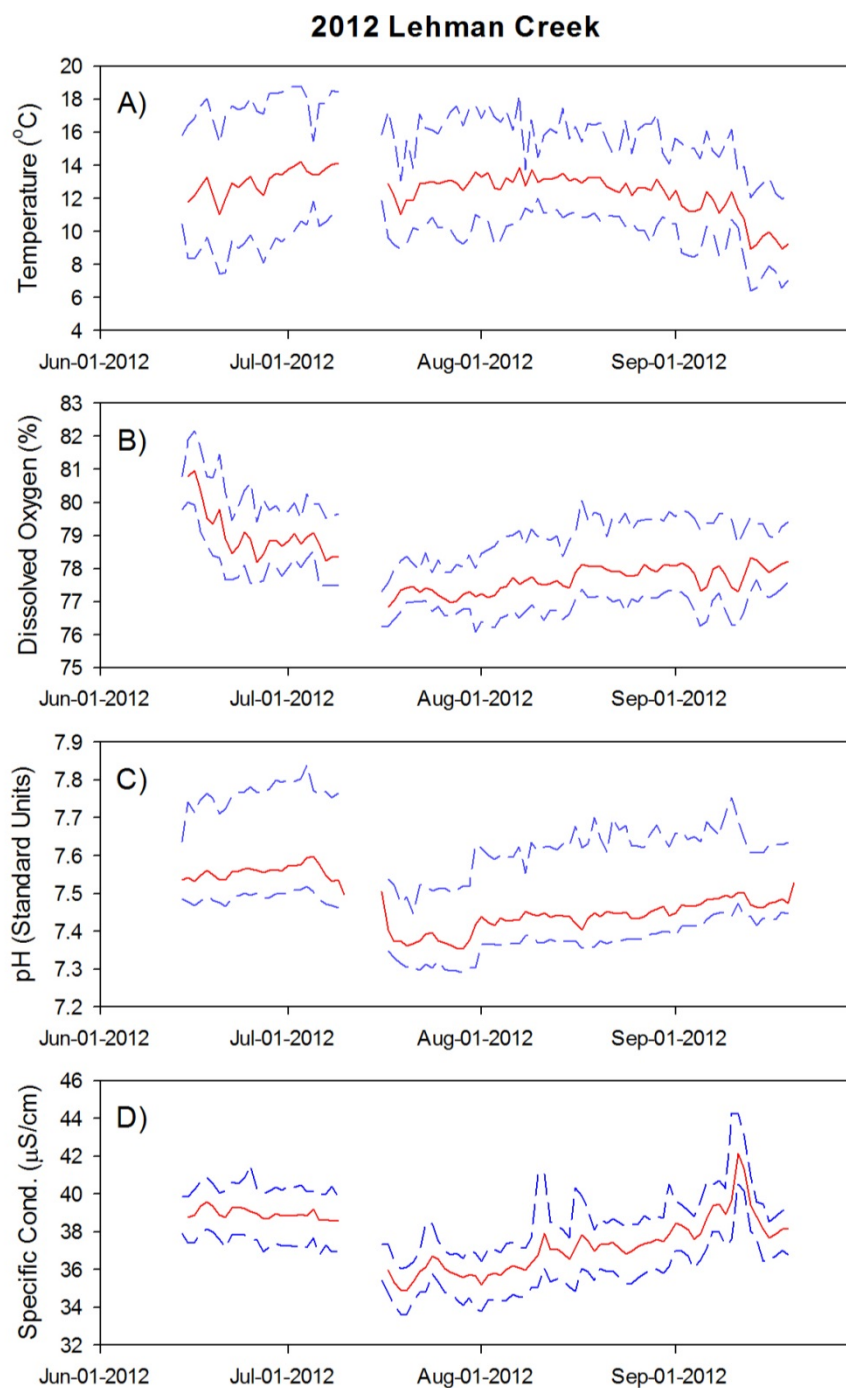


Figure 13. Lehman Creek water quality data from the 2012 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

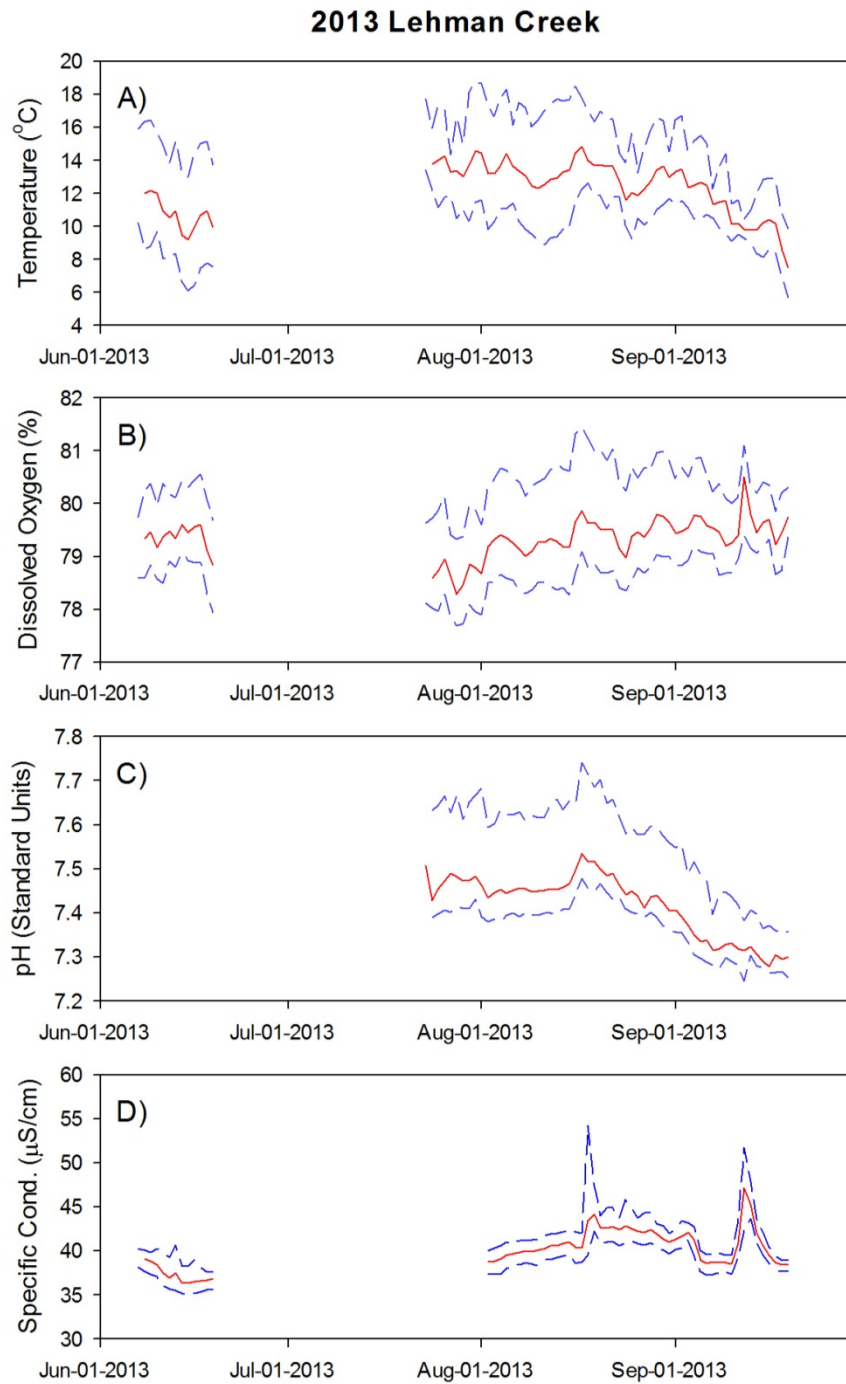


Figure 14. Lehman Creek water quality data from the 2013 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

Lower Snake Creek

In 2011, water flowed in Lower Snake Creek all summer, and a sonde was deployed from July 20 to September 22.

In 2012, a sonde was deployed on June 20, and removed due to low flow on June 28.

In 2013, a sonde was deployed on June 21, and removed due to low flow on July 18.

The average values of each parameter in five index periods are presented in Table 5. The daily average, minimum, and maximum values of each parameter are plotted in Figures 15 to 17.

Table 5. Average water quality parameter values in Lower Snake Creek, 2009-2013.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp °C	2009	11.1	-	-	-	-
	2010	11.6	13.6	13.5	12.5	10.7
	2011	-	10.9 ^b	11.5	11.8	10.3
	2012	-	-	-	-	-
	2013	14.4	-	-	-	-
Median pH Standard Units	2009	8.23	-	-	-	-
	2010	8.36	8.41	8.39	8.35	8.37 ^a
	2011	-	8.25 ^b	8.24	8.24	8.21
	2012	-	-	-	-	-
Mean SpCond µS/cm	2013	8.12	-	-	-	-
	2009	148	-	-	-	-
	2010	175	214 ^a	174	186	209 ^a
	2011	-	156 ^b	176	170	174
	2012	-	-	-	-	-
Mean DO % Saturation	2013	160 ^b	-	-	-	-
	2009	81.1	-	-	-	-
	2010	83.1	82.8	82.1	82.9	83.1 ^a
	2011	-	83.1 ^b	82.6	82.7	82.9
	2012	-	-	-	-	-
	2013	77.9	-	-	-	-

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

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

2011

Water temperature (Figure 15A) in Lower Snake Creek increased gradually from mid-July to the end of August, reaching a high of 12.5°C. At the very end of August, it decreased rapidly by about 2°C and then slowly decreased during September, reaching a low of 9.6°C.

The dissolved oxygen saturation (Figure 15B) decreased rapidly from a high of 84.1% on July 23 to a low of 81.6% on July 28. It then gradually increased back up to 83.0% at the end of September.

The pH (Figure 15C) decreased continuously over the period of deployment from a peak of 8.31 on July 19 to 8.18 at the end of September.

The specific conductance (Figure 15D) increased rapidly from a low of 141 $\mu\text{S}/\text{cm}$ on July 22 to 184 $\mu\text{S}/\text{cm}$ on August 2. It decreased gradually throughout August and then increased gradually throughout September, reaching a high of 188 $\mu\text{S}/\text{cm}$ on September 21.

2012

In 2012, records were sparse for all water quality parameters in Lower Snake Creek, covering only the week from June 20 to June 27. Water temperature (Figure 16A) was approximately 12°C. The dissolved oxygen saturation (Figure 16B) varied between 79.9% and 80.5%. The pH (Figure 16C) increased gradually from 8.14 to 8.20. The specific conductance (Figure 16D) increased rapidly from 161 $\mu\text{S}/\text{cm}$ to 172 $\mu\text{S}/\text{cm}$.

2013

In 2013, records were also sparse for all water quality parameters in Lower Snake Creek, covering only the month from June 21 to July 17. Water temperature (Figure 17A) increased from a low of 9.9°C to a high of 15.8°C. The dissolved oxygen saturation (Figure 17B) varied between 77.3% and 78.9%. The pH (Figure 17C) was 8.11 early in the deployment before increasing slightly in mid-July to a high of 8.20. The specific conductance (Figure 17D) increased steadily from a low of 129 $\mu\text{S}/\text{cm}$ to a high of 175 $\mu\text{S}/\text{cm}$.

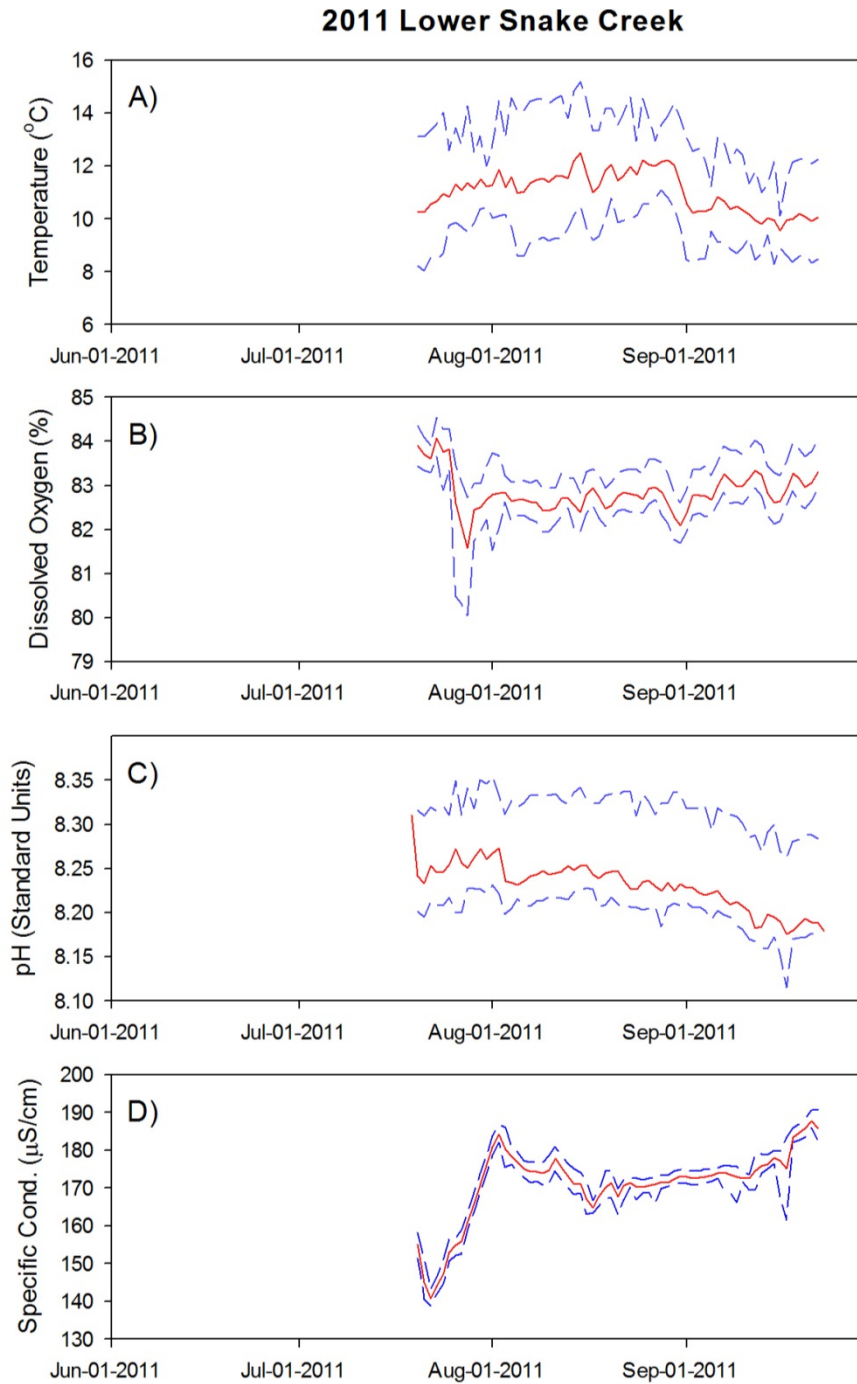


Figure 15. Lower Snake Creek water quality data from the 2011 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

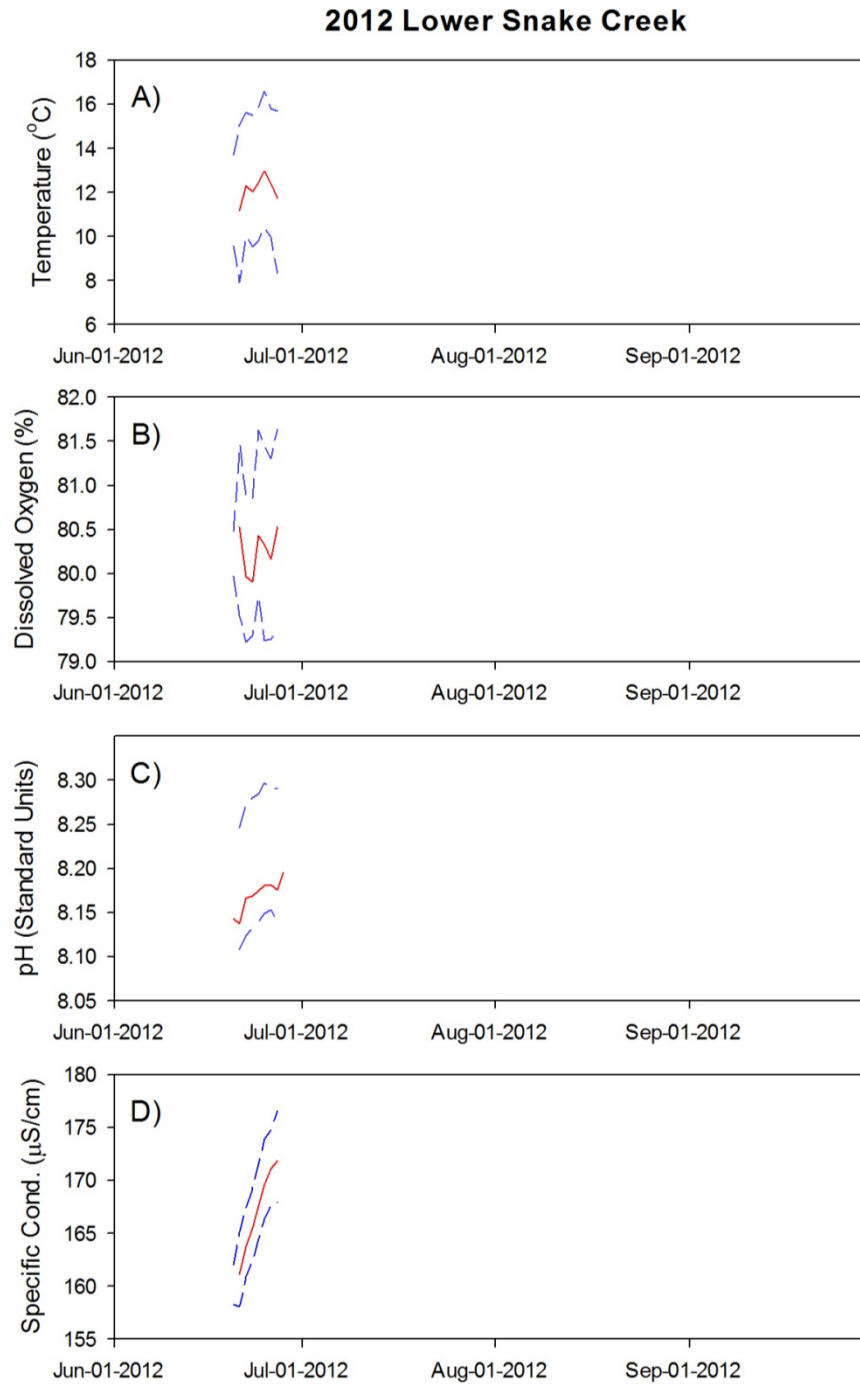


Figure 16. Lower Snake Creek water quality data from the 2012 field season. The creek was dry after June 28. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

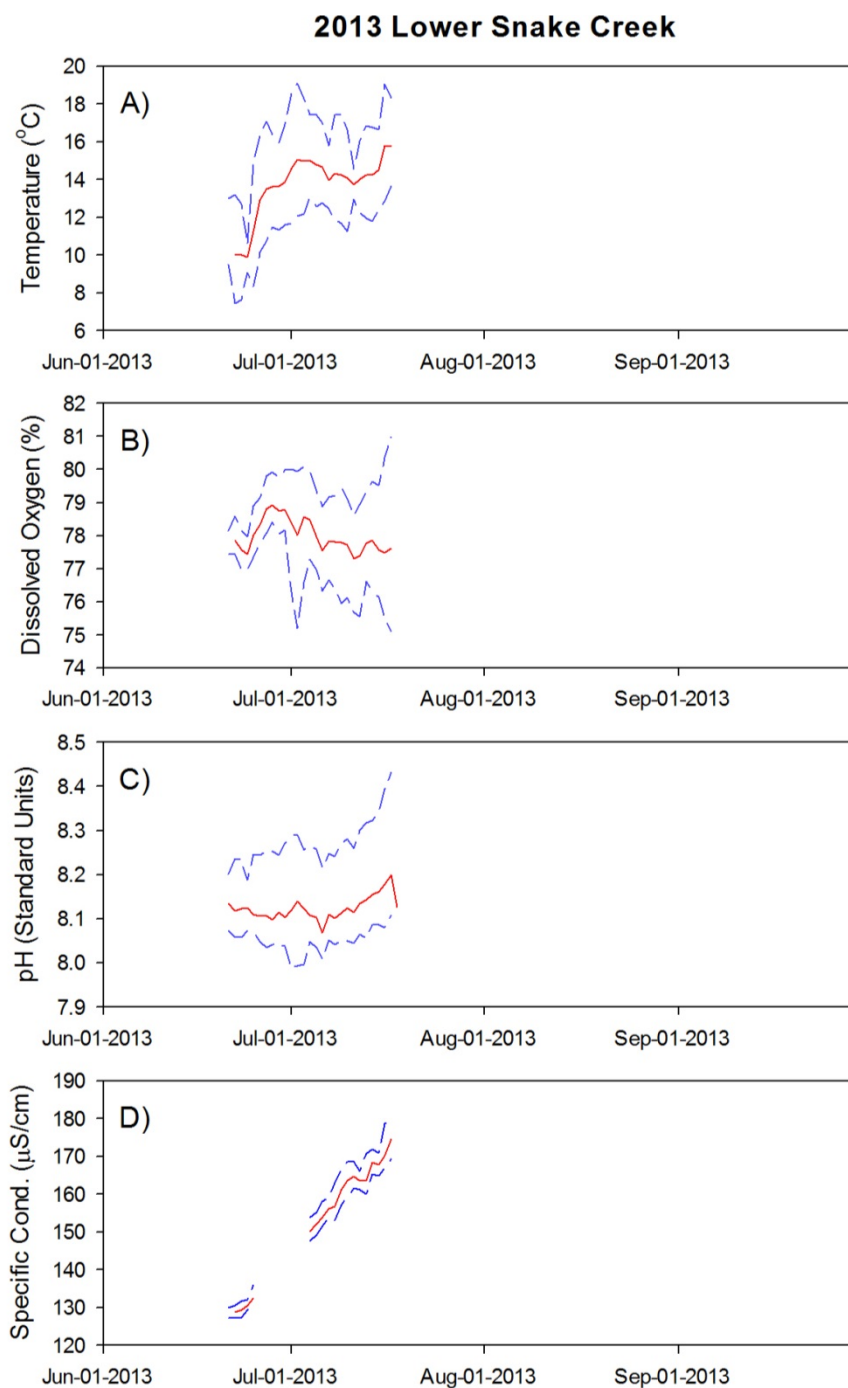


Figure 17. Lower Snake Creek water quality data from the 2013 field season. The creek was dry after July 18. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

Upper Snake Creek

No sonde was deployed in Upper Snake Creek in 2011.

In 2012, a sonde was deployed from July 17 to September 19. Dissolved oxygen data was not collected until August 1, when the sensor was replaced.

In 2013, a sonde was deployed from July 18 to September 19.

The average values of each parameter in five index periods are presented in Table 6. The daily average, minimum, and maximum values of each parameter are plotted in Figures 18 and 19.

Table 6. Average water quality parameter values in Upper Snake Creek, 2009-2013.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp °C	2009	-	-	-	-	-
	2010	7.6	9.5	9.5	-	-
	2011	-	-	-	-	-
	2012	-	10.7 ^a	11.4 ^a	11.3	9.6
	2013	-	11.4 ^a	10.4	11.1	10.5
Median pH Standard Units	2009	-	-	-	-	-
	2010	7.57	7.60	7.57	-	-
	2011	-	-	-	-	-
	2012	-	-	8.05	8.08	8.12
	2013	-	7.90 ^a	7.90	7.87	7.87
Mean SpCond µS/cm	2009	-	-	-	-	-
	2010	48	47	-	-	-
	2011	-	112 ^a	111	114	119
	2012	-	113 ^a	118	119	117
	2013	102	105	110	112	113
Mean DO % Saturation	2009	-	-	-	-	-
	2010	75.8	75.9	73.2	-	-
	2011	-	-	-	-	-
	2012	-	-	76.5 ^a	74.3	74.9
	2013	-	73.6 ^b	74.8	74.9	75.1

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

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

2012

Water temperature (Figure 18A) in Upper Snake Creek remained steady from late July to the end of August, with a high of 11.9°C. It decreased throughout September to a low of 7.7°C.

The dissolved oxygen saturation (Figure 18B) decreased continuously during the first half of August from a high of 78.4% on August 2 to a low of 73.9% on August 19. It then increased gradually until the end of September.

The pH (Figure 18C) decreased slightly in early August to a low of 8.03 on August 12. It then increased gradually until the end of September. The peak of 8.19 on September 10 corresponds to a rain event.

The specific conductance (Figure 18D) remained relatively steady from mid-July to mid-August. It then increased in late August before becoming steady again in mid-September and reaching a high of 120 $\mu\text{S}/\text{cm}$ on September 16. The dip of 114 $\mu\text{S}/\text{cm}$ on September 11 and the dip of 109 $\mu\text{S}/\text{cm}$ on July 24 correspond to rain events.

2013

Water temperature (Figure 19A) in Upper Snake Creek remained relatively steady throughout July and August, with values fluctuating between 9.6°C and 11.9°C. The wide dip in mid-August seems to be a result of greater diurnal temperature difference. Water temperature decreased rapidly in mid-September to a low of 7.1°C.

The dissolved oxygen saturation (Figure 19B) increased during late July from a low of 72.7% on July 20. It remained steady around 75.0% throughout August before reaching a peak of 75.7% on September 5. It began to decrease slightly during mid-September.

The pH (Figure 19C) decreased gradually over the period of deployment from a high of 7.96 on July 18 to a low of 7.84 on September 12. The dip in mid-September occurred around the time of a rain event.

The specific conductance (Figure 19D) increased continuously from a low of 110 $\mu\text{S}/\text{cm}$ in mid-July to about 120 $\mu\text{S}/\text{cm}$ in mid-August. It became more variable during late August and into September, with values fluctuating between a peak of 122 $\mu\text{S}/\text{cm}$ on August 30 and a dip of 108 $\mu\text{S}/\text{cm}$ on September 12. The dips in September occurred around the times of rain events.

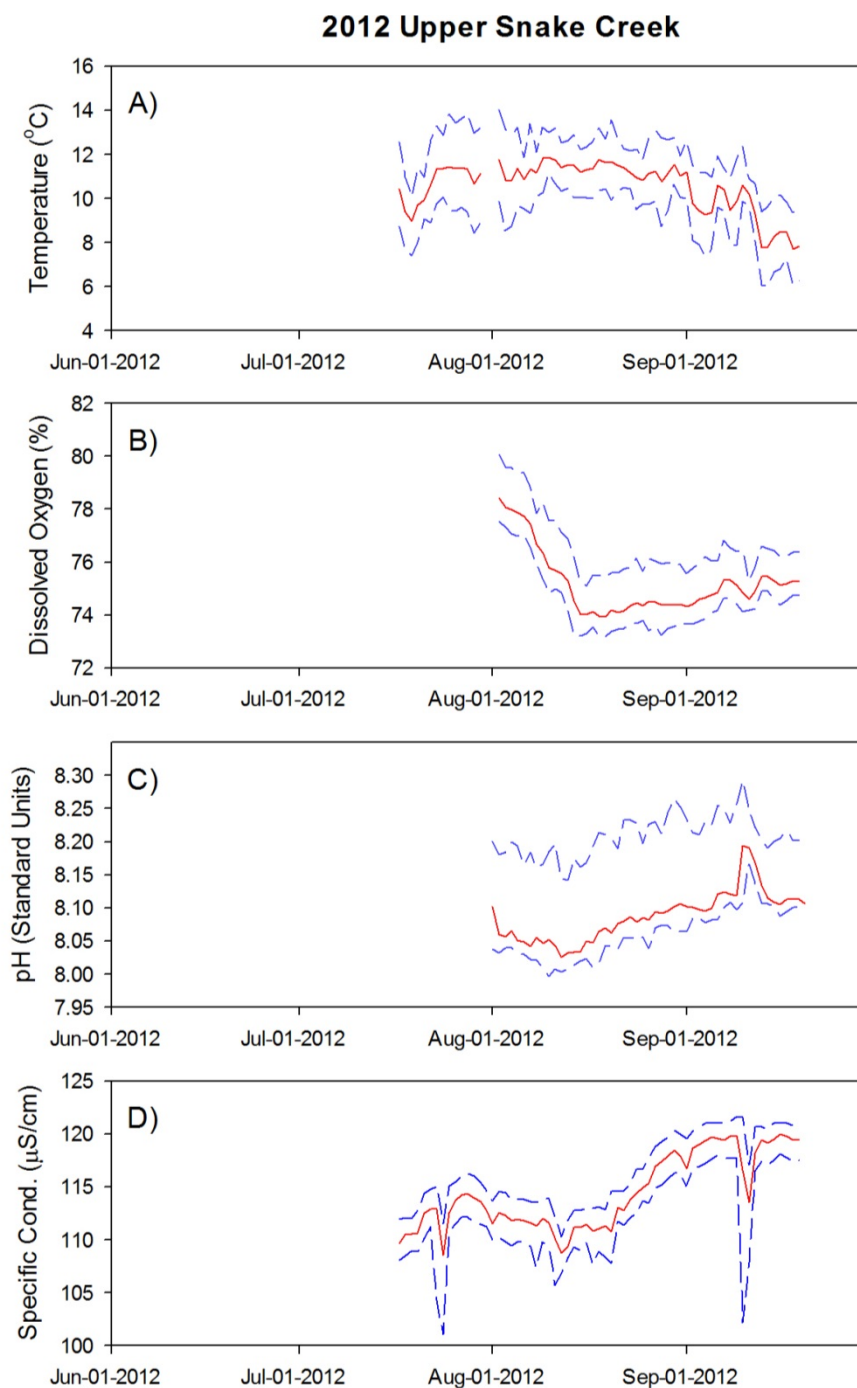


Figure 18. Upper Snake Creek water quality data from the 2012 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

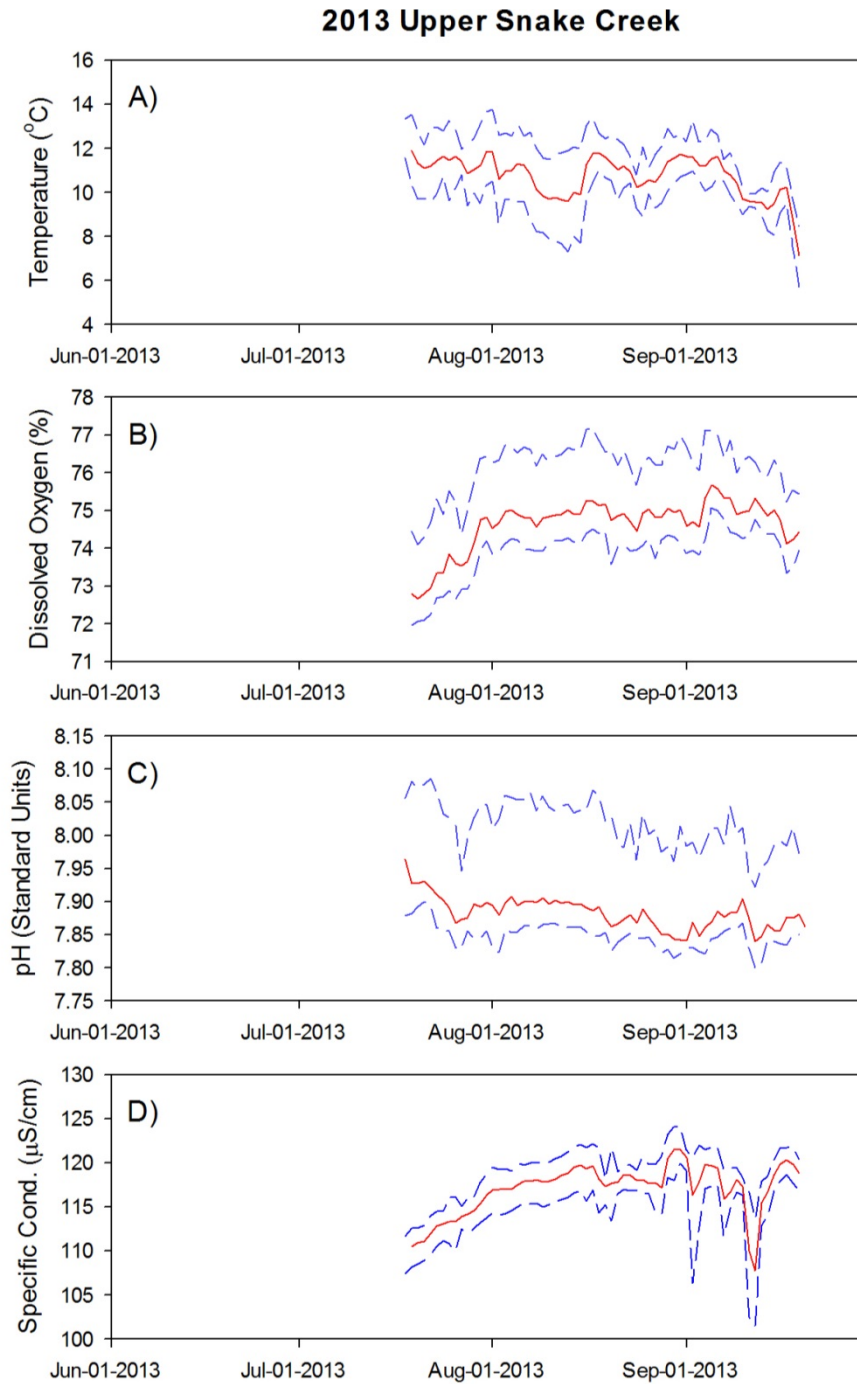


Figure 19. Upper Snake Creek water quality data from the 2013 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

Strawberry Creek

In 2011, a sonde was deployed in Strawberry Creek from July 1 to September 21. Large swings and poor quality data in the specific conductivity record were deleted.

In 2012, a sonde was deployed from June 20 to September 16, with a gap from July 6 to July 16 for sonde maintenance. The pH meter was malfunctioning and not calibrating properly at the beginning of the record.

In 2013, a sonde was deployed from June 8 to September 19. Battery malfunctions resulted in lost data from late August to mid-September.

The average values of each parameter in five index periods are presented in Table 7. The daily average, minimum, and maximum values of each parameter are plotted in Figures 20 to 22.

Table 7. Average water quality parameter values in Strawberry Creek, 2009-2013.

Parameter	Year	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15
Mean Temp °C	2009	-	-	11.97 ^a	-	-
	2010	10.79	13.19	13.02	12.38	10.10 ^a
	2011	9.3	10.6	11.3	12.3	10.2
	2012	-	14.0 ^a	14.9	14.3	12.2
	2013	15.0	15.5	14.0 ^b	-	-
Median pH Standard Units	2009	-	-	8.05 ^a	-	-
	2010	8.00 ^a	8.02	7.93	8.07	8.06
	2011	-	8.25 ^b	8.26	8.25	8.26
	2012	-	7.90 ^a	7.81	7.88	7.88
	2013	7.88	7.96	7.90 ^b	-	-
Mean SpCond µS/cm	2009	-	-	120 ^a	-	-
	2010	94	108	177	131	124
	2011	73 ^b	93 ^b	-	114 ^b	122 ^b
	2012	-	156 ^a	157	157	163
	2013	163	168	176 ^b	-	-
Mean DO % Saturation	2009	-	-	78.2 ^a	-	-
	2010	79.1 ^b	80.7	78.1	78.9	78.9
	2011	78.8	79.2	78.6	79.2	80.0
	2012	-	75.7 ^a	78.1	80.5	77.5
	2013	72.4	73.2	73.0 ^b	-	-

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

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

2011

Water temperature (Figure 20A) in Strawberry Creek increased throughout July and August from a low of 8.7°C on July 1 to a high of 13.0°C on August 27. It then decreased rapidly at the very end of August and continued to decrease gradually until the end of September.

The dissolved oxygen saturation (Figure 20B) remained steady throughout July, with values fluctuating between 78.4% and 79.5%. It decreased in early August to a low of 78.2% and then increased from mid-August to the end of September, with a high of 80.6% on September 8.

The pH (Figure 20C) increased continuously throughout July from a low of 7.70 on June 30. It leveled out around 7.96 in August before increasing again slightly in September and reaching high of 8.02 on September 8.

The specific conductance (Figure 20D) increased from 73 $\mu\text{S}/\text{cm}$ on July 7 to 133 $\mu\text{S}/\text{cm}$ on September 6. It decreased rapidly in early September and then increased again rapidly in mid-September to a high of 141 $\mu\text{S}/\text{cm}$.

2012

Water temperature (Figure 21A) in Strawberry Creek increased during late June. It became steadier during July and August, with values fluctuating between 14.0°C and 15°C. It reached a peak of 15.6°C on August 2. Water temperature then decreased from late August to the end of September, with a low of 9.9°C on September 13.

The dissolved oxygen saturation (Figure 21B) decreased gradually over June and July to a low of 74.4% on July 30. It increased continuously during the first half of August to a high of 81.9% on August 17 and then decreased gradually until mid-September.

The pH (Figure 21C) decreased continuously from a high of 7.94 on July 17 to a low of 7.79 on August 3. It then increased slightly during mid-August before leveling out in late August and September.

The specific conductance (Figure 21D) increased from a low of 140 $\mu\text{S}/\text{cm}$ on June 21 to a high of 166 $\mu\text{S}/\text{cm}$ on September 5. The dip of 152 $\mu\text{S}/\text{cm}$ on September 11 corresponds to a rain event.

2013

Water temperature (Figure 22A) in Strawberry Creek decreased slightly in mid-June to a low of 10.0°C on June 20 and then rapidly increased to a high of 16.4°C on July 4. It remained steady throughout July until decreasing again in early August. After the gap in the record, water temperature reached another low of 8.9°C on September 19.

The dissolved oxygen saturation (Figure 22B) decreased gradually in June from a high of 76.5% on June 8. It leveled out in July and early August, with values fluctuating between 71.0% and 74.3%. After the gap in the record, saturation reached another high of 77.2% on September 14. The sharp dip of 67.7% on July 6 may be the result of an unreliable record.

The pH (Figure 22C) decreased from a high of 8.08 on June 8 to a low of 7.84 on July 8. It increased gradually throughout July and then decreased again slightly in August.

The specific conductance (Figure 22D) remained steady throughout most of June, with a low of 144 $\mu\text{S}/\text{cm}$ on June 15. It increased gradually from late June to the end of July and then leveled out again in August at 176 $\mu\text{S}/\text{cm}$. After the gap in the record, specific conductance reached a high of 186 $\mu\text{S}/\text{cm}$ on September 14.

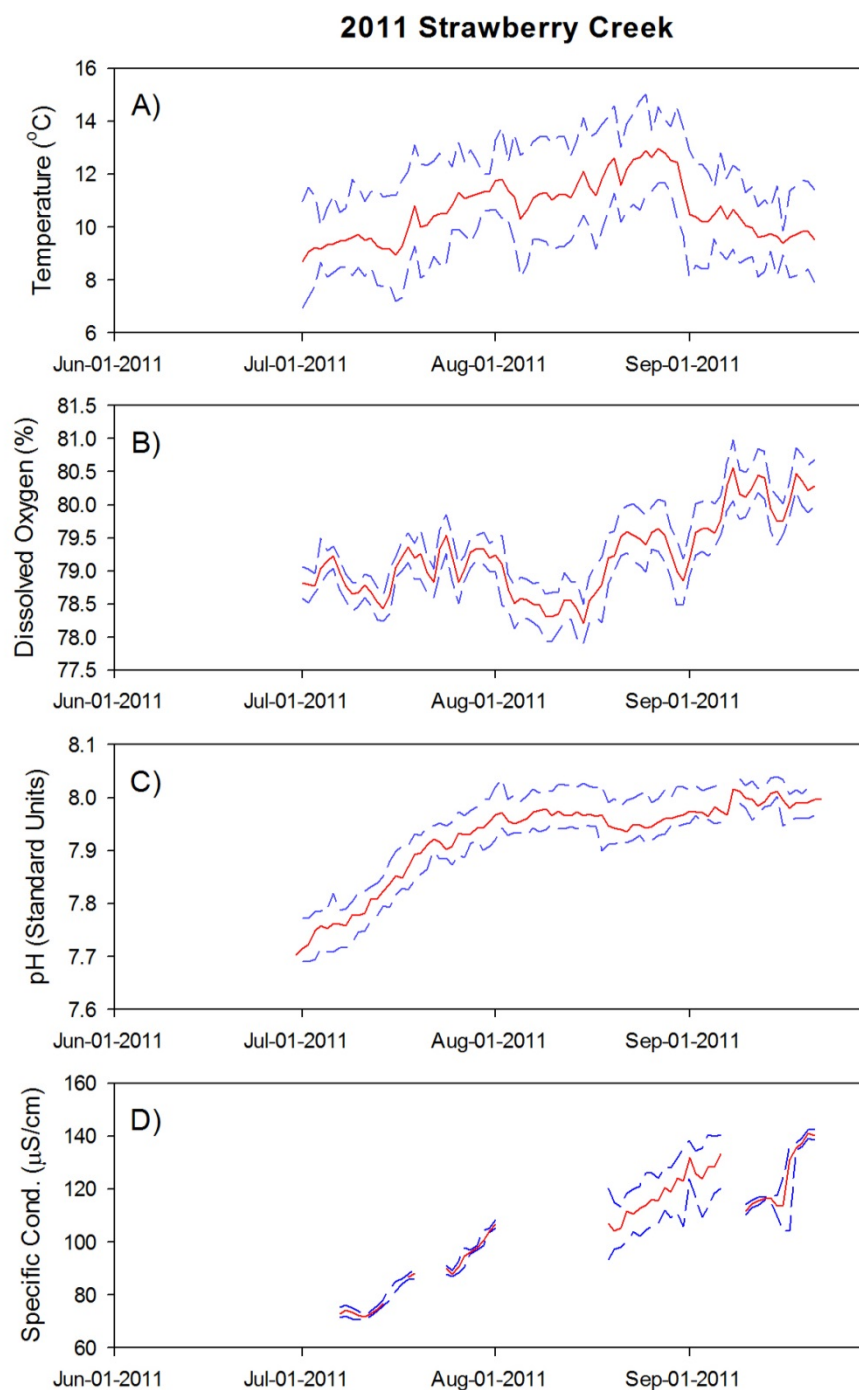


Figure 20. Strawberry Creek water quality data from the 2011 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

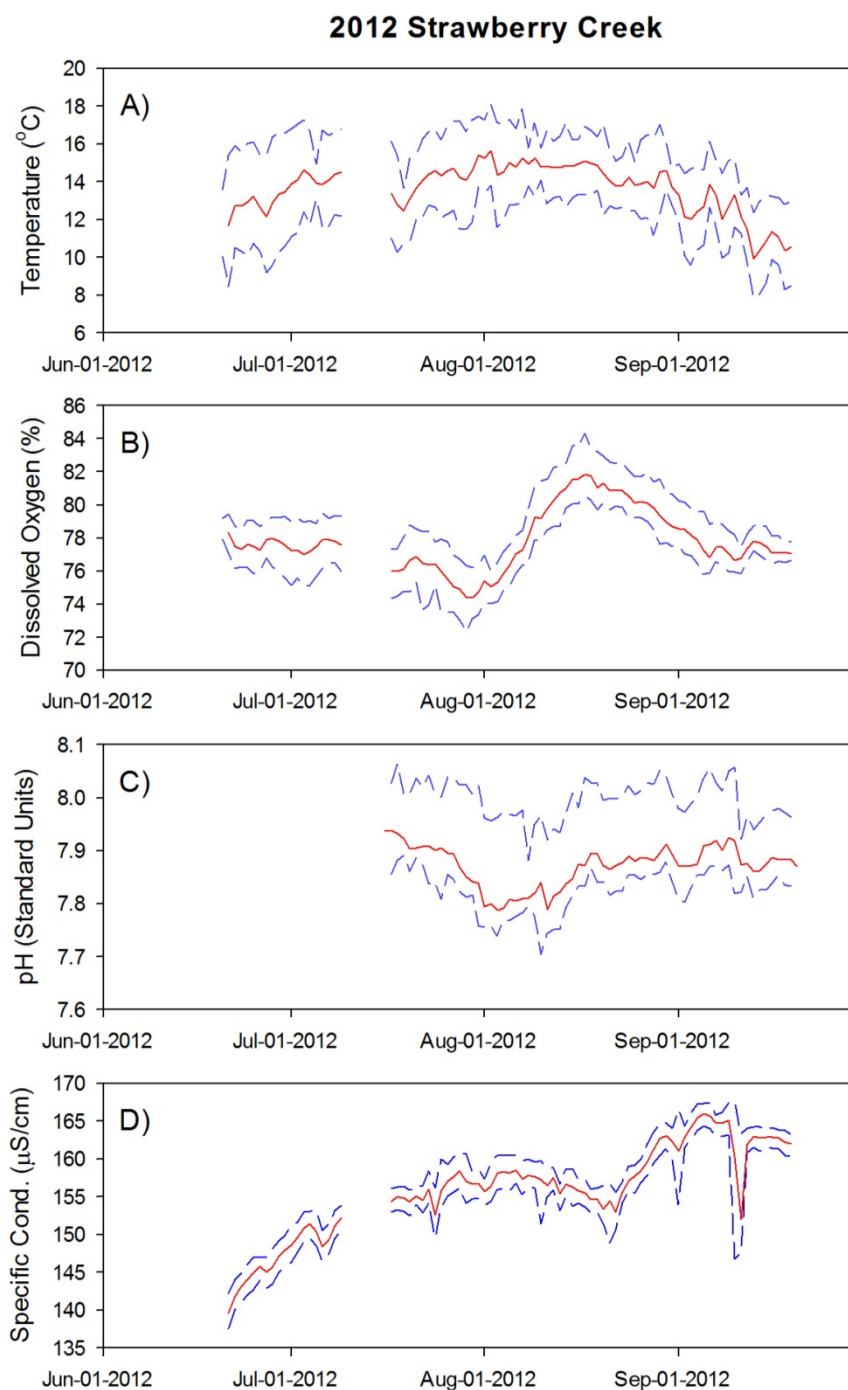


Figure 21. Strawberry Creek water quality data from the 2012 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

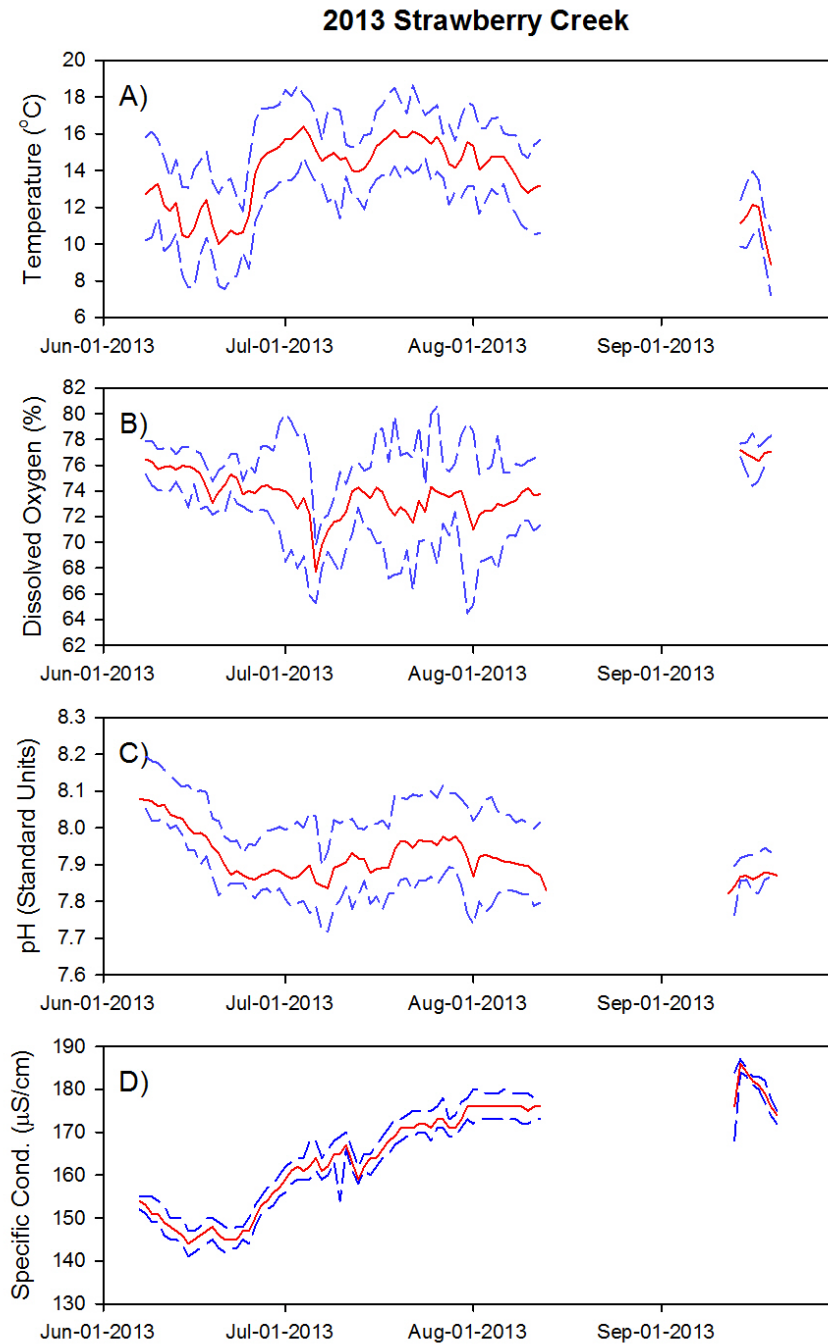


Figure 22. Strawberry Creek water quality data from the 2013 field season. A. Daily mean, minimum, and maximum temperature values. B. Daily mean, minimum, and maximum dissolved oxygen saturation values. C. Daily median, minimum, and maximum pH values. D. Daily mean, minimum, and maximum specific conductance values.

Stream Water Chemistry

Stream water samples were collected from nine streams at the locations given in Table 8 and shown in Figure 1. The sites were chosen randomly to ensure that the results were representative of aquatic habitat condition 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 (DO), pH, and specific conductance (SpCond). 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, and the medians of the four measurements are reported here.

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). All of the measured values meet these standards.

Table 8. Water quality parameters in GRBA streams. Each value is the median of three measurements.

Stream	UTM Coords NAD83 11S m	Visit Date	Temperature °C	Dissolved Oxygen mg/L	pH	Spec Conductance µS/cm
Snake	E 737569 N 4326941	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
Baker	E 736781 N 4315879	8/31/2010	4.9	9.20	7.59	41.9
		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
Lehman	E 734703 N 4322017	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
Pine	E 729600 N 4319780	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
Ridge	E 729383 N 4318560	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
South Fork	E 743243	9/2/2010	8.8	9.45	7.99	398.2

Table 8. Water quality parameters in GRBA streams. Each value is the median of three measurements (continued).

Stream	UTM Coords NAD83 11S m	Visit Date	Temperature °C	Dissolved Oxygen mg/L	pH	Spec Conductance µS/cm
Big Wash	N 4307414	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
Mill	E 736689 N 4324562	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
Shingle	E 729424 N 4320644	8/29/2013	11.4	7.07	7.84	72.5
		8/18/2009	7.0	-	8.00	66.2
		9/1/2010	6.7	9.71	8.01	70.0
Strawberry	E 735651 N 4326941	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
		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

Nutrients

The nutrient concentrations measured in the stream water samples are all very low (Table 9). The highest Total Nitrogen (TN) and total Phosphorus (TP) values from the years of 2011 to 2013 were 0.64 mg/L and 0.041 mg/L, respectively. All TP values were less than 0.10 mg/L and met the Nevada water quality standard for Class A Waters.

From 2011 to 2013, the Total Dissolved Nitrogen (TDN) values were greater than TN values in four of the stream samples. As discussed in Appendix 1, two of the samples fall within the range of expected variability. In the other two samples, TDN exceeds TN by an amount that is outside the expected range of variability, indicating that either the samples were contaminated during filtration or contaminated bottles were used.

Table 9. 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	0.002	0.013	0.011
	9/7/2010	0.05	0.06	0.003	0.007	0.005
	8/31/2011	0.06	0.04	0.004	0.007	0.004
	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

Table 9. Nutrient concentrations in GRBA streams (continued).

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
Baker	8/27/2009 ^a	0.15	0.15	0.051	0.017	0.016
	8/31/2010	0.13	0.15	0.091	0.008	0.009
	9/1/2011	0.22	0.23	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
Lehman	8/27/2009 ^a	0.20	0.24	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
	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
Pine	8/28/2009	0.12	0.17 ^b	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
Ridge	8/28/2009	0.44	0.33	0.264	0.027	0.019
	8/26/2010	0.31	0.38 ^b	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
South Fork	9/2/2009	0.12	0.13	0.080	0.005	0.004
Big Wash	9/2/2010	0.10	0.12	0.070	0.002 ^c	0.003
	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 ^b	0.100	0.003	0.001 ^d
Mill	7/31/2009	0.45	-	-	0.074	-
	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
Shingle	8/18/2009	0.22	-	-	0.030	-
	9/1/2010	0.08	0.11	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
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

a. Sample collected at stream gage.

b. TDN value greater than TN value with the difference outside the expected range of variability, indicating contamination of the sample.

c. Concentration above the method detection limit (MDL) but below the minimum level of quantification (ML).

d. Concentration below level of detection.

Major Ions and Acid Neutralization Capacity

Water samples were analyzed for sodium, potassium, calcium, magnesium, sulfate, and chloride (Table 10). 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 neutralization capacity (ANC) of each stream was measured. ANC is expressed in milliequivalents per liter (meq/L), that is, the number of millimoles 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.

Table 10. 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
	9/1/2011	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
Baker	8/27/2009 ^a	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
	9/1/2011	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
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
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
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
South Fork	9/2/2009	3.21	0.49	58.70	16.26	2.45	2.93	3771
Big Wash	9/2/2010	3.08	0.45	62.57	14.55	3.11	2.76	3583
	9/1/2011	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
	8/29/2013	3.21	0.66	7.39	2.01	0.74	1.89	557
Mill	7/31/2009	-	-	-	-	-	-	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

Table 10. Major ion concentrations and acid neutralization capacity in GRBA streams (continued).

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
Shingle	8/18/2009	-	-	-	-	-	-	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
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
	8/27/2013	6.18	0.82	19.39	4.06	1.55	3.70	1099

a. Sample collected at stream gage.

Stream Benthic Macroinvertebrates

Benthic macroinvertebrate (BMI) samples were collected from nine streams at the locations given in Table 8 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 11.

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 BMI communities in streams. 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.

Table 11. 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	55	19	24
	9/7/2010	858	61	24	12
	9/1/2011	823	26	13	11
	8/30/2012	2924	29	17	14
	8/27/2013	2938	34	20	12
Baker	8/27/2009 ^a	820	60	24	24
	8/31/2010 ^a	3563	41	18	38
	9/1/2011	861	18	11	18
	8/31/2012	1727	19	12	13
	8/28/2013	2550	24	16	17

Table 11. Population metrics for BMI samples collected in GRBA streams (continued).

Stream	Sampling Date	Abundance (per m2)	# of Taxa (Richness)	# of EPT Taxa (EPT Richness)	% Dominant Taxon
Lehman	8/27/2009 ^a	566	54	26	32
	8/30/2010	870	39	18	19
	8/30/2011	738	18	9	17
	8/31/2012	2116	19	12	14
	8/29/2013	4119	19	12	11
Pine	8/28/2009	1090	51	22	9
	8/26/2010	1973	55	19	14
	9/2/2011	1338	18	10	23
	9/6/2012	2424	21	10	11
	8/30/2013	3655	25	11	11
Ridge	8/28/2009	1891	45	20	12
	8/26/2010	4840	50	19	16
	9/2/2011	981	16	8	17
	9/6/2012	11647	15	6	18
	8/30/2013	7975	23	11	9
South Fork Big Wash	9/2/2009	506	35	11	16
	9/2/2010	1467	41	13	19
	9/1/2011	1039	23	11	16
	8/29/2012	746	19	9	18
	8/28/2013	2802	18	7	28
Mill	7/31/2009	1252	53	26	27
	9/7/2010	4502	62	26	18
	9/1/2011	1016	23	11	12
	8/31/2012	2446	36	19	9
	8/29/2013	2506	30	17	14
Shingle	8/18/2009	614	57	21	12
	9/1/2010	1062	65	24	11
	9/2/2011	915	27	13	18
	9/6/2012	1842	29	17	12
	8/30/2013	4836	27	15	11
Strawberry	9/28/2009	311	46	20	12
	8/24/2010	1477	57	23	19
	8/30/2011	518	15	7	40
	8/30/2012	2570	33	16	12
	8/27/2013	3448	29	17	21

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

Monitoring Results from Lakes

The results of lake level and temperature monitoring, water quality depth profile collection, lake water chemistry monitoring, and lake water clarity monitoring activities are summarized below. All of the lakes were visited in 2011 and 2012. Johnson Lake and Dead Lake were not visited in 2013 due to adverse weather conditions and the government shutdown.

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 12. Each lake's water level measurements are reported relative to a lake-specific benchmark (assigned a relative elevation of 100 m), so water levels cannot be compared between lakes.

Table 12 also includes ice-on dates (the date of the first ice formation as determined from the 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 days), as the first ice of the season often melts quickly. The ice-off dates are more accurate, perhaps ± 1 day.

Table 12. Measured water levels in GRBA lakes.

Lake	Sampling Date	Relative Lake Level (m) Benchmark = 100 m	Ice-On Date	Ice-Off Date
Stella	8/27/2009 ^a	97.76	-	-
	9/21/2010	98.51	11/5/09	-
	9/27/2011	98.76	-	-
	9/25/2012	97.87	-	4/20/12
	9/24/2013	98.52	10/10/12	5/7/13
Teresa	8/27/2009 ^a	97.25	-	-
	9/21/2010	98.10	11/13/09	-
	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
Brown	9/21/2010	99.27	-	-
	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
Baker	9/25/2009	98.98	-	-
	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	-	-
	9/25/2013	99.36	10/11/12	5/15/13
Johnson	9/24/2009	98.81	-	-
	9/23/2010	98.98	11/13/09	5/31/10
	9/28/2011	99.09	-	-
	9/26/2012	99.06	10/6/12	4/28/13

Table 12. Measured water levels in GRBA lakes (continued).

Lake	Sampling Date	Relative Lake Level (m) Benchmark = 100 m	Ice-On Date	Ice-Off Date
Dead	9/23/2010	99.02	-	-
	9/28/2011	101.33	-	-
	9/26/2012	98.10	10/12/12	5/1/13

a. Lake level measured outside of the index period.

Stella Lake

Stella Lake was visited in 2011, 2012, and 2013, but the pressure transducer deployed in September 2010 was not recovered in September 2011, resulting in the loss of all WY2011 data. A replacement pressure transducer was not deployed until October, and the lake level was not surveyed at the time of deployment, therefore the lake level data from before ice-on in WY2012 is not usable.

Lake level and temperature data for Stella Lake are shown in Figure 23. In WY2012, the water level reached a maximum value of 98.79 m on May 12, 2012, and a minimum value of 98.14 m on September 24, 2012. In WY2013, The water level reached a maximum value of 99.09 m on May 29, 2013, and a minimum value of 98.09 m on December 1, 2012.

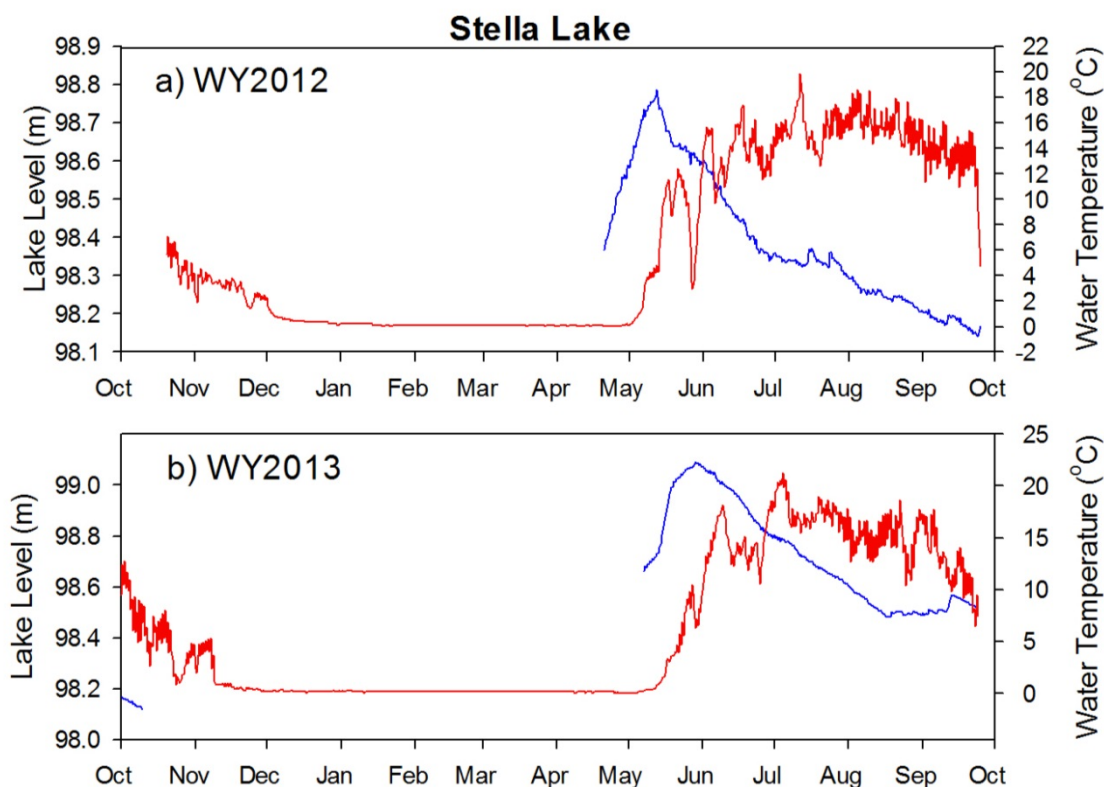


Figure 23. Water level records (blue lines) and temperature records (red lines) for Stella Lake.

Teresa Lake

Teresa Lake was visited in 2011, 2012, and 2013, and the pressure transducer was successfully recovered each time. However, the pressure sensor appears to have been damaged in the winter of 2012. Therefore, no usable water level data were collected after the WY2012 ice-on date.

Lake level and temperature data for Teresa Lake are shown in Figure 24. In WY2011, The water level reached a maximum value of 101.55 m on July 5, 2011, and remained at approximately that level until August 4, 2011. The minimum value of 98.02 m was reached on October 3, 2010.

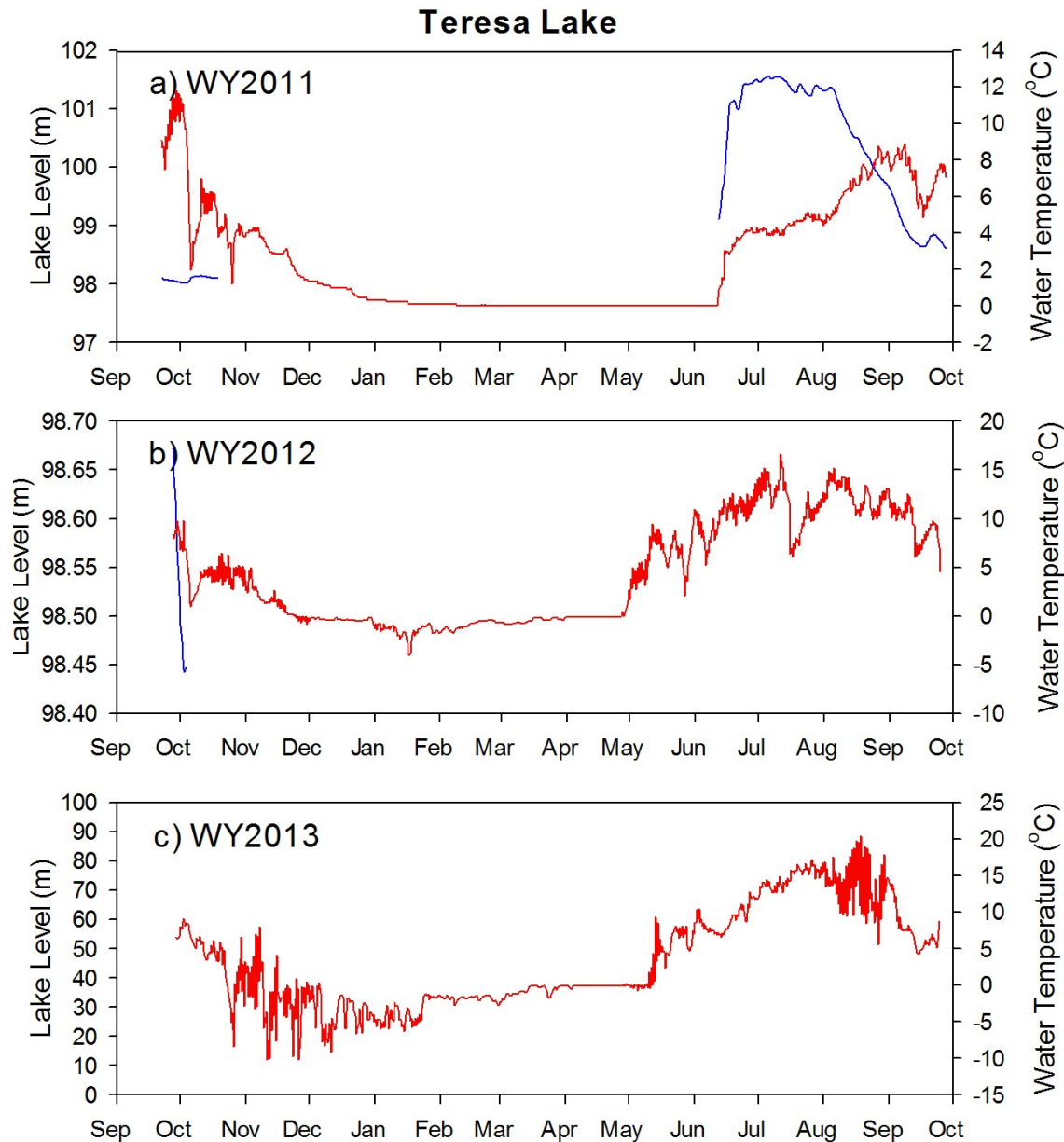


Figure 24. Water level records (blue lines) and temperature records (red lines) for Teresa Lake.

Brown Lake

Brown Lake was visited in 2011, 2012, and 2013 and the pressure transducer was successfully recovered each time.

Lake level and temperature data for Brown Lake are shown in Figure 25. In WY2011, the water level reached a maximum value of 99.95 m on June 25, 2011, and a minimum value of 99.15 m on March 30, 2011. In WY2012, the water level reached a maximum value of 99.47 m on May 6, 2012, and a minimum value of 98.68 m on March 14, 2012. In WY2013, the water level reached a maximum value of 99.64 m on May 29, 2013, and a minimum value of 98.64 m on March 16, 2013. In late summer WY2013, the water level rose to a maximum of 99.41 m on September 14, 2013, presumably due to summer precipitation.

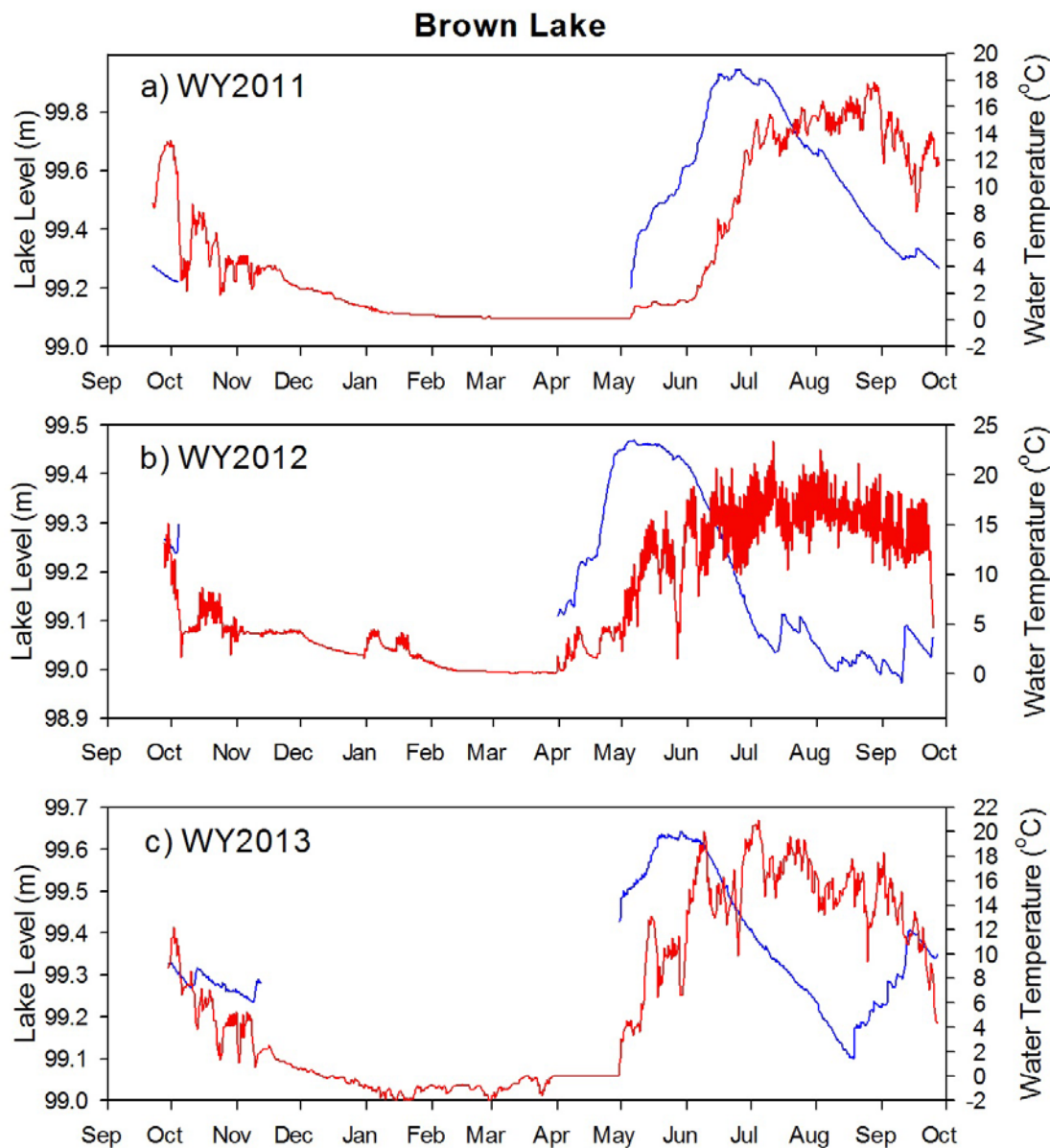


Figure 25. Water level records (blue lines) and temperature records (red lines) for Brown Lake.

Baker Lake

Baker Lake was visited in 2011, 2012, and 2013, and the pressure transducer was successfully recovered each time. However, the WY2012 data was lost due to a malfunction in the device used to download the data.

Lake level and temperature data for Baker Lake are shown in Figure 26. In WY2011, the water level reached a maximum value of 100.78 m on June 16, 2011, and a minimum value of 99.08 m on September 15, 2011. In WY2013, the water level reached a maximum value of 99.61 m on May 18, 2013, and a minimum value of 98.90 m on January 23, 2013. In late summer WY2013, the water level rose to a maximum of 99.50 m on September 16, 2013, presumably due to summer precipitation.

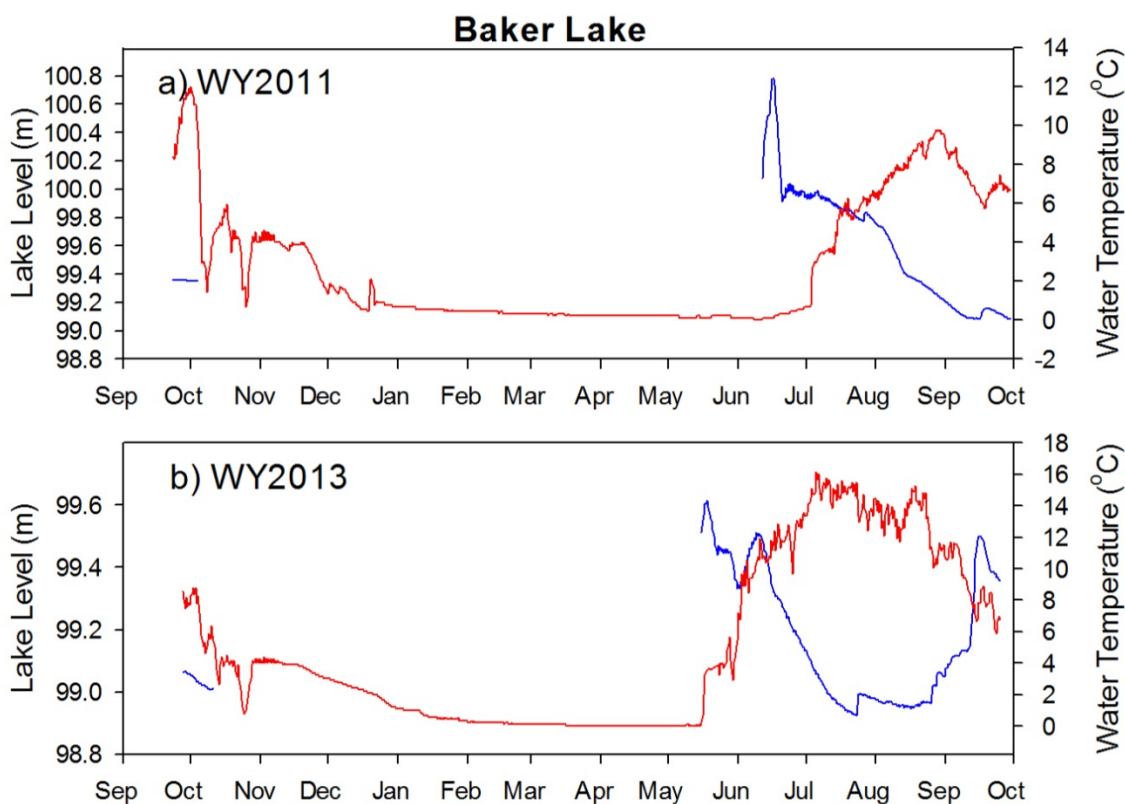


Figure 26. Water level records (blue lines) and temperature records (red lines) for Baker Lake.

Johnson Lake

No lake level data were recovered for Johnson Lake in 2011 (the pressure transducer malfunctioned or was improperly deployed) or 2012 (the pressure transducer was not recovered). Johnson Lake was not visited in 2013 due to the government shutdown, but the pressure transducer was recovered in September 2014 with data from the 2013 and 2014 water years. These data are not tied to a lake level measured during a field visit, so they cannot be used quantitatively. The recovered record has been graphed in Figure 27 for the purposes of qualitative interpretation.

Lake level and temperature data for Johnson Lake are shown in Figure 27. In WY2013, the water level reached a maximum value on May 16, 2013, and a minimum value on October 5, 2012. In late summer WY2013, the water level rose until reaching a maximum on September 14, 2013, presumably due to summer precipitation.

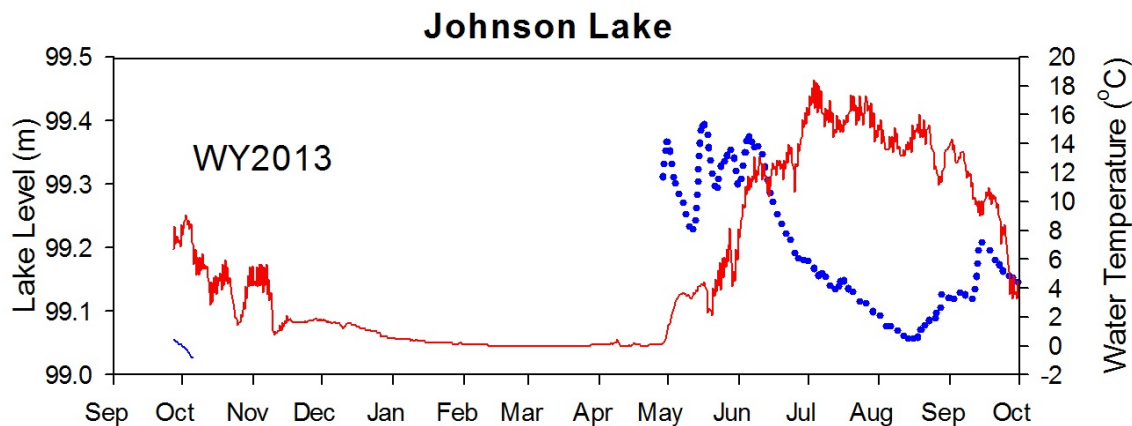


Figure 27. Water level record (blue line), water level record not tied to a lake level reading (dotted blue line), and temperature record (red line) for Johnson Lake.

Dead Lake

The pressure transducer that was deployed in Dead Lake in September 2010 was not recovered in September 2011 due to high water levels. The pressure transducer was found in September 2012, but no data was recovered. Dead Lake was not visited in 2013 due to the government shutdown, but the pressure transducer was recovered in September 2014 with data from the 2013 and 2014 water years. These data are not tied to a lake level measured during a field visit, so they cannot be used quantitatively. The recovered record has been graphed in Figure 28 for the purposes of qualitative interpretation.

Lake level and temperature data for Dead Lake are shown in Figure 28. In WY2013, The water level reached a maximum value on May 18, 2013, and a minimum value on August 11, 2013.

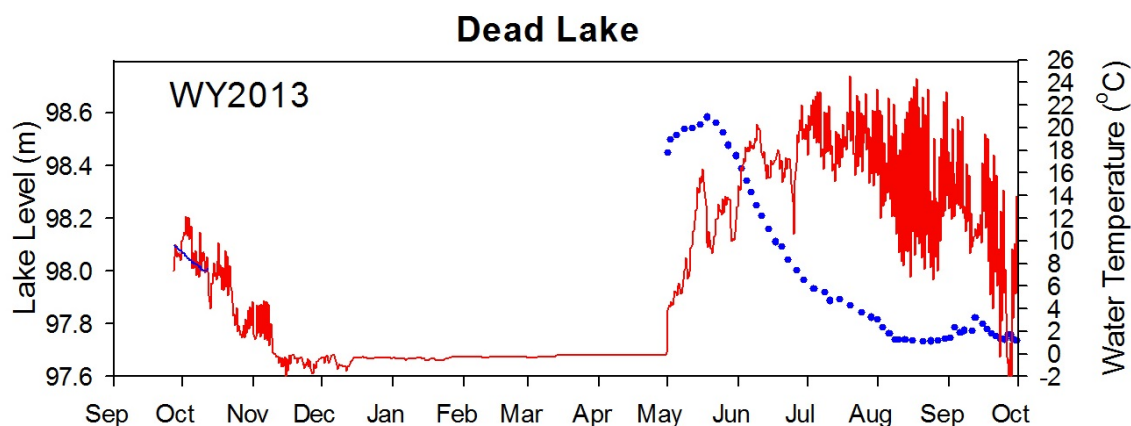


Figure 28. Water level record (blue line), water level record not tied to a lake level reading (dotted blue line), and temperature record (red line) for Dead Lake.

Lake Water Clarity

Lake water clarity was assessed in the field by measuring Secchi depth. In all visits except for Dead Lake in 2011 and 2012, the Secchi disk was visible on the bottom of the lake (Table 13). While the lakes at GRBA are likely too shallow to detect small changes in water clarity using this method, these data allow any major decrease in water clarity (for example, the 2011 and 2012 algal bloom in Dead Lake) to be documented.

Table 13. 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)
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)
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)
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)
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)
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)

a. Lake monitored outside of index period.

Lake Water Chemistry

Lake water samples were collected by hand-dipping near the deepest point in each lake. These 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

Depth profiles of four water quality parameters (temperature, DO, pH, and SpCond) were measured at six lakes. Measurements were made at the lake surface, the bottom, and several points in between.

The 2011 depth profiles are given in Table 14, the 2012 depth profiles in Table 15, and the 2013 depth profiles in Table 16. No stratification is apparent in any of the depth profiles. This observation, combined with the variations in temperature recorded at depth (Figures 23 to 28), likely indicate that the lakes are frequently mixed.

Table 14. Water quality depth profiles for 2011 collected in GRBA lakes.

Lake and Sampling Date	Depth m	pH	DO mg/L	SpCond µS/cm	Temperature °C
Stella 9/27/2011	0.00	7.40	6.44	29.8	11.9
	0.30		6.77	29.8	11.8
	0.61		6.67	29.8	11.7
	0.91		6.30	30.0	11.7
Teresa 9/27/2011	0.00	7.30	8.30	17.9	8.8
	0.30		8.35	17.8	8.3
	0.61		8.03	17.8	7.9
	0.91		8.22	17.9	7.8
	1.22		8.51	17.7	7.5
	1.49		7.13	17.8	7.4
Brown 9/27/2011	0.00	6.70	6.55	20.6	13.0
	0.30		6.60	20.7	12.8
	0.61		6.67	20.5	12.8
	0.91		6.63	20.6	12.8
Baker 9/29/2011	0.00	6.60	7.10	15.7	12.5
	0.61		6.97	15.7	12.0
	1.22		6.99	15.7	11.6
	1.83		6.55	15.8	9.6
	2.16		8.88	15.6	9.4
Johnson 9/28/2011	0.00	6.20	7.04	29.5	12.0
	0.61		6.78	29.7	11.9
	1.22		6.85	29.6	11.0
	1.83		6.97	29.6	10.7
	2.44		7.03	29.6	10.5
	3.05		6.82	29.6	10.3
Dead 9/28/2011	0.00	6.30	6.59	24.3	15.8
	0.61		6.64	24.3	13.2
	1.22		7.29	25.5	11.9
	1.83		7.01	25.6	11.6
	2.44		6.26	24.6	11.5
	3.05		6.53	24.2	11.4

Table 15. Water quality depth profiles for 2012 collected in GRBA lakes.

Lake and Sampling Date	Depth m	pH	DO mg/L	SpCond µS/cm	Temperature °C
Stella 9/25/2012	0.00	8.33	6.25	33.3	4.7
	0.30		6.52	34.1	4.5
	0.61		6.66	34.0	4.4
	0.70		0.01	50.5	6.6
Teresa 9/25/2012	0.00	7.96	6.87	20.9	5.9
	0.30		6.48	20.9	4.7
	0.61		6.82	20.9	4.8
	0.91		6.85	20.9	4.9
	1.22		6.93	29.8	4.9
	1.43		0.11	20.9	4.8
Brown 9/25/2012	0.00	7.61	6.92	25.7	6.8
	0.23		7.07	25.6	6.6
	0.38		6.98	25.7	6.8
	0.55		2.08	25.6	6.7
Baker 9/27/2012	0.00	7.00	6.92	17.8	7.6
	0.30		6.94	17.6	7.3
	0.91		7.02	17.7	7.0
	1.52		7.01	17.6	6.8
	2.10		6.99	17.5	6.6
Johnson 9/26/2012	0.00	8.40	7.18	37.0	7.5
	0.30		7.16	37.0	7.3
	0.91		7.38	37.0	7.1
	2.13		7.36	37.0	6.8
	3.05		6.93	37.0	6.7
Dead 9/26/2012	0.00	7.20	7.25	19.9	9.7
	0.15		6.77	20.1	8.8
	0.24		5.32	19.9	8.9
	0.40		5.87	19.9	8.6

Table 16. Water quality depth profiles for 2013 collected in GRBA lakes.

Lake and Sampling Date	Depth m	pH	DO mg/L	SpCond $\mu\text{S/cm}$	Temperature $^{\circ}\text{C}$
Stella 9/24/2013	0.00	8.06	6.86	33.3	6.7
	0.30		6.22	33.3	6.7
	0.61		6.54	33.2	6.7
	0.79		0.06	42.1	7.6
Teresa 9/23/2013	0.00	7.47	7.31	25.2	5.9
	0.61		7.22	25.2	5.7
	1.22		7.15	25.1	5.4
	1.83		7.37	25.0	5.4
Brown 9/24/2013	0.00	7.37	0.10	25.2	6.2
	0.30		6.70	24.8	9.9
	0.61		6.71	24.6	9.8
	0.70		6.48	24.5	9.8
Baker 9/25/2013	0.00	7.42	24.6	18.7	5.9
	0.61		7.13	18.6	5.8
	1.22		6.81	18.7	5.9
	1.83		7.17	18.7	5.9
	2.29		7.06	18.7	5.9
			6.67	18.7	6.0

Nutrients

Nutrient concentrations measured in the lake water samples (Table 17) are generally similar to the concentrations measured in the stream water samples. From 2011 to 2013, the highest total nitrogen (TN) value was 1.08 mg/L, and the highest total phosphorus (TP) value was 0.218 mg/L. Total dissolved nitrogen (TDN) values were close to TN values, but nitrate + nitrite values were more variable depending on the lake. This suggests that the dominant form of N in late summer may be dissolved organic nitrogen or that dissolved organic nitrogen may be present with nitrate + nitrite. Total dissolved phosphorus (TDP) values were significantly less than TP values in many of the samples, suggesting that both particulate and dissolved phosphorus are present in the lakes.

Table 17. 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	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 ^e	0.011	0.007
Teresa	8/27/2009 ^a	0.21	0.39 ^b	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

Table 17. Nutrient concentrations in GRBA lakes (continued).

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	-	-	-	-	-	-
	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
	9/24/2013	0.41	0.35	0.011	0.009	0.004
Baker	9/25/2009	0.26	0.24	0.052	0.025	0.019
	9/22/2010	0.28	0.29	0.068	0.033	0.026
	9/29/2011	0.27	0.37 ^b	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
Johnson	9/24/2009	0.20	0.21	0.004	0.008	0.006
	9/23/2010	0.21	0.23	0.004	0.009	0.008
	9/28/2011	0.14	0.13	0.003	0.006	0.005
	9/26/2012	0.16	0.14	0.011	0.006	0.003
	-	-	-	-	-	-
Dead	-	-	-	-	-	-
	9/23/2010	0.82	0.95 ^b	0.001 ^d	0.051	0.039
	9/28/2011	0.54	0.45	0.001 ^e	0.029	0.018
	9/26/2012	1.08	0.88	0.001 ^e	0.218	0.044
	-	-	-	-	-	-

a. Lake sampled outside of index period.

b. TDN value greater than TN value with the difference outside the expected range of variability, indicating contamination of the sample.

c. Likely an erroneous value—discussed in text.

d. Concentration is above the method detection limit (MDL) but below the minimum level of quantification (ML).

e. Concentration is below level of detection.

Major Ions and Acid Neutralization Capacity

Water samples were analyzed for sodium, potassium, calcium, magnesium, sulfate, and chloride (Table 18). Systematic changes in the concentrations 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.

In addition, the acid neutralizing capacity (ANC) of each lake was measured. Lakes with ANC values of less than 100 µeq/L are often considered to be sensitive to acidification (e.g., Campbell et al 2004, Stoddard et al. 2008, Burns et al. 2011). By this measure, none of the lakes sampled from 2011 to 2013 would be classified as sensitive to acidic deposition during the index period.

Table 18. 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
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
Brown	-	-	-	-	-	-	-	-
	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
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
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
	-	-	-	-	-	-	-	-
Dead	-	-	-	-	-	-	-	-
	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
	-	-	-	-	-	-	-	-

a. Lake sampled outside of index period.

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) are discussed in Appendix A. There were two major QA/QC issues encountered with 2011-2013 data: missing lake level records and missing continuous water quality data.

As described in the “Lake Level and Ice-Free Period” section of the report, only 10 of the 18 lake level records are usable (56%). Of the eight missing records, two were due to a broken pressure transducer, two were due to improperly deployed pressure transducers, and four were due to lost pressure transducers. MOJN has adjusted deployment methods with the goal of reducing the number of lost transducers, and no longer uses the malfunctioning shuttle that resulted in the improper deployments. Data loss due to broken pressure transducers is likely unavoidable, but the impact may be reduced by reviewing the data as soon as possible after it is retrieved.

As described in Appendix A, many days of 2011-2013 water quality data were not collected due to sonde and sensor malfunction. While MOJN and GRBA have worked together to replace or repair broken instruments, the completeness of the data would benefit from replacing the sensors before they are unusable (e.g., once their performance begins to degrade). As the protocol matures, more data will be available regarding sensor lifetime, and it may become possible to replace them on a schedule.

Discussion

The overall water quality of the streams and lakes in GRBA is generally excellent. Both the streams and the lakes have low nutrient concentrations, high pH values, low temperatures, and high levels of oxygen saturation. The observed BMI communities in the streams are consistent with unimpaired water quality.

Water year 2011 had greater-than-average precipitation, snow pack, and stream discharge, while water years 2012 and 2013 were much drier. Interestingly, the very different hydrologic conditions in these years did not have a major effect on water quality with the exception of stream temperature. The July and August stream temperatures in 2011 were lower in all streams than in 2012 and 2013. BMI abundance was also lower in 2011 than in 2012 or 2013 in eight of the nine sampled streams.

The first five years of monitoring have provided valuable baseline data on the health of the aquatic ecosystems in GRBA and provided information on how they respond to wet and dry years. MOJN I&M will prepare synthesis reports incorporating these data following the publication of the stream discharge records and the 2014 annual report.

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Appendix A: QA/QC Measurements

This appendix reports on the results of all QA/QC measurements made in the field and the laboratory in the 2011, 2012, and 2013 field seasons.

Instrument Testing

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

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

Instrument	Owner	Type	Parameters	Manufacturer	Model #
A	GRBA	sonde	All 4	YSI	6920 V2
B	MOJN	sonde	All 4	YSI	6920 V2
C	MOJN	sonde	All 4	YSI	6920 V2
D	MOJN	sonde	All 4	YSI	6920 V2
E	MOJN	sonde	All 4	YSI	6920
2	GRBA	handheld	DO, SpCond, T	YSI	85
3	GRBA	handheld	DO, SpCond, T	YSI	85
4	GRBA	handheld	DO, SpCond, T	YSI	85
Fish5	GRBA	handheld	DO, SpCond, T	YSI	85
556	MOJN	handheld	All 4	YSI	556
pH-2	GRBA	handheld	pH	Oakton	10
pH-3	GRBA	handheld	pH	Oakton	10
pH-Fish5-A	GRBA	handheld	pH	Oakton	10
pH-Fish5-B	GRBA	handheld	pH		

Temperature Sensor Comparison

Temperature sensors are not calibrated. Instead, temperature sensors are compared to each other once a year in water baths of different temperatures to detect problematic performance. The standard is that the measurements should be within 0.2°C of each other. As Table A-2 shows, the standard was met or exceeded by only 0.01°C in all cases except for the ice water baths in 2012 and 2013. It is difficult to keep ice water baths at a constant temperature (they are often colder at the top where the ice is melting), so the problem is with the water baths rather than the temperature sensors.

Table A-2. Temperature sensor comparison results.

Year	2011			2012			2013	
Bath*	R	I	H	I	R	H	I	R
A	17.46	1.05	39.42	-	-	-	0.02	19.44
B	17.41	1.09	39.37	-	-	-	0.76	19.48
C	17.49	1.11	39.43	4.46	19.3	30.22	0.3	19.38
D	-	-	-	3.73	19.25	30.13	0.99	-
E	17.48	1.12	39.43	3.75	19.12	30.02	0.48	19.59
3	17.6	1.2	39.4	3.0	19.3	30.1	-	-
4	17.5	1.2	39.4	-	-	-	-	-
Fish5	17.5	1.2	39.5	3.2	19.2	30.1	0.9	19.5
556	-	-	-	3.25	19.24	30.17	-	-

Table A-2. Temperature sensor comparison results (continued).

Year	2011			2012			2013	
Bath*	R	I	H	I	R	H	I	R
Range	0.19	0.15	0.13	1.46	0.18	0.2	0.97	0.21

*R = water at or near room temperature, I = ice water bath, H = hot tap water

Head-to-Head Testing and AMS+ Calculation

The head-to-head instrument comparison was carried out in Baker Creek near Upper Baker Creek Campground. As Table A-3 shows, no problems were encountered with the temperature or specific conductivity measurements.

Table A-3. Head-to-head comparison of water quality measurements made using different instruments.

Year	Instrument	Temperature (°C)	SpCond (µS/cm)	pH	DO (mg/L)	DO (%)
2011	A	8.76	40.86	7.52	9.07	
	C	8.79	40.71	7.68	9.20	
	E	8.82	36.14	7.43	9.16	
	2	8.83	40.66		9.20	
	3	8.89	41.17		9.11	
	4	8.80	41.94		9.17	
	Fish5	8.89	40.40		8.94	
	pH-Fish5-A			7.76		
	pH-2			6.70		
	pH-3			6.89		
2012	C	10.13	36.91	7.53		77.95
	D	10.20	36.93	9.83		80.34
	E	10.20	36.57	8.84		
	3	10.19	39.34		8.36	
	Fish5	10.20	37.43		8.70	
	pH-Fish5-A			7.76		
	pH-2			7.94		
	MOJN556	10.03	39.00	6.31	7.25	
2013	A	9.36	37.51	7.43		75.85
	B	9.55	39.17	7.18		76.14
	C	9.62	37.54	7.15		76.04
	D	9.70	36.78	7.43		75.66
	E	9.67	39.44	9.61		76.55
	Fish5	9.60	38.34		8.78	
	pH Testr 30 (Fish 5)			7.12		
	pHTestr30NEW(Fish5)			7.85		

AMS+ is a metric of measurement sensitivity in an ambient condition such as a well-mixed flowing stream. It is affected by instrument noise and natural heterogeneity. Seven repeated measurements are made in rapid succession in situ. AMS+ is then calculated as:

$$AMS+ = t \times s ,$$

where:

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

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

The AMS+ values for the instruments are given in Table A-4. The data quality objectives (DQOs) for AMS+ are 0.3°C for temperature, 5 µS/cm for specific conductivity, 0.3 for pH, and 0.4 mg/L for dissolved oxygen. These targets were met for all sensors except for the pH sensors in sondes D and E in 2012, which were subsequently replaced.

Table A-4. AMS+ values for water quality instruments used during the field season. Bolded values exceed DQOs.

Instrument	Year	Temperature (°C)	SpCond (µS/cm)	pH	DO (mg/L)	DO (%)
A	2011	0.0981	1.4015	0.0140	0.0303	
	2013	0.1321	0.1565	0.0217		0.0522
B	2013	0.1363	0.3046	0.1396		0.3001
C	2011	0.1036	1.8093	0.1282	0.0362	
	2012	0.2587	0.0240	0.0564		0.1883
	2013	0.1327	0.0233	0.0723		0.1601
D	2012	0.2143	0.0422	0.3199	0.1734	
	2013	0.1028	0.0499	0.0496	0.0827	
E	2011	0.0825	10.7954	0.0821	0.0479	
	2012	0.2850	0.0989	2.0787		
	2013	0.1243	0.0457	0.1548		0.1170
2	2011	0.1809	0.4204		0.1705	
3	2011	0.1401	0.1809		0.0512	
	2012	0.1401	0.1982		0.0198	
4	2011	0.0000	0.1982		0.0334	
Fish5	2011	0.1401	0.0000		0.0292	
	2012	0.0000	0.1809		0.0280	
	2013	0.0000	0.1982		0.0362	
pH Testr 30 (Fish 5)	2011			0.0198		
	2012			0.0413		
	2013			0.0332		
pH Testr 10 (unit 2)	2011			0.2917		
	2012			0.0198		
pH Testr 3+	2011			0.1170		
MOJN 556	2012	0.0256	0.0000	0.2515	0.3157	
pHTestr30NEW(Fish5)	2013			0.0140		

Stream Cross-Section Data

Tables A-5 to A-7 show the stream cross-section data collected from 2011 to 2013. For each cross-section, measurement 1 was made on the left bank looking upstream. Subsequent measurements were made increasingly to the right. All of the tested streams were well-mixed, demonstrating that the water quality measurements collected by the sondes are representative of the water quality of the entire stream at the monitoring location.

Table A-5. 2011 stream cross-section data for selected water quality parameters.

		1 ← Left	2	3	4 Right →	5
Strawberry Creek	Temp (°C)	8.5	8.5	8.6	8.6	8.6
	pH	7.85	7.90	7.91	7.9	7.89
	DO (mg/L)	9.16	9.30	9.21	9.29	9.21
	SpCond (µS/cm)	73.1	73.1	72.9	73.2	73.1
	RawCond (µS/cm)	50.2	50.1	50.0	50.1	50.1
Lehman Creek	Temp (°C)	9.7	9.7	9.6	9.7	-
	pH	7.56	7.63	7.64	7.64	7.63
	DO (mg/L)	8.96	9.20	9.22	9.09	-
	SpCond (µS/cm)	32.3	31.9	32.2	32.3	-
	RawCond (µS/cm)	22.8	22.6	22.7	22.9	-

Table A-6. 2012 stream cross-section data for selected water quality parameters.

		1 ← Left	2	3	4 Right →	5
Lower Snake Creek	Temp (°C)	13.9	13.9	13.9	13.8	13.8
	SpCond (µS/cm)	158.8	158.6	158.7	158.8	158.7
Strawberry Creek	Temp (°C)	12.9	12.9	12.9	12.8	12.9
	SpCond (µS/cm)	139.0	139.0	139.0	139.1	139.0
Lehman Creek	Distance (m)	0.1	0.5	1.0	1.5	2.0
	Temp (°C)	16.8	16.7	16.7	16.6	16.6
	SpCond (µS/cm)	37.8	37.9	37.9	37.9	38.0
Baker Creek	Temp (°C)	13.9	13.9	13.9	13.9	13.9
	SpCond (µS/cm)	34.1	34.0	33.9	33.9	33.8

Table A-7. 2013 stream cross-section data for selected water quality parameters.

		1 ← Left	2	3	4	5 Right →	6
Strawberry Creek	Distance (m)	0.0	0.2	0.4	0.6	0.8	1.0
	Temp (°C)	15.4	15.5	15.5	15.5	15.5	15.5
	SpCond (µS/cm)	153.3	153.3	153.1	153.1	153.2	153.2
Baker Creek	Distance (m)	0.0	0.8	1.6	2.4	3.2	4.0
	Temp (°C)	12.9	12.9	12.9	12.9	12.9	12.9
	SpCond (µS/cm)	29.7	29.7	29.8	29.7	29.6	29.7
Lehman Creek	Distance (m)	0.0	0.4	0.8	1.2	1.6	2.0
	Temp (°C)	15.5	15.4	15.4	15.4	15.4	15.4
	SpCond (µS/cm)	38.9	39.1	39.0	39.0	39.0	39.0

Laboratory QA/QC

The discussion below summarizes QA/QC checks and procedures for laboratory analytical data collected during 2011, 2012, and 2013. All analyses were performed by the Cooperative Chemical Analytical Laboratory (CCAL).

Laboratory Detection Limits and Quantitation Limits

CCAL met the desired measurement quality objectives (MQOs) for detection limits. Several analytical results were between the detection limit (MDL) and the quantitation limit (ML), meaning that the analytes were detected, but their concentrations could not be quantified. These data have been flagged, and they should not be used in long term trend analyses without careful consideration.

Dissolved Concentrations Exceeding Total Concentrations

One observed problem with the laboratory data was that five of the total dissolved nitrogen (TDN) values were greater than their corresponding total nitrogen (TN) values. As shown in Table A-8 and Table A-9, the laboratory performed duplicate analyses on the samples where the discrepancy was observed. They concluded that two of the discrepancies were within the range of normal variability, but three of the samples did not conform to analytical expectations. The most likely explanation for these three discrepancies is that trace amounts of nutrients were introduced into the samples during field filtration. Six similar discrepancies were found in the 2009 and 2010 data (Moret et al. 2013), so there is some evidence that field techniques have improved over time.

Table A-8. Summary of 2011 laboratory analyses with TDN > TN.

	Total Nitrogen (mg/L)	Total Dissolved Nitrogen (mg/L)
Baker Creek	0.22	0.23
Duplicate Analysis	0.22	
Lab Report: results “fall within the expected normal variability... data are analytically equal in concentration”		
Baker Lake	0.27	0.37
Duplicate Analysis	0.26	0.39
Lab Report: data “do not conform to analytical expectations... reanalysis results exhibit the same pattern”		
Pine Creek	0.12	0.17
Duplicate Analysis	0.15	0.21
Lab Report: data “do not conform to analytical expectations... reanalysis results exhibit the same pattern”		

Table A-9. Summary of 2013 laboratory analyses with TDN > TN.

	Total Nitrogen (mg/L)	Total Dissolved Nitrogen (mg/L)
Lehman Creek	0.54	0.55
Lab Report: results “fall within precision limits and are analytically equal in concentration”		
South Fork Big Wash	0.14	0.17
Lab Report: data “do not conform to analytical expectations...reanalysis confirmed original results”		

Duplicate Analyses

In 2011, CCAL performed 41 duplicate analyses on 13 samples. In 2010, CCAL performed 31 duplicate analyses on 12 samples. In 2013 CCAL performed 27 duplicate analyses on 12 samples. In all three years, 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:

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

where:

S_1 = the larger test result value, and

S_2 = the smaller test result value.

The results of the duplicate analyses and RPD calculations are given in Tables A-10 to A-12. None of the calculated RPD values exceed the laboratory precision MQO of 30% specified in the QAPP with the exception of the TP and TDP analyses for South Fork Big Wash in 2011. In these two cases, all of the values were at or below the minimum detection limit and well below the minimum level of quantification, so quantitative analytical precision standards are not applicable.

Table A-10. 2011 duplicate laboratory analyses and relative percent difference (RPD) values.

Sample	Analysis	Original Result	Duplicate Result	RPD
Baker Creek	TN (mg/L)	0.22	0.22	0%
Baker Creek	TP (mg/L)	0.011	0.011	0%
Baker Creek	TDP (mg/L)	0.010	0.010	0%
Baker Lake	TN (mg/L)	0.27	0.26	4%
Baker Lake	TDN (mg/L)	0.37	0.39	5%
Baker Lake	TP (mg/L)	0.020	0.020	0%
Brown Lake	TDP (mg/L)	0.008	0.008	0%
Brown Lake	Ca (mg/L)	1.95	1.93	1%
Brown Lake	Mg (mg/L)	0.55	0.55	0%
Brown Lake	SO4 (mg-S/L)	0.25	0.25	0%
Brown Lake	Cl (mg/L)	0.67	0.66	2%
Johnson Lake	Na (mg/L)	0.79	0.80	1%
Johnson Lake	K (mg/L)	0.21	0.21	0%
Lehman Creek	Ca (mg/L)	3.36	3.30	2%
Lehman Creek	Mg (mg/L)	0.66	0.65	2%
Lehman Creek	SO4 (mg-S/L)	0.29	0.29	0%
Lehman Creek	Cl (mg/L)	0.31	0.31	0%
Lehman Creek	DOC (mg/L)	0.72	0.71	1%
Mill Creek	TN (mg/L)	0.17	0.15	13%
Mill Creek	TDN (mg/L)	0.14	0.13	7%
Mill Creek	pH	8.0	7.9	1%
Mill Creek	Cond (µS/cm)	58.60	58.70	0%

Table A-10. 2011 duplicate laboratory analyses and relative percent difference (RPD) values (continued).

Sample	Analysis	Original Result	Duplicate Result	RPD
Mill Creek	Na (mg/L)	3.18	3.20	1%
Mill Creek	K (mg/L)	0.59	0.59	0%
Mill Creek	Alk CaCO ₃ (mg/L)	25.50	25.50	0%
Pine Creek	TN (mg/L)	0.17	0.15	13%
Pine Creek	TDN (mg/L)	0.20	0.21	5%
Pine Creek	NO ₃ + NO ₂ (mg-N/L)	0.111	0.111	0%
Ridge Creek	TP (mg/L)	0.025	0.026	4%
Snake Creek	TN (mg/L)	0.06	0.07	15%
Snake Creek	TDN (mg/L)	0.04	0.04	0%
Snake Creek	TDP (mg/L)	0.004	0.004	0%
Snake Creek	NO ₃ + NO ₂ (mg-N/L)	0.004	0.003	29%
S. Fork Big Wash	TP (mg/L)	0.002 ^a	0.001 ^a	67%
S. Fork Big Wash	TDP (mg/L)	0.001 ^a	0.002 ^a	67%
Stella Lake	TN (mg/L)	0.28	0.27	4%
Stella Lake	pH	7.7	7.7	0%
Stella Lake	Cond (µS/cm)	28.6	28.6	0%
Stella Lake	Alk CaCO ₃ (mg/L)	14.17	14.37	1%
Strawberry Creek	TDN (mg/L)	0.11	0.10	10%
Teresa Lake	TN (mg/L)	0.48	0.48	0%

a. Concentration is below MQL.

Table A-11. 2012 duplicate laboratory analyses and relative percent difference (RPD) values.

Sample	Analysis	Original Result	Duplicate Result	RPD
Baker Creek	pH	7.1	7.1	0%
Baker Creek	Cond (µS/cm)	27.10	26.70	1%
Baker Creek	Alk CaCO ₃ (mg/L)	8.50	8.29	3%
Baker Lake	NO ₃ + NO ₂ (mg-N/L)	0.307	0.310	1%
Brown Lake	TDN (mg/L)	0.52	0.50	4%
Brown Lake	SO ₄ -S (mg/L)	0.56	0.57	2%
Brown Lake	Cl (mg/L)	1.12	1.15	3%
Johnson Lake	NO ₃ + NO ₂ (mg-N/L)	0.011	0.011	0%
Lehman Creek	Ca (mg/L)	3.51	3.60	3%
Lehman Creek	Mg (mg/L)	0.70	0.70	0%
Ridge Creek	SO ₄ -S (mg/L)	0.67	0.68	1%
Ridge Creek	Cl (mg/L)	0.54	0.54	0%
Shingle Creek	Na (mg/L)	1.95	1.98	2%
Shingle Creek	K (mg/L)	0.31	0.31	0%
Snake Creek	TN (mg/L)	0.11	0.11	0%
Snake Creek	TDN (mg/L)	0.08	0.08	0%
Snake Creek	TP (mg/L)	0.017	0.017	0%
Snake Creek	TDP (mg/L)	0.012	0.012	0%
S. Fork Big Wash	SO ₄ -S (mg/L)	3.97	3.95	1%
Stella Lake	TN (mg/L)	0.43	0.43	0%
Stella Lake	TDN (mg/L)	0.31	0.32	3%
Stella Lake	TP (mg/L)	0.019	0.019	0%

Table A-11. 2012 duplicate laboratory analyses and relative percent difference (RPD) values (continued).

Sample	Analysis	Original Result	Duplicate Result	RPD
Stella Lake	TDP (mg/L)	0.007	0.007	0%
Stella Lake	Na (mg/L)	1.35	1.36	1%
Stella Lake	K (mg/L)	0.69	0.68	1%
Strawberry Creek	TDN (mg/L)	0.06	0.05	18%
Strawberry Creek	TDP (mg/L)	0.006	0.005	18%
Teresa Lake	TDN (mg/L)	0.69	0.69	0%
Teresa Lake	TDP (mg/L)	0.006	0.007	15%
Teresa Lake	Ca (mg/L)	2.01	2.05	2%
Teresa Lake	Mg (mg/L)	0.52	0.52	0%

Table A-12. 2013 duplicate laboratory analyses and relative percent difference (RPD) values.

Sample	Analysis	Original Result	Duplicate Result	RPD
Baker Creek	DOC (mg/L)	0.91	0.93	2%
Baker Lake	TP (mg/L)	0.014	0.014	0%
Brown Lake	TP (mg/L)	0.009	0.009	0%
Lehman Creek	TN (mg/L)	0.54	0.54	0%
Lehman Creek	TDP (mg/L)	0.007	0.006	15%
Lehman Creek	Ca (mg/L)	3.85	3.96	3%
Lehman Creek	Mg (mg/L)	0.77	0.75	3%
Pine Creek	NO ₃ + NO ₂ (mg-N/L)	0.077	0.078	1%
Pine Creek	Na (mg/L)	1.19	1.20	1%
Pine Creek	K (mg/L)	0.22	0.23	4%
Ridge Creek	pH	7.7	7.7	0%
Ridge Creek	Alk CaCO ₃ (mg/L)	17.97	18.37	2%
Ridge Creek	Cond (µS/cm)	43	43	0%
Shingle Creek	TN (mg/L)	0.1	0.1	0%
Shingle Creek	TP (mg/L)	0.013	0.014	7%
Shingle Creek	Cl (mg/L)	0.57	0.57	0%
Shingle Creek	SO ₄ -S (mg/L)	0.66	0.67	2%
Snake Creek	NO ₃ + NO ₂ (mg-N/L)	0.004	0.004	0%
Snake Creek	TP (mg/L)	0.009	0.008	12%
S. Fork Big Wash	SO ₄ -S (mg/L)	4.23	4.22	0%
Stella Lake	TDN (mg/L)	0.35	0.36	3%
Stella Lake	Ca (mg/L)	3.85	3.86	0%
Stella Lake	Mg (mg/L)	0.68	0.67	1%
Strawberry Creek	TDN (mg/L)	0.1	0.1	0%
Strawberry Creek	TDP (mg/L)	0.01	0.01	0%
Teresa Lake	Na (mg/L)	0.74	0.74	0%
Teresa Lake	K (mg/L)	0.32	0.33	3%

Field Filtration Blank

A field filtration blank was submitted to CCAL in 2012 to evaluate the extent to which contamination is introduced by sample handling and filtration in the field. All of the analyses typically performed on filtered samples were performed on the blank (Table A-13). The only

constituent present at a concentration greater than the MDL was Cl, which was present at a concentration of approximately 0.01 mg/L, much lower than the concentrations typically observed in field samples.

Table A-13. 2012 nutrient and major ion concentrations for field filtration blank.

TDN mg/L	NO ₃ + NO ₂ mg-N/L	TDP mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cl mg/L
0.01 ^a	0.001 ^a	0.000 ^a	0.04	0.01 ^a	0.06 ^a	0.00 ^a	0.01

a. Concentration is below level of detection.

Effectiveness and Completeness

Effectiveness, E, is calculated as:

$$E = (U / N) \times 100 \quad ,$$

where:

U = number of usable 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:

$$C = (U / P) \times 100 \quad ,$$

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 2011, 2012, and 2013, and all of the visits resulted in usable chemistry, BMI, and water quality data.

Annual Lake Visits

All of the lakes were visited in 2011 and 2012. In 2013, two of the lakes were not visited due to the government shutdown. Usable chemistry and water quality data was generated at each visit (E = 100%), so the overall completeness for the three years (16 lake visits out 18 planned lake visits) is 89%.

Lake Level Records

As described in the “Lake Level and Ice-Free Period” section of the report, only 10 of the 18 lake level records are usable (C = 56%). Of the eight missing records, two were due to a broken pressure transducer, two were due to improperly deployed pressure transducers, and four were due to lost

pressure transducers. MOJN is working to improve the completeness of the lake level monitoring program.

Continuous Water Quality

The effectiveness and completeness statistics for the continuous water quality monitoring are summarized in Tables A-14 to A-16. Many of the periods of missing or unusable data are due to sonde malfunction. MOJN is working to develop procedures for timely sensor replacement that should increase the C and E of the monitoring program. Some of the gaps are due to high flows in the early part of the season or low flows in the later part of the season, and are therefore unavoidable.

Table A-14. Effectiveness and completeness of continuous water quality monitoring for 77-day index period in 2011.

Stream	Parameter	Days of Data (N)	Days of Usable Data (U)	% Effectiveness (E)	% Completeness (C), P = 77
Baker	Temperature	62	62	100.0	80.5
	DO	62	62	100.0	80.5
	pH	63	63	100.0	81.8
	SpCond	62	62	100.0	80.5
	Average	62.25	62.25	100.0	80.8
Lehman	Temperature	77	75	97.4	97.4
	DO	77	56	72.7	72.7
	pH	77	44	57.1	57.1
	SpCond	77	19	24.7	24.7
	Average	77	48.5	63.0	63.0
Lower Snake	Temperature	58	58	100.0	75.3
	DO	58	58	100.0	75.3
	pH	59	59	100.0	76.6
	SpCond	58	58	100.0	75.3
	Average	58.25	58.25	100.0	75.6
Upper Snake	Temperature	0	0	-	0.0
	DO	0	0	-	0.0
	pH	0	0	-	0.0
	SpCond	0	0	-	0.0
	Average	0	0	-	0.0
Strawberry	Temperature	77	77	100.0	100.0
	DO	77	77	100.0	100.0
	pH	77	77	100.0	100.0
	SpCond	77	46	59.7	59.7
	Average	77	69.25	89.9	89.9

Table A-15. Effectiveness and completeness of continuous water quality monitoring for 77-day index period in 2012.

Stream	Parameter	Days of Data (N)	Days of Usable Data (U)	% Effectiveness (E)	% Completeness (C), P = 77
Baker	Temperature	77	67	87.0	87.0
	DO	77	60	77.9	77.9
	pH	77	45	58.4	58.4
	SpCond	77	68	88.3	88.3
	Average	77	60	77.9	77.9
Lehman	Temperature	77	71	92.2	92.2
	DO	77	71	92.2	92.2
	pH	77	72	93.5	93.5
	SpCond	77	71	92.2	92.2
	Average	77	71.25	92.5	92.5
Lower Snake	Temperature	0	0	-	0.0
	DO	0	0	-	0.0
	pH	0	0	-	0.0
	SpCond	0	0	-	0.0
	Average	0	0	-	0.0
Upper Snake	Temperature	61	59	96.7	76.6
	DO	61	45	73.8	58.4
	pH	61	46	75.4	59.7
	SpCond	61	61	100.0	79.2
	Average	61	52.75	86.5	68.5
Strawberry	Temperature	77	70	90.9	90.9
	DO	77	70	90.9	90.9
	pH	77	62	80.5	80.5
	SpCond	77	70	90.9	90.9
	Average	77	68	88.3	88.3

Table A-16. Effectiveness and completeness of continuous water quality monitoring for 77-day index period in 2013.

Stream	Parameter	Days of Data (N)	Days of Usable Data (U)	% Effectiveness (E)	% Completeness (C), P = 77
Baker	Temperature	77	65	84.4	84.4
	DO	77	60	77.9	77.9
	pH	77	55	71.4	71.4
	SpCond	77	61	79.2	79.2
	Average	77	60.25	78.2	78.2
Lehman	Temperature	77	55	71.4	71.4
	DO	77	55	71.4	71.4
	pH	77	55	71.4	71.4
	SpCond	77	45	58.4	58.4
	Average	77	52.5	68.2	68.2
Lower Snake	Temperature	77	17	22.1	22.1
	DO	77	17	22.1	22.1
	pH	77	18	23.4	23.4
	SpCond	77	14	18.2	18.2
	Average	77	16.5	21.4	21.4

Table A-16. Effectiveness and completeness of continuous water quality monitoring for 77-day index period in 2013 (continued).

Stream	Parameter	Days of Data (N)	Days of Usable Data (U)	% Effectiveness (E)	% Completeness (C), P = 77
Upper Snake	Temperature	60	60	100.0	77.9
	DO	60	59	98.3	76.6
	pH	60	60	100.0	77.9
	SpCond	60	60	100.0	77.9
	Average	60	59.75	99.6	77.6
Strawberry	Temperature	77	45	58.4	58.4
	DO	77	45	58.4	58.4
	pH	77	48	62.3	62.3
	SpCond	77	47	61.0	61.0
	Average	77	46.25	60.1	60.1

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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