Water Quality Monitoring in Yellowstone National Park 2007

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Introduction

In 2007, 19 water quality sites were monitored in Yellowstone National Park; 12 sites are on major rivers and 7 sites on Yellowstone Lake (Figure 1). The monitoring is conducted in cooperation with the Vital Signs Monitoring Program of the Greater Yellowstone Network (GRYN). Most of the stream water quality sites are located near U.S. Geological Survey discharge gaging stations. Stream discharge strongly influences limnological processes and flow-weighted measurements can be calculated for chemical parameters when they are collected near gage stations.

The purpose of the long-term water quality program is to acquire baseline information for Yellowstone's surface waters that can be used to evaluate overall ecosystem health, ascertain impacts of potential stressors (e.g., road construction activities or accidental sewage spills), identify any changes that may be associated with water quality degradation, and guide resource management decisions related to water quality. In 2007, each site received one visit each month to collect data on core water quality parameters that include water temperature, dissolved oxygen, pH, specific conductance, and turbidity. Water samples were brought back to the laboratory for total suspended solids (TSS) analysis. In addition, various chemical parameters were collected from 10 of these sites that include anions (sulfate, chloride, bicarbonate and carbonate), cations (calcium, magnesium, sodium, and potassium), and nutrients (total phosphorus, orthophosphate, nitrate-nitrogen, nitrite-nitrogen, and ammonia-nitrogen). Dissolved and total metals (arsenic, copper, iron, and selenium) in water and sediment are measured twice annually during high and low flow periods on upper Soda Butte Creek at the park boundary near Silver Gate, Montana.

The objectives of this project were as follows:

1) Collect water quality baseline information
2) Enter water quality information into an electronic (STORET) database.
3) Write draft water quality report for Yellowstone National Park.

Core Water Quality Parameters

In general, physical and chemical characteristics of water quality are related to seasonal changes, elevation, precipitation events, and presence or absence of thermal features. Water temperature and dissolved oxygen (DO) are closely tied because colder water holds more oxygen. With the exception of the Gardner River, overall water temperatures were generally lowest and DO concentrations highest on sites located within the Yellowstone River drainage which has minimal geothermal activity compared to the Madison River drainage. Surface water temperatures at water quality stations ranged between -0.2 and 25.5 degrees Celsius (°C) in 2007. The lowest and highest mean annual temperatures were both recorded within the Yellowstone River drainage on upper Soda Butte Creek (4.7°C; range -0.1-13.8°C) and Gardner River (16.0°C; range 10.6-.1°C) respectively (Figure 28a). Meanwhile, average DO concentrations (mean for all sites ranged from 8.5-10.8 mg/L) remained relatively consistent among sample sites.

The acidity of surface water in Yellowstone, measured in pH, commonly ranges from 2.0 to 9.0 standard units (SU), with most waters having a pH near neutral (6.5-7.5) to slightly basic (7.5-8.5). The pH is influenced by water source, local geology, atmospheric deposition, geothermal contributions, and biological factors. Within site variation of pH was quite low; most differences occurred spatially across the park and among sites. The Madison River, for example, receives water from the Firehole and Gibbon rivers, both of which are influenced by geothermal activity. The mean pH at the Firehole River was 8.21 SU (range 7.8-8.6). In contrast, the Gibbon River had a mean of 6.9 SU (range 5.7-7.9). Very acidic geothermal water that flowing into the Gibbon River contributes to the lower pH values at this site.

Specific conductance, turbidity, and total suspended solids (TSS) are directly related to stream flow.

Specific conductance is a measure of a solution's resistance to conducting electricity. The ability of water to conduct electrical current increases with an increase in ion content (i.e., anions and cations), hence, the purer the water, the lower the specific conductance. (Wetzel, 2001). Specific conductance at all sites was lower during high flow periods of May and June, and higher during low flow periods of late summer and winter. Specific conductance was higher at stream sites that received geothermal inputs that include Pelican Creek and Gardner River, within the Yellowstone River basin; and the Firehole, Gibbon, and Madison rivers, within the Madison River basin. Yellowstone Lake operates as a buffer to the upper Yellowstone River system which consequently leads to low annual variation in specific conductance, turbidity, and TSS. Yellowstone River at Fishing Bridge (at lake outlet) had the lowest mean specific conductance of 100 µSiemens (µS cm-1) with a range between 95-123 µS cm-1. Conversely, the water quality station on the Gardner River exhibited the highest mean specific conductance of 573 µScm-1 and a range between 103-827 µScm-1. Both turbidity and TSS are a measure of water clarity. Turbidity readings, which are measured in nephelometric turbidity units (NTU); TSS concentrations are measured in mg/L. For both parameters water clarity remains very good throughout the year with more turbid conditions being observed during snowmelt and after rainfall events, which is typical of mountain streams with minimal sediment contributions.

Chemical Constituents of Surface Waters

Beginning in May 2006, we began collecting water samples for chemical analysis at 10 stream water quality sites within the Yellowstone and Madison river drainages. The added parameters include select anions, cations, and nutrients. These dissolved chemicals are used to varying degrees by aquatic plants for basic cellular structure, metabolism, growth, and development. In Yellowstone, dissolved concentrations of ions and nutrients are most closely related to natural factors such as geology, discharge, geothermal input, grazing, and uptake by aquatic plants; as well as to anthropogenic sources such as sewage spills, runoff from paved road surfaces, and acid mine drainage.

In Yellowstone, 2007 represented the first calendar year that complete set of chemical data were collected as part of the long-term water quality monitoring program. Generally, dissolved ion concentrations in Yellowstone waters are relatively low, with higher concentrations observed during low flow conditions and lower concentrations being observed during high flow conditions.

Relative concentrations of major anions and cations were calculated for each site and a unique pattern of relative dissolved ion concentrations were observed between the Yellowstone and Madison River drainages (Figure 2). For the most part, relative concentrations of bicarbonate (HCO_3^{2-}) ions were dominant at all water quality stations. However, concentrations of other major ions seemed to vary according to watershed. Lamar River drainage, within the Yellowstone River basin, had higher concentrations of calcium (Ca^{2+}) ions compared to the Yellowstone River mainstem which had higher concentrations of sulfate ($SO4^{2-}$) ions by comparison. In addition to bicarbonate ions, both sodium (Na+) and chloride (Cl-) were present in approximately equal proportions within the Madison River basin (Figure 29). Both phosphorus and nitrogen concentrations remained very low for all sites sampled. Mean total phosphorus concentrations were highest on the Firehole River (0.23 mg/L) with a range between 0.18 and 0.30 mg/L. Ortho-Phosphate, nitrate, nitrite, and ammonia were very low with most concentrations occurring below the analytical detection limits. Descriptive statistics for all chemical parameters at 10 water quality monitoring sites are given in Tables 1 and 2.

Regulatory Monitoring on Soda Butte Creek

In conjunction with routine water quality monitoring we also sampled dissolved and total metals (arsenic, copper, iron, and selenium) in water and total metals in sediments on Soda Butte Creek near the park's northeast boundary. The state of Montana has listed Soda Butte Creek upstream of the park's Northeast Entrance as "water quality impaired" because of elevated metal concentrations from the McClaren mine tailings located near Cooke City and within the Soda Butte Creek floodplain. On 14 June and 20 September (periods of high and low stream flow, respectively), we collected water and sediment for analysis of arsenic, copper, iron, and selenium. Samples were obtained in both the morning and evening to capture diurnal variations. Total and dissolved arsenic, copper, and selenium were below analytical detection limits in all water samples (Table 3). Levels of both dissolved and total iron concentration in water did not exceed State of Montana aquatic-life standards for any sample event. In June and September, dissolved iron was below detection limits while total iron had recorded values of 0.393 and 0.535 mg/L in June and 0.536 and 0.55 mg/L in September. Total hardness was near 41 mg/L in June and near 94 mg/L in September.

In the sediment samples, arsenic and selenium were below detection limits during both sample days. For both copper and iron, concentrations tended to be lower in June than in September: copper (11.60 and 23.80 mg/kg respectively) and iron (14,500 and 25,500 mg/kg respectively). Concentrations of arsenic and copper in sediments were well below the probable effect concentrations listed by Ingersoll and MacDonald (2002), at 33 mg/kg and 149 mg/kg respectively. There are no recognized standards for iron and selenium in sediments.

Yellowstone Lake Limnology

Yellowstone Lake is the largest high alpine lake in the contiguous United States and is the most prominent body of water in Yellowstone National Park. Understanding Yellowstone Lake limnology is an important element in comprehending the ecology of lake trout and aids park fisheries biologists with the lake trout suppression program. Seven water quality sites on Yellowstone Lake were sampled once each month between May and October, 2007. These sites are located throughout the Yellowstone Lake basin (Figure 1). Water temperature, dissolved oxygen, specific conductance, and turbidity measurements were recorded using a multiparameter probe. In addition, with weather permitting, temperature profile data was collected from the West Thumb and South Arm area of Yellowstone Lake. Water samples were also collected at each location for total suspended solids (TSS) and volatile suspended solids analysis.

Data Management

All water quality data collected in 2007 was entered into the NPSTORET database. A data validation and verification report was completed and submitted to the GRYN for approval.

Figure 1. Major watersheds and surface waters of Yellowstone National Park, with sites established for long-term water quality monitoring on streams (12 sites-yellow circles) and Yellowstone Lake (7 sites-green circles).

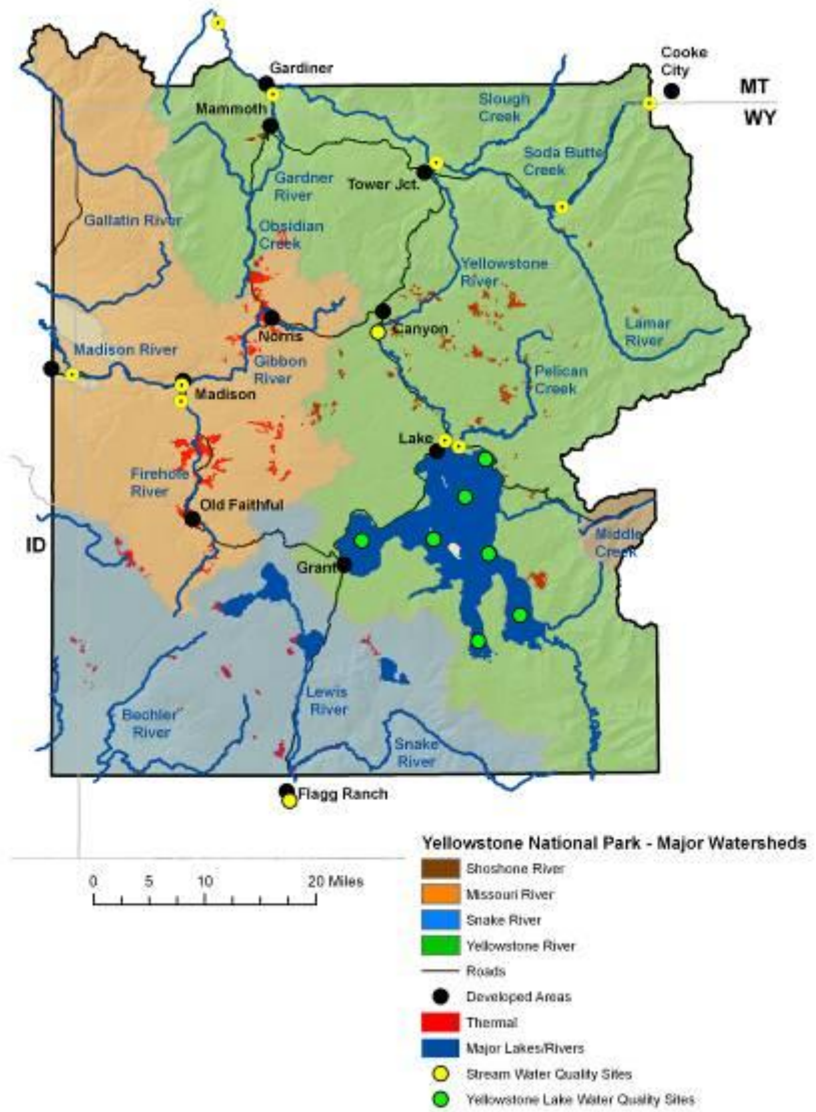

Figure 2. Average annual percent ion concentration of seven measured ions from water quality sites on rivers and streams in Yellowstone National Park. The concentric heptagons represent the 10th and 20th percentile respectively from the center with remaining percentiles not shown. (SO4 = sulfate, Cl = Chloride, CaCO3 = bicarbonate, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium).

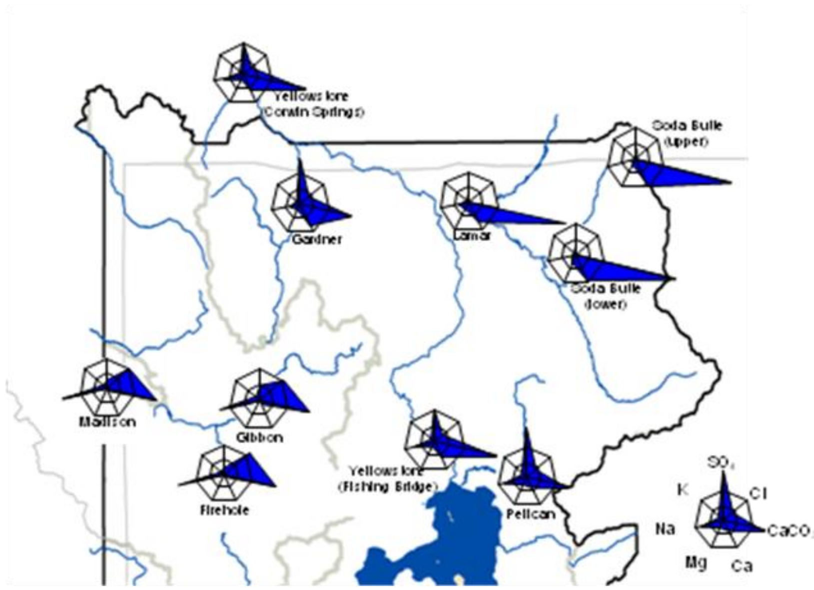

Table 1. Chemical characteristics of Yellowstone National Parks surface waters in the Yellowstone River drainage, 2007.

		Anions			Cations				Nutrients				
									Phosphorus		Nitrogen		
Stream/River	Statistic	SO_4	Cl	Alkalinity	Ca	Mg	Na	K	Total	Ortho_P	Nitrate	Nitrite	Ammonia
Yellowstone River Fishing Bridge	Mean	16.6	6.7	38.0	6.8	3.5	12.9	2.6	-	-	-	-	-
	Minimum	7.6	4.3	31.0	4.8	2.2	8.6	1.6	-	-	-	-	-
	Maximum	102.0	26.7	95.0	20.6	14.3	48.0	11.9	0.09	0.5	0.2	-	0.9
	Std. dev.	27.0	6.3	18.0	4.4	3.4	11.1	2.9	-	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	12	12	12	12	12
Yellowstone River Corwin Springs	Mean	30.0	10.6	61.2	15.7	4.9	19.1	4.1	0.07	-	-	-	-
	Minimum	6.5	2.0	34.0	7.6	2.4	5.3	1.3	0.03	-	-	-	-
	Maximum	46.4	16.6	76.0	22.7	7.1	29.2	6.5	0.10	0.2	0.3	-	0.2
	Std. dev.	13.7	4.9	13.8	5.0	1.5	7.9	1.7	0.02	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	12	12	12	12	12
Pelican Creek	Mean	75.3	19.4	67.4	15.4	10.3	35.6	9.1	0.10	-	-	-	0.4
	Minimum	7.7	1.0	17.0	3.7	2.1	3.7	1.6	-	-	-	-	-
	Maximum	119.0	30.3	94.0	23.0	15.9	53.9	14.0	0.15	0.3	0.3	-	0.9
	Std. dev.	38.6	10.1	27.5	6.1	4.5	17.4	4.3	0.03	-	-	-	0.3
	N. obs.	12	12	12	12	12	12	12	12	12	12	12	12
Soda Butte Creek at park boundary	Mean	8.1	-	84.3	23.9	5.5	4.2	0.4	0.05	-	-	-	-
	Minimum	5.1	-	44.0	11.4	2.5	3.1	0.2	-	-	-	-	-
	Maximum	10.9	-	109.0	32.3	7.2	5.3	0.5	0.10	0.4	-	-	-
	Std. dev.	2.0	-	21.3	7.0	1.6	0.6	0.1	0.02	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	11	12	12	12	11
Soda Butte Creek near confluence with Lamar River	Mean	7.2	-	114.8	28.9	9.5	3.9	1.5	0.07	-	-	-	-
	Minimum	3.9	-	64.0	15.2	4.5	2.5	0.7	0.04	-	-	-	-
	Maximum	9.0	-	147.0	36.8	12.7	4.6	2.1	0.17	0.4	-	-	0.1
	Std. dev.	1.7	-	27.6	7.4	2.8	0.6	0.5	0.04	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	10	12	12	12	10
Lamar River	Mean	6.5	-	79.0	18.1	6.1	7.3	1.3	0.08	-	-	-	-
	Minimum	1.5	-	34.0	7.2	2.3	2.5	0.6	-	-	-	-	-
	Maximum	9.8	-	104.0	23.9	8.2	9.9	1.7	0.21	0.2	-	-	-
	Std. dev.	2.6	-	24.6	5.9	2.1	2.5	0.4	0.06	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	11	12	12	12	11
Gardner River	Mean	123.6	31.7	151.8	65.7	18.0	30.3	11.5	0.08	-	-	-	-
	Minimum	32.7	7.4	77.0	27.8	6.5	8.2	3.2	0.05	-	-	-	-
	Maximum	227.0	55.6	216.0	95.3	29.1	53.2	20.5	0.11	0.2	0.2	-	-
	Std. dev.	50.2	12.6	35.5	18.2	5.9	12.0	4.6	0.02	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	11	12	12	12	11

Table 2. Chemical characteristics of Yellowstone National Parks surface waters in the Madison River drainage, 2007.

		Anions			Cations				Nutrients				
									Phosphorus		Nitrogen		
Stream/River	Statistic	SO_4	Cl	Alkalinity	Ca	Mg	Na	K	Total	Ortho_P	Nitrate	Nitrite	Ammonia
Firehole River	Mean	13.3	68.3	109.3	5.1	0.4	95.1	8.0	0.23	-	-	-	-
	Minimum	8.4	40.8	71.0	3.6	0.4	57.0	5.0	0.18	-	-	-	-
	Maximum	15.6	76.6	121.0	5.7	0.5	107.0	9.0	0.30	0.3	-	-	-
	Std. dev.	1.9	10.3	14.2	0.5	0.0	13.8	1.2	0.04	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	10	12	12	12	10
Gibbon River	Mean	27.2	57.0	96.0	8.5	1.2	78.3	11.0	0.12	-	-	-	-
	Minimum	16.3	31.4	43.0	5.9	1.0	43.3	6.6	0.06	-	-	-	-
	Maximum	35.5	76.8	114.0	10.5	1.5	97.0	14.1	0.17	0.3	-	-	0.1
	Std. dev.	6.4	15.2	21.1	1.3	0.2	18.5	2.5	0.03	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	10	12	12	12	10
Madison River	Mean	14.2	55.9	100.8	6.1	0.7	90.2	8.7	0.17	-	-	-	-
	Minimum	1.3	2.1	7.9	4.6	0.6	57.3	5.8	0.11	-	-	-	-
	Maximum	18.9	71.7	124.0	7.1	0.8	106.0	10.4	0.23	0.3	-	-	-
	Std. dev.	5.0	19.8	33.9	0.6	0.0	13.4	1.2	0.04	-	-	-	-
	N. obs.	11	11	11	11	11	11	11	11	11	11	11	11

Table 3. Concentrations of select metals on Soda Butte Creek at park boundary during June and September 2007.

Date	Matrix	Analysis	Time (MST)	Hardness	Arsenic	Copper	Iron	Selenium
14-Jun	Aqueous*	Dissolved metals	719		<0.01	<0.005	<0.1	<0.01
			1745		<0.01	<0.005	<0.1	<0.01
		Total metals	719	41.6	<0.01	<0.005	0.393	<0.01
			1745	40.1	<0.01	<0.005	0.535	<0.01
	Sediment**	Total Metals	719		<1	11.6	14,500	<5
20-Sep	Aqueous*	Dissolved metals	833		<0.01	<0.005	<0.1	<0.01
			1713		<0.01	<0.005	<0.1	<0.01
		Total metals	833	94.3	<0.01	<0.005	0.536	<0.01
			1713	94.1	<0.01	<0.005	0.55	<0.01
	Sediment**	Total metals	833		<1	23.8	25,500	<5

*Aqueous measurement units are recorded in mg/l

**Sediment measurement units are recorded in mg/kg