DATA SUMMARY FOR MONITORING OF SPRINGS

IN BIGHORN CANYON NATIONAL RECREATION AREA

2007 DATA

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TABLE OF CONTENTS

Introduction

Aridland seeps and springs in Bighorn Canyon National Recreation Area (BICA) were identified as a vital sign for the Greater Yellowstone Inventory and Monitoring Network (GRYN). Seeps and spring ecosystems have an ecological importance disproportionate to their spatial extent in this desert environment. Protecting seep and spring resources requires in-depth understanding of their ecological character, controlling factors, and natural variability over space and time.

A monitoring protocol was developed to track the ecological condition of BICA springs. To date only protocols for the physical parameters have been developed. There are 28 springs confirmed springs in the park. 24 springs have been established in NPSTORET. 20 of those have been sampled for baseline water quality. Three sites have not been sampled for water quality due to dry conditions. One site cannot be sampled until the park archeologist rules out disturbance to cultural resources. Two sites are seeps on the canyon walls above the reservoir and are not accessible. Four springs were used during protocol development and have been sampled for water quality seasonally since Fall 2004.

This report aims to assess spring water quality based on data collected during 2007. Specifically, the objectives are to 1) summarize the spring water quality 2007 data set, 2) assess the nutrient status of springs according to the EPA 1986 water quality standards (US Environmental Protection Agency 1987), and 3) analyze the chemical character of spring sites.

Methods

Data was collected according to Data Collection of Water Quality SOP #5 (Schmitz and others 2007a) and analyzed according to the Data Analysis SOP #9 (Schmitz and others 2007b).

Results and Discussion

Data Summary and Chemical Characterization

2007 water quality data for BICA springs was collected for the four pilot springs and three additional sites. The pilot springs are Layout, Headgate, Hillsboro Main, and N Davis. The additional sites include Lockhart Stockpond, Finley, and Mason-Lovell. Lockhart Stockpond was a lingering gap from the 2006 baseline dataset. Finley was a new site identified from aerial photos. Field parameters were collected from Mason-Lovell during the macroinvertebrate study in May 2007. These data are summarized in the tables below in the following format. Data from pilot springs are shown first with the data for each spring shown in a different table (Table 1through Table 4). Data from the remaining sites are grouped in a single table at the end of this subsection (Table 5).

Bicarbonate levels indicate that Layout, Hillsboro, Headgate, Finley, and Lockhart Stockpond springs are moderately sensitive (between 50 and 200 mg/L) to changes in pH caused by nutrients, organic inputs, and acid deposition (Camarero and others 1995). North Davis spring is not sensitive due to high acid neutralizing capacities (above 200 mg/L). No spring bicarbonate levels exceed the minimum recommended standard for aquatic life of 20 mg/L (Table 6) (US Environmental Protection Agency 1987).

The calcium: magnesium molar ratio is commonly used as an indicator of flow path and source area (e.g. (Jensen and others 1997). Calcium: magnesium near 1.0 indicates water flow paths through dolomitic formations; 1.0-3.0 indicates a combination of limestone and dolomitic formations; >3.0 indicates primarily limestone formations. Finley spring has a calcium: magnesium of 2.8 suggesting that is emerges from the base of the Chugwater Siltstone formation. Lockhart Stockpond spring has a calcium: magnesium of 3.9 suggesting that it emerges from the Tensleep Sandstone formation.

Pilot Springs

Table 1. Layout Spring emerges from the Bighorn Dolomite-Madison Limestone.

StationID	Date	pH	DO	DO	T	SpEC	Turbidity	Q	HCO_3	CO_3	Ca	K	Mg	Na	Cl
			mg/L	%sat	°C	µS	NTU	L/s	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LAYOUTSPR1	3/14/2007	7.66	9.50	87	5.5	311.90	0.57	62.892	120	0.00	44.60	0.43	15.70	ND	ND
LAYOUTSPR1	5/21/2007	7.90	10.20	92	4.7	333.00	0.57	62.892	200	0.00	45.30	0.39	15.50	ND	ND
LAYOUTSPR1	9/26/2007	7.29	10.58	97	5.4	316.50	0.57	11.780	182	0.00	45.50	0.39	15.30	0.59	ND
LAYOUTSPR1	12/18/2007	7.03	9.97	92	5.3	278.00	0.30	11.298	165	0.00	44.30	0.40	15.30	0.77	ND
	Mean	7.47	10.06	92	5.2	309.85	0.50	37.216	167	0.00	44.93	0.41	15.45	0.68	NA
	Standard Deviation	0.39	0.45	4	0.3	23.09	0.14	29.649	34	0.00	0.57	0.02	0.19	0.13	NA
	Minimum	7.03	9.50	87	4.7	278.00	0.30	11.298	120	0.00	44.30	0.39	15.30	0.59	0.0
	Maximum	7.90	10.58	97	5.5	333.00	0.57	62.892	200	0.00	45.50	0.43	15.70	0.77	0.0

NA – not applicable; ND – below detection limit; NR – not reported.

Table 2. Headgate Seep occurs near the base of the Bighorn Dolomite, just uphill from a major fault to the west.

StationID	Date	pH	DO	DO	T	SpEC	Turbidity	WT100	HCO3	CO3	Ca	K	Mg	Na	Cl
			mg/L	%sat	°C	µS	NTU	m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HDGTSEEP1	3/14/2007	7.45	8.44	82.10	8.0	369.90	NA	0.00	133	0.00	43.30	1.72	23.90	3.21	2.15
HDGTSEEP1	5/21/2007	7.54	6.94	73.50	11.2	403.60	NA	0.00	193	0.00	41.20	2.07	23.40	3.54	1.91
HDGTSEEP1	9/26/2007	7.13	7.47	84.20	13.9	399.60	NA	0.00	194	0.00	229.00	1.94	68.40	18.40	2.57
HDGTSEEP1	12/18/2007	7.51	9.07	88.10	7.3	324.00	NA	0.00	195	0.00	39.30	1.55	22.50	3.22	1.69
	Mean	7.41	7.98	82	10.1	374.28	NA	0.00	179	0.00	88.20	1.82	34.55	7.09	2.08
	Standard Deviation	0.19	0.96	6	3.1	36.73	NA	0.00	31	0.00	93.88	0.23	22.57	7.54	0.38
	Minimum	7.13	6.94	74	7.3	324.00	NA	0.00	133	0.00	39.30	1.55	22.50	3.21	1.69
	Maximum	7.54	9.07	88	13.9	403.60	NA	0.00	195	0.00	229.00	2.07	68.40	18.40	2.57

NA – not applicable; ND – below detection limit; NR – not reported.

Table 3. Hillsboro Main Spring emerges from the Tensleep Sandstone.

StationID	Date	pH	DO	DO	T	SpEC	Turbidity	Q	HCO_3	CO_3	Ca	K	Mg	Na	Cl
			mg/L	%sat	°C	µS	NTU	L/s	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HLSBMNSPR1	3/14/2007	7.13	8.01	82	10.2	579.40	0.57	16.260	139	0.00	75.80	0.70	29.30	5.81	1.14
HLSBMNSPR1	5/21/2007	7.36	8.41	87	10.3	578.50	0.57	1.855	210	0.00	70.40	0.64	27.10	5.55	1.04
HLSBMNSPR1	9/27/2007	7.48	8.35	86	10.2	515.90	0.57	5.650	208	0.00	73.70	0.66	28.40	6.00	1.04
HLSBMNSPR1	12/18/2007	7.35	8.40	88	10.1	500.00	0.57	4.672	186	0.00	72.40	0.64	28.00	6.01	ND
	Mean	7.33	8.29	86	10.2	543.45	0.57	7.109	186	0.00	73.08	0.66	28.20	5.84	1.07
	Standard Deviation	0.15	0.19	3	0.1	41.50	0.00	6.309	33	0.00	2.27	0.03	0.91	0.22	0.06
	Minimum	7.13	8.01	82	10.1	500.00	0.57	1.855	139	0.00	70.40	0.64	27.10	5.55	1.04
	Maximum	7.48	8.41	88	10.3	579.40	0.57	16.260	210	0.00	75.80	0.70	29.30	6.01	1.14

NA – not applicable; ND – below detection limit; NR – not reported.

Table 4. North Davis Spring emerges from the Chugwater Siltstone.

StationID	Date	pH	DO	DO	T	SpEC	Turbidity	Q	HCO3	CO3	Ca	K	Mg	Na	Cl
			mg/L	%sat	°C	µS	NTU	L/s	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
NDAVISPR1	3/14/2007	7.22	4.70	43	5.3	2115	NA	0.045	249	0.00	309.00	1.83	125.00	49.90	4.33
NDAVISPR1	5/21/2007	6.69	4.19	43	11.9	1592	NA	0.060	256	0.00	202.00	1.56	83.90	37.20	3.70
NDAVISPR1	9/26/2007	6.78	2.10	22	9.7	1442	NA	0.052	360	0.00	198.00	1.90	78.60	35.40	3.10
NDAVISPR1	12/19/2007	6.85	4.08	37	4.5	1382	NA	0.014	265	0.00	186.00	1.42	74.60	31.40	2.68
	Mean	6.89	3.77	36	7.9	1633	NA	0.043	282	0.00	223.75	1.68	90.53	38.48	3.45
	Standard Deviation	0.23	1.14	10	3.6	333	NA	0.020	52	0.00	57.24	0.23	23.30	7.99	0.72
	Minimum	6.69	2.10	22	4.5	1382	NA	0.014	249	0.00	186.00	1.42	74.60	31.40	2.68
	Maximum	7.22	4.70	43	11.9	2115	NA	0.060	360	0.00	309.00	1.90	125.00	49.90	4.33

NA – not applicable; ND – below detection limit; NR – not reported.

Non-pilot Springs Visited Once

Table 5. Non-pilot springs visited once.

StationID	Date	pH	DO	DO	T	SpEC	Turbidity	Q	HCO3	CO3	Ca	K	Mg	Na	Cl
			mg/L	%sat	°C	µS	NTU	L/s	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
FINLEYSPR1	5/20/2007	6.97	7.88	82.40	10.8	1867	NA	0.215	183	0.00	269.00	3.34	97.10	35.50	5.11
LOCKPNDSP1	12/19/2007	7.37	7.87	79.60	8.5	2458	NA	0.078	119	0.00	457.00	2.32	116.00	25.60	3.90
MASLOVSPR1	5/19/2007	6.52	4.60	57.00	14.9	3385	NA	NA	NA	0.00	NA	NA	NA	NA	NA
	Mean	6.95	6.78	73	11.4	2570	NA	0.147	151	0.00	363.0	363.00	2.83	106.55	30.55
	Standard Deviation	0.43	1.89	14	3.2	765	NA	0.097	45	0.00	132.9	132.94	0.72	13.36	7.00
	Minimum	6.52	4.60	57	8.5	1867	NA	0.078	119	0.00	269.0	269.00	2.32	97.10	25.60
	Maximum	7.37	7.88	82	14.9	3385	NA	0.215	183	0.00	457.0	457.00	3.34	116.00	35.50

NA – not applicable; ND – below detection limit; NR – not reported.

Chemical Profiles

The Piper plot (e.g. trilinear, ternary) is a visual reference for describing the chemical character of the water sample. The four piper plots below (Figure 1) summarize the chemical stability of the four pilot springs and Finley and Lockhart Stockpond 2007 season. The data show that all springs were chemically stable through the 2007 water year.

Finley emerges from the Chugwater Siltstone and is chemically classified as a calcium sulfate spring (Figure 2). This type is characteristically high in sulfate due to the gypsiferous inclusion of this formation (Richards 1955). Lockhart Stockpond spring emerges from the Tensleep Sandstone and is chemically classified as calcium sulfate spring (Figure 3). Because there was only one observation of these two springs, the chemical stability cannot be determined at this time.

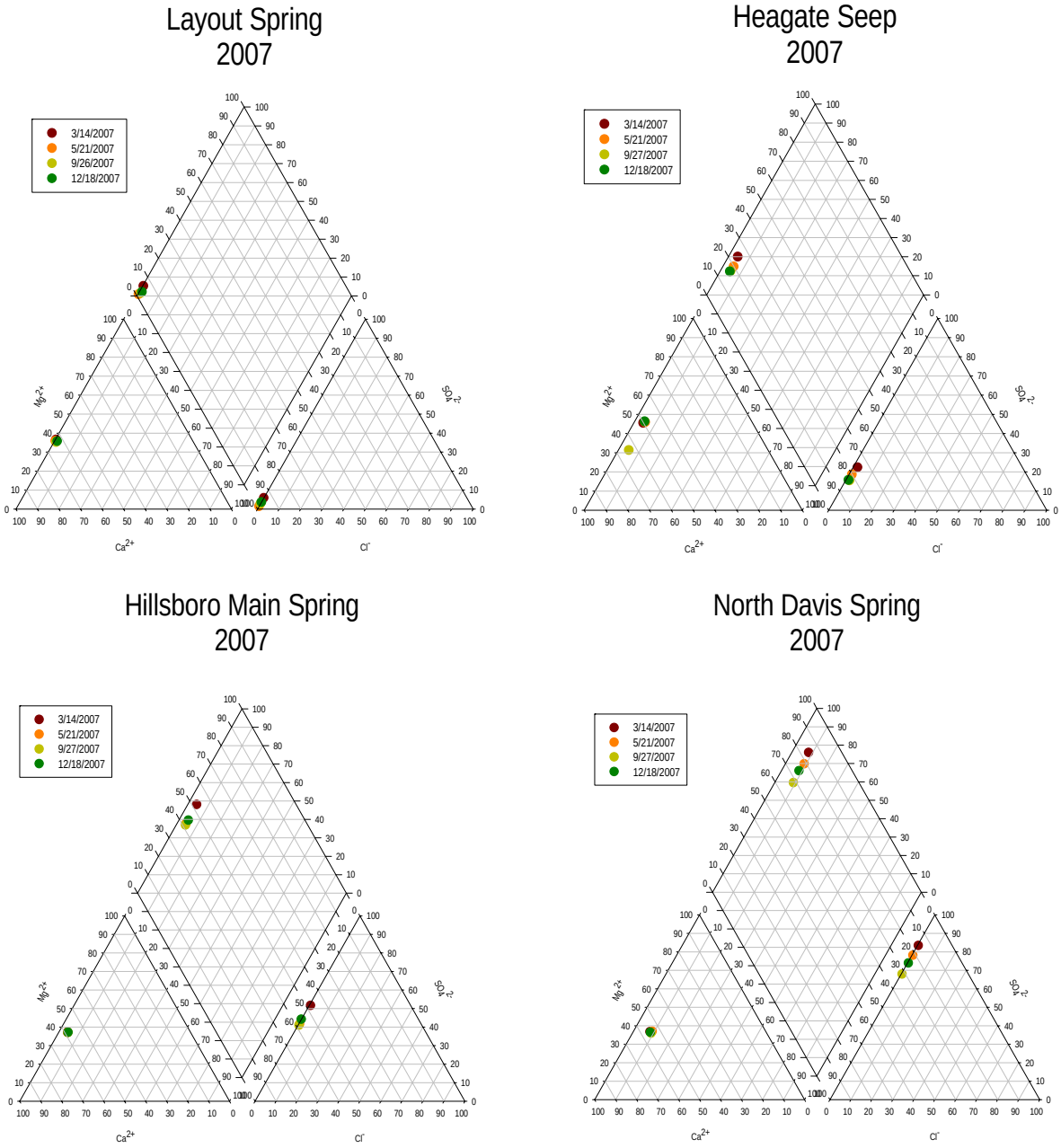

Figure 1. Seasonal chemical profiles of pilot springs indicate stable chemical compositions.

Finley Spring
May 2007

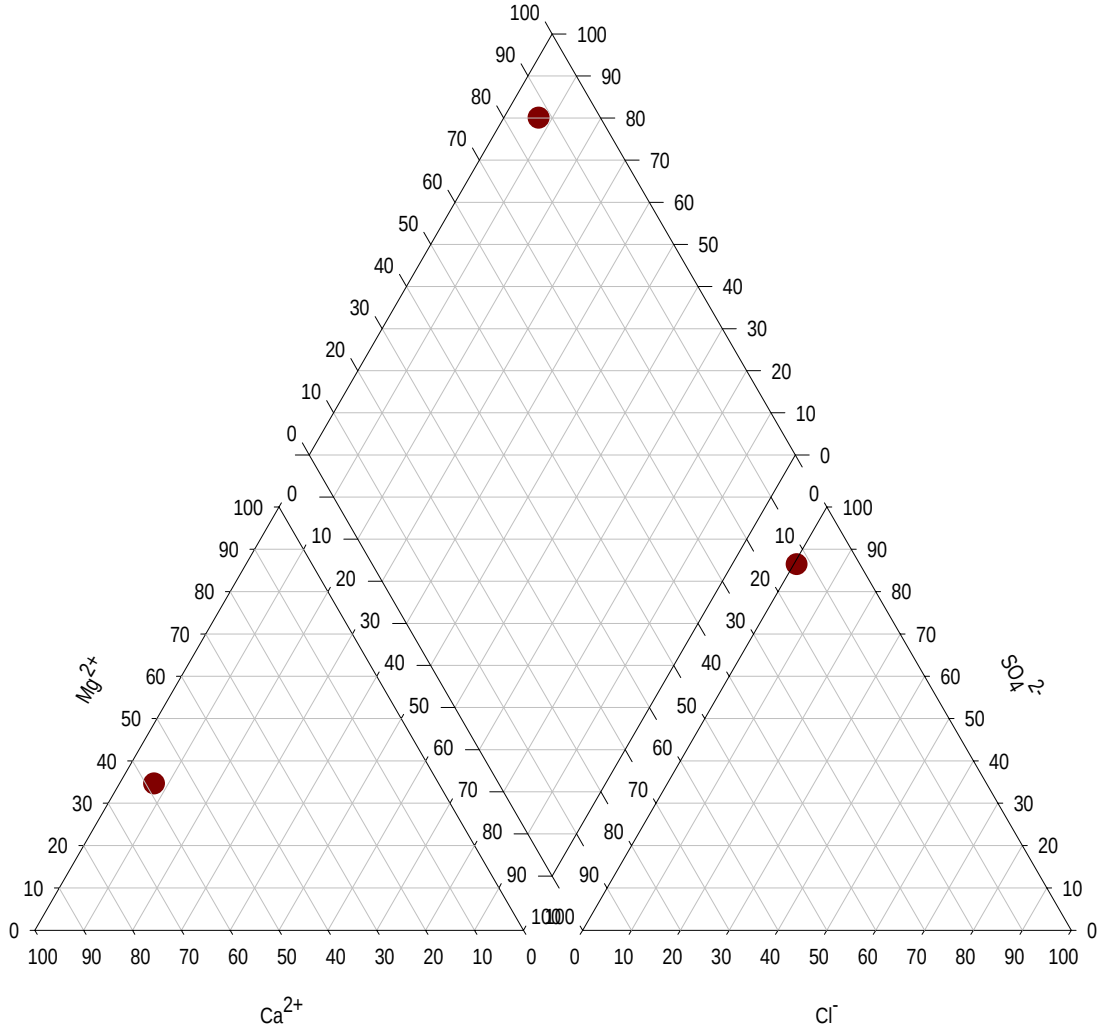

Figure 2. Finley spring is chemically classified as a calcium sulfate spring and emerges from the Chugwater Silstone formation.

Lockhart Stockpond Spring
December 2007

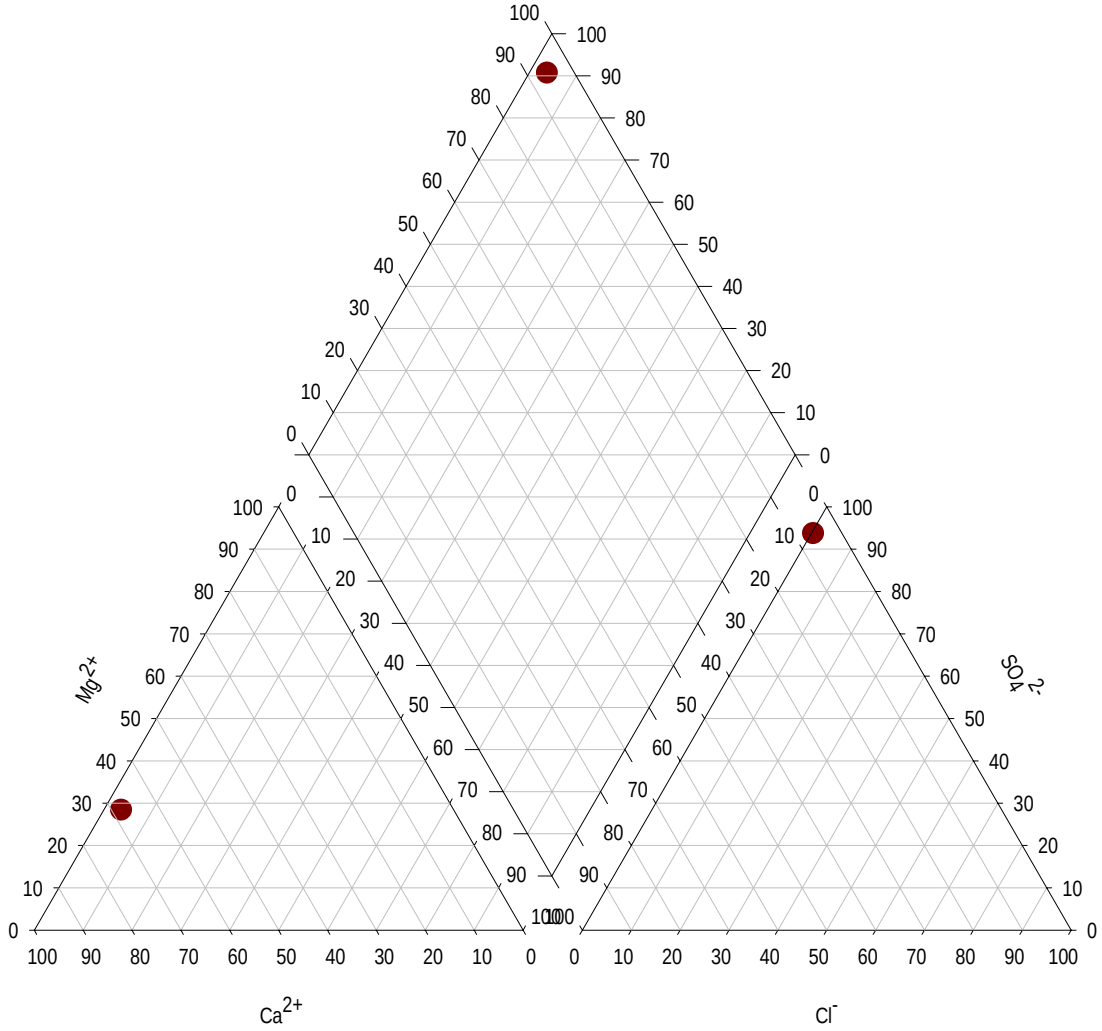

Figure 3. Lockhart Stockpond spring is chemically classified as a calcium sulfate spring and emerges from the Tensleep Sandstone formation.

Spring Nutrient Assessment

BICA spring nutrient concentrations were assessed according to the Water Quality Criteria for 1986 (Table 6) (US Environmental Protection Agency 1987). North Davis, Finley, and Lockhart Stockpond springs exceed recommended aquatic life standards for sulfate concentrations (Table 7 through Table 11) due to the influence of gypsiferous units in the Chugwater and overlying formations. No springs exceed recommended standards for aquatic life for nitrate or phosphate concentrations.

Table 6. Nutrient level standards based on the Water Quality Criteria for 1986 (US Environmental Protection Agency 1987), also known as the "Gold Book".

Regulatory parameter	Std. Type	Std. Value
		Mg/l
Nitrate (mg/l)	Ambient water	10
Sulfate (mg/l)	Ambient water	250
Phosphate	Flowing waters	100
Acid neutralizing capacity	Ambient water	<20

Currently there are no total maximum daily load (TMDL) criteria for nutrients on the Lower Bighorn River for Montana. The tables below calculate nutrient loads for sulfate, nitrate, and ortho-phosphate for pilot and non-pilot springs sampled in 2007. They are graphed in Figure 4. Of particular interest are the sulfate loads. Sulfate levels, and to a lesser extent nitrate, rise with spring runoff. This suggests that the groundwater recharge that occurs in the spring flushes sulfate pools that have accumulated due to chemical weathering during low groundwater flow during the winter (e. g.Rice and Bricker 1995). Because the concentrations of sulfate exceed aquatic life standards and are naturally occurring, these data can be used in the future to document trends in nutrient exports from BICA springs should TMDLs be set for the Lower Bighorn River watershed.

Pilot Springs

Table 7. Nutrient exports for Layout Spring. Shaded values indicate exceedances of water quality standards for aquatic life.

StationID	Date	NO_3	NO_3 Load	OrthoP	P Load	SO_4	SO_4 Load
		mg/L	kg/yr	mg/L	kg/yr	mg/L	kg/yr
LAYOUTSPR1	3/14/2007	0.28	0.00545	ND	ND	5.96	0.11819
LAYOUTSPR1	5/21/2007	0.14	0.00276	ND	ND	2.38	0.04720
LAYOUTSPR1	9/26/2007	0.24	0.00088	ND	ND	4.32	0.01605
LAYOUTSPR1	12/18/2007	0.22	0.00078	ND	ND	5.01	0.01785
	Mean	0.22	0.00247	ND	ND	0.22	0.04982
	Standard Deviation	0.06	0.00219	ND	ND	0.06	0.04776
	Minimum	0.14	0.00078	ND	ND	0.14	0.01605
	Maximum	0.28	0.00545	ND	ND	0.28	0.11819

NA – not applicable; ND – below detection limit; NR – not reported.

Table 8. Nutrient exports for Headgate Seep. Shaded values indicate exceedances of water quality standards for aquatic life.

StationID	Date	NO3	NO3 Load	OrthoP	P Load	SO4	SO4 Load
		mg/L	kg/yr	mg/L	kg/yr	mg/L	kg/yr
HDGTSEEP1	3/14/2007	0.73	NA	ND	NA	31.10	NA
HDGTSEEP1	5/21/2007	0.51	NA	ND	NA	35.60	NA
HDGTSEEP1	9/26/2007	0.49	NA	ND	NA	28.90	NA
HDGTSEEP1	12/18/2007	0.64	NA	ND	NA	29.30	NA
	Mean	0.59	NA	ND	NA	31.23	NA
	Standard Deviation	0.11	NA	ND	NA	3.07	NA
	Minimum	0.49	NA	ND	NA	28.90	NA
	Maximum	0.73	NA	ND	NA	35.60	NA

NA – not applicable; ND – below detection limit; NR – not reported.

Table 9. Nutrient exports for Hillsboro Main Spring. Shaded values indicate exceedances of water quality standards for aquatic life.

StationID	Date	NO3	NO3 Load	OrthoP	P Load	SO4	SO4 Load
		mg/L	kg/yr	mg/L	kg/yr	mg/L	kg/yr
HLSBMNSPR1	3/14/2007	0.16	0.00084	ND	ND	119.00	0.61009
HLSBMNSPR1	5/21/2007	0.14	0.00008	0.22	0.00013	119.00	0.06960
HLSBMNSPR1	9/27/2007	0.15	0.00026	ND	ND	115.00	0.20487
HLSBMNSPR1	12/18/2007	0.14	0.00020	ND	ND	116.00	0.17088
	Mean	0.15	0.00035	0.20	0.00013	117.25	0.26386
	Standard Deviation	0.01	0.00034	NA	NA	2.06	0.23786
	Minimum	0.14	0.00008	0.20	0.00013	115.00	0.06960
	Maximum	0.16	0.00084	0.20	0.00013	119.00	0.61009

NA – not applicable; ND – below detection limit; NR – not reported.

Table 10. Nutrient exports for North Davis Spring. Shaded values indicate exceedances of water quality standards for aquatic life.

StationID	Date	NO3	NO3 Load	OrthoP	P Load	SO4	SO4 Load
		mg/L	kg/yr	mg/L	kg/yr	mg/L	kg/yr
NDAVISPR1	3/14/2007	ND	ND	ND	ND	1020.00	0.01447
NDAVISPR1	5/21/2007	ND	ND	0.42	0.00001	741.00	0.01402
NDAVISPR1	9/26/2007	ND	ND	ND	ND	612.00	0.01003
NDAVISPR1	12/19/2007	ND	ND	ND	ND	605.00	0.00263
	Mean	ND	ND	0.42	0.00001	744.50	0.01029
	Standard Deviation	ND	ND	NA	NA	194.02	0.00548
	Minimum	ND	ND	0.42	0.00001	605.00	0.00263
	Maximum	ND	ND	0.42	0.00001	1020.00	0.01447

NA – not applicable; ND – below detection limit; NR – not reported.

Non-pilot Springs

Table 11. Nutrient exports for non-pilot springs. Shaded values indicate exceedances of water quality standards for aquatic life.

StationID	Date	NO3	NO3 Load	OrthoP	P Load	SO4	SO4 Load
		mg/L	kg/yr	mg/L	kg/yr	mg/L	kg/yr
FINLEYSPR1	5/20/2007	0.31	0.00002	ND	ND	969.00	0.06569
LOCKPNDSP1	12/19/2007	0.66	0.00002	ND	ND	1510.00	0.03718
MASLOVSPR1	5/19/2007	NA	0.00000	NA	NA	NA	NA
	Mean	0.48	0.00001	ND	ND	1239.50	0.03429
	Standard Deviation	0.25	0.00001	ND	ND	382.54	0.03294
	Minimum	0.31	0.00000	ND	ND	969.00	0.00000
	Maximum	0.66	0.00002	ND	ND	1510.00	0.06569

NA – not applicable; ND – below detection limit; NR – not reported.

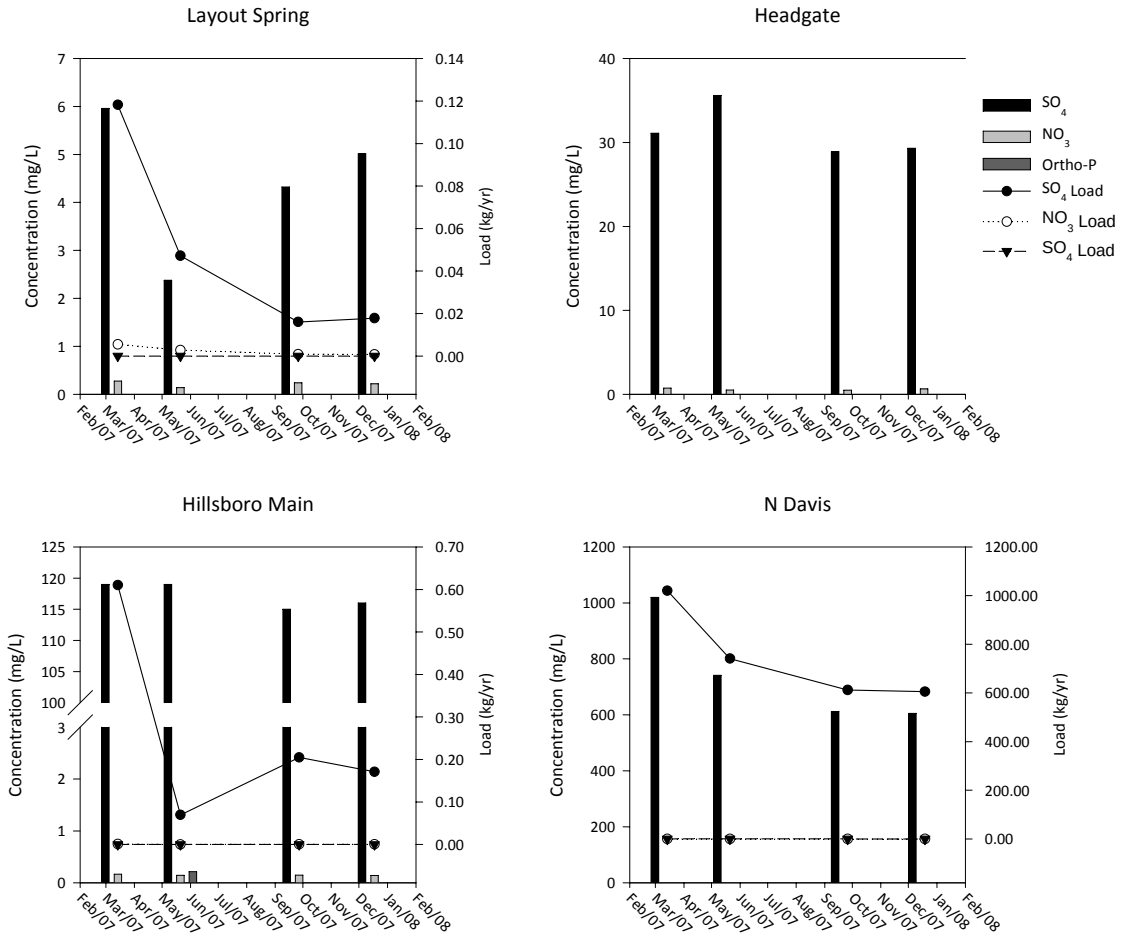

Figure 4. Nutrient exports for pilot springs through the seasonal sampling.

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