BIGHORN LAKE AND BIGHORN RIVER WATER QUALITY MONITORING: SAMPLING AND ANALYSIS PLAN-2019

RI

PROTECT • PRESERVE • ENHANCE

2019

PREPARED FOR:

BIGHORN RIVER ALLIANCE

THE RESEARCH INITIATIVE

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1.0 Introduction and Background Information

The Bighorn River Alliance (BHRA) recognizes that the long-term health of the Bighorn River fishery is dependent upon the ecological integrity of the entire river corridor. To better understand how the Bighorn River ecosystem responds to natural and human factors, the BHRA developed a Research Initiative (August 2018) outlining several studies to closely examine the biology (aquatic and terrestrial plant and animal life), hydrology, water quality, and channel geomorphology of the river. The underlying premise is that an interdisciplinary information base is crucial in meeting BHRA's objectives to support the long-term health of the river.

2.0 Objectives

BHRA's Research Initiative identifies water quality as a major study to determine how the river's water quality interrelates with other river features (i.e. hydrology, fisheries, benthic macroinvertebrates, riparian forest, etc.) and to better understand how natural and human drivers are influencing river health and function.

The Bighorn River Water Quality Long-Term Monitoring Program is focused on seeking answers to the following questions:

1. What is responsible for the frequency, extent, duration, and timing of high turbidity in the Bighorn River?
2. What are the physical, chemical, and biological constituents in the water column that affect aquatic plant and algae growth?
3. How do Bighorn Lake destratification and Yellowtail Dam flow releases influence water quality in the Bighorn River?
4. What effects do irrigation withdrawals, irrigation returns, and tributaries have on the water quality in the Bighorn River?
5. What effect do the Afterbay Dam releases (quantity, timing, and gate) have on total gas saturation (PSAT) levels in the river from the dam to the Saint Xavier Bridge?
6. What are the long-term trends in water quality in the Bighorn River?

3.0 Sampling Parameters

Water Temperature: Water temperature is one of the most important characteristics of an aquatic system. Water temperature is affected by air temperature, tributary inputs, groundwater, agricultural runoff, and especially releases out of Yellowtail Dam. Water temperatures vary widely along the Bighorn River, both spatially and seasonally. The further downstream from Yellowtail Dam, water temperatures fluctuate significantly between night and day (diurnal temperature changes). Temperature is also important because of its influence on water chemistry. Higher water temperatures can dissolve more salts and minerals causing the specific conductivity to rise. Conversely, warm water holds less dissolved oxygen than cold water.

Dissolved Oxygen (DO): Dissolved oxygen in the Bighorn River is essential for a healthy aquatic ecosystem. The need for oxygen depends on the species and life stage; cold-water fish on the

upper river require higher concentrations than warm water species further downstream. DO is greatly influenced by aeration from the Yellowtail Dam and Afterbay releases. Additionally, it comes directly from the atmosphere and photosynthesis by aquatic plants during the day. Deceases in DO occurs from aquatic plant respiration at night and late summer plant decomposition.

Specific Conductivity (SC): Specific conductivity is a measure of the water's capability to pass electrical flow that is directly related to the amount of dissolved salts and inorganic materials in the water. It is an early indicator of change in water quality affected by dam releases, tributary inflows, agricultural run-off, geologic effects, etc. High levels of dissolved solids will lower dissolved oxygen which adversely affects fish and other aquatic life. SC levels often determine aquatic species present on a certain section of river due, in part, to their level of tolerance to dissolved salts.

Turbidity: Turbidity is a measure of water clarity and can serve as an indirect indication of suspended solids (sediment and/or algae) in the water. High turbidity often leads to increased water temperature, low dissolved oxygen, and impairments to aquatic life.

Suspended Solids: Total suspended solids (TSS) includes anything non-soluble that is drifting or floating in the water, from sediment, silt, sand to plankton and algae. They are particles larger than 2 microns. Anything less is considered a dissolved solid. Volatile suspended solids (VSS) is the organic component of TSS that includes plankton and algae.

Chlorophyll-a: Chlorophyll is bound within cells of algae and other phytoplankton found in surface water. Chlorophyll-a is the most abundant form of chlorophyll. Monitoring chlorophyll levels is a direct way of tracking algal growth. Chlorophyll measurements can be utilized as an indirect indicator of nutrient levels, generally phosphorus and nitrogen, and suspended solids/turbidity.

Nutrients – Nitrogen and Phosphorus: Nitrogen and phosphorus are essential nutrients for plants and small amounts are an important component of healthy rivers. Large inputs of nutrients often lead to excessive growth of aquatic plants and/or algae that can degrade fish habitat and alter flows. Low concentrations of dissolved oxygen and high water temperatures can increase the availability of nutrients to aquatic plants.

Selenium: Selenium is a nutritionally essential element for aquatic life in small amounts, but toxic at higher concentrations. It bioaccumulates in the aquatic food chain and chronic exposure in fish and aquatic invertebrates can cause reproductive impairments and adversely affect juvenile growth and mortality. Selenium is released into lakes and rivers by natural sources via weathering and by human sources, such as mining, coal-fired power plants, and irrigated agriculture.

4.0 Water Sampling Locations and Protocols

4.1 Bighorn Lake

The water quality of the Bighorn River is primarily determined by Yellowtail Dam releases from Bighorn Lake. To understand spatial and temporal changes in the chemical, physical, and biological properties of the Bighorn River, it is important to understand how the distribution and stratification of key water quality parameters in Bighorn Lake change throughout the year.

4.1.1 Bighorn Lake Monitoring Site Location

Site	Latitude	Longitude	Site Description
WQL1	45.3059	-107.9582	~ 100 meters from Yellowtail Dam

The monitoring site near Yellowtail Dam will provide water quality data for the full depth profile with supplemental data at the key inlet elevations on the dam. Site WQL1 is in a restricted zone. Access will require approval from the Bureau of Reclamation.

4.1.2 Bighorn Lake: Depth Profile – *In Situ* Measurements

Methods: The reservoir depth near Yellowtail Dam is ~ 400 feet. The depth profile will be completed using a calibrated YSI EXO3 sonde that will continuously record data from the surface to near the reservoir bottom. The sonde will be carefully attached to a terracord or steel cable, then lowered/raised using a downrigger and electric winch. While the depth profile is being taken, the boat's position will be maintained using an automated GPS-positioning system connected to a trolling motor. Once collected, the data will be downloaded to a laptop/tablet (software not compatible with Apple products) via Bluetooth or a direct USB connection. Pre-calibration of the sonde will be undertaken in the lab/office prior to each field trip.

Frequency/Schedule: 2X/month (April – October) – Coordinate with Bighorn River sampling schedule.

Parameters: Conductivity, Water Temperature, Dissolved Oxygen, Total Algae (chlorophyll-a and blue green algae), Turbidity, and Depth.

4.1.3 Bighorn Lake - Water Sample Collection

Method: Water quality sample sets will be collected in sterilized bottles provided by Energy Laboratories (Billings, MT). Four bottles will be necessary per sample set. Precautions should be made to avoid bias or contamination:

- The collection of water samples at Site WQL1 will be done using a Van Dorn water sampler. Individual sample sets (4 bottles/set) will be collected at four depths: one meter below the surface, penstock and spillway inlet elevation(s), and two meters above the bottom. Sample duplicates will also be collected, and field blanks made, according to Quality Assurance and Quality Control requirements outlined in Section 5.0.
- Rinse the sample bottles and lids three times with ambient water and completely fill the fourth time.
- Preservative will be added to the appropriate bottles in the sample set and the lid tightly secured. Sample labels will be filled out and placed on each bottle for proper identification in the field and for tracking in the laboratory. Samples will be stored in a cooler with ice until delivered to the lab within 2-3 days.
- All sample deliveries to the laboratory will be accompanied by a chain-of-custody form. Chain of custody forms will be used to identify the contents of each shipment and maintain the custodial integrity of the samples.

Frequency/Schedule: 2 times/month (April – October) on the same schedule as the Bighorn River samples are collected.

Parameters: Total Persulfate Nitrogen, Total Phosphorus, Total Suspended Solids, Volatile Suspended Solids (organic fraction), Total Selenium

Sample Handling Procedures: Field samples will be collected and preserved in accordance with the specifications outlined in MDEQ's Field Procedures Manuel for Water Quality Assessment Monitoring (2012). The following chart outlines the bottle type/size and preservatives for each sample set.

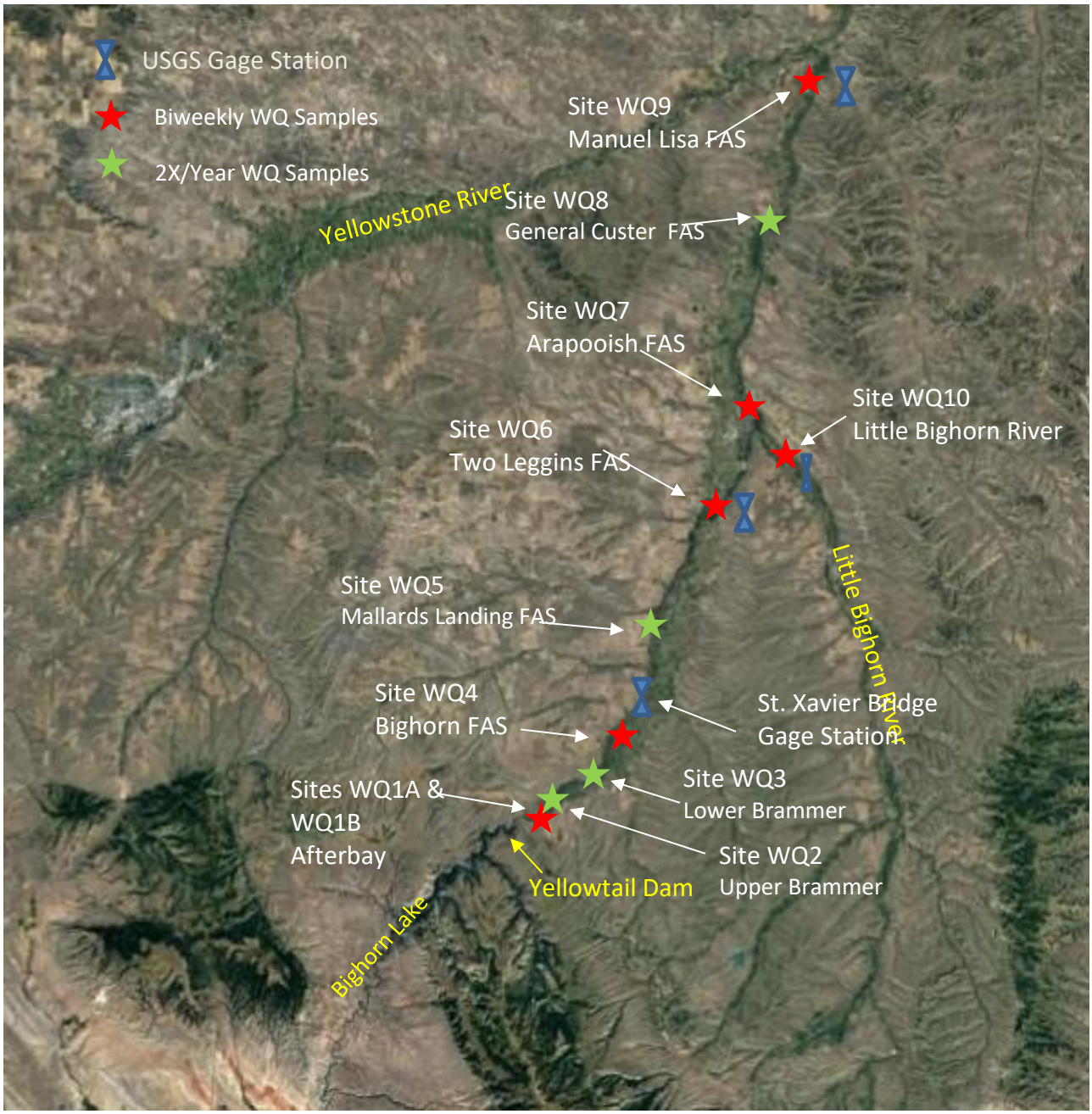
Parameter	Bottle Size	Container	Preservation	Storage	Holding time
Total Persulfate Nitrogen (TPN)	250 ml	HDPE bottle	None	Cool to <6 °C (on	28 days
Total Phosphorus (TP)	250 ml	HDPE bottle	H_2SO_4	Cool to <6 °C (on	28 days
TSS and VSS	1000 ml	HDPE bottle	None	Cool to <6 °C (on	7 days
Total Selenium	250 ml	HDPE bottle	5 ml conc. HNO_3	Cool to <6 °C (on ice)	180 days

4.2 Bighorn River

The water quality of the Bighorn River is primarily determined by Yellowtail Dam releases, tributary inflows, irrigation return flows, and river corridor management. To understand the spatial and temporal changes in the chemical, physical, and biological properties of the Bighorn River, and to identify sources that influence water quality and aquatic habitat conditions, a network of strategically located sample sites from the Afterbay to the Yellowstone River confluence will be established. Several of the water quality sampling sites will be in the same location as the benthic macroinvertebrate collections sites (Refer to *Long-Term Monitoring of the Lower Bighorn River: Sampling and Analysis Plan (SAP) for Aquatic Benthic Macroinvertebrates for site locations).*

4.2.1 Bighorn River Monitoring Site Locations

Site	Latitude	Longitude	Nearest River Mile	Site Description	Frequency
WQ1A	45.3170	-107.9183	86	Below Afterbay Dam – Right Bank	April – October 2X/Month
WQ1B	45.3193	-107.9194	86	Below Afterbay Dam – Left Bank	April – October 2X/Month
WQ2	45.3286	-107.8985	85	Upper Brammer	2X/year w/Macroinvert. Sampling
WQ3	45.3823	-107.8115	75	Lower Brammer	2X/year w/Macroinvert. Sampling
WQ4	45.4163	-107.7898	72	Bighorn FAS	April – October 2X/Month
WQ5	45.5217	-107.7258	63	Mallards Landing FAS	2X/year w/Macroinvert. Sampling
WQ6	45.6445	-107.6600	52	Two Leggins FAS	April – October 2X/Month
WQ7	45.7566	-107.5653	41	Arapooish FAS	April – October 2X/Month
WQ8	45.9274	-107.5744	24	General Custer FAS	2X/year w/Macroinvert. Sampling
WQ9	46.1449	-107.4644	1	Manuel Lisa FAS	April – October 2X/Month
WQ10	45.7357	-107.5575	-	Little Bighorn River Confluence	April – October 2X/Month



Bighorn River Monitoring Sites & USGS Gage Stations

4.2.2 Site Location Description and Rationale

Sites WQ1A and WQ1B - Afterbay: These two sites are located directly downstream from Yellowtail Afterbay at the same locations as the Bureau of Reclamation's hydrolabs. The water quality data collected will complement the water quality data that the BOR is collecting. The data collected at Sites WQ1A and WQ1B will be compared with the water quality released from Bighorn Lake (Site WQL1) and record water quality variations between the two Afterbay gate releases.

The Bureau of Reclamation has recently established three continuous water quality monitoring stations associated with the Afterbay Dam. Each station has a Hydrolab MS5 multiparameter water quality instrument, atmospheric barometer and data collection platform. The water quality parameters collected at each site include total dissolved gas, dissolved oxygen, water depth, water temperature, PH, and specific conductivity. Hourly data is transmitted via satellite telemetry to the Bureau of Reclamation's Hydromet database. The main objective for these stations is to monitor Total Gas Supersaturation (PSAT – computation using barometric pressure and total dissolved gas) and differentiate the effects of the sluice gate (south bank) and the radial gates that release water from the Afterbay Dam into the Bighorn River.

The USGS Gage Station below the Afterbay Dam is designated: *USGS 06287000 Bighorn River near St. Xavier, MT.* The gage station records continuous flow and water temperature data that will supplement the sampling data.

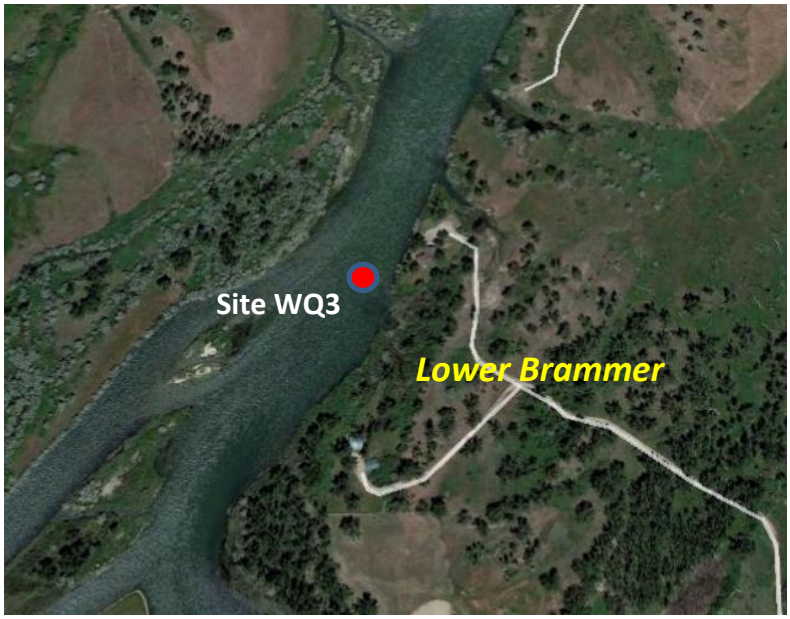
Site WQ1A and WQ1B below the Yellowtail Afterbay Dam.

Site WQ2 – Upper Brammer: Benthic macroinvertebrate sample site. Water quality samples will be collected two times per year on the same days as the macroinvertebrate samples are taken. Flows will be recorded from the USGS Gage Station (*USGS 06287000 Bighorn River near St. Xavier, MT)* located approximately 1 mile upstream. Close coordination between the water quality and macroinvertebrate samplers will be necessary to set sampling dates.

After the first year of sampling, data from Sites WQ1A and WQ1B will be compared to Site WQ2 to determine if river mixing has changed the water quality enough to warrant changing the sampling frequency at Site WQ2 from twice/year to biweekly.

Site WQ2 – Upper Brammer

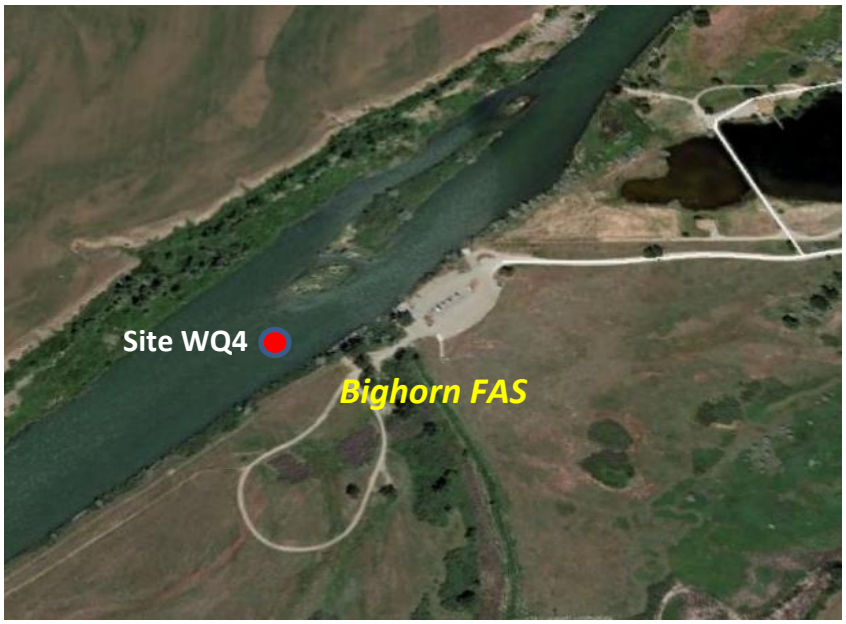
Site WQ3 – Lower Brammer: Benthic macroinvertebrate sample site. Water quality samples will be collected two times per year on the same days as the macroinvertebrate samples are taken. Flows will be recorded from the USGS Gage Station below the Afterbay Dam (*USGS 06287000 Bighorn River near St. Xavier, MT)* located approximately 8 miles upstream. Close coordination between the water quality and macroinvertebrate samplers will be necessary to set sampling dates.



Site WQ3 – Lower Brammer

Site WQ4 – Bighorn FAS: Samples will be taken upstream from the Bighorn Fishing Access Site boat ramp. This site provides a spatial sampling of the Bighorn River that captures the influence of Soap Creek inflows (~ 2 miles upstream). This site is also a benthic macroinvertebrate sampling site.

The USGS Gage Station designated: *USGS 06287800 Bighorn River at bridge, at St. Xavier, MT* at the St. Xavier Bridge will be used to estimate flows when samples are collected. The gage station is located 4 miles downstream from Site WQ4.



Site WQ4 at the Bighorn Fishing Access Site.

Site WQ5 – Mallards Landing FAS: Benthic macroinvertebrate sample site. This site may also reflect the influence of Rotten Grass Creek that enters the Bighorn River approximately 3 miles upstream.

Water quality sampling will occur two times per year on the same dates as the macroinvertebrate samples are taken. Flows will be estimated from the USGS Gage Station designated: *USGS 06287800 Bighorn River at bridge, at St. Xavier, MT* located at the St. Xavier Bridge located approximately 4 miles upstream. Close coordination between the water quality and macroinvertebrate samplers will be necessary to set sampling dates.

Site WQ5 at the Mallards Landing Fishing Access Site

Site WQ6 – Two Leggins FAS: Samples will be taken at the Two Leggins Fishing Access Site immediately upstream from the Highway 313 bridge. This site is near the end of the cold-water reach and ~ 10 miles upstream from the Little Bighorn River confluence. It provides an end-point site to evaluate spatial trends on the upper cold-water reach. In combination with Site WQ7 (Arapooish FAS), this site will bracket the Little Bighorn River confluence to determine its influence on the Bighorn River below Hardin. This site is also a benthic macroinvertebrate sampling site.

The USGS Gage Station designated: *USGS 06288400 Bighorn River at Two Leggins Bridge, near Hardin, MT"* will provide flow when samples are collected.

Site WQ6 at the Two Leggins Fishing Access Site.

Site WQ7 – Arapooish FAS: This site is located at the Arapooish Fishing Access Site ~ 2 miles downstream from the Little Bighorn River confluence. It serves as the downstream bracket of the Little Bighorn River in combination with Site WQ6 located at Two Leggins FAS. The site provides water quality data on the Bighorn River reflecting its transition to a warm-water ecosystem that approaches historic conditions. This site is also a benthic macroinvertebrate sampling site.

There is no USGS Gage Station near this site, but discharge will be estimated by combining discharges recorded at the USGS Gage Stations at Site WQ6 and the lower Little Bighorn River.

Site WQ7 at the Arapooish Fishing Access Site.

Site WQ8 – General Custer FAS: Benthic macroinvertebrate sample site. Water quality sampling will occur two times per year on the same dates as the macroinvertebrate samples are taken. Flows will be extrapolated from flows estimated at Site WQ7 and the USGS Gage Station designated: *Bighorn River above Tullock Creek near Bighorn, MT,* located at Site WQ8 approximately 25 miles downstream. Close coordination between the water quality and macroinvertebrate samplers will be necessary to set sampling dates.

Site WQ8 at the General Custer Fishing Access Site.

Site WQ9 – Manuel Lisa FAS: This site is located at the Manuel Lisa Fishing Access Site ~ 1 mile upstream from the Yellowstone River confluence. It serves as the lowermost spatial trend site for the Bighorn River and a characterization of the river's water quality contribution to the Yellowstone River. This site is also a benthic macroinvertebrate sampling site.

Montana DEQ and the USGS have been monitoring water quality at this site as part of their Statewide Monitoring Network to document biological and water quality conditions and temporal change.

The USGS Gage Station designated: *Bighorn River above Tullock Creek near Bighorn, MT.,* located approximately 2 miles upstream from Site WQ9, will provide flow measurements.

Site WQ9 at the Manuel Lisa Fishing Access Site

Site WQ10 – Little Bighorn River Confluence: This site is located near the USGS Gage Station next to the Sarpy Creek Road Bridge, 0.8 mile upstream from the Bighorn River confluence. Site WQ10 will characterize the Little Bighorn River's water quality contribution to the Bighorn River.

The Crow Tribe has periodically monitored water quality at this site as part of their long-term water quality monitoring program. The BHRA and the Crow Tribe should work cooperatively to coordinate future water quality monitoring to avoid duplicating efforts.

The USGS Gage Station designated: *Little Bighorn River near Hardin, MT.,* located at this site provides continuous flow measurements.

Site WQ10: Little Bighorn River at Sarpy Road Bridge.

4.2.3 Bighorn River - *In Situ* Measurements

Methods: Field measurements will be collected *in* situ at each monitoring site using a calibrated YSI EXO3 sonde. Measurements will be taken prior to the collection of water samples or other physical disturbances to the water column or channel bottom. After the data is collected, it will be downloaded to a laptop/tablet (software not compatible with Apple products) via Bluetooth or a direct USB connection.

Frequency/Schedule: 2X/month (April – October) at most sites. For select benthic macroinvertebrate sites, it will be 2X/year – Refer to Section 4.3.1.

Parameters: Conductivity, Water Temperature, Dissolved Oxygen, Total Algae (chlorophyll-a and blue green algae), Turbidity, and Ambient Air Temperature.

Air temperature will also be measured in a shaded area with good air circulations and allowed to stabilize for approximately 15 minutes.

4.2.4 Bighorn River - Water Sample Collection

Parameters: Total Persulfate Nitrogen, Total Phosphorus, Total Suspended Solids, Volatile Suspended Solids (organic fraction), Total Selenium

Method: Water quality sample sets will be collected in sterilized bottles provided by Energy Laboratories (Billings, MT). Precautions should be made to avoid bias or contamination:

- Wade into the river as far as safely possible before collecting the samples. A water sampling extension pole may be used to help collect samples, especially during high flows.
- Avoid upstream disturbances. Walk upstream to the sample location and take the samples facing upstream.
- Do not take surface water. Collect sample sets 3 to 6 inches below the surface, rinse the four sample bottles and lids three times with ambient water and completely fill the fourth time.
- Be sure there is thorough mixing of river water. Do not sample immediately downstream from irrigation return, drain ditch, or tributary inflows.
- After each sample set (4 bottles) has been collected, add the appropriate preservative and secure the lids tightly. Sample labels will be filled out. Sample sets will be stored in a cooler with ice until delivered to the lab within 2-3 days.
- Refer to Table 1 in Section 4.2.3 for a list of monitoring parameters, bottle size and type needed, preservatives used (if applicable), sample storage method, and holding times.
- Chain of custody forms will be completed for all sample sets collected submitted to the lab.

Frequency/Schedule: 2 times/month (April – October) for the water quality monitoring sites. For all benthic macroinvertebrate sites, water sample sets will be taken at least 2 times/year – Refer to Section 4.2.1.

Sample Handling Procedures: Refer to Section 4.1.3

4.2.5 Bighorn River – Water Temperature Loggers

U22 Hobo Pendant Water Temperature Loggers will be deployed at each monitoring site location except for Site WQ1A and WQ1B where water temperature is being continuously recorded by

the BOR hydrolabs below the Afterbay. These loggers will provide water temperature data that will show temporal and spatial differences as well as diel variations for each site.

4.2.6 Bighorn River - Future Considerations

1. The BHRA may choose to increase the number of sample sites that would include the major tributaries – Soap Creek, Rotten Grass Creek, and Beauvais Creek – and select irrigation return flows. The additional sites would more fully characterize tributary and irrigation influences on the Bighorn River's water quality and aquatic habitat. The Crow Tribe periodically collects water sample on tributaries in the Bighorn River Basin. For the tributaries that the BHRA and the Crow Tribe have a common interest, they should work cooperatively on water quality monitoring.
2. Montana DEQ has established a monitoring site on the Yellowstone River upstream from the Bighorn River confluence. By working cooperatively with Montana DEQ, monitoring dates can be coordinated to compare Bighorn River inflows (Site WQ9) with the receiving Yellowstone River.

4.3 Bighorn Lake Tributaries

The Shoshone and Bighorn Rivers are the principal tributaries into Bighorn Lake. Each river has a USGS gage station located near their confluences with the lake that currently records discharge and gage height in real-time (15-60 minute intervals). Discharge records for the Shoshone River gage station near Lovell run from 1966 to current day and the Bighorn River near Kane run from 1928 to current day. Water quality sensors are not deployed at either gage station at the present time.

USGS Gage Stations on the Shoshone and Bighorn Rivers.

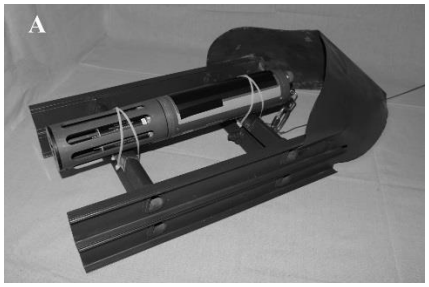
The Wyoming Department of Environmental Quality, US Geological Survey, National Park Service, and others have collected numerous physical, chemical, and biological field samples on or near the Shoshone and Bighorn River gage stations. Flow-sediment relationships have been established for both rivers, however; a detailed temporal and correlation analysis of the other water quality parameters has not been done. The BHRA Sampling Analysis Plan does not include water quality monitoring of the Shoshone and Bighorn River inflows to Bighorn Lake, but the BHRA should maintain close communication with the Wyoming DEQ and USGS on their monitoring activities.

5.0 Quality Assurance and Quality Control

Quality Assurance and Quality Control (QA/QC) are control measures to demonstrate the accuracy and precision of the sampling and analytical procedures. The water quality data must be of sufficient quality to be comparable both spatially and temporally. The QA/QC requirements include:

- **YSI Sonde Calibration:** Pre-calibration of the YSI EXO3 will be completed in the office prior to each field trip. The accuracy and precision of the sonde are verified by certified control standards. All calibrations, reading checks, and maintenance will be recorded in the field logbook.

YSI EXO3 Sonde with 5 Sensors



Sonde Deployment Platform

- **Hobo Water Temperature Logger Calibration:** Calibration, operation, maintenance, and deployment are detailed in the HOBO user's guide, step-by-step instructions. MDEQ's has draft deployment Standard Operating Procedures (SOP) that should also be referenced. These guides include information on:
    - Logger maintenance, programming/launching
    - Forms and equipment for accuracy checks
    - Field deployment strategies
    - Data download and processing
    - Data presentation

U22 Hobo Pendant MX Water Temperature Logger

There may be other water temperature loggers available from MFWP. They would need to be carefully checked for functionality and accuracy prior to deployment.

- **Field Duplicate Samples:** To assess precision associated with all steps in the water sample collection and analysis process, field duplicates will be collected. A field duplicate is a duplicate water sample at the same place and same time as other samples are taken. Sampling locations for duplicate samples will be randomly selected. A duplicate sample will be collected for each parameter for every sampling trip. Field duplicate samples will be collected, preserved, stored, and handled in the same manner described for the regular samples. A separate sample number and site number will be assigned to each duplicate and submitted as "blind" samples to the lab.
- **Field Blanks:** To assess potential laboratory accuracy, field blanks will be collected and analyzed. Field blanks are deionized water which are treated as a sample. They are used to identify errors or contamination in sample collection and analysis. Field blanks are prepared in the field after sampling the last site. One field blank will be prepared for each sampling trip. A separate sample number and site number will be assigned to each blank and submitted as "blind" samples to the lab.
- **Data Quality Assurance/Data Validity:** All data collected by BHRA will undergo a series of checks to ensure that the data are of sufficient quality and conform to project objectives. Soon after receipt of data deliverables from the lab, data verification and validation should occur. The BHRA Research Manager is responsible for verifying that the laboratory data deliverables are complete and consistent with the requirements established in this SAP.

6.0 Data Management and Analysis

Site conditions, weather, photo numbers/descriptions, pertinent field data, etc. will be recorded on a field form or in a water quality sampling log.

Copies of laboratory analytical reports and electronic data spreadsheets will be provided by Energy Labs to the BHRA Water Quality Technician. A quality assurance/data validity review of field and analytical data will be completed following receipt of the laboratory data. Data generated during the project will be maintained by BHRA and entered into an EXCEL spreadsheet and/or database to be determined. If a cooperative agreement is forged between MDEQ and BHRA, the maintenance and analysis of data will be jointly done.

Following every field season, the BHRA Water Quality Technician will be responsible for completing a report that summarizes the BHRA sampling data (2015-16), current and past seasons sampling data, depicts temporal and spatial trends, explores relationships between the water quality data and other ecological variables, and recommends revisions to the SAP for future monitoring. Submission of the report will be followed by an annual presentation to the BHRA and other stakeholders.

7.0 Monitoring Cost Estimate

- EXO3 Sonde with 5 sensor ports: depth, conductivity/water temperature, DO, turbidity, and total algae (chlorophyll-a/ blue green) with signal output adapter, 250 meter terracord, and 4 meter cable (river). Depth range: 0-250 meters.
    - EXO3 Sonde (March 2019 YSI quote): ~ $15,000.

- Wheeled Carrying Case (August 2019 YSI quote) ~ $415.
- Field Tablet (Windows software – not compatible with Apple): ~ $500.
- Calibration Standards (SC, pH, and Turbidity) ~ $550.

- U22 Hobo Pendant MX Water Temperature Loggers (10 @ $150 ea.) ~$1,500.
  Note: Water temperature loggers may be available from MFWP at no cost.

- Laboratory Sample Analysis

Location	No. of sampling sites	No. of sample sets	Sample Trips April - October	No. of sample sets per year
Bighorn Lake (Depth Profile)	1	4	14	56
Bighorn River (WQ Sites)	7	1	14	98
Bighorn River (Macroinvertebrate Sites)	4	1	2	8
Field Duplicates	-	1	14	14
Field Blanks	-	1	14	14
Total				182

- Lab Costs (Energy Lab Quote July 2019); $135./sample set for parameters listed under Section 4.1.3; 182 samples @ $135./sample set ~ $24,570.

- Water Quality Program Coordinator: 120 hours/year @ $100./hr. ~ $12,000.
- Water Quality Technician: 80 hours/month for 7 months @ $20./hr. ~ $11,200.
  Estimated Travel Expenses (Technician) ~ $2,000.
- Trolling motor with GPS control system ~ $1,500.
- Boat and trailer with winch system* ~ $4,000*
  * Costs are highly variable depending upon size, age, and condition.

8.0 Cooperative Partnerships

Bureau of Reclamation (BOR): The BOR may be interested in a collaborative agreement to share in the costs of equipment and lab analysis. Sites WQL1, WQ1A, and WQ1B may be of special interest to supplement their hydrolab measurements below the Afterbay.

Crow Tribe: A cooperative agreement between the BHRA and Crow Tribe to coordinate their respective monitoring programs on the Bighorn River and tributaries from Yellowtail Dam to the Little Bighorn River confluence. This agreement would help avoid monitoring duplication, allow for more rigorous monitoring of the Bighorn River and major tributaries, create an opportunity to

share water quality and benthic macroinvertebrate data, and provide a venue to collaborate on restoration and research projects that would mitigate water quality impairments.

Montana Fish Wildlife and Parks (MFWP): It is beneficial to maintain the close relationship between the BHRA and the MFWP. The MFWP provides valuable insight on the Bighorn River fishery and how flow and land use management variables influence population numbers, size, and condition. BHRA can coordinate on public outreach, river user surveys, and river research that would assist MFWP with their fish management objectives.

Big Horn Conservation District (BHCD): The BHCD is the primary county agency that has been entrusted by the state to promote resource conservation on non-tribal private lands in Big Horn County. There may be several opportunities for the BHRA and the BHCD to partner on water quality improvement projects along the Bighorn River riparian corridor and on adjacent irrigated lands in the valley.

Montana Department of Environmental Quality (MDEQ): The Montana DEQ has an interest in water quality on the Bighorn River, primarily from the Little Bighorn River confluence to the Yellowstone River. A cooperative agreement may include joint field/equipment training, data sharing and analysis, collaborative monitoring, etc. for both water quality and benthic macroinvertebrate monitoring.

Wyoming Department of Environmental Quality (WDEQ): The BHRA should encourage the WDEQ, the USGS, and the National Park Service (NPS) to continue monitoring discharge and water quality on the Shoshone and Bighorn River inflows to the Bighorn Lake. The BHRA, WDEQ, and NPS could jointly review Shoshone and Bighorn Rivers discharge and water quality data to determine if definitive connections can be made between the Shoshone and Bighorn Rivers inflows, Bighorn Lake algal blooms, and the water quality associated with Yellowtail Dam releases. This review would look at longitudinal exchange (not turnover) and/or nutrient-based algal blooms in the reservoir, and how this might influence high turbidity levels from Yellowtail Dam releases.

9.0 Adaptive Management

Adaptive management is an iterative approach to review and adjust the Sampling Analysis Plan (SAP) as monitoring results and ecological relationships on the Bighorn River become better understood. This process is also important if BHRA research objectives and priorities change over time.

The effectiveness of adaptive management relies upon the participation of people, organizations, and agencies who use, manage, and have an interest in the Bighorn River. Several, but not all, stakeholders are listed under Chapter 8.0 Cooperative Partnerships. The BHRA will host an annual Bighorn River Water Quality Working Group meeting every winter to discuss previous monitoring results, spatial and temporal trends, water quality drivers, SAP adjustments, and the coordination of water quality monitoring for the coming year.

10.0 References

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