DATA SUMMARY FOR MONITORING OF WATER QUALITY IN BIGHORN CANYON NATIONAL RECREATION AREA 2007 DATA

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Executive Summary

This report provides a summary water quality data and monitoring activities aimed to assess the water quality of streams and rivers in Bighorn Canyon National Recreation Area in 2007. E. coli results will be presented separately. Results were evaluated according to national and state standards, depending on the location of the station.

Overall, water quality in the park is compliant with most national and state standards. The Wyoming standards are directly tied to the support of cold and warm water fisheries. Turbidity values at Bighorn River at Kane, Shoshone River near Lovell, and Crooked Creek exceed the Wyoming standards for this use. Sulfate values often exceed national and state standards. However, the source of sulfate is likely geologic in origin. Phosphorus values tend to be exceeded during spring runoff. With the application of best management practices for reducing the amount of time livestock spend in riparian areas. This exceedance can be improved in the future.

Introduction

This report provides a summary water quality data and monitoring activities aimed to assess the water quality of streams and rivers in Bighorn Canyon National Recreation Area in 2007. It is intended to assist resource manager decision making by documenting the current condition of water resources with respect to national, Wyoming, and Montana water quality standards, as well as the antidegradation component of the Clean Water Act.

Objectives

To achieve these goals, this report summarizes chemical data with respect to national, Wyoming, and Montana water quality standards, documents the degree to which measurement quality objectives were met, describes notable events and observations, and makes recommendations for changes in the water quality monitoring protocol. *E. coli* data will be addressed in a separate report.

Background

EPA Water Quality Criteria

The EPA aquatic life standards for water quality were used to assess the chemical condition of BICA stream and rivers. BICA does not monitor for any of the national priority pollutants. The criteria for non-priority pollutants are primarily based on the 1986 Gold Book (US Environmental Protection Agency 1987). However, criteria for ammonia are based on EPA-822-R-99-014 (US Environmental Protection Agency 1999). These standards are presented in Table 1.

WY Classification of BICA Streams and Rivers

The Wyoming surface water standards are based on the Wyoming Surface Water Classification List (Wyoming Department of Environmental Quality 2007). Class 2 waters in WY are designated as waters known to support fish or drinking water supplies or where those uses are attainable. The subcategory 2AB applies to waters known to support game fish or spawning and nursery areas at least seasonally, their perennial tributaries and adjacent wetlands, as well as those waters where game fishery and drinking water uses are attainable. All lower quality uses apply including non-game fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value.

Game fish are defined as those species present in the Wyoming Game and Fish Department's *Stream and Lakes Inventory Database* as of June 2000. These include cold and warm water game fish. Cold water game fish include burbot (*Lota*), grayling (*Thymallus*), trout, salmon and char (*Salmo, Oncorhynchus* and *Salvelinus*), and whitefish (*Prosopium*). Warm water game fish include bass (*Micropterus* and *Ambloplites*), catfish and bullheads (*Ameiurus*, *Ictalurus*, *Noturus* and *Pylodictus*), crappie (*Pomoxis*), yellow perch (*Perca*), sunfish (*Lepomis*), walleye and sauger (*Stizostedion*), pike (*Esox*), sturgeon (*Scaphirhynchus*) and freshwater drum (*Aplodinotus*) (Wyoming Department of Environmental Quality 2007).

The water quality criteria for BICA streams and rivers with in Wyoming closely follow the national standards with the exception of turbidity. Wyoming criteria for turbidity are stricter and vary with warm and cold water fisheries Table 1.

MT Classification of BICA Streams and Rivers

Montana Surface Water Quality Standards and Procedures aim to "conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry, recreation, and other beneficial uses" (Montana Dept. of Environmental Quality 2006b). BICA streams and rivers are classified under these standards as B-1 and F-1. While the Montana Numeric Water Quality Standards apply to all waters, classified waters have additional limits that apply. B-1 waters are suitable for drinking (after conventional treatment); full contact; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; agricultural and industrial water supply. The Bighorn River at St. Xavier is classified as B-1 and is subject to stricter water quality criteria for temperature, pH, and turbidity, as outlined in Table 1. F-1 waters are streams with low or sporadic flow that, because of natural hydrogeomorphic or hydrologic conditions, are not able to support fish. They are suitable for secondary contact recreation, wildlife, and aquatic life not including fish. The criteria for F-1 waters follow national standards. North Trail Creek, Davis Creek and Layout Creek are classified as F-1 waters and are subject to the national EPA criteria shown in Table 1.

Table 1. Water quality criteria for national, Wyoming, and Montana standards.

Regulatory Parameter	Std. Type	EPA Standard[1]	WY 2AB Standard[2]	MT Standard[3]
Temperature (°C)				0-19 Normal ± 0.5
pH	Aquatic Life (chronic)	6.5 – 9.0	6.5 – 9.0	6.5 – 8.5 Normal ± 0.5
Dissolved Oxygen	Aquatic Life	+	+	+
Turbidity (NTU)	Aquatic Life	50		
Turbidity (NTU)	Cold water fisheries		10	Normal + 5
Turbidity (NTU)	Warm water fisheries		15	
Alkalinity (mg/L)	Aquatic Life (chronic)	<20	<20	<20
Chloride (mg/L)	Fresh Water/Aquatic Life (acute)	860	860	860
Chloride (mg/L)	Fresh Water/Aquatic Life (chronic)	230	230	230
Sulfate (mg/L)	Aquatic Life	250	250	250
Phosphorus (mg/L)	Aquatic Life	0.1		0.1
Ammonia	Aquatic Life	#	#	#
Nitrate (mg/L)	Water/Organism Consumption	10	10	10

Ammonia is pH and temperature dependent and varies of fish species and life stage. See Appendix A
+Dissolved oxygen standards vary with fish species and life stage. See Appendix B.
[1](US Environmental Protection Agency 1987; US Environmental Protection Agency 1999; US Environmental Protection Agency 2006)
[2] (Wyoming Department of Environmental Quality 2007)
[3] (Montana Dept. of Environmental Quality 2006a; Montana Dept. of Environmental Quality 2006b)

Table 2. Classification of park streams and rivers according to state classification systems.

Station	WY Surface Water Classification	WY Game & Fish Inventory Database Classification	MT Water-Use Classification
Big Horn River at Kane	2AB		

Crooked Creek	2AB	2AB	
Shoshone River	2AB	2AB	
Big Horn River St Xavier			B-1
Trail			F-1
Davis			F-1
Layout			F-1

Antidegradation

The antidegradation concept was developed to preserve the quality of waters that exceeds standards for identified beneficial uses. The policy requires that waters that exceed standards for identified beneficial uses must be maintained at the higher quality. Continued water quality monitoring of waters entering the park will provide credible data of waters that exceed current classifications, if they exist. Because the park receives waters from outside the park influenced by agriculture, industry, and municipalities, the park needs to be an active participant in discussions about decisions, policy, permitting, and management of upstream water quality resources. By doing so, the park can ensure that quality does not fall below existing conditions, and that existing water uses are fully maintained and protected.

Methods

Study Area

Fixed stations along steam and river were chosen for several different reasons. Bighorn River at Kane, Shoshone River near Lovell, and Bighorn River at St. Xavier were chosen because they are on the 303d list. Further, Bighorn River at Kane, Shoshone River near Lovell, and Crooked Creek were chosen to determine the water quality entering the park. North Trail Creek was chosen to capture the effects of the campground. Davis Creek was chosen to document the influence of grazing. Layout Creek at Headgate and Layout Spring were chosen to monitor a stream with few anthropogenic impacts. Layout Spring replaced Layout Creek at Headgate for the last two sampling events of 2007. Layout Creek below the road was chosen to identify effects of cattle trailing, wild horse use, and the park road on water quality.

Table 3. Station names and IDs for regulatory and non-regulatory sites.

Regulatory Stations	
Station Name	Station ID
Bighorn River at Xavier, MT	BICA_BHR1
Bighorn River at Kane, WY	BICA_BHR2
Shoshone River near Lovell, WY	BICA_SHR2
Non-regulatory Stations	
Station Name	Station ID
Crooked Creek, WY	BICA_CCR1
Layout Creek at Headgate, MT	BICA_LCR1
Layout Spring, MT	BICA_LAYOUTSPR1
Layout Creek below road, MT	BICA_LCR2
North Trail Creek, MT	BICA_TRC1
Davis Creek, MT	BICA_DACR1

Field & Analytical Methods

All data were collected using standard methods, most of which are documented in SOP#5 (field parameters) and SOP#6 (regulatory parameters).

Measurement Quality Objectives

Field and Sample Data

Overall, the consistency of the field data meets the data quality criteria for the regulatory and non-regulatory programs. With the exception of the field measurements listed below, all field data meet the data quality objectives of the regulatory and non-regulatory programs. The following data are rejected based on duplicate results that do not meet program criteria.

BHR1	5/19/07	071391030B01	pH
BHR2	12/17/07	073511542B01	pH
LCR1	3/13/07	070721145B01	DO%

Quality Control Data

Field (measurements taken *in situ*) and field sample (samples collected in the field and analyzed in the lab) meet the data quality objectives of the regulatory and non-regulatory programs. With the exception of the field sample listed below, all field and field sample data meet the data quality objectives of the regulatory and non-regulatory. The following data are rejected based on duplicate results that do not meet program criteria.

LCR2	3/15/07	070740930B17	Alkalinity, HCO3

Laboratory Quality Control Data

Laboratory quality control procedures and methods were consistently completed for all 2007 samples. Method blanks, laboratory control spikes, sample matrix spikes, and sample matrix spike duplicates for all samples met acceptance criteria.

Results

The 2007 results are organized in a park-wide summary (Table 4), regulatory stations (Table 5), and non-regulatory stations (Table 6). The regulatory and non-regulatory sections list the exceedances for each station according to national and state standards.

Park Summary

The number of samples taken for each type of analysis along with summary statistics are shown in Table 4. A total of 833 observations were made in 2007. Of those 536 were regular observations and 341 were quality control observations. 220 observations were made at regulatory stations and 316 were made at non-regulatory stations.

Regulatory Stations

BICA_BHR1 – Bighorn River at St. Xavier (Montana)

- Two exceedances of the sulfate standards for EPA and Montana. The source of sulfate in this river is likely due to geology.
- Two exceedances of the phosphate standards for EPA and Montana. Common sources of phosphorus are human and animal waste (Hem 1985).

BICA_BHR2 – Bighorn River at Kane (Wyoming)
- Two exceedances of the WY turbidity standard for cold and warm water fisheries.
- Three exceedances of the sulfate standards for EPA and Wyoming. The source of sulfate in this river is likely due to geology.
- One exceedance of the phosphate standard for EPA. Common sources of phosphorus are human and animal waste (Hem 1985).

BICA_SHR2 – Shoshone River near Lovell (Wyoming)
- One exceedance of the WY turbidity standard for cold and warm water fisheries.
- One exceedance of the EPA turbidity standard.

<u>Non-regulatory Stations</u>

BICA_CCR1 – Crooked Creek (Wyoming)
- One exceedance of the WY turbidity standard for cold and warm water fisheries.
- Three exceedances of the sulfate standards for EPA and Wyoming. The source of sulfate in this river is likely due to geology.
- One exceedance of the phosphate standard for EPA. Common sources of phosphorus are human and animal waste (Hem 1985).

BICA_DACR1 – Davis Creek (Montana)
- One exceedance of the sulfate standards for EPA and Montana. The source of sulfate in this river is likely due to geology.
- One exceedance of the phosphate standard for EPA. Common sources of phosphorus are human and animal waste (Hem 1985).

BICA_LCR1 – Layout Creek at Headgate (Montana)
- No exceedances.

BICA_LCR2 – Layout Creek below road (Montana)
- No exceedances.

BICALAYOUTSPR1 – Layout Spring (Montana)
- No exceedances.

BICA_TRC1 – North Trail Creek (Montana)
- Four exceedances of the sulfate standards for EPA and Montana. The source of sulfate in this river is likely due to geology.

Table 4. Summary of results from all stations combined, combined regulatory stations, and combined non-regulatory stations.

	T	pH	SpEC	DO	DO%	Turb	Q	Ca	K	Mg	Na	Cl	HCO_3	CO_3	Alk	SO_4	P	NH_3	NO_3
All Stations	°C		µS	mg/L	%	NTU	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Count	31	27	27	27	27	12	23	27	27	27	27	27	27	27	27	27	27	27	27
Average	8.3	8.06	843	10.6	105	22	547.888	94.97	2.61	32.84	39.76	6.10	209.61	1.63	210.87	286.03	0.054	0.042	0.35
SD	5.5	0.32	379	1.6	22	35	804.798	54.00	1.97	18.09	35.21	6.84	44.07	4.20	44.58	247.59	0.116	0.193	0.36
Minimum	0.0	7.25	300	8.1	84	1	0.014	36.80	0.31	10.80	0.00	0.00	96.50	0.00	96.50	0.00	0.000	0.000	0.00
Maximum	20.4	8.80	1578	14.9	201	124	2660.000	270.00	7.01	76.80	108.00	26.20	290.00	14.00	290.00	813.00	0.325	1.000	1.25
Regulatory Stations																			
Count	12	12	12	12	12	6	10	12	12	12	12	12	12	12	12	12	12	12	12
Average	8.3	8.04	837	11.4	116	38	1253.700	82.22	4.45	27.17	74.00	11.45	199.21	2.42	200.71	256.27	0.068	0.010	0.62
SD	7.0	0.42	186	1.8	29	44	777.079	22.49	1.34	7.10	20.35	6.77	44.58	4.89	44.47	84.64	0.126	0.036	0.33
Minimum	0.0	7.25	407	8.1	84	3	151.000	36.80	2.01	10.80	27.90	0.00	96.50	0.00	96.50	89.20	0.000	0.000	0.23
Maximum	20.4	8.80	1145	14.9	201	124	2660.000	127.00	7.01	39.90	108.00	26.20	275.00	14.00	275.00	413.00	0.325	0.125	1.25
Non-regulatory Stations																			
Count	19	15	15	15	15	6	13	15	15	15	15	15	15	15	15	15	15	15	15
Average	8.2	8.08	849	9.9	97	6	4.956	105.17	1.14	37.38	12.37	1.82	217.93	1.00	219.00	309.84	0.042	0.067	0.14
SD	4.2	0.22	490	1.1	5	10	8.923	69.05	0.76	22.76	12.96	2.60	43.34	3.61	44.47	326.88	0.111	0.258	0.22
Minimum	1.4	7.47	300	8.1	91	1	0.014	44.00	0.31	15.60	0.00	0.00	162.00	0.00	164.00	0.00	0.000	0.000	0.00
Maximum	15.3	8.34	1578	11.8	108	27	33.230	270.00	2.24	76.80	33.90	10.20	290.00	14.00	290.00	813.00	0.316	1.000	0.83
# QC samples																			
Count	27	27	27	27	27	12	0	16	15	16	16	15	16	16	16	15	15	17	15

Table 5. Summary results for regulatory stations. Values shaded in gray indicate exceedances of EPA standards. Values shaded in orange indicate exceedances of Wyoming standards for cold and warm water fisheries.

Date	T	pH	SpEC	DO	DO%	Turb	Q	Ca	K	Mg	Na	Cl	HCO_3	CO_3	Alk	SO_4	P	NH_3	NO_3
	°C		µS	mg/L	%	NTU	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BHR1 – Bighorn River at S. Xavier																			
3/15/2007	3.5	7.90	865	13.0	114	NA	1470	86.30	4.31	28.70	76.90	11.10	190.00	0.00	190.00	284.00	0.000	0.000	0.72
5/19/2007	4.3	7.68	926	12.4	116	NA	1500	86.30	4.41	28.70	78.60	12.90	207.00	0.00	207.00	278.00	0.325	0.000	0.54
9/27/2007	11.3	8.06	707	9.9	105	7	1740	72.60	3.38	24.20	60.40	8.95	186.00	0.00	186.00	212.00	0.000	0.000	0.45
12/20/2007	7.2	7.84	808	11.6	113	3	1900	76.70	4.01	25.80	75.20	8.87	176.00	0.00	176.00	249.00	0.287	0.000	0.41
Count	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4
Average	6.6	7.87	826	11.7	112	5	1652	80.48	4.03	26.85	72.78	10.46	189.75	0.00	189.75	255.75	0.153	0.000	0.53
SD	3.5	0.16	93	1.3	5	3	204	6.93	0.46	2.23	8.37	1.93	12.92	0.00	12.92	32.93	0.177	0.000	0.14
Minimum	3.5	7.68	707	9.9	105	3	1470	72.60	3.38	24.20	60.40	8.87	176.00	0.00	176.00	212.00	0.000	0.000	0.41
Maximum	11.3	8.06	926	13.0	116	7	1900	86.30	4.41	28.70	78.60	12.90	207.00	0.00	207.00	284.00	0.325	0.000	0.72
BHR2 – Bighorn River at Kane																			
3/13/2007	0.4	7.84	925	10.5	84	NA	1370	82.80	7.01	27.80	85.30	20.50	190.00	0.00	190.00	317.00	0.000	0.125	0.29
5/19/2007	16.6	7.81	407	8.1	109	NA	2660	36.80	2.01	10.80	27.90	0.00	96.50	0.00	96.50	89.20	0.204	0.000	0.30
9/27/2007	14.3	8.36	957	9.6	109	29	845	90.00	4.69	31.90	94.30	15.20	198.00	4.00	202.00	349.00	0.000	0.000	0.23
12/17/2007	0.0	7.25	1145	12.6	103	25	NA	127.00	6.41	39.90	108.00	26.20	252.00	0.00	252.00	413.00	0.000	0.000	0.48
Count	4	4	4	4	4	2	3	4	4	4	4	4	4	4	4	4	4	4	4
Average	7.8	7.82	858	10.2	101	27	1625	84.15	5.03	27.60	78.88	15.48	184.13	1.00	185.13	292.05	0.051	0.031	0.32
SD	8.9	0.45	316	1.9	12	3	934	37.03	2.24	12.28	35.24	11.25	64.58	2.00	64.90	141.00	0.102	0.063	0.11
Minimum	0.0	7.25	407	8.1	84	25	845	36.80	2.01	10.80	27.90	0.00	96.50	0.00	96.50	89.20	0.000	0.000	0.23
Maximum	16.6	8.36	1145	12.6	109	29	2660	127.00	7.01	39.90	108.00	26.20	252.00	4.00	252.00	413.00	0.204	0.125	0.48
SHR2 – Shoshone River near Lovell																			
3/12/2007	7.8	8.18	887	10.7	103	NA	385	93.90	5.13	30.40	66.20	9.29	240.00	0.00	240.00	243.00	0.000	0.000	0.73
5/19/2007	20.4	8.80	862	14.9	201	NA	151	64.60	3.91	24.10	88.80	10.10	191.00	11.00	191.00	245.00	0.000	0.000	0.83
9/27/2007	14.5	8.64	635	11.7	133	42	516	64.60	3.35	21.10	61.90	6.58	189.00	14.00	203.00	155.00	0.000	0.000	1.16
12/20/2007	0.0	8.10	917	12.2	99	124	NR	105.00	4.77	32.60	64.50	7.67	275.00	0.00	275.00	241.00	0.000	0.000	1.25
Count	4	4	4	4	4	2	3	4	4	4	4	4	4	4	4	4	4	4	4
Average	10.7	8.43	825	12.4	134	83	351	82.03	4.29	27.05	70.35	8.41	223.75	6.25	227.25	221.00	0.000	0.000	0.99
SD	8.8	0.34	129	1.8	47	58	185	20.62	0.81	5.36	12.43	1.58	41.52	7.32	38.06	44.03	0.000	0.000	0.25
Minimum	0.0	8.10	635	10.7	99	42	151	64.60	3.35	21.10	61.90	6.58	189.00	0.00	191.00	155.00	0.000	0.000	0.73
Maximum	20.4	8.80	917	14.9	201	124	516	105.00	5.13	32.60	88.80	10.10	275.00	14.00	275.00	245.00	0.000	0.000	1.25

Table 6. Summary results for non-regulatory stations. Values shaded in gray indicate exceedances of EPA standards. Values shaded in orange indicate exceedances of Wyoming standards for cold and warm water fisheries.

Date	T	pH	SpEC	DO	DO%	Turb	Q	Ca	K	Mg	Na	Cl	HCO_3	CO_3	Alk	SO_4	P	NH_3	NO_3
	°C		µS	mg/L	%	NTU	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CCR1 – Crooked Creek																			
3/13/2007	8.4	7.96	945	10.2	101	NA	33.230	126.00	1.66	42.80	33.00	1.52	254.00	0.00	254.00	293.00	0.000	0.000	0.26
5/20/2007	15.3	8.09	584	8.1	93	NA	5.500	74.30	1.37	23.60	9.08	10.20	244.00	0.00	244.00	83.20	0.315	0.000	0.83
9/27/2007	12.8	8.32	911	9.8	108	5	2.999	127.00	2.24	42.30	33.90	1.38	269.00	14.00	283.00	300.00	0.000	0.000	0.00
12/19/2007	1.9	8.08	939	11.7	99	27	8.673	132.00	1.34	39.70	28.20	1.14	272.00	0.00	272.00	264.00	0.000	0.000	0.31
Count	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Average	9.6	8.11	845	9.9	100	16	12.601	114.83	1.65	37.10	26.05	3.56	259.75	3.50	263.25	235.05	0.079	0.000	0.35
SD	5.9	0.15	174	1.5	6	16	13.948	27.14	0.42	9.10	11.58	4.43	13.12	7.00	17.54	102.43	0.158	0.000	0.35
Minimum	1.9	7.96	584	8.1	93	5	2.999	74.30	1.34	23.60	9.08	1.14	244.00	0.00	244.00	83.20	0.000	0.000	0.00
Maximum	15.3	8.32	945	11.7	108	27	33.230	132.00	2.24	42.80	33.90	10.20	272.00	14.00	283.00	300.00	0.315	0.000	0.83
DACR1 – Davis Creek																			
3/13/2007	NA	NA	NA	NA	NA	NA	dry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5/20/2007	11.2	8.21	1244	8.7	92	NA	NA	141.00	1.76	62.40	25.60	2.01	272.00	0.00	272.00	491.00	0.316	0.000	0.00
Count	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Average	9.5	8.21	1244	8.7	92	NA	NA	141.00	1.76	62.40	25.60	2.01	272.00	0.00	272.00	491.00	0.316	0.000	0.00
SD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Minimum	1.9	8.21	1244	8.7	92	NA	NA	141.00	1.76	62.40	25.60	2.01	272.00	0.00	272.00	491.00	0.316	0.000	0.00
Maximum	15.3	8.21	1244	8.7	92	NA	NA	141.00	1.76	62.40	25.60	2.01	272.00	0.00	272.00	491.00	0.316	0.000	0.00
LCR1 - Layout Creek at Headgate																			
3/13/2007	4.8	8.24	300	10.4	91	NA	1.370	44.00	0.45	16.30	0.55	0.00	162.00	1.00	164.00	6.97	0.000	0.000	0.20
5/20/2007	7.0	8.34	327	9.6	91	NA	5.670	45.40	0.31	15.60	0.00	0.00	184.00	0.00	184.00	2.57	0.000	0.000	0.12
Count	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Average	7.2	8.29	313	10.0	91	NA	3.520	44.70	0.38	15.95	0.28	0.00	173.00	0.50	174.00	4.77	0.000	0.000	0.16
SD	5.8	0.07	19	0.5	0	NA	3.041	0.99	0.10	0.49	0.39	0.00	15.56	0.71	14.14	3.11	0.000	0.000	0.05
Minimum	1.9	8.24	300	9.6	91	NA	1.370	44.00	0.31	15.60	0.00	0.00	162.00	0.00	164.00	2.57	0.000	0.000	0.12
Maximum	15.3	8.34	327	10.4	91	NA	5.670	45.40	0.45	16.30	0.55	0.00	184.00	1.00	184.00	6.97	0.000	0.000	0.20
LCR2 – Layout Creek below road																			
3/15/2007	1.4	7.91	405	11.8	97	NA	NA	57.80	0.43	21.20	1.64	0.00	290.00	0.00	290.00	35.10	0.000	0.000	0.00
5/20/2007	9.8	8.29	338	9.1	92	NA	4.490	46.80	0.36	16.30	0.00	0.00	187.00	0.00	187.00	0.00	0.000	0.000	0.00
9/26/2007	11.9	8.12	387	8.9	96	1	0.014	52.00	0.41	20.40	1.59	0.00	201.00	0.00	201.00	20.70	0.000	0.000	0.00
12/19/2007	3.3	8.11	400	11.0	96	1	0.014	57.00	0.37	20.40	1.52	0.00	195.00	0.00	195.00	30.10	0.000	0.000	0.00
Count	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Average	6.6	8.11	382	10.2	95	1	1.506	53.40	0.39	19.58	1.19	0.00	218.25	0.00	218.25	21.48	0.000	0.000	0.00
SD	5.1	0.16	31	1.4	2	0	2.584	5.09	0.03	2.22	0.79	0.00	48.18	0.00	48.18	15.51	0.000	0.000	0.00
Minimum	1.4	7.91	338	8.9	92	1	0.014	46.80	0.36	16.30	0.00	0.00	187.00	0.00	187.00	0.00	0.000	0.000	0.00
Maximum	11.9	8.29	405	11.8	97	1	4.490	57.80	0.43	21.20	1.64	0.00	290.00	0.00	290.00	35.10	0.000	0.000	0.00
TRC1 – North Trail Creek																			
3/13/2007	7.1	7.86	1534	9.7	93	NA	0.882	270.00	2.04	76.80	19.90	3.16	177.00	0.00	177.00	813.00	0.000	0.000	0.15
5/20/2007	11.6	8.05	1578	8.9	94	NA	0.110	224.00	1.97	69.00	19.50	2.80	183.00	0.00	183.00	808.00	0.000	0.000	0.11
9/26/2007	11.5	8.14	1491	9.8	105	2	0.657	51.20	0.39	20.10	1.64	2.63	182.00	0.00	182.00	728.00	0.000	1.000	0.00
12/18/2007	5.7	7.47	1349	10.5	98	3	0.819	129.00	1.97	73.80	9.38	2.48	197.00	0.00	197.00	772.00	0.000	0.000	0.16
Count	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Average	9.0	7.88	1488	9.7	98	2	0.617	168.55	1.59	59.93	12.61	2.77	184.75	0.00	184.75	780.25	0.000	0.250	0.10
SD	3.0	0.30	99	0.7	5	1	0.351	97.81	0.80	26.74	8.78	0.29	8.58	0.00	8.58	39.33	0.000	0.500	0.07
Minimum	5.7	7.47	1349	8.9	93	2	0.110	51.20	0.39	20.10	1.64	2.48	177.00	0.00	177.00	728.00	0.000	0.000	0.00
Maximum	11.6	8.14	1578	10.5	105	3	0.882	270.00	2.04	76.80	19.90	3.16	197.00	0.00	197.00	813.00	0.000	1.000	0.16
LAYOUTSPR1 – Layout Spring																			
9/26/2007	5.4	7.29	316.50	10.58	97	0.57	11.780	45.50	0.39	15.30	0.59	0.000	182	0.00	182	4.32	0.000	0.000	0.24
12/18/2007	5.3	7.03	278.00	9.97	92	0.30	11.298	44.30	0.40	15.30	0.77	0.000	165	0.00	165	5.01	0.000	0.000	0.22
Count	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mean	5.2	7.47	309.85	10.06	92	0.50	37.216	44.93	0.41	15.45	0.68	0.000	167	0.00	167	0.22	0.000	0.000	0.22
SD	0.3	0.39	23.09	0.45	4	0.14	29.649	0.57	0.02	0.19	0.13	0.000	34	0.00	34	0.06	0.000	0.000	0.06
Minimum	4.7	7.03	278.00	9.50	87	0.30	11.298	44.30	0.39	15.30	0.59	0.000	120	0.00	120	0.14	0.000	0.000	0.14
Maximum	5.5	7.90	333.00	10.58	97	0.57	62.892	45.50	0.43	15.70	0.77	0.000	200	0.00	200	0.28	0.000	0.000	0.28

Discussion and Management Implications

There were exceedances for turbidity, sulfate, and phosphate. The turbidity exceedances occurred in two regulatory and one non-regulatory station and pertained to cold and warm water fisheries in Wyoming. The stations were Bighorn River at Kane, Shoshone River near Lovell, and Crooked Creek. These three stations are downstream of parts of the watershed with significant agricultural activities that likely increase erosion beyond natural levels. Because these rivers and streams occur at the park boundary, the park has little control over the land management affecting their water quality. The park can participate in management discussions, classification hearings, and encourage best management practices upstream of the park boundary.

The status of nutrients in park waters shows a number of exceedances of national, Wyoming, and Montana sulfate standards. The source of sulfate is likely due to the geology of the region. Therefore, there is little the park can do to reduce the amount of sulfate in its waters. The phosphorus exceedances are likely due to animal waste. Further, they tend to occur during spring runoff. Applying best management practices within the park and encouraging them outside the park on neighboring lands may reduce phosphorus levels in the future. In particular, reducing the amount of time livestock spends in riparian areas, which are inundated in the spring, may improve phosphorus levels.

Table 7. The number of stations and observations that exceed water quality criteria for national, Wyoming, and Montana standards. Exceedances are shaded in gray.

Characteristic	Standard Type	EPA	# Sta/Obs	WY 2AB Waters	# WY Sta/Obs	MT B-1 & F-1 Waters	# MT Sta/Obs
Temperature (°C)	Aquatic life						0-19 Normal ± 0.5
pH	Aquatic life (chronic)	6.5 – 9.0	0/0	6.5 – 9.0	0/0	6.5 – 8.5 Normal ± 0.5	0/0
Dissolved Oxygen (mg/L)	Aquatic life	+	0/0	+	0/0	+	0/0
Turbidity (NTU)	Aquatic life	50	1/1		-	Normal + 5	-
Turbidity (NTU)	Cold water fisheries		-	10	3/4		
Turbidity (NTU)	Warm water fisheries		-	15	3/4		
Alkalinity (mg/L)	Aquatic life (chronic)	<20	0/0	<20	0/0	<20	0/0
Chloride (mg/L)	Fresh water/ Aquatic life (acute)	860	0/0	860	0/0	860	0/0
Chloride (mg/L)	Fresh water/ Aquatic life (chronic)	230	0/0	230	0/0	230	0/0
Sulfate (mg/L)	Aquatic life	250	5/13	250	2/5	250	3/7
Phosphorus (mg/L)	Aquatic life	0.1	4/5	0.1	2/2	0.1	2/3
Ammonia (mg/L)	Aquatic life	#	0/0	#	0/0	#	0/0
Nitrate (mg/L)	Water/ Organism consumption	10	0/0	10	0/0	10	0/0

Ammonia is pH and temperature dependent and varies of fish species and life stage. See Appendix A
+Dissolved oxygen standards vary with fish species and life stage. See Appendix B.

Recommendations

Add percent saturation of dissolved oxygen to the required field parameters.

The field duplicates have not included of discharge measurements to date. For quality control and quality assurance purposes duplicate discharge measurements should be made once per day of sampling.

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Appendix A: Ammonia Toxicity Criteria

Source: Wyoming state water quality classification

Appendix C
Ammonia Toxicity Criteria

(a) The ammonia values in the tables below are expressed in milligrams ammonia nitrogen per liter (mg N/L) and vary with temperature and/or pH, and fish species or fish life stage. The ammonia criteria for pH values not represented in the tables can be calculated using the formulas in section (b) of this appendix.

pH-Dependent Values of the Acute Criterion (CMC)[1] for Ammonia

Acute Values, mg N/L		
pH	Salmonids Present	Salmonids Absent
6.5	32.6	48.8
6.6	31.3	46.8
6.7	29.8	44.6
6.8	28.1	42.0
6.9	26.2	39.1
7.0	24.1	36.1
7.1	22.0	32.8
7.2	19.7	29.5
7.3	17.5	26.2
7.4	15.4	23.0
7.5	13.3	19.9
7.6	11.4	17.0
7.7	9.65	14.4
7.8	8.11	12.1
7.9	6.77	10.1
8.0	5.62	8.40
8.1	4.64	6.95
8.2	3.83	5.72
8.3	3.15	4.71
8.4	2.59	3.88
8.5	2.14	3.20
8.6	1.77	2.65
8.7	1.47	2.20
8.8	1.23	1.84
8.9	1.04	1.56
9.0	0.885	1.32

Appendix C
Ammonia Toxicity Criteria

Temperature and pH Dependent Values of the Chronic Criterion (CCC)[(2)]
for Fish Early Life Stages <u>Present</u>

	Temperature, °C									
pH	0	14	16	18	20	22	24	26	28	30
6.5	6.67	6.67	6.06	5.33	4.68	4.12	3.62	3.18	2.80	2.46
6.6	6.57	6.57	5.97	5.25	4.61	4.05	3.56	3.13	2.75	2.42
6.7	6.44	6.44	5.86	5.15	4.52	3.98	3.50	3.07	2.70	2.37
6.8	6.29	6.29	5.72	5.03	4.42	3.89	3.42	3.00	2.64	2.32
6.9	6.12	6.12	5.56	4.89	4.30	3.78	3.32	2.92	2.57	2.25
7.0	5.91	5.91	5.37	4.72	4.15	3.65	3.21	2.82	2.48	2.18
7.1	5.67	5.67	5.15	4.53	3.98	3.50	3.08	2.70	2.38	2.09
7.2	5.39	5.39	4.90	4.31	3.78	3.33	2.92	2.57	2.26	1.99
7.3	5.08	5.08	4.61	4.06	3.57	3.13	2.76	2.42	2.13	1.87
7.4	4.73	4.73	4.30	3.78	3.32	2.92	2.57	2.26	1.98	1.74
7.5	4.36	4.36	3.97	3.49	3.06	2.69	2.37	2.08	1.83	1.61
7.6	3.98	3.98	3.61	3.18	2.79	2.45	2.16	1.90	1.67	1.47
7.7	3.58	3.58	3.25	2.86	2.51	2.21	1.94	1.71	1.50	1.32
7.8	3.18	3.18	2.89	2.54	2.23	1.96	1.73	1.52	1.33	1.17
7.9	2.80	2.80	2.54	2.24	1.96	1.73	1.52	1.33	1.17	1.03
8.0	2.43	2.43	2.21	1.94	1.71	1.50	1.32	1.16	1.02	0.897
8.1	2.10	2.10	1.91	1.68	1.47	1.29	1.14	1.00	0.879	0.773
8.2	1.79	1.79	1.63	1.43	1.26	1.11	0.973	0.855	0.752	0.661
8.3	1.52	1.52	1.39	1.22	1.07	0.941	0.827	0.727	0.639	0.562
8.4	1.29	1.29	1.17	1.03	0.906	0.796	0.700	0.615	0.541	0.475
8.5	1.09	1.09	0.990	0.870	0.765	0.672	0.591	0.520	0.457	0.401
8.6	0.920	0.920	0.836	0.735	0.646	0.568	0.499	0.439	0.386	0.339
8.7	0.778	0.778	0.707	0.622	0.547	0.480	0.422	0.371	0.326	0.287
8.8	0.661	0.661	0.601	0.528	0.464	0.408	0.359	0.315	0.277	0.244
8.9	0.565	0.565	0.513	0.451	0.397	0.349	0.306	0.269	0.237	0.208
9.0	0.486	0.486	0.442	0.389	0.342	0.300	0.264	0.232	0.204	0.179

Appendix C
Ammonia Toxicity Criteria

Temperature and pH Dependent Values of the Chronic Criterion (CCC)[(2)]
for Fish Early Life Stages Absent

	Temperature, °C									
pH	0-7	8	9	10	11	12	13	14	15*	16*
6.5	10.8	10.1	9.51	8.92	8.36	7.84	7.35	6.89	6.46	6.06
6.6	10.7	9.99	9.37	8.79	8.24	7.72	7.24	6.79	6.36	5.97
6.7	10.5	9.81	9.20	8.62	8.08	7.58	7.11	6.66	6.25	5.86
6.8	10.2	9.58	8.98	8.42	7.90	7.40	6.94	6.51	6.10	5.72
6.9	9.93	9.31	8.73	8.19	7.68	7.20	6.75	6.33	5.93	5.56
7.0	9.60	9.00	8.43	7.91	7.41	6.95	6.52	6.11	5.73	5.37
7.1	9.20	8.63	8.09	7.58	7.11	6.67	6.25	5.86	5.49	5.15
7.2	8.75	8.20	7.69	7.21	6.76	6.34	5.94	5.57	5.22	4.90
7.3	8.24	7.73	7.25	6.79	6.37	5.97	5.60	5.25	4.92	4.61
7.4	7.69	7.21	6.76	6.33	5.94	5.57	5.22	4.89	4.59	4.30
7.5	7.09	6.64	6.23	5.84	5.48	5.13	4.81	4.51	4.23	3.97
7.6	6.46	6.05	5.67	5.32	4.99	4.68	4.38	4.11	3.85	3.61
7.7	5.81	5.45	5.11	4.79	4.49	4.21	3.95	3.70	3.47	3.25
7.8	5.17	4.84	4.54	4.26	3.99	3.74	3.51	3.29	3.09	2.89
7.9	4.54	4.26	3.99	3.74	3.51	3.29	3.09	2.89	2.71	2.54
8.0	3.95	3.70	3.47	3.26	3.05	2.86	2.68	2.52	2.36	2.21
8.1	3.41	3.19	2.99	2.81	2.63	2.47	2.31	2.17	2.03	1.91
8.2	2.91	2.73	2.56	2.40	2.25	2.11	1.98	1.85	1.74	1.63
8.3	2.47	2.32	2.18	2.04	1.91	1.79	1.68	1.58	1.48	1.39
8.4	2.09	1.96	1.84	1.73	1.62	1.52	1.42	1.33	1.25	1.17
8.5	1.77	1.66	1.55	1.46	1.37	1.28	1.20	1.13	1.06	0.990
8.6	1.49	1.40	1.31	1.23	1.15	1.08	1.01	0.951	0.892	0.836
8.7	1.26	1.18	1.11	1.04	0.976	0.915	0.858	0.805	0.754	0.707
8.8	1.07	1.01	0.944	0.885	0.829	0.778	0.729	0.684	0.641	0.601
8.9	0.917	0.860	0.806	0.756	0.709	0.664	0.623	0.584	0.548	0.513
9.0	0.790	0.740	0.694	0.651	0.610	0.572	0.536	0.503	0.471	0.442

* At 15 °C and above, the criterion for fish early life stages absent is the same as the criterion for fish early life stages present.

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Appendix C
Ammonia Toxicity Criteria

(b) For pH values not expressed in the table above, ammonia toxicity criteria can be calculated as follows:

(i) <u>Salmonids or other sensitive cold water species present</u>:

$$CMC = \frac{0.275}{1+10^{7.204-pH}} + \frac{39.0}{1+10^{pH-7.204}}$$

(ii) <u>Salmonids or other sensitive cold water species absent</u>:

$$CMC = \frac{0.411}{1+10^{7.204-pH}} + \frac{58.4}{1+10^{pH-7.204}}$$

(iii) <u>Criterion Continuous Concentration (CCC) when fish early life stages are present</u>

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) \bullet MIN(2.85,\ 1.45 \bullet 10^{0.028 \bullet (25-T)})$$

(iv) <u>Criterion Continuous Concentration (CCC) when fish early life stages are absent</u>

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) \bullet 1.45 \bullet 10^{0.028 \bullet (25 - MAX(T,7))}$$

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[1] Criterion Maximum Concentration (CMC) refers to the one-hour average concentration of total ammonia nitrogen (in mg N/L) not to be exceeded more than once every three (3) years. The CMC can also be referred to as the acute value.

[2] Criterion Continuous Concentration (CCC) refers to the 30-day average concentration of total ammonia nitrogen (in mg N/L) not to be exceeded more than once every three (3) years. In addition, the highest 4-day average within the 30-day period should not exceed 2.5 times the CCC. The CCC can also be referred to as the chronic value. The CCC values are implemented on Class 2 waters with an assumption that early life stages of fish are present. This assumption can be rebutted, but only where a permittee, discharge permit applicant or affected party provides sufficient site-specific information to support a conclusion that the assumption is not appropriate for that waterbody.

Appendix B: Dissolved Oxygen

Source: Wyoming State Water Quality Standards

Minimum Dissolved Oxygen Criteria* (mg/L)

	Cold water Criteria		Class 2C and Warm water Criteria		
	Early Life Stages(1),(2)		Early Life Stages (2)	Other Life Stages	
30 Day Mean	NA	6.5	NA	5.5	
7 Day Mean	9.5 (6.5)	NA	6.0	NA	
7 Day Mean Minimum(3)	NA	5.0	NA	4.0	
1 Day Minimum(3)	8.0 (5.0)	4.0	5.0	3.0	

(1) These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.

(2) Includes all embryonic and larval stages and all juvenile forms to 30-days following hatching.

(3) All minima should be considered as instantaneous concentrations to be achieved at all times.

* These limitations apply to Class 1, 2A, 2B and 2C waters only and in no case shall be interpreted to require dissolved oxygen concentrations greater than 100 percent saturation at ambient temperature and elevation.