Surface and Ground Water Quality of the Big Lost River Basin

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Introduction

The Big Lost River Basin in east-central Idaho is an important tributary to the Eastern Snake Plain Aquifer (ESPA) and provides resources locally for agricultural and recreational activity. Surface and ground water resources are used extensively in the basin for domestic, irrigation, and stock purposes. Few water quality investigations have been conducted in the region, especially in recent years.

The Idaho Department of Water Resources (IDWR), through a Supplemental Environmental Project grant from the U.S. Department of Energy, conducted a project in September 2020 to characterize current surface and ground water quality conditions in the Big Lost River Basin (Figure 1). Water samples were collected from 50 wells and eight surface water sites and analyzed for major ions, nutrients, physical parameters, and stable isotopes (Figure 2). Data collected in this study were analyzed to summarize background water quality conditions and highlight any water quality concerns.

Previous Studies

Crosthwaite et al. (1970) sampled water quality at 13 surface water stations, 12 wells, and four springs. The water type was identified as calcium bicarbonate for all sample types. One well, south of the city of Moore, yielded a nitrate result (11 mg/L) exceeding the Maximum Contaminant Level (MCL) of 10 mg/L set by the United States Environmental Protection Agency (U.S. EPA), although the MCL had not been set at the time of publication (U.S. EPA, 2021a). Three wells and multiple surface water samples contained iron concentrations exceeding the EPA Secondary Maximum Contaminant Level (SMCL) of 0.3 mg/L, which is a level not hazardous to human health but may result in an undesirable aesthetic or taste (U.S. EPA, 2021b).

IDWR regularly monitors wells in the Big Lost River Basin as part of its Statewide Ground Water Quality Monitoring Program (Statewide Program). Wells in the Statewide Program, however, are sampled on a five-year rotation and high-density monitoring in specific locations is not a priority. Seven wells previously sampled by the Statewide Program were also sampled in this study.

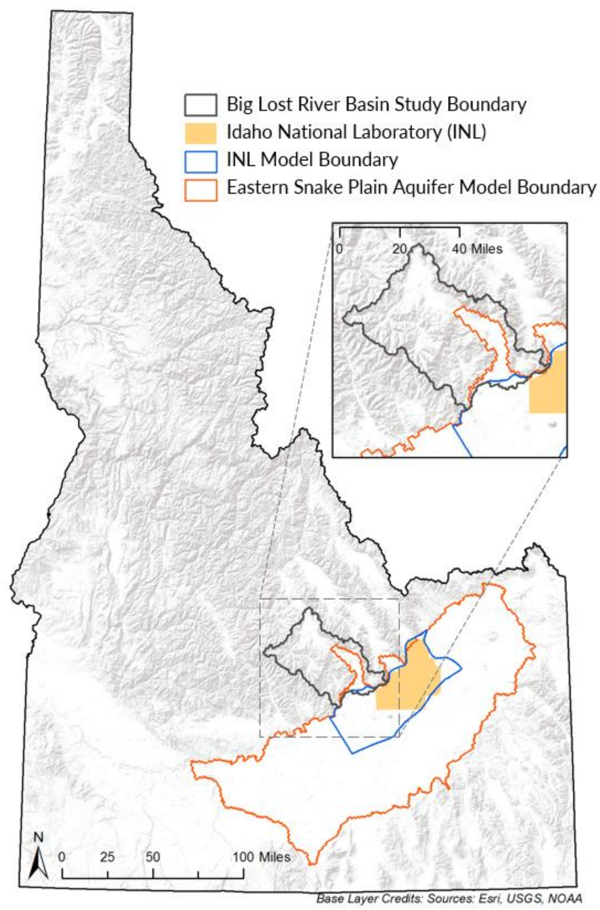

Figure 1: *Overview of study area.*

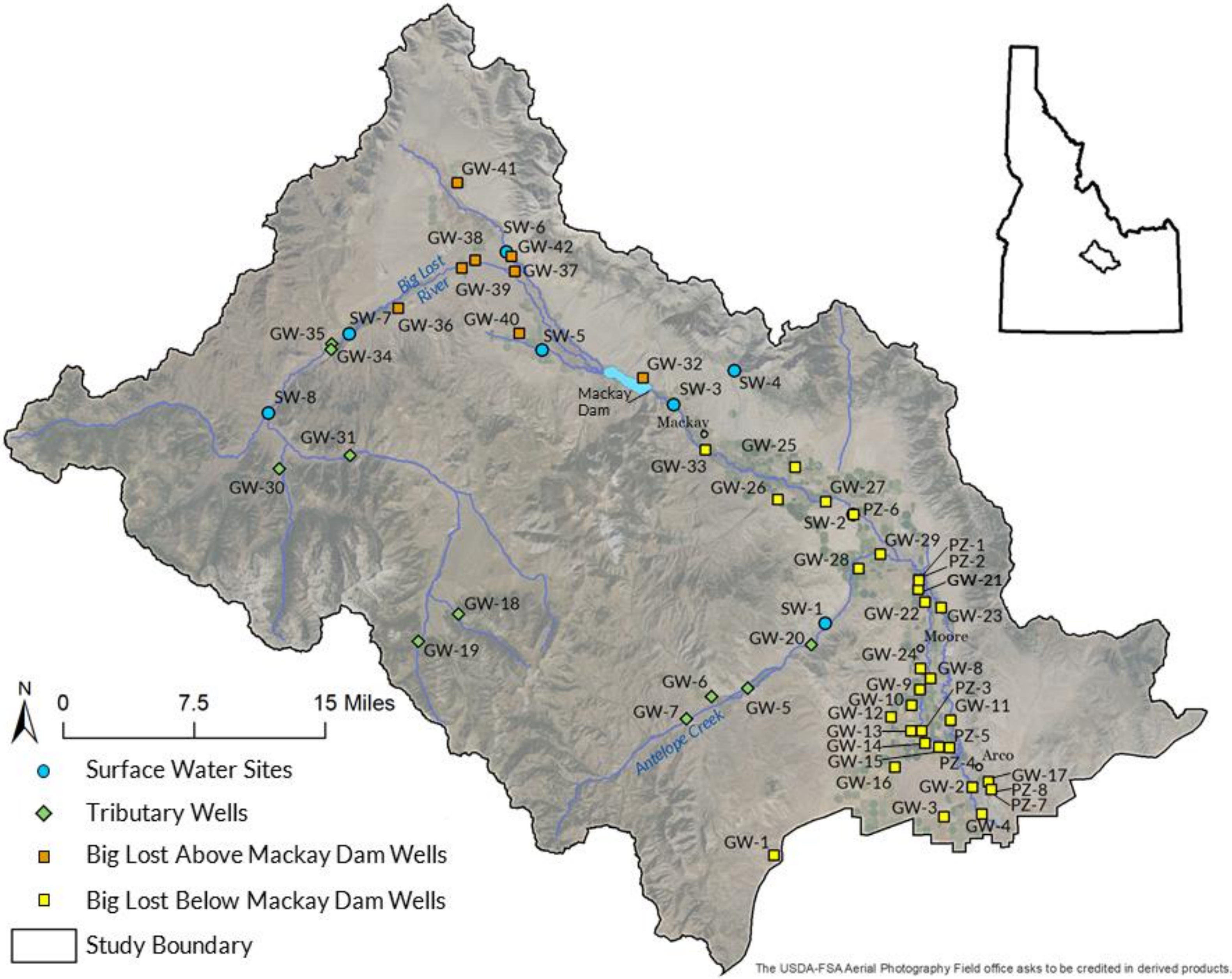

Figure 2*: Sampling locations for the 2020 IDWR Big Lost River Basin water quality study. Sites are divided into groups for comparative geochemical analysis later in the report. PZ labels indicate piezometer locations, GW indicates well locations, and SW indicates surface water locations. Corresponding site information is presented in Tables 1 and 2.*

The Idaho National Laboratory (INL) monitors water quality within its boundaries to the southeast of the Big Lost River Basin to inform their groundwater model (Figure 1) and help characterize contaminant transport at the site (Ackerman et. al., 2010). The results from this study may help inform the next version of the INL groundwater model.

Study Area

The study area includes the Big Lost River valley and surrounding tributary valleys. The boundary used in this study (Figure 1) was originally developed by Clark (in review) and is roughly bounded to the southeast by the INL model boundary, however, it contains irrigated land that is within the INL model boundary. The basin receives a wide range of precipitation and exhibits varied geology (Figure 3). Elevations range from 5,240 ft near Arco to 12,667 ft on Mount Borah, the highest point in Idaho.

Geology

The geologic history of the Big Lost River Basin can be interpreted from the various mountain ranges and canyons that surround the Big Lost River valley. The Pioneer Range to the west contains a core of metamorphic rocks from the Archean, while subsequent passive margin depositional basins are represented in Paleozoic-age deposits in the Pioneer, White Knob, and Lost River Ranges (Zinsser, 2021). Deformation caused by Mesozoic-era Cordilleran orogenic activity is revealed in thrust faults across the region (Lewis et. al., 2012). Tertiary magmatism produced the Challis Volcanic Group, among other minor rocks, and was followed by the late-Tertiary, Basin-and-Range derived extension forming the current Big Lost River valley (Zinsser, 2021). The valley, oriented in the northwest-southeast direction, is actively extending by way of north-northwest-striking normal faults, including the Lost River Fault (Link & Janecke, 1999). Quaternary unconsolidated sediments, the most recent geologic products in the basin, are derived from glacial, fluvial, alluvial, and volcanic processes, some of which are still influential today.

Hydrogeology

The ground water system in the Big Lost River Basin can be divided into four hydrogeologic units spread throughout the basin (Figure 3) including (1) Paleozoic sedimentary rocks, (2) Tertiary volcanic rocks which dominate the northwest section of the basin and the tributary valleys, (3) Quaternary basalt rocks, and (4) Quaternary unconsolidated sediments which make up the main, and most used, alluvial aquifer (Zinsser, 2021). Recharge to the aquifer system is derived from losing reaches of the Big Lost River and from tributary streams, excess irrigation and irrigation canal infiltration, and precipitation (Clark, in review; Crosthwaite, Thomas, & Dyer, 1970; Sukow, 2017).

Surface Water

The Big Lost River is the main surface water feature of the basin, although several important tributaries flow into the main Big Lost River valley. Below Mackay Dam, there is a complex interaction between surface water and ground water, with multiple gaining and losing reaches of the Big Lost River affected by aquifer lithology, valley geometry, snowpack, and surface-water management (Dudunake & Zinsser, 2021). The Big Lost River ceases to flow south of Arco, transitioning to underflow to the regional ESPA (Crosthwaite, Thomas, & Dyer, 1970).

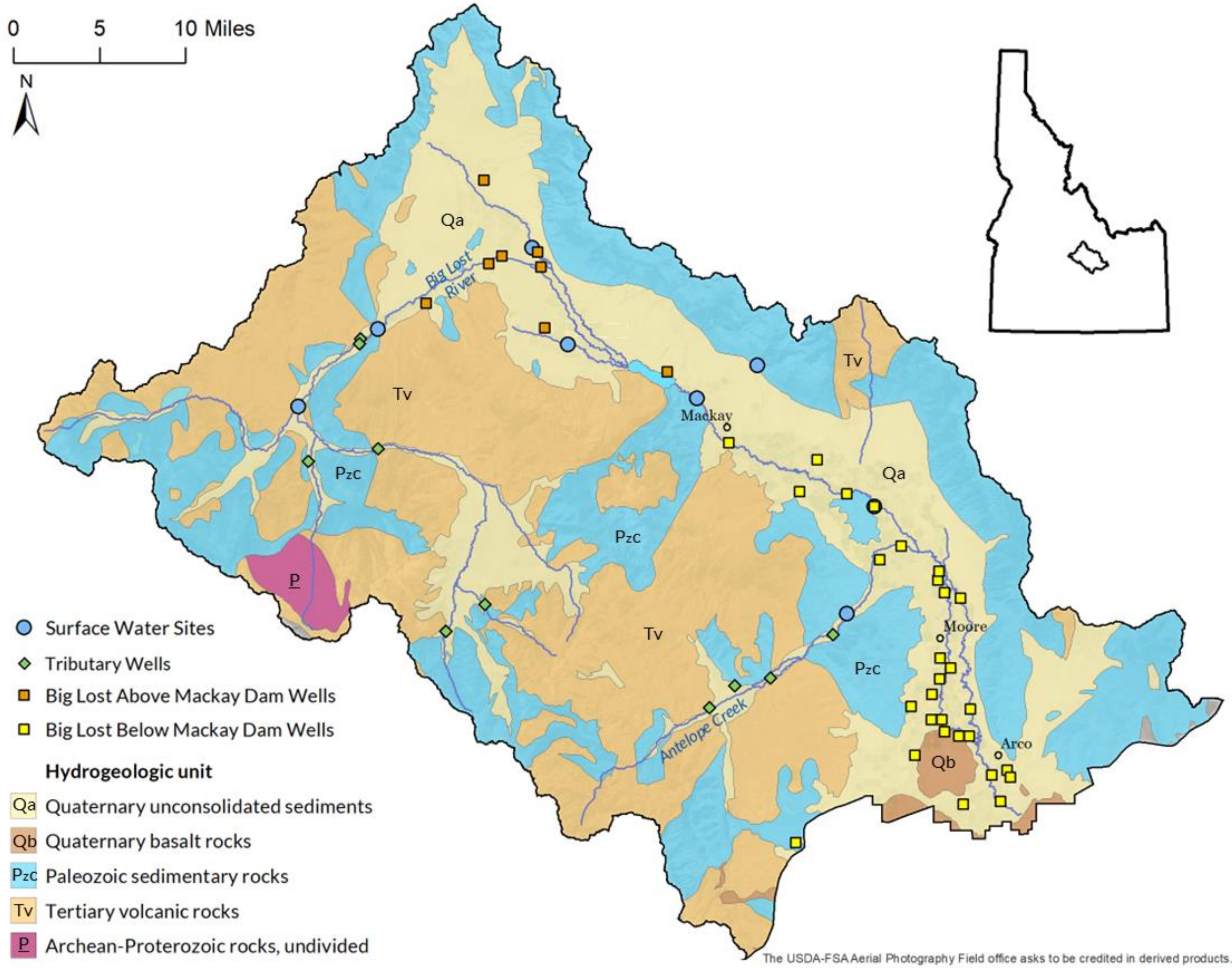

***Figure 3**: Hydrogeologic units in the Big Lost River Basin. Adapted from Lewis (2012) following the method from Zinsser (2021).*

Table 1*: Information for ground water sampling sites in the Big Lost River basin. See Figure 2 for locations.*

IDWR Well Station Name	Study ID#	Sample Date	Latitude	Longitude	Altitude (ft)	Total Well Depth (ft)	Study Group
03N 24E 25AAD1	GW-1	9/1/2020	43.5643	-113.5359	5840	400	Big Lost Below Mackay Dam
03N 26E 01BDA1	GW-2	9/2/2020	43.620	-113.308	5302	60	Big Lost Below Mackay Dam
03N 26E 10DDC1	GW-3	9/1/2020	43.5954	-113.3414	5325	285	Big Lost Below Mackay Dam
03N 26E 12DDA1	GW-4	9/2/2020	43.5974	-113.2981	5282	--	Big Lost Below Mackay Dam
04N 24E 02DAB1	GW-5	9/9/2020	43.7034	-113.5646	6020	60	Tributary
04N 24E 09BAA1	GW-6	9/3/2020	43.6968	-113.6059	6135	36	Tributary
04N 24E 18ADA1	GW-7	9/8/2020	43.6785	-113.6351	6273	60	Tributary
04N 26E 03BBB1	GW-8	9/8/2020	43.7105	-113.3549	5433	120	Big Lost Below Mackay Dam
04N 26E 04CAD1	GW-9	9/8/2020	43.7014	-113.3675	5430	120	Big Lost Below Mackay Dam
04N 26E 08DAA1	GW-10	9/2/2020	43.6884	-113.3767	5417	140	Big Lost Below Mackay Dam
04N 26E 14BCD2	GW-11	9/2/2020	43.6755	-113.3324	5443	120	Big Lost Below Mackay Dam
04N 26E 18AAC1	GW-12	9/2/2020	43.6786	-113.4009	5446	260	Big Lost Below Mackay Dam
04N 26E 20AAA1	GW-13	9/2/2020	43.6669	-113.3779	5397	180	Big Lost Below Mackay Dam
04N 26E 21DBD1	GW-14	9/2/2020	43.6569	-113.3623	5394	120	Big Lost Below Mackay Dam
04N 26E 22DCC1	GW-15	9/11/2020	43.653	-113.3456	5390	210	Big Lost Below Mackay Dam
04N 26E 31AAA1	GW-16	9/1/2020	43.6369	-113.3968	5384	240	Big Lost Below Mackay Dam
04N 27E 31CDC1	GW-17	9/1/2020	43.6241	-113.2898	5305	60	Big Lost Below Mackay Dam
05N 21E 13ADA1	GW-18	9/10/2020	43.766	-113.896	8100	46	Tributary
05N 21E 22DCA1	GW-19	9/10/2020	43.7435	-113.9418	7910	115	Tributary
05N 25E 28BBA1	GW-20	9/11/2020	43.7396	-113.4913	5840	615	Tributary
05N 26E 04CDD1	GW-21	9/3/2020	43.7847	-113.3674	5554	100	Big Lost Below Mackay Dam
05N 26E 09DAC1	GW-22	9/3/2020	43.7742	-113.3609	5525	140	Big Lost Below Mackay Dam
05N 26E 10DCD1	GW-23	9/4/2020	43.7693	-113.3426	5512	60	Big Lost Below Mackay Dam
05N 26E 33BDD1	GW-24	9/3/2020	43.7188	-113.3668	5446	140	Big Lost Below Mackay Dam
06N 25E 05BAA1	GW-25	9/4/2020	43.8868	-113.5088	5748	60	Big Lost Below Mackay Dam
06N 25E 07CDA1	GW-26	9/11/2020	43.860	-113.529	5833	120	Big Lost Below Mackay Dam
06N 25E 10CCD1	GW-27	9/4/2020	43.8581	-113.474	5748	255	Big Lost Below Mackay Dam
06N 25E 35DDA1	GW-28	9/11/2020	43.8021	-113.4366	5636	160	Big Lost Below Mackay Dam
06N 26E 30CCD1	GW-29	9/3/2020	43.8138	-113.4116	5604	100	Big Lost Below Mackay Dam
07N 20E 33CDD1	GW-30	9/10/2020	43.8863	-114.1014	7065	264	Tributary
07N 21E 31BAD1	GW-31	9/10/2020	43.8973	-114.0202	7139	60	Tributary
07N 23E 02DDA1	GW-32	9/9/2020	43.9614	-113.6831	6085	82	Big Lost Above Mackay Dam
07N 24E 28CDD1	GW-33	9/11/2020	43.9015	-113.6118	5881	101	Big Lost Below Mackay Dam
08N 20E 25CDA1	GW-34	9/10/2020	43.9900	-114.0409	6699	--	Tributary
08N 20E 36BAA1	GW-35	9/10/2020	43.9856	-114.0418	6683	230	Tributary
08N 21E 15CBD1	GW-36	9/9/2020	44.0197	-113.9646	6516	40	Big Lost Above Mackay Dam
08N 22E 03DBD1	GW-37	9/9/2020	44.0504	-113.8303	6257	38	Big Lost Above Mackay Dam
08N 22E 05BAA1	GW-38	9/9/2020	44.0596	-113.8761	6340	87	Big Lost Above Mackay Dam
08N 22E 06ACD1	GW-39	9/9/2020	44.0532	-113.8915	6355	103	Big Lost Above Mackay Dam
08N 22E 27ADA1	GW-40	9/8/2020	43.9989	-113.8256	6195	80	Big Lost Above Mackay Dam
09N 22E 07DBA1	GW-41	9/11/2020	44.1238	-113.8967	6316	42	Big Lost Above Mackay Dam
09N 22E 34DCA1	GW-42	9/9/2020	44.0628	-113.8343	6270	100	Big Lost Above Mackay Dam
05N 26E 04BDD1	PZ-1	9/2/2020	43.7926	-113.3673	5552.67	20	Big Lost Below Mackay Dam
05N 26E 04BDD3	PZ-2	9/2/2020	43.7924	-113.3673	5552.67	60	Big Lost Below Mackay Dam
04N 26E 21ABB4	PZ-3	9/1/2020	43.6670	-113.3653	5393.09	60	Big Lost Below Mackay Dam
04N 26E 23CCC1	PZ-4	9/2/2020	43.6529	-113.3340	5356.39	20	Big Lost Below Mackay Dam
04N 26E 23CCC3	PZ-5	9/2/2020	43.6530	-113.3340	5356.39	60	Big Lost Below Mackay Dam
06N 25E 14DAD2	PZ-6	9/1/2020	43.8471	-113.4422	5654.04	40	Big Lost Below Mackay Dam
03N 27E 06ACD1	PZ-7	9/2/2020	43.6179	-113.2864	5298.47	20	Big Lost Below Mackay Dam
03N 27E 06ACD3	PZ-8	9/2/2020	43.6178	-113.2864	5298.47	60	Big Lost Below Mackay Dam

***Table 2**: Information for surface water sampling sites in the Big Lost River basin. See Figure 2 for locations.*

USGS Gage Station Name	Study ID#	USGS ID#	Sample Date	Discharge (ft^3/s)	Latitude	Longitude	Altitude	Study Group
Antelope Lower	SW-1	--	9/3/2020	--	43.7568	-113.4753	5795	Surface Water
Rothwell SW	SW-2	--	9/3/2020	--	43.8470	-113.4425	5649	Surface Water
Big Lost River Mackay Below Mackay Reservoir	SW-3	13127000	9/3/2020	332	43.9392	-113.6483	5946	Surface Water
Lower Cedar Creek Above Diversion	SW-4	13128900	9/3/2020	9.99	43.9669	-113.5778	6823	Surface Water
Warm Springs Creek Below Diversion	SW-5	13124265	9/3/2020	19.9	43.9851	-113.7991	6142	Surface Water
Thousand Springs Creek	SW-6	13122000	9/3/2020	4.00	44.0667	-113.8403	6262	Surface Water
Big Lost River at Howell Ranch	SW-7	13120500	9/3/2020	88.3	43.9983	-114.0211	6626	Surface Water
North Fork Big Lost River at Wild Horse	SW-8	13120000	9/3/2020	22.0	43.9328	-114.1139	6862	Surface Water

Methods

Site Selection

Surface and ground water sites were selected for sampling to provide adequate spatial coverage throughout the basin.

Ground Water Wells

Forty-two wells were sampled (Figure 2) including 38 domestic wells, two public water supply wells, one industrial/commercial well, and one stockwater well.

Piezometers

IDWR installed two-inch piezometers at seven sites from fall of 2019 through the fall of 2021 to investigate surface water-ground water interactions in the Big Lost River valley. Three piezometers were completed to varying depths at each of the seven sites for a total of 21 piezometers installed throughout the basin. Eight of the 21 individual piezometers were sampled across five piezometer sites. Generally, the shallowest (20 ft) and deepest (60 ft) piezometers at each location were sampled, however, some that were selected did not contain enough water column to sufficiently pump.

Surface Water

Samples were collected at eight surface water sites. Six of the eight sites were selected because they are adjacent to U.S. Geological Survey (USGS) stream gage locations (Figure 2). However, the Antelope Creek and Rothwell SW sites, SW-1 and SW-2, respectively, were chosen due to proximity to piezometer locations.

Sample Collection

Data and sample collection procedures for the study were consistent with the Standard Operating Procedures for the Statewide Program (IDWR, 2020).

Field parameters, including temperature, pH, specific conductivity, and dissolved oxygen, were recorded in the field (Appendix B, Table B.1), and used to determine stability prior to sample collection. Ground water well samples were collected via existing pumps installed in each well. Piezometer samples were collected using a portable submersible pump. Surface water samples were collected using basic grab sample techniques.

Laboratory Analyses

The Idaho Bureau of Laboratories (IBL) conducted analyses for major ions, metals, and nutrients using EPA Methods 200.7, 200.8, 300.0, 350.1, 353.2, and 365.1. Internal laboratory spikes and duplicates were also completed as part of IBL's quality assurance program. Information regarding reporting limits and methodology can be found in Appendix B, Table B.1. Isotope analysis was completed by cavity ringdown spectroscopy at Boise State University in the Stable Isotope Laboratory.

Field quality assurance/quality control protocols consisted of ten duplicate samples along with four blank samples to determine the integrity of the field team's sample handling, the cleanliness of the sample containers, and the accuracy of the laboratory methods.

Water Quality Results and Discussion

Water quality sample results and analyses are summarized and presented in the following sections. The sampled wells and piezometers were divided into three study groups based on their location (Figure 2) to aid in discussion of the results. The well groups include: (1) Big Lost Valley above Mackay Dam (n=8), (2) Big Lost Valley below Mackay Dam (n=32), and (3) tributary (n=10). These groups were created with reference to the geologic model divisions designated in Zinsser (2021). Surface water sites (n=8) were divided into a fourth group.

Physical Parameters

Physical water quality parameters were collected at each site (Appendix A, Table A.1), and summary statistics are presented in Table 3 and Figure 4. The physical parameters of dissolved oxygen, pH, specific conductance, and temperature were measured in the field, while total dissolved solids (TDS) and alkalinity were analyzed and provided by IBL.

TDS concentrations varied widely in all study groups, with the highest variability in the Big Lost above Mackay Dam wells. Overall, TDS concentrations were higher in the Big Lost below Mackay Dam wells, averaging 226 mg/L versus 150 mg/L in Big Lost above Mackay Dam wells, 154 mg/L in tributary wells, and 151 mg/L in surface water samples (Figure 4).

Major Ions and Metals

Study samples were analyzed for the major cations calcium, magnesium, potassium, and sodium (Table A.2, Appendix A). The major anions analyzed in the study were chloride, fluoride, and sulfate. Metals analyzed included dissolved iron, cadmium, copper, manganese, selenium, uranium, and arsenic. Summary statistics of major ion and metal results are presented in Table 3.

There were no EPA MCL exceedances for major ions or metals in any samples tested. However, two wells, GW-1 and GW-19, had manganese concentrations above the EPA SMCL of 0.05 mg/L. A high concentration of manganese has the potential to cause water discoloration, black staining, and a "bitter metallic taste" (U.S. EPA, 2021b). Also, wells GW-19 and GW-30 exceeded the EPA iron SMCL of 0.3 mg/L. High concentrations of iron are associated with a rusty-colored water, metallic taste, and reddish or orange staining (U.S. EPA, 2021b).

Table 3: Summary results for physical parameters, major ions, metals, nutrients, and isotopes for all study groups, September 2020.

Parameter type	Parameter	Surface Water				Tributary				Big Lost Above Mackay Dam				Big Lost Below Mackay Dam			
		Max	Min	Mean[1]	Median	Max	Min	Mean[1]	Median	Max	Min	Mean[1]	Median	Max	Min	Mean[1]	Median
Physical Parameters	Alkalinity (mg/L)	205	83.8	119.7	110	170	83.8	111.2	100	258	64.6	119.3	102	246	126	175.9	175.5
	Dissolved Oxygen (mg/L)	12.9	7.89	9.31	8.77	6.9	0.01	3.9	8.25	9.52	3.87	7.31	7.95	15	0.8	7.52	7.85
	pH	9.1	8.2	8.7	8.8	8.1	6.9	7.5	7.5	8.9	7.5	8.2	8.2	8.1	7.2	7.7	7.75
	Specific Conductance (µS/cm)	485.5	155.5	259.6	244.5	532.6	241.6	346.8	292.8	893.2	195.1	386.8	322.5	770.6	354.3	537.9	209.5
	Total dissolved solids (mg/L)	250	37	151	155	310	110	154	135	380	17	149.8	150	340	140	226.3	230
	Water Temperature (°C)	20.3	8.9	15.1	15.7	12.1	7.3	8.85	8.25	12.1	7	9.1	9.1	18.2	7.3	11.1	11
Major Ions and Metals	Arsenic (µg/L)	2.4	<2	0.8-2.1	<2	3.9	<2	1.28-2.48	<2	<2	<2	<2	<2	2.2	<2	0.14-2.01	<2
	Cadmium (µg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Calcium (mg/L)	50	27	36.3	37	57	26	35.5	33	64	21	34.3	31.5	85	42	57	57
	Chloride (mg/L)	4.2	0.59	2.30	2.47	6.09	0.77	2.39	1.98	22.6	0.89	4.44	1.86	27.7	2.69	6.46	4.44
	Copper (µg/L)	<1	<1	<1	<1	6.3	<1	1.7-2.3	<1	2.4	<1	0.61-1.24	<1	2.6	<1	0.13-1.07	<1
	Fluoride (mg/L)	0.26	<0.2	0.16-0.23	0.23	0.31	<0.2	0.03-0.21	<0.2	0.27	<0.2	0.1-0.22	<1	0.59	<0.2	0.06-0.22	<0.2
	Iron (mg/L)	0.05	<0.01	0.025-0.029	0.03	0.96	<0.01	0.15-0.154	0.03	0.02	<0.01	0.005-0.013	<0.01	0.06	<0.01	0.008-0.016	<0.01
	Magnesium (mg/L)	22	5.9	10.2	8.7	14	5	8.1	7.2	34	4.4	10.9	6.5	21	4.3	12.3	12
	Manganese (mg/L)	0.017	<0.001	0.0056-0.006	0.004	0.18	<0.001	0.0226-0.023	0.002	0.003	<0.001	0.0004-0.001	<0.001	0.015	<0.001	0.005-0.0058	<0.001
	Potassium (mg/L)	1.5	0.3	0.98	0.96	3	0.66	1.15	0.95	3.2	0.67	1.23	1.05	2	0.74	1.25	1.2
	Selenium (µg/L)	2.9	<2	0.36-2.11	<2	2.1	<2	0.21-2.01	<2	3.3	<2	0.41-2.16	<2	5.3	<2	0.78-2.28	<2
	Silica (mg/L)	14	4.7	8.9	9.2	32	9.9	14.5	12.5	15	8.7	12	11.5	27	10	15.6	15
	Sodium (mg/L)	5.8	0.8	4.1	4.7	10	2.6	5.6	5.1	20	2.6	6.1	3.9	18	4.8	7.9	6.6
	Sulfate (mg/L)	33.1	14.5	19.3	17.5	45.1	6.38	20.1	17.8	40.6	10.2	17	14.1	35	11	21.4	20.5
	Uranium (µg/L)	2.4	<1	1.4-1.5	1.5	2.5	<1	1.4-1.7	1.4	2.1	<1	1.08-1.45	1.4	3.9	<1	2.43-2.46	2.4
Nutrients	Ammonia (mg/L)	0.058	<0.05	0.007-0.051	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Nitrate (mg/L)	0.28	<0.01	0.038-0.045	<0.01	0.37	<0.01	0.125-0.127	0.07	3.9	0.04	0.62	0.12	6.6	0.06	1.46	1.2
	Phosphorus (mg/L)	0.06	0.01	0.02	0.015	0.21	0.01	0.04	0.03	0.03	0.01	0.02	0.02	0.12	0.01	0.03	0.02
Isotopes	δ2H (‰)	-129.0	-137.6	-132.4	-132.4	-130.4	-141.1	-134.4	-133.4	-132.1	-135.7	-134.1	-134.2	-130.7	-142.6	-133.1	-132.6
	δ18O (‰)	-16.8	-18.0	-17.5	-17.5	-17.0	-18.2	-17.6	-17.6	-17.0	-17.9	-17.4	-17.4	-17.0	-18.3	-17.4	-17.3

[1]When results included values below a detection limit, a range for the mean was calculated by replacing the below-detection-limit results with a value of zero (lower possible end of range) and the value of the detection limit (higher possible end of range).

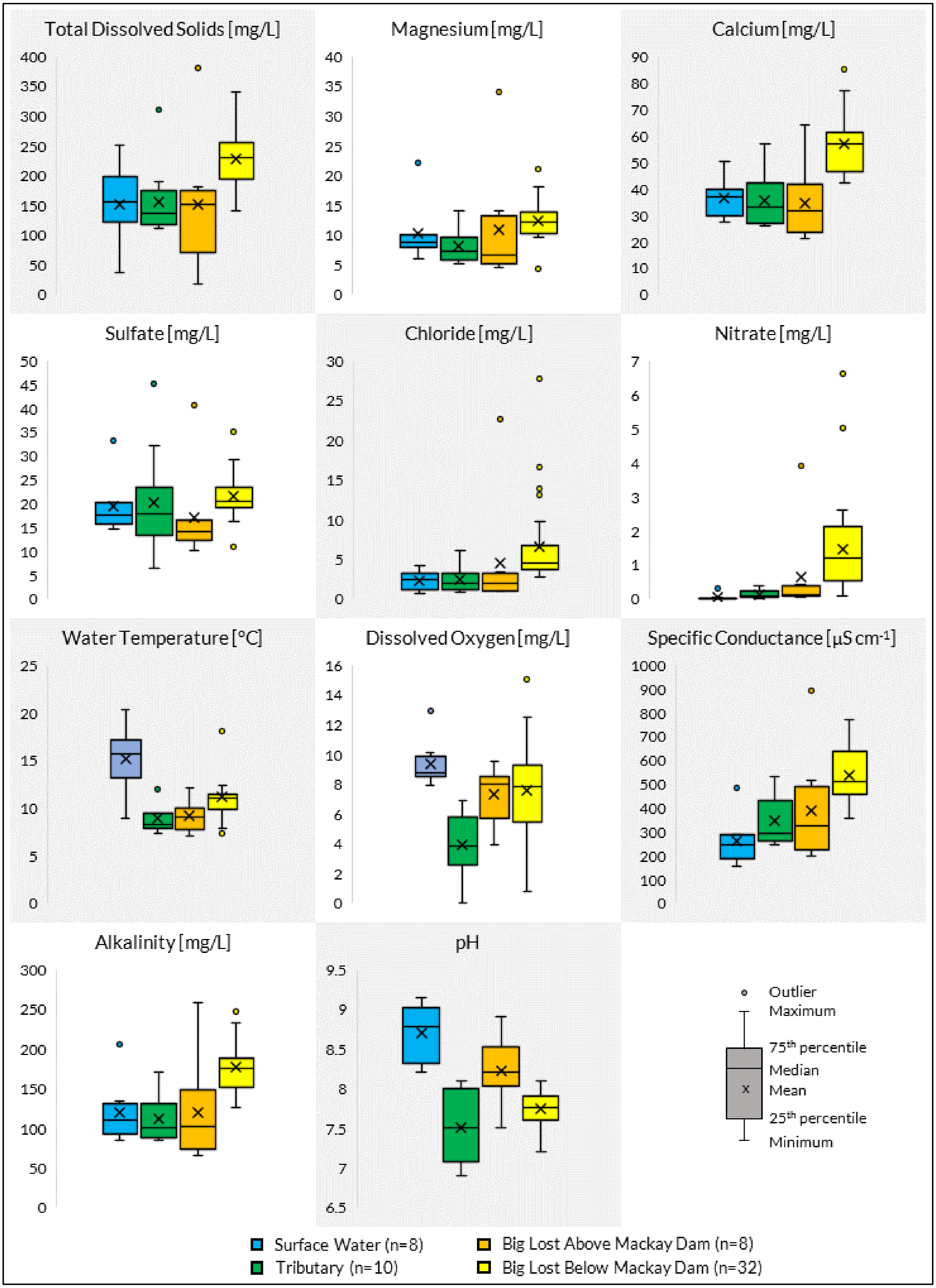

***Figure 4**: Box-and-whisker plots for selected analyte and physical parameter concentrations from this study.*

The results for sampled wells imply a general pattern of increasing TDS concentrations in the alluvial aquifer system from the upper regions of the basin to the mouth of the valley. Major ion concentrations (e.g., calcium, chloride) largely follow this pattern, with higher average concentrations of a given ion generally found in wells near the southern portion of the basin (Figure 4). Conceptually, this pattern could be explained by a decreasing ground water gradient and increasing aquifer thickness towards the valley mouth. This would allow for longer ground water residence time and more interaction with aquifer materials, or by increased agricultural activity and human alteration of the landscape (Hopkins & Bartolino, 2013; Zinsser, 2021).

Major ion concentrations can also designate a dominant chemical water type and provide another measure of variability when plotted on a trilinear diagram, described by Piper (1944). Sample results across all study groups overwhelmingly indicate water of a calcium bicarbonate type, shown by the clustered nature of points on the trilinear diagram (Figure 5). This water type can suggest surface and ground water experienced little geochemical change from the original precipitation source (Hopkins & Bartolino, 2013).

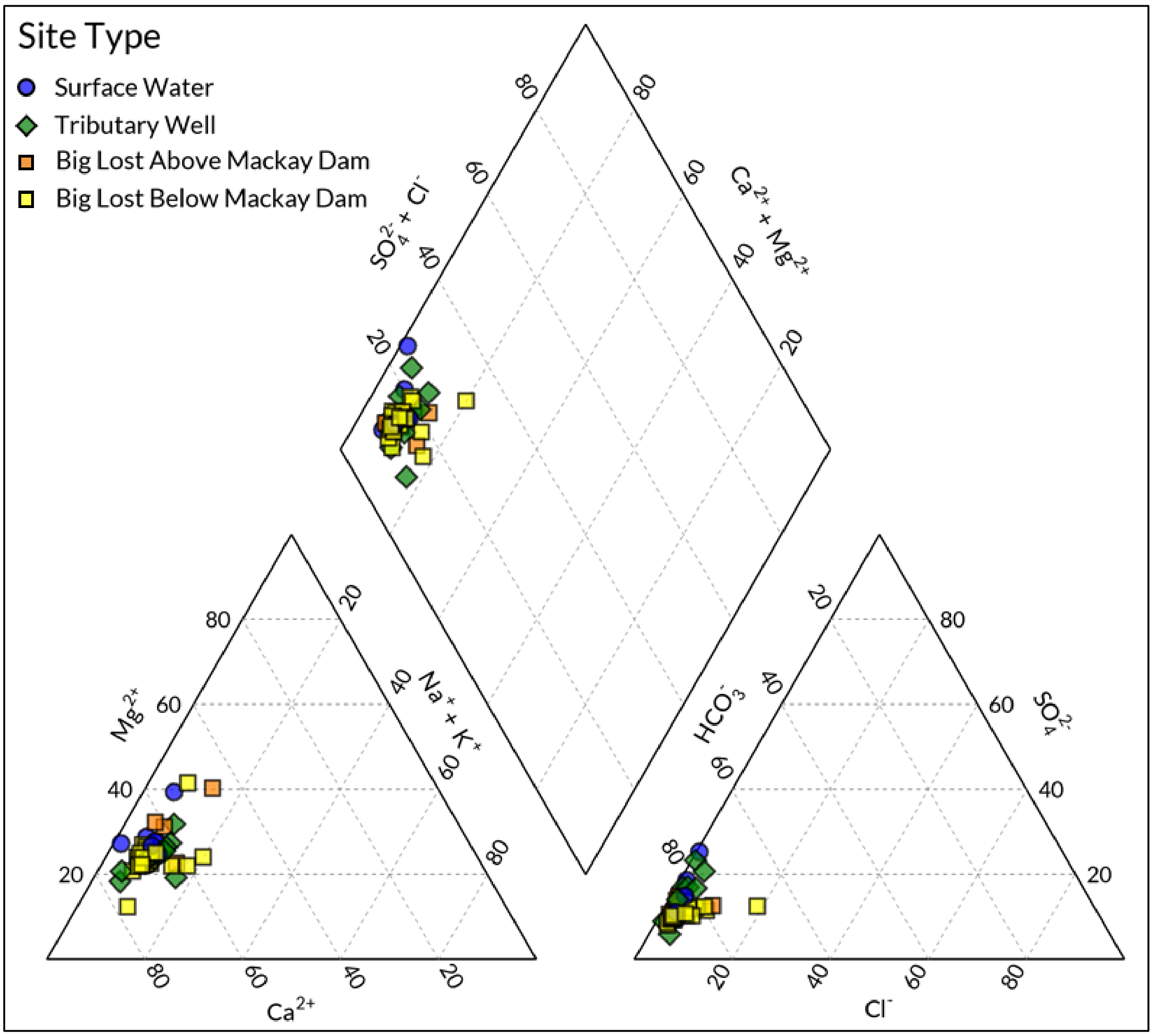

Figure 5*: Major ion composition of all study samples from this study. Calcium bicarbonate water type is dominant; clustering indicates limited variability across the study area.*

Nutrients

Study samples were analyzed for nitrate[1], ammonia, and phosphorous (Table 3). Nitrate concentrations in all samples were below the EPA MCL of 10 mg/L. Most nitrate concentrations above the reporting limit were found in the group Big Lost below Mackay Dam wells (Figure 4), with the highest levels, up to 6.6 mg/L in well GW-14, found in the Moore to Arco area (Figure 6). Nitrate concentrations appear to increase approaching the mouth of the valley.

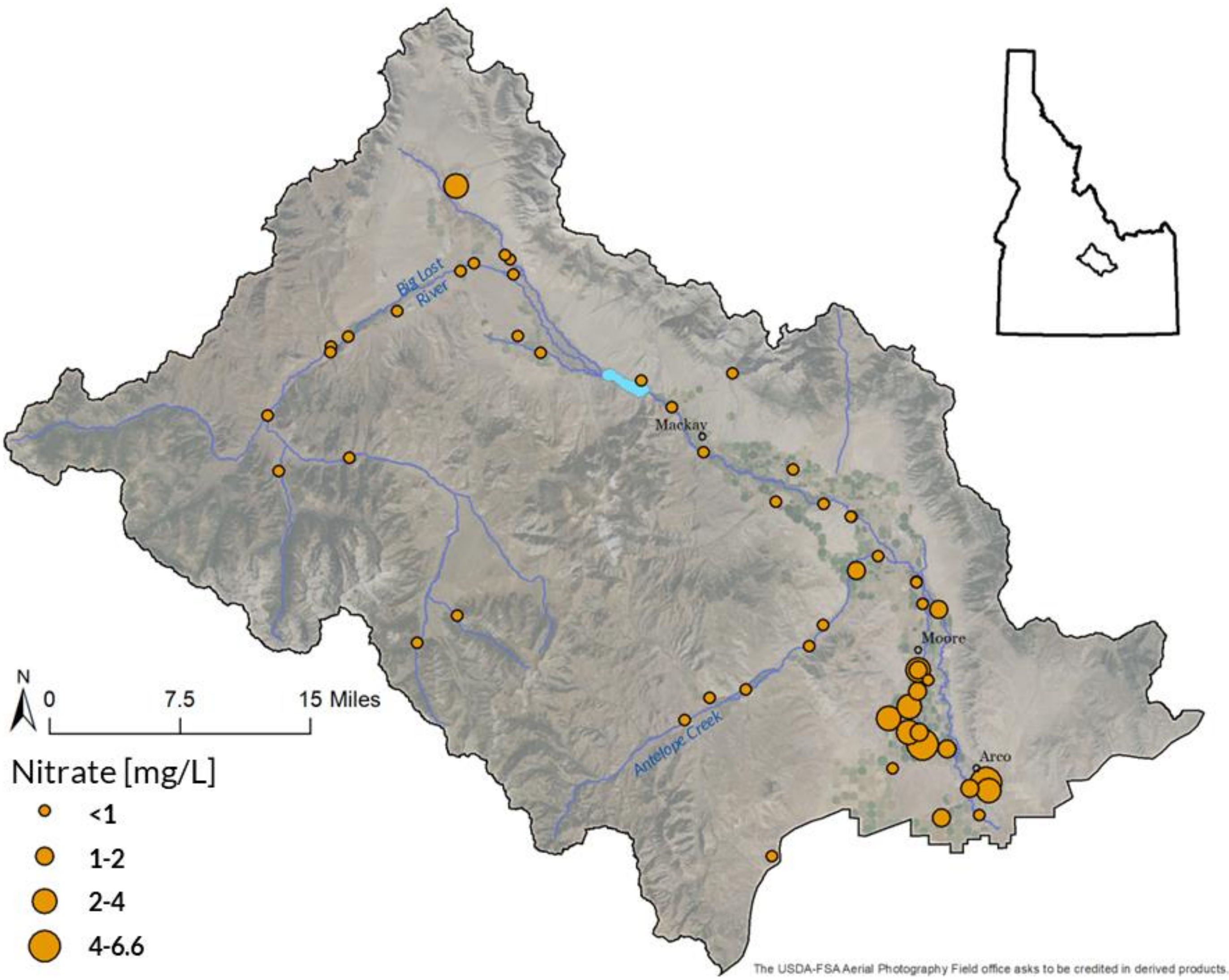

Figure 6: *Nitrate results for all study samples.*

Seven wells sampled in this study have historical data available through IDWR's Statewide Program. One well located south of Arco (GW-17) provides a long-term view of nitrate concentrations and shows an increase from 0.43 mg/L in 1993 to 5 mg/L in 2020 (Figure 7).

[1] This report uses the term nitrate for ease of displaying and communicating results. The analysis performed is the sum of nitrate and nitrite, reported as N. Nitrite concentrations are typically negligibly low in surface and ground water systems. Additional analysis information can be found in Appendix B, Table B.1.

Potential sources of higher than background nitrate concentrations in ground water samples between Moore and Arco include agricultural activities, septic systems, or other anthropogenic impacts. When fertilizer is applied in excess of plant needs, irrigation water can flush nitrate from the soil into the ground water system. An improperly functioning septic system can also result in excess nitrate being transported through the soil, where it can leach into the aquifer. As only one of the seven wells with historic data shows a nitrate increase over time, more information is needed to determine elevated nitrate sources in the area.

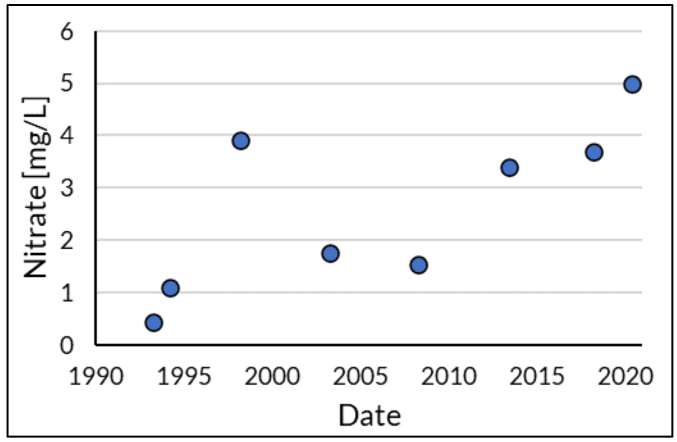

***Figure 7**: Nitrate concentrations for GW-17 from this study (2020) and from historic Statewide Program data (1993-2018).*

Stable Isotopes

Stable isotopes in water, specifically $\delta^{18}O$ and $\delta^{2}H$, can provide insight into source water location, ground water residence time, and evaporative processes of a hydrological system (West, February, & Bowen, 2014). $\delta^{18}O$ is the ratio of the stable isotopes ^{18}O and ^{16}O, and $\delta^{2}H$ is the ratio of the stable isotopes ^{2}H and ^{1}H; both ratios are relative to a known standard and reported in the unit per mil (‰, parts per thousand). A table of $\delta^{18}O$ and $\delta^{2}H$ results and uncertainties from the study are presented in Appendix A, Table A.2, and summary statistics are shown in Table 3. The relatively high level of uncertainty observed in the isotope results in this study leads to similar uncertainty in the observations made in this section below.

The Global Meteoric Water Line (GMWL; Craig, 1962) and a Local Meteoric Water Line (LMWL) developed for southeastern Idaho, western Wyoming, and south-central Montana (Benjamin et. al., 2004) were plotted with $\delta^{18}O$ and $\delta^{2}H$ values gathered from study samples (Figure 8). Higher $\delta^{18}O$ values, expressed in values plotted to the right of a LMWL, can reflect evaporation as the water progresses through the system or extended water-rock interaction from longer residence time (Adkins & Bartolino, 2010). Lower $\delta^{18}O$ values can imply the presence of new water to the system or recharge from a higher-elevation source. Figure 8 shows most values plotted to the right of the LMWL which may suggest an evaporative signal prevalent in most study samples.

The spatial distribution of $\delta^{18}O$ values throughout the study area is presented in Figure 9. The wells in Copper Basin, located at the headwaters of the Big Lost River Basin, show decreased ^{18}O, implying proximity to source water and little influence from evaporation. Wells in Antelope Creek exhibit an excess of ^{18}O, suggesting the potential for more influence by evaporation or from lower-elevation source water.

Excluding GW-1, which resides outside of the main Big Lost River valley, and GW-16, cased to 240' in fractured basalt, valley wells above and below Mackay Dam exhibit a relatively small range in $\delta^{2}H$ and $\delta^{18}O$ values. This pattern could imply similar source water and evaporative effects in the Quaternary unconsolidated sediments of the main Big Lost River valley. The excess in ^{18}O shown in these results could be indicative of the surface water-ground water interaction so prevalent in the Big Lost River Basin below Mackay Dam (Dudunake & Zinsser, 2021); it is likely evaporation from surface water and canals aggregates ^{18}O and that water then enters the ground water system.

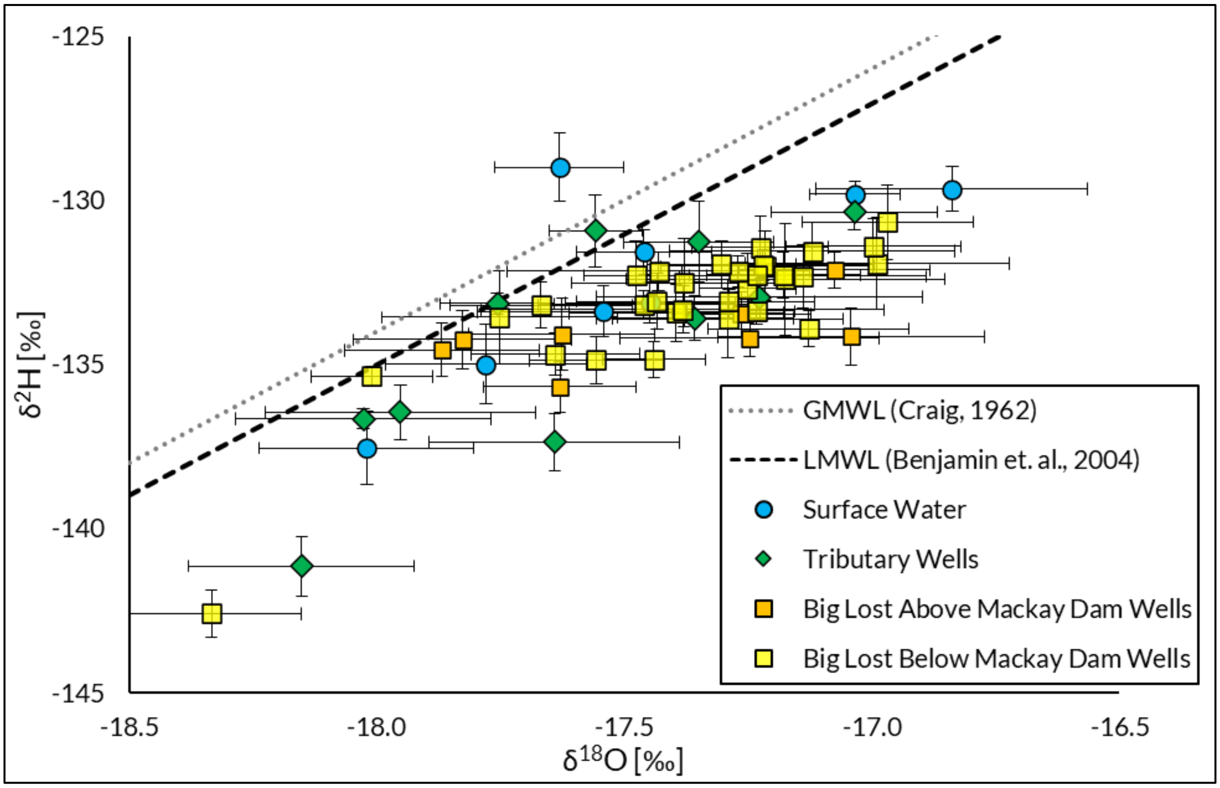

Figure 8: *$\delta^{18}O$ and $\delta^{2}H$ results for all sample locations. Uncertainty, one standard deviation, for isotope results is shown as error bars on the chart, and is also presented in Appendix A, Table A.2.*

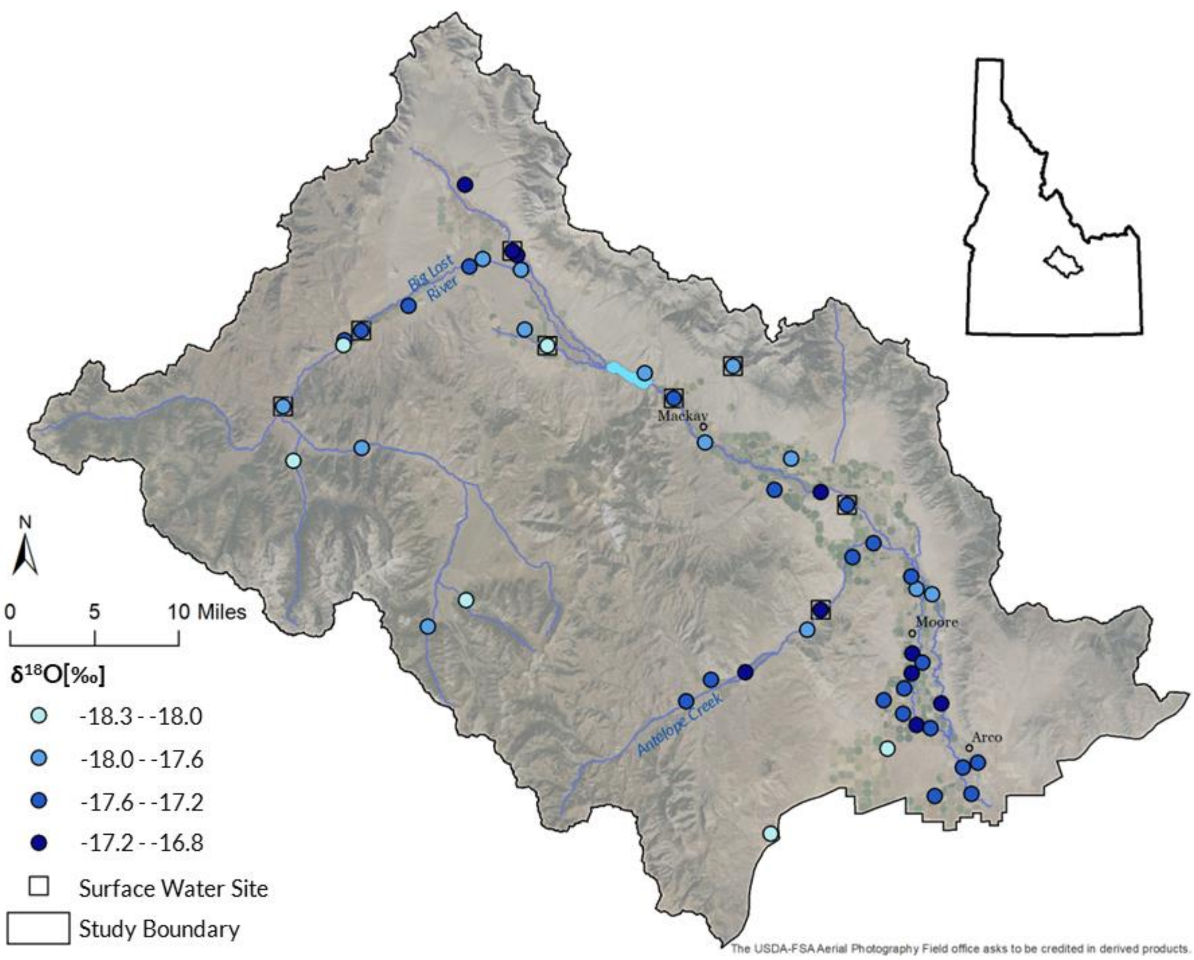

Figure 9: *$\delta^{18}O$ results for all study samples.*

Quality Control Results

Ten replicate and four blank samples were gathered to examine the quality of sample collection and laboratory methods used in the study. A relative percent difference (RPD) analysis was used to quantify the change between study samples and study replicates:

$$RPD = [(S_s - R_s)/((S_s + R_s)/2)] * 100$$

where

S_s = Concentration of the study sample

R_s = Concentration of the replicate sample

Results from the RPD analysis are presented in Appendix C, Table C.1. RPD results above 20% were flagged, indicating a high percentage difference in study sample versus replicate sample results. In this study, RPD results above 20% were generally found when the analyte concentrations were close to the reporting limit, inflating the difference between study and replicate samples. The RPD analysis revealed acceptable data quality for the study.

The four blank samples collected during the study revealed no results above the reporting limit for all analytes analyzed.

Conclusions and Recommendations

In this study, general water chemistry was analyzed from 50 wells and 8 surface water sites to characterize current surface and ground water quality conditions in the Big Lost River Basin. No EPA MCL exceedances were found, while two manganese SMCL exceedances and two iron SMCL exceedances were identified. The dominant water type of all samples was found to be a calcium bicarbonate type, which implies water that has undergone minimal geochemical change from its source. Study results provide a useful water quality baseline that can guide further studies, aid in management, and provide information to water users.

Yearly, dedicated sampling throughout the basin in wells with historic data could provide insight into water quality changes over time and help illuminate emerging issues, particularly related to land use changes and population growth. Future studies could explore nitrate concentrations above background level in the Moore to Arco area to determine potential sources and outline nutrient risks. One well located south of Arco exhibits increasing nitrate over time and could be investigated further to determine if a localized source is present.

The development of a more localized LMWL and seasonal isotope sampling could help identify ground water recharge sources throughout the year, aiding in the understanding of water supply in the basin. Additional sampling could also help alleviate some of the high uncertainty that accompanied isotope testing in this study.

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Appendices

Appendices can be accessed at https://idwr.idaho.gov/wp-content/uploads/sites/2/water-data/groundwater-quality/publications/BigLostAppendices.pdf

Appendix A –Water Quality Results

Results are displayed Appendix A. Groundwater data are also available on IDWR's Groundwater Data Portal at https://idwr-groundwater-data.idaho.gov/.

Appendix B –Analysis Methods

Appendix C –Blank and Replicate Results