Yellowstone Ecological Research Center
RiverNET Community Water Monitoring Program
Upper Yellowstone River Watershed
Sampling and Analysis Plan

Prepared for the Montana Department of Environmental Quality
April2019

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1.0 INTRODUCTION

1.1 Project Area Overview

The RiverNET Community Water Monitoring Program (RiverNET) began monitoring water quantity in the Upper Yellowstone River Watershed in 2018. Our primary goal is to establish seasonal baselines for nutrients in tributaries and reaches of the Upper Yellowstone River, and to start building a long-term dataset for analyzing environmental changes and trends. Our secondary goal is to compare the quality of data produced from volunteer data collectors (i.e., citizen scientists) and field analysis methods (i.e., handheld colorimeters) with that of data produced from trained technicians and EPA-certified water quality laboratories. These goals are part of a broader effort that also includes monitoring water temperature and depth (and thus discharge through depth-to-discharge rating curves) by using continuous, in-stream sensors, adding these parameters to our nascent long-term dataset.

The program was founded in response to the 2016 fish kill on the Upper Yellowstone, caused by an outbreak of Proliferative Kidney Disease-causing *Tetracapsulodes bryosalmonae* parasites, and the need for better information on the environmental conditions that catalyzed the fish kill. It is a collaboration between the Yellowstone Ecological Research Center (YERC) and local partners (e.g., Upper Yellowstone Watershed Partnership, Sweet Grass County Conservation District). Our project area between Gardiner, MT, and Big Timber, MT, includes the entire Yellowstone Headwaters (Hydrologic Unit Code (HUC) 10070001) and Upper Yellowstone (HUC 10070002) subbasins (hereafter 'Upper Yellowstone Watershed'; **Figure 1**), although we are designing our methods, data management, volunteer management, and overall program structure to be scalable and transferable to other watersheds in the Greater Yellowstone Ecosystem. We spent the first season of the project testing potential methods, refining protocols, and building support within the community.

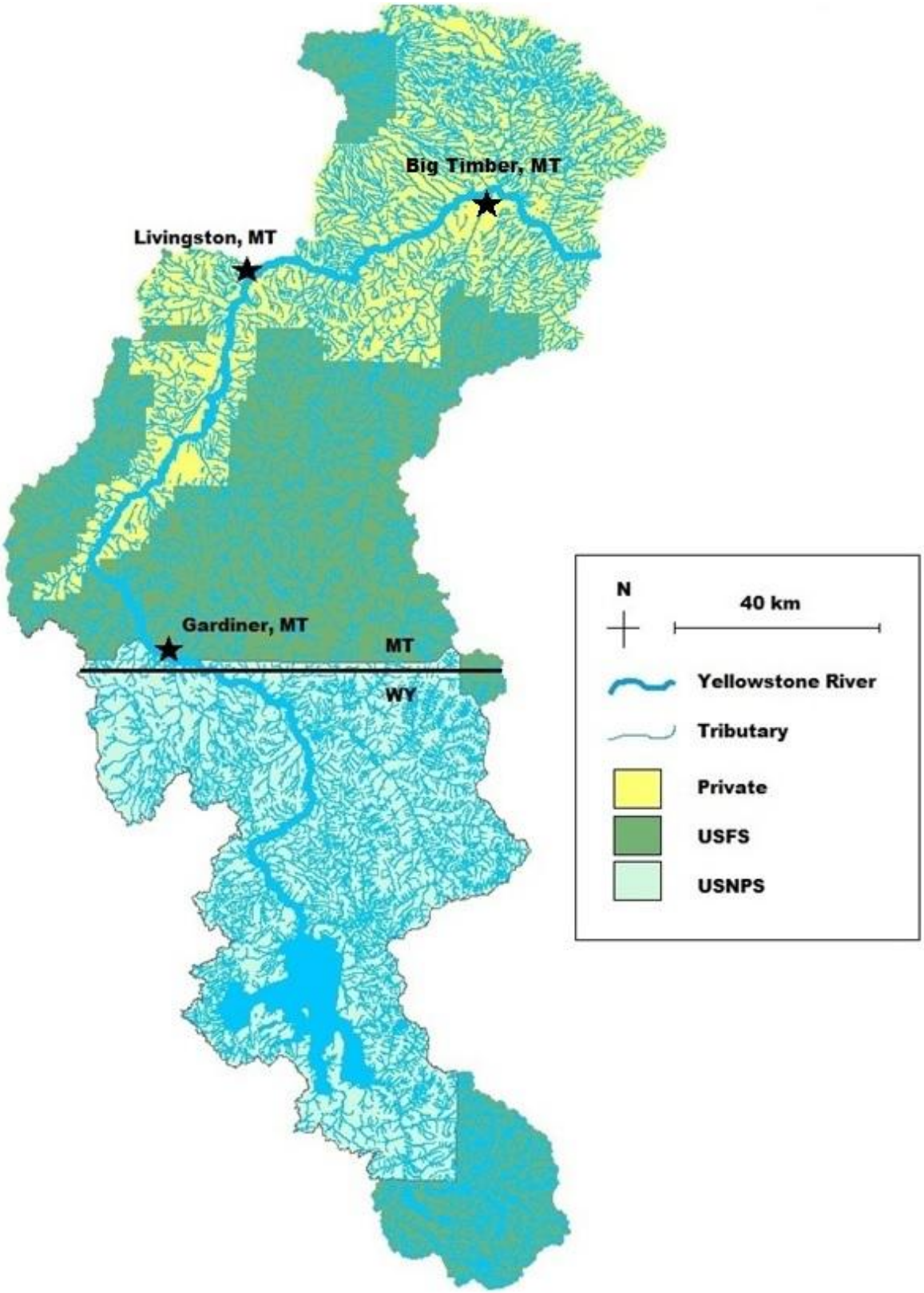

Figure 1: The Upper Yellowstone Watershed

1.2 Project Goals and Objectives

The water quality monitoring goals of RiverNET (**Table 1**) are:

1. To establish seasonal (pre-growing season, growing season, post-growing season) baselines for water quality and quantity parameters (e.g., nutrient concentrations, discharge) on tributaries and reaches of the Upper Yellowstone River.
2. To build a long-term dataset of these parameters with which to analyze interannual trends, detect outliers, and assess environmental changes (e.g., land use, climate, species occurrence) using these data as response or predictor variables.
3. To develop a sustainable community science program in the Upper Yellowstone Watershed to continue long-term monitoring that complements more formal water monitoring efforts (i.e., those of Montana DEQ).

Table 1: Project Goals and Objectives

Goal	Question	Objective	Data Analysis/ Product
Establish seasonal baselines for water quality/quantity parameters in the Upper Yellowstone River Watershed.	What are the current seasonal levels for parameters affecting water quality/quantity in the Upper Yellowstone River and its tributaries?	RiverNET will establish monitoring sites at major tributaries and representative reaches of the main stem in order to collect samples (for nutrients), install stream gauges (for discharge), and record manual observations (e.g., pH, temperature, algae cover), visiting each site at least once during the pre-growing, growing, and post-growing seasons.	After one year of data collection and analysis (2019), we will publish seasonal baseline data for each site and each parameter -- nutrient concentrations (total phosphorus, total nitrogen, orthophosphate, nitrate, nitrite), discharge, temperature, pH, algae cover -- in online public databases (i.e., YERC Website, MT-eWQX).
Build a long-term dataset of water quality/quantity parameters in the Upper Yellowstone River Watershed in order to analyze interannual trends, detect outliers, and/or assess environmental changes.	Are these seasonal levels changing, in what way (increasing or decreasing), and at what scale (local or universal)? Are data outliers indicators of environmental changes? How are these parameters *affected by* environmental changes from land use (e.g., agriculture, urban development, mining) and climate (e.g., drought, snow), and how are they *affecting* conditions for aquatic species (e.g., trout, PKD-parasite)?	RiverNET will continue collecting data every year (at each site at least once during each season) by establishing a long-term community science monitoring program, adding those data to the publicly accessible database.	These data will be available to all researchers studying environmental changes in the Upper Yellowstone River Watershed, where they may be used as *response* variables (e.g., for assessing the effect of changing livestock management practices on water nutrient concentrations) or as *predictor* variables (e.g., for assessing the effect of water temperature on PKD-parasite density). Data outliers may also provide early warnings of potential changes.
Develop a sustainable community science program to continue long-term monitoring that complements more formal monitoring efforts.	Can low-cost, fast-turnaround, user-friendly water monitoring tools operated by citizen scientists obtain data with sufficient sensitivity,	RiverNET will compare results from volunteer-collected samples analyzed with Hach colorimeters to duplicates analyzed at an EPA-certified laboratory	Community science results will be assessed qualitatively (by visually comparing them (+/- accuracy) to true values) and quantitatively (through paired sample *t*-tests).

Goal	Question	Objective	Data Analysis/ Product
	precision, and accuracy to be useful for conservation decision-making?	(i.e., true values) to determine whether the Hach results align with the true values within the reported accuracy interval.	Systems deemed sufficient (results align with true values) will be reported (along with their assessment results) in community science protocols.

1.3 Project Budget

See Appendix A, Table 7

2.0 SAMPLING PROCESS

2.1 Study Design

Sampling Locations

YERC staff and RiverNET volunteers will collect grab samples from 26 sites (**Table 2; Figure 2**), which include:

- *n* = 9 sites on the Yellowstone River **main stem**, chosen for consistent spatial distribution, access, and locations above and below important tributaries
- *n* = 17 sites on or at the mouths of tributaries, prioritized with local expert opinion (Pat Byorth, Trout Unlimited) to include:
    - *n* = 6 **1st priority tributaries**, chosen for consistent spatial distribution as well as for having one or more important factors (high volume, trout spawning habitat, major irrigation source, land use conflicts, etc.), sampled at the mouth
    - *n* =6 **2nd priority tributaries**, chosen for consistent spatial distribution but lacking any of the factors described for 1st priority tributaries, sampled at the mouth
    - *n* = 5 **3rd priority sites/tributaries**, which are (a) additional sites on a 1st or 2nd priority tributary to monitor confounding factors (i.e., upstream of an irrigation diversion, point source, or tributary mouth), or (b) additional tributaries that are severely modified by land use (mining, irrigation).

These sites are currently (2019) located upstream of Livingston, MT, and are the same as those sampled during our pilot year (2018). In future years, we intend to add sites on the main stem and tributaries at Livingston, MT, and downstream through Big Timber, MT.

We will also deploy in-stream sensors measuring depth and temperature (Onset MX2001) at sites Big1, Big2, Mil1, and Mil2; an in-stream sensor (Hydrolab DS5X) measuring depth, temperature, pH, specific conductivity, dissolved oxygen, and turbidity at site **Yel6**; and staff gauges for manually measuring depth at sites Mul1, Ced1, Tom1, Fri1, Eig1, Pin1, and Pin2. Rating curves (see section 2.2.1 below) for converting depth-to-discharge will be calculated for each site with a stream gauge. Additional sites for sensors and/or stream gauges will be added as funding allows.

Sampling Timing

We will collect samples during three seasonal intervals:

- **pre-growing season**: from mid-May to mid-June, during spring run-off.
- **growing season**: from July 1 through September 30, which is the time period when Base Numeric Nutrient Standards for Wadeable Streams in this ecoregion apply (MTDEQ 2014), and
- **post-growing season**: in mid-November, during winter base-flow.

Sensor data will be recorded at hourly intervals year-round.

Analytical Methods

We will analyze all samples (**Table 3**) for concentrations of orthophosphate, total phosphorus (TP), total persulfate nitrogen (TPN), and nitrate plus nitrite (NPN), using two different methods: (a) in-house analysis using Hach DR900 Colorimeters, and (b) analysis at an independent, EPA-certified lab (Energy Labs).

- For the in-house analysis, we will collect samples from all sites (n = 26) during one pre-growing season sampling event and one post-growing season sampling event, and during sampling events occurring every two weeks throughout the growing season.
- For the independent analysis, we will collect samples from all of the main stem and 1st priority tributary sites (n = 15) during one sampling event each season. In addition to these routine samples, we will also collect two duplicate samples for each of the four nutrient parameters from randomly selected sites during each sampling event (n = 8 total duplicates per sampling event), as well as prepare one blank sample for each of the four nutrient parameters during each sampling event (n = 4 total blank samples per sample event) for quality assurance/quality control purposes (**Table 9**).

Additional parameters -- water temperature, pH, algae cover, bank conditions, manual depth measurements (where applicable) -- will be recorded manually during each site visit. Sensor data will be downloaded during each site visit at the latest (volunteers may download data more frequently). These data will be added to the nutrient concentration databases.

Orthophosphate, total phosphorus, total nitrogen, nitrate + nitrite, temperature, pH, algae cover, and bank conditions will be recorded at all sites. Additionally, depth/discharge will be recorded at sites with a staff gauge (+), depth/discharge and temperature will be recorded at sites with an Onset MX2001 sensor (*), and depth/discharge, temperature, pH, specific conductivity, dissolved oxygen, and turbidity will be recorded at sites with a Hydrolab DS5X sensor (**) (**Table 2**).

Table 2: Monitoring site ID (main stem sites in bold), location, and rationale for site selection.

Site ID	Location	Latitude	Longitude	Rationale for site selection
Gar1	Gardiner River	45.029	-110.7	1st priority tributary: high volume
Yel1	Yellowstone River, Gardiner Airport	45.045	-110.738	Priority main stem: start of study area for main stem, upstream from Gardiner wastewater treatment plant
Lan1	Landslide Creek	45.046	-110.746	2nd priority tributary
Yel2	Yellowstone River Corwin Springs Fishing Access (FA)	45.107	-110.79	Priority main stem: downstream from Gardiner wastewater treatment plant, USGS stream gauge location
Mul1+	Mulherin Creek	45.128	-110.806	2nd priority tributary
Ced1+	Cedar Creek	45.143	-110.813	1st priority tributary: cutthroat trout spawning habitat

Site ID	Location	Latitude	Longitude	Rationale for site selection
Yel3/ Tom1+	Yellowstone RIver, Tom Miner Confluence	45.199	-110.911	Priority main stem; *and* 1st priority tributary: high volume, cutthroat trout spawning habitat
Joe1	Joe Brown Creek	45.165	-110.839	2nd priority tributary
Sph1	Sphinx Creek	45.171	-110.875	2nd priority tributary
Big1*	Big Creek	45.298	-110.831	1st priority tributary: high volume, major irrigation source
Big2*	Big Creek Pre-Diversion	45.307	-110.8718	3rd priority site
Dry1	Dry Creek Pre-Diversion	45.318	-110.827	3rd priority tributary
Yel4	Yellowstone River, Reedfly Farm	45.329	-110.773	Priority main stem: upstream from Emigrant, downstream from terminus of Dry Creek diversion/Mutual Canal
Emi1	Emigrant Gulch	45.321	-110.71	3rd priority tributary
Fri1+	Fridley Creek, South Fork	45.342	-110.754	2nd priority tributary
Yel5	Yellowstone River, Grey Owl FA	45.398	-110.704	Priority main stem: upstream from Mill Creek
Eig1+	Eight Mile Creek	45.409	-110.699	2nd priority tributary
Mil1*	Mill Creek	45.413	-110.649	1st priority tributary: high volume, major irrigation source
Mil2*	Mill Creek, Pre-Diversion	45.340	-110.594	3rd priority site
Yel6**	Yellowstone RIver, Dan Bailey/ Paradise FA	45.421	-110.637	Priority main stem: downstream from Mill Creek confluence
Yel7	Yellowstone River, Mallard's Rest FA	45.483	-110.62	Priority main stem: upstream from Pine Creek confluence
Pin2+	Pine Creek, upper	45.498	-110.518	3rd priority site
Pin1+	Pine Creek, lower	45.505	-110.568	1st priority tributary: high volume
Yel8	Yellowstone River, Pine Creek Fishing Access	45.512	-110.583	Priority main stem: downstream from Pine Creek confluence
Yel9	Yellowstone River, Carter's Bridge FA	45.597	-110.566	Priority main stem: end of study area, USGS stream gauge location

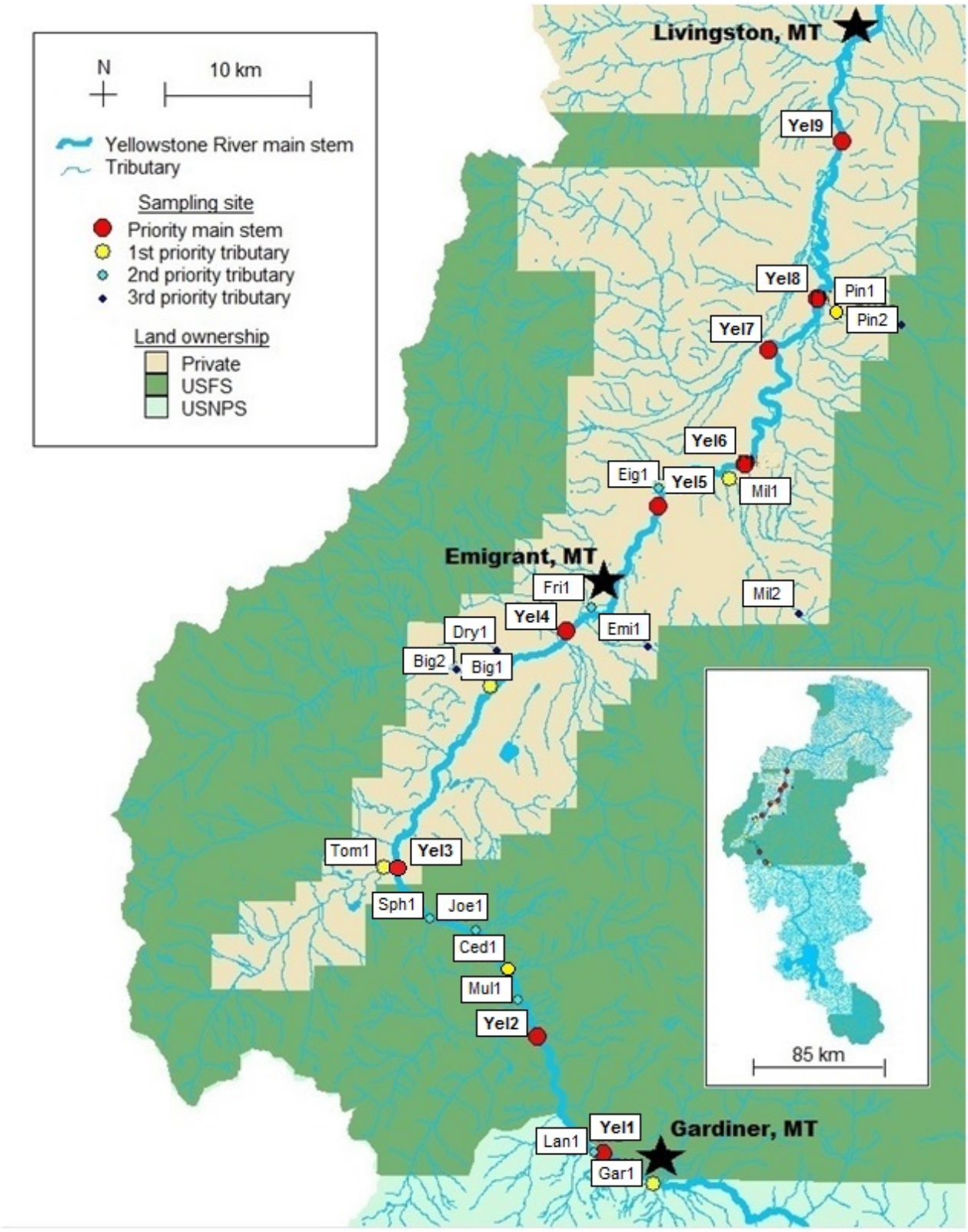

Figure 2: The Yellowstone River from Yellowstone National Park to Livingston, MT, showing RiverNET sampling sites (**Table 2**) and land ownership. The inset map shows the area in the context of the Upper Yellowstone Watershed.

Table 3: Timing and purpose of the sampling for each parameter (different analytical approaches indicated with a number following the parameter label, if applicable).

Parameter	Sampling Occurrence	Sites	Goal Addressed (Section 2.0)	Approach
Algae Cover	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1 & 2	Visual Estimate
Bank Vegetation	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1 & 2	Photographs
Depth (1)	Hourly, April-October	Big1, Big2, Mil1, Mil2, **Yel6**	1 & 2	Onset MX2001; Hydrolab DS5X
Depth (2)	Once pre-growing season; 2x/month growing season; Once post-growing season	Mul1, Ced1, Tom1, Fri1, Eig1, Pin1, Pin2	1 & 2	Staff Gauge
Dissolved Oxygen	Hourly, April-October	**Yel6**	1 & 2	Hydrolab DS5X
Nitrate+Nitrite (1)	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1, 2, & 3	Hach DR900
Nitrate+Nitrite (2)	Once pre-growing season; Once growing season Once post-growing season	Gar1, **Yel1**, Ced1, **Yel2**, Tom1, Big1, **Yel4**, **Yel5**, Mil1, **Yel6**, **Yel7**, Pin1, **Yel8**, **Yel9**	1, 2, & 3	Independent, EPA-certified laboratory (i.e., Energy Labs)
Orthophosphate (1)	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1, 2, & 3	Hach DR900
Orthophosphate (2)	Once pre-growing season; Once growing season Once post-growing season	Gar1, **Yel1**, Ced1, **Yel2**, Tom1, Big1, **Yel4**, **Yel5**, Mil1, **Yel6**, **Yel7**, Pin1, **Yel8**, **Yel9**	1, 2, & 3	Independent, EPA-certified laboratory (i.e., Energy Labs)
pH (1)	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1 & 2	Handheld pH meter
pH (2)	Hourly, April-October	**Yel6**	1 & 2	Hydrolab DS5X
Specific Conductivity	Hourly, April-October	**Yel6**	1 & 2	Hydrolab DS5X

Parameter	Sampling Occurrence	Sites	Goal Addressed (Section 2.0)	Approach
Temperature (1)	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1 & 2	Handheld thermometer
Temperature (2)	Hourly, April-October	Big1, Big2, Mil1, Mil2, **Yel6**	1 & 2	Onset MX2001; Hydrolab DS5X
Total Persulfate Nitrogen (1)	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1, 2, & 3	Hach DR900
Total Persulfate Nitrogen (2)	Once pre-growing season; Once growing season Once post-growing season	Gar1, **Yel1**, Ced1, **Yel2**, Tom1, Big1, **Yel4**, **Yel5**, Mil1, **Yel6**, **Yel7**, Pin1, **Yel8**, **Yel9**	1, 2, & 3	Independent, EPA-certified laboratory (i.e., Energy Labs)
Total Phosphorus (1)	Once pre-growing season; 2x/month growing season; Once post-growing season	All	1, 2, & 3	Hach DR900
Total Phosphorus (2)	Once pre-growing season; Once growing season Once post-growing season	Gar1, **Yel1**, Ced1, **Yel2**, Tom1, Big1, **Yel4**, **Yel5**, Mil1, **Yel6**, **Yel7**, Pin1, **Yel8**, **Yel9**	1, 2, & 3	Independent, EPA-certified laboratory (i.e., Energy Labs)
Turbidity	Hourly, April-October	**Yel6**	1 & 2	Hydrolab DS5X

2.2 Sampling Methods

Pre-growing season sampling will occur once between mid-May and mid-June, during spring run-off when nutrient levels are expected to be at their annual peak due to bank erosion. We will collect one sample (see **Appendix E: Field Sampling Protocols**) from each site (n = 26) to be analyzed for orthophosphate, TP, TPN, and NPN, at YERC using a Hach DR900. We will also collect one sample for each of these four parameters from a subset of priority main stem and 1st priority tributary sites (n = 15), plus two duplicate samples for each parameter from randomly selected sites within the subset and one field blank for each parameter, to be analyzed at an independent, EPA-certified lab (i.e., Energy Labs; **Table 4**). At each site visit, temperature, pH, algae cover, and bank vegetation photos will be recorded at all sites, while depth/discharge will be downloaded or recorded at sites with a sensor or staff gauge, respectively.

Growing season sampling will occur every two weeks from July 1 through September 30. During each of these sampling events, we will collect one sample from each site (n = 26) to be analyzed at YERC for orthophosphate, TP, TPN, and NPN; we will also manually record temperature, pH, algae cover, and bank

vegetation photos, and depth/discharge where applicable. During one sampling event around the time of summer baseflow (i.e., early August), we will collect one sample for each of the four parameters from a subset of priority main stem and 1st priority tributaries (n = 15), plus duplicates and field blanks, to be analyzed at an independent lab as described above.

Post-growing season sampling will occur once in late November, when aquatic vegetation will have little effect on ambient water nutrient levels, with a sampling plan mirroring that of the pre-growing season. All samples during all sampling seasons will be collected primarily by YERC staff as well as by trained volunteers.

Table 4: Analytical Suite for Samples sent to Energy Lab

Parameter	Preferred Method	Alternate Method	Required Reporting Limit (ug/L)	Holding Time Days	Bottle	Preservative
Total Persulfate Nitrogen (TPN)	A4500-N C	A4500-N B	40	28	250ml HDPE	≤6°C
Dissolved Orthophosphate as P	EPA 365.1	A4500-P F	1	45	250ml HDPE	Filter 0.45 um, then freeze
Total Phosphorus as P	EPA 365.1	A4500-P F	3	28	250 ml HDPE	H_2SO_4 and ≤6°C
Nitrate-Nitrite as N	EPA 353.2	A4500-NO3 F	10			

Orthophosphate, TP, TPN, and NPN will be analyzed from grab samples collected in HDPE jars and transported in an ice-filled cooler, following protocols listed in **Appendix E** and Section 5.2.1 of the Montana Department of Environmental Quality Water Quality Planning Bureau Field Procedures Manual for Water Quality Assessment Monitoring Version 3.0 (MTDEQ 2012).

Samples to be analyzed at YERC will be collected in one 750 mL jar per site, and analyzed within 36 hours using Hach DR900 colorimeters (**Table 5a**) following manufacturer protocols. Each sample will be analyzed three times for each parameter, and the averaged results and standard deviations will be manually recorded.

Samples to be analyzed at an independent lab will be collected in three 250 mL jars per site: one for orthophosphate, one for TPN, and one for TP and NO_{2+3}. The orthophosphate sample will be filtered through a 0.45 um filter and frozen. The TPN sample and the TP and NO_{2+3} sample will be stored at temperatures <6°C, and the TP and NO_{2+3}sample will be additionally treated with sulfuric acid preservatives manufactured for treating 250 mL samples (~4 mL 17.6% H_2SO per sample). Two duplicate samples per parameter will also be collected at randomly selected sites during each of these sampling events; one set of field blanks per parameter will also be prepared during each sampling event using laboratory-grade de-ionized water. All samples will be shipped to the lab in an ice-filled cooler as soon as possible after they are collected and within the holding time specified in **Table 4**.

For every grab sample collected, temperature and pH will be measured directly in the field using handheld instruments (pHep HI98107, Hanna Instruments) and manually recorded. The pH sensor on this instrument will

be calibrated by YERC staff prior to the pre-growing season sampling season following a two point calibration procedure with standards at pH 4.01 and pH 10.01, and throughout the year the electrode will be maintained as needed following manufacturer instructions. The temperature sensor is factory calibrated and should not require maintenance.

Algae cover will be estimated for the spatial area visible to the data collector/observer looking directly down from where the sample is being collected, and classified for (a) microalgae, (b) filamentous algae, (c) macrophytes, and (d) moss, according to the percent coverage categories described in MTDEQ's Guidance for Completing the Aquatic Plant Visual Assessment Form (0 = 0%, 1 = <10%, 2 = 10-40%, 3 = 40-75%, 4 = >75%; Attachment H, MTDEQ 2012). We will also assess the predominant color and condition for each aquatic plant type, the thickness of microalgae, and the length of filamentous algae, according to those protocols (Attachment H, MTDEQ 2012). Photographs of stream bank conditions and vegetation will also be taken of the banks flanking the sample site, and submitted with the data following MTDEQ site documentation protocols (Section 7.3.1, MTDEQ 2012). The location of both the aquatic plant assessment and the bank photo point will be determined by the grab sample location.

In addition to grab samples, *in-situ* sensors at select locations will continuously record depth and temperature (Onset MX2001; **Table 5b**) or depth, temperature, pH, turbidity, dissolved oxygen, and specific conductivity, (Hydrolab DS5X; **Table 5c**). The Onset MX2001 units have a Bluetooth transmitter, so data will be recorded by field staff during the field sampling events (two-week intervals) at the latest, or by volunteers at more frequent intervals. These pressure transducer-based sensors have integrated barometric pressure sensors that automatically correct for atmospheric pressure, while the temperature sensor is factory calibrated, so no external calibration is necessary for the Onset MX2001. The Hydrolab DS5X is paired with a cellular transmitter (Stevens Water Monitoring Systems eTracker) for remote, real-time data retrieval, and its sensors will be calibrated prior to the pre-growing season sampling season following manufacturers instructions and SOP 1.6.

Table 5a: Performance of the Hach DR900 colorimeter

Parameter	Method	Measurement Range	Resolution	Accuracy
Orthophosphate	Ascorbic acid (Hach 8048)	0.02 to 2.50 mg/L	0.02 mg/L	± 0.02 mg/L
Phosphorus, total	Acid persulfate digestion (Hach 8190)	0.06 to 3.50 mg/L	0.06 mg/L	± 0.07 mg/L
Nitrogen, total	Persulfate digestion (Hach 10071)	0.5 to 25.0 mg/L	0.4 mg/L	± 0.5 mg/L
Nitrate	Chromotropic acid* (Hach 10020)	0.2 to 30 mg/L	0.2 mg/L	± 0.5 mg/L
Nitrite	Diazotization (Hach 10019)	0.003 to 0.500 mg/L	0.003 mg/L	± 0.006 mg/L

* We chose this method over the more sensitive cadmium reduction method (Hach 8192) to avoid safety and environmental hazards associated with cadmium exposure

Table 5b: Performance of the Onset MX2001 data logger

Parameter	Method	Measurement Range	Resolution	Accuracy
Water temperature	Factory-calibrated sensor	-20 to 50 ^{o}C	0.1 ^{o}C	± 0.44 ^{o}C
Water level	Ceramic capacitive pressure sensor with integrated barometric pressure sensor	0 to 400 cm	0.14 cm	± 0.03 cm

Table 5c: Performance of the Hydrolab DS5X multiprobe

Parameter	Method	Measurement Range	Resolution	Accuracy
Water temperature	Factory-calibrated sensor	-5 to 50 °C	0.01 °C	± 0.1 °C
Water level	Factory-calibrated sensor	0 to 10 m	0.001 m	± 0.01 m
pH	Combination glass bulb electrode with refillable reference electrode	pH 0-14	0.01 pH units	± 0.2 pH units
Dissolved oxygen (concentration)	Optical luminescence	0 to 30 mg/L	0.01 or 0.1 mg/L**	± 0.01 or 0.02 mg/L**
Conductivity	Four nickel electrode cell	0 to 200 mS/cm	0.001, 0.01, or 0.1 uS/cm**	± 0.001 mS/cm or ± 1%**
Turbidity	Nephelometric – Optical, 90° Scatter	0-4000 FNU	0.1 FNU	± 0.3 FNU or ± 5%**

** range-dependant resolution/accuracy values (see Hach 2006)

2.2.1 Depth-to-Discharge Conversion

At every site where depth is monitored (RN10-11, 18-19, and 20), we will calculate a rating curve to convert depth to discharge following steps described by Rantz et al. (1982). To do so, we will:

(1) select the site based on the considerations listed by Rantz et al. (1982), and monument the site with a staff gauge,
(2) visit each site 8-10 times between low flow (i.e., early March) and high flow (i.e., early June) to record (a) depth (stage) measurement according to the installed staff gauge, and (b) discharge using a conventional current-meter (Flowatch, JDC Electronics) method (specifically, the midsection method for assessing cross-section area and velocity), and
(3) analyze the paired depth and discharge measurements for each site through regression analysis to calculate its rating curve.

We will report both the raw depth and the converted discharge data for each observation, as well as the rating curve formula and our protocols and data used to calculate that rating curve, on our Website.

2.2.2 "Community Science" Management

We will work with local volunteers to both collect grab samples and download data from the Bluetooth-enabled Onset MX2001 sensors. This will require recruitment, training, and supervision, as well as additional quality control measures from trained staff.

2.3 Field Forms

Grab sample data will initially be recorded on paper datasheets provided by YERC, then manually entered into digital databases. Sensor data will be transmitted via cellular or Bluetooth and email, and automatically entered into their digital databases.

2.4 Laboratory Methods and Sample Handling Process

Grab samples will be stored in a cooler with ice until they are analyzed. They will then be analyzed following analyst protocols and equipment manufacturer methods (depending on whether they are analyzed at YERC or at

an independent lab). Approved (QA/QC-passed) results will then be published on YERC's Website as soon as they are available.

3.0 QUALITY CONTROL REQUIREMENTS

3.1 Quality Assurance and Quality Control Overview

QA/QC procedures for grab samples analyzed at YERC will include (1) analyzing each sample three times, and reporting both the average value and the variance (standard deviation) for each sample, and (2) testing the accuracy of the Hach DR900 colorimeters by analyzing standards for each parameter at least once per year.

QA/QC procedures for grab samples analyzed at an independent lab will include (1) collecting two duplicates from a randomly selected site for each parameter at each sampling event, and (2) preparing one blank sample of laboratory-grade deionized water transported into the field, poured into sample jars, and handled like any other sample, to be analyzed alongside our routine samples. Results from both duplicates and blanks will provide means of assessing (a) proper functioning of analysis equipment, and (b) adherence to sample collection and handling protocols.

For in-situ sensors, we will (1) inspect and clean the sensors every two weeks during the growing season and every month during the non-growing season, and (2) recalibrate sensors (if applicable) with standard solutions (pH, conductivity, dissolved oxygen) and measured depth and barometric pressure observations (depth) following manufacturer protocols every time the sensors' batteries are replaced.

3.2 Data Quality Indicators

3.2.1 Representativeness

Representativeness refers to the extent to which measurements represent an environmental condition in time and space. This is a judgmental sampling design using the following rational:

3.2.1.1 Spatial Representation:

Sampling sites were chosen to represent the potential of landscape characteristics and land use/land cover to influence water quality. We also sought to select sites with consistent spacing (i.e., Euclidean distance) between other sampling sites or, in the case of in-situ sensors, existing sensors (i.e., USGS stream gauges). Our long-term goal is to comprehensively sample each major tributary in the Upper Yellowstone Watershed.

3.2.1.2 Temporal representation:

We will collect grab samples during pre-growing season, growing season, and post-growing season sampling events to establish seasonal baselines while accounting for seasonally variable environmental factors affecting water nutrient levels, both biotic (e.g., growing aquatic plants uptaking free nutrients) and abiotic (e.g., bank erosion causing a spike in soil nutrient input). Such a temporal sampling plan mirrors that of similar monitoring programs like that of the Gallatin River Task Force. In addition, we will also collect grab samples at an increased frequency (every two weeks) during the growing season, for a higher resolution dataset to establish local growing season trends and outliers.

For in-situ sensors, we will record data every hour, in keeping with USGS stream gauge sampling. Sensors will remain in place year-round unless the site is subject to freezing solid, in which case the sensor will be withdrawn in late November and reinstalled in late March to avoid damage from freezing.

3.2.2 Comparability

Comparability expresses the confidence with which one data set can be compared to another. To achieve a comparable result, both the field collection method and the analytical method must be comparable. This is achieved through the use of Standard Operating Procedures (SOPs – DEQ or USGS) for field collection and the use of the same analytical methods published by the EPA or USGS in the laboratory.

We selected parameters that are common to other water monitoring programs, so our data could be compared to those of other watersheds, considering watershed-specific differences. And we will consistently use the same protocols and SOPs for data collection and analysis between sites and seasons, so our data from one year can be compared to our data from another year, considering site- and season/year-specific differences.

We will use statistical methods (e.g., ANOVA) to assess the variance between samples analyzed with the Hach DR900 colorimeter and corresponding samples (collected at the same site, at the same time, following the same protocols) analyzed by an independent lab, to determine if/how these data can be compared considering the different analysis methods.

3.2.3 Completeness

Completeness is a measure of the amount of data prescribed for assessment activities and the usable data actually collected, expressed as a percentage. At the end of each sampling event, the project leader and/or field coordinator will review collected samples to ensure that grab samples from each sampling site (as well as blank samples and duplicates, if applicable) were collected. If any sites were missed, the project leader and/or field coordinator will strive to collect the sample within 24 hours. The overall project goal is 95% completeness, which accounts for possible weather, access, and other availability challenges, as well as the possibility that volunteer fishing guides were unable to collect the sample due to client obligations.

3.2.4 Sensitivity

Sensitivity refers to the limit of a measurement to reliably detect a characteristic of a sample. For analytical methods, sensitivity is expressed as the method detection limit (MDL). Sensitivity quality controls for all laboratory methods will follow the frequency and criteria specified in the analytical method.

3.2.4.1 Corrective Action

If analytical method controls fail to meet the specified limit, the data will be qualified as necessary. In addition, if appropriate, additional samples will be collected. If field blanks fail, qualify all associated project data with a "B".

3.2.5 Precision

Precision refers to the degree of agreement among repeated measurements of the same characteristic. This project will rely on analytical and field duplicates to assess precision based on their relative percent difference (RPD).

$$RPD\ as\ \% = \frac{D_1 - D_2}{(\frac{D_1 + D_2}{2})} \times\ 100$$

where:

D_1= first replicate result
D_2= second replicate result

3.2.5.1 Laboratory Precision

Precision quality control for all laboratory methods will follow the frequency specified in the associated analytical method. The criteria used to assess analytical method precision shall be:

Water Samples: 20% RPD for duplicate results > 5 times the MDL

3.2.5.2 Overall Precision

Frequency of field co-located duplicates will be 10% of all samples collected in the field. The criteria used to assess overall precision shall be:

Water samples: 25% RPD for duplicate results > 5 times the MDL

3.2.5.3 Corrective Action

If laboratory duplicates fail this limit, qualify the data as needed. If the field duplicates fail this limit, qualify all associated results with a "J".

Bias is directional error from the true value. In this context, it is an extension of the representativeness concept applied to an individual sample. Bias can occur either at sample collection or during measurement.

Accuracy is the combination of high precision and low bias. Accuracy of individual measurements will be assessed by reviewing the analytical method controls (i.e. laboratory control sample, continuing calibration verification, standard reference material). Depending on the parameter and method, the criteria used for this assessment will be the limits that Hach, Ott Hydromet (a Hach subsidiary), Onset, or the independent laboratories developed through control charting of each method's performance or based on individual method requirements.

3.3 Training

YERC will hold informational meetings and training to recruit volunteers for the project each year during the spring, and as necessary before sampling events while recruiting new fishing guide volunteers who will be available that day. We will also produce videos demonstrating techniques, both for a training reference and independent observational review of techniques, and provide all documentation (e.g., protocols, sampling and analysis plans) on our Website alongside the data. If possible, we would also like for our staff to attend the annual training sessions that DEQ hosts for its field personnel.

3.4 Changes to the Field Sampling Plan

As conditions in the field may vary, it may become necessary to implement minor modifications to sampling as presented in this plan. If for any reason field staff collecting a sample feel conditions are unsafe—e.g., high or swift waters, weather conditions, ice conditions, etc.—they are not to collect the sample(s). Modifications to the approved plan will be documented.

3.5 Field Health and Safety Procedures

With all YERC projects, **crew safety** is prioritized above project objectives.

- Be careful working around rivers with cold, swift currents

- Be mindful of the weather, and don't be on the water if thunderstorms are approaching
- Be careful driving to and from collection sites, especially when merging on or off of Highway U.S. 89, which has a speed limit of 70 mph.
- Be careful working on slippery river rocks: a 102-year-old rancher on the nearby Boulder River I knew used to always warn fishermen that "those rocks are a lot harder than you are."
- Avoid excessive sun exposure, which could result in severe sunburns, heat exhaustion, or heat stroke.
- Be aware of rattlesnakes: don't put your hands or feet anyplace you can't see.
- You have both the **right** and the **responsibility** to shut down any operation that you feel is unsafe or that you are otherwise uncomfortable with.

Also, please be courteous and respectful of other river users, interacting with them and answering questions as best you can.

Please report all minor injuries to your supervisor at YERC, and for all major emergencies call 911.

3.4 Data Management, Record Keeping & Reporting

Analytical laboratories shall prepare and analyze the samples in accordance with the chain-of-custody forms and the methods requested in Table 4. These standard operating procedures (SOPs) must be controlled under a Laboratory Quality Assurance Program (LQAP) with sufficient rigor. Results from laboratory QC samples are submitted with the laboratory data report.

All data will be entered into spreadsheets digitally stored at YERC and made available on the YERC Website (http://yellowstoneresearch.org) and the Upper Yellowstone Watershed Partnership Website (https://www.upperyellowstone.org/waterquality). It will also be entered to MT-eWQX (http://deq.mt.gov/Water/wqinfo/datamgmt/MTEWQX), while the rating curves we produce will also be published on YERC's Website and at the Montana State Library's Yellowstone River GIS Clearinghouse (as per our agreement with the Sweet Grass Conservation District and Montana Fish, Wildlife, and Parks, which funded that work). Original paper copies of the data sheets will be filed in the YERC office. Information regarding Montana's water quality standards, historic data from the Upper Yellowstone River watershed, and trend analyses will be made available alongside the data on the YERC and Upper Yellowstone Watershed Partnership Websites to help users interpret the information.

3.5 Project Team Responsibilities

The Project Managers (**Table 6**) are YERC Executive Director, Robert Crabtree, YERC Ecologist/Lab Manager, Patrick Cross, and YERC Field Coordinator, Morgan Squires. Responsibilities of the project managers will include scheduling events, recruiting and training volunteers, maintaining and storing equipment, composing reports, coordinating educational events, completing data analysis, managing fieldwork, and supervising laboratory analysis.

During each sampling event the Field Coordinator will ensure: (1) the safety of all volunteer monitors, (2) the proper use of all equipment, (3) that routine measurements are taken, and (4) that all QA/QC measures are followed. Other Project Managers will independently review that all QA/QC measures are followed while assisting and supervising the work of the Field Coordinator (**Table 7**).

Table 6: Project Manager Roles and Responsibilities

Person	Role	Contact Information	Responsibilities
Morgan Squires	Field Coordinator	406-556-1414 cross@yellowstoneresearch.org	- Recruit and train volunteers for each sampling event. - Assign sampling sites (as well as blanks and duplicates) to volunteers. - Review completeness of volunteer-collected samples, and if necessary collect any samples that volunteers failed to collect. - Assist YERC Field/Laboratory Technicians in collecting samples and maintaining in-situ sensors. - Attend local meetings (e.g., watershed group, conservation district) to represent the project, and other public outreach.
Patrick Cross	Project Manager	406-556-1414 cross@yellowstoneresearch.org	- Hire, train, and supervise Field Coordinator and Field/Laboratory Technicians. - Coordinate with agencies (i.e., DEQ) to ensure procedures comply with SOPs. - Supervise calibration, installation, and maintenance of in-situ sensors. - Perform data quality assessment and identifying data qualifiers. - Supervise data entry (completed by YERC Field/Laboratory Technicians).
Robert Crabtree	Assistant Project Manager	406-556-1414 crabtree@yellowstoneresearch.org	- Ensure that all data published on the Web has passed QA/QC.

3.6 Data Routing

Table 7: Data Routing Process

Task	Information/ Data	Primary Responsibility	Secondary Responsibility
Review for completeness	Field forms	Field Coordinator	Project Manager
Data entry	Field forms (grab samples); data downloads (in-situ sensors)	Project Manager	Field Coordinator
Lab coordination	Sample chain of custody forms, electronic data deliverables	Project Manager	Assistant Project Manager
Data entry into Websites	Lab results, field measurements, site information	Project Manager	Assistant Project Manager

4.0 ASSESSMENT RESULTS

4.1 Data Analysis

All data collected during YERC sampling events will be collected in the field and then analyzed in the lab, either in the YERC office in Bozeman or, in the case of QA/QC duplicates and other samples as indicated in **Table 3**, an independent, certified lab. Data will then be entered into spreadsheets maintained by YERC, and uploaded into the aforementioned Web databases. In addition to providing downloadable data, we will also provide data plots that include DEQ water quality standards for a reference, and that identify data exceeding DEQ water quality standards as possible indicators of water bodies not meeting those standards. We will design plots so that comparable data can be examined together (e.g., allowing side-by-side comparisons of different sample sites on the same body of water, but not different sample sites on different bodies of water), as well as provide basic information about each parameter (e.g., natural and anthropogenic sources, ecological effects) to help users interpret the results.

In addition to assembling baseline data (Goal 1) and starting long-term monitoring (Goal 2), we will also analyze the data analyzed with Hach DR900 colorimeters compared to those analyzed at an independent lab (Goal 3), by (a) visually comparing colorimeter values to the lab values to determine whether the colorimeter values (within the accuracy interval reported by the manufacturer) align with the lab values for each *individual* group of paired values (same parameter, sample location, and sample event; different analytical methods), and (b) conducting parameter-specific paired sample *t*-tests across *all* pooled paired values for a given parameter. The pooled analyses will help determine whether particular colorimeter-based tests complement (i.e., are in concordance with) the lab results as a whole, while the individual analyses will help identify ranges of values where the two respective techniques are more or less concordant.

4.2 Data Communication

This data will be available for public viewing and download on the YERC Website (https://www.yellowstoneresearch.org) and the Upper Yellowstone Watershed Partnership Website (https://www.upperyellowstone.org/waterquality).

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Appendix A – Project and Analytical Budgets

Table 8: 2019 *RiverNET* Project Budget

Category	Line Item	Cost
Equipment	Hach DRB200 Reactor	$1,049
	Onset MX2001 Data Logger (x2)	$2,000
	Equipment maintenance	$500
Supplies	Potassium Persulfate pillow packets (x300)	$106
	Total Nitrogen Reagent Set (x300)	$954
	NitraVer3 (x300)	$114
	NitriVer3 (x300)	$411
	Lab supplies (e.g., gloves, pipettes, cylinders)	$225
	Gasoline	$1,200
Personnel	Field coordinator (60 days @ $100/day)	$6,000
	Field tech per diem ($900/month, for 2 techs for 4 months)	$7,200
TOTAL		**$19,759**

Table 9: 2019 DEQ VM Lab Analysis Support Program Request

Parameter	Cost per Analyte	# of Sites	# of visits per site	# of Routine Samples	# of Field Blanks	# of Field Duplicates	Total # samples	Total Cost
				(= # sites x # visits per site)	(one per sampling event)	(two per sampling event)	(= # routine samples + # dups + # blanks)	(= Total # samples x cost per parameter)
Orthophosphate	$10	15	3	45	3	6	54	$540
Total Phosphorus (TP)	$10	15	3	45	3	6	54	$540
Total Persulfate Nitrogen (TPN)	$15	15	3	45	3	6	54	$810
Nitrate + Nitrite (NO_3+NO_2)	$8	15	3	45	3	6	54	$432
Shipping	$12	-	-		-	-	6	$72
								$2,394

Appendix B – QA/QC Terms and Definitions

Accuracy. A data quality indicator, accuracy is the extent of agreement between an observed value (sampling result) and the accepted, or true, value of the parameter being measured. High accuracy can be defined as a combination of high precision and low bias.

Analyte. Within a medium, such as water, an analyte is a property or substance to be measured. Examples of analytes would include pH, dissolved oxygen, bacteria, and heavy metals.

Bias. Often used as a data quality indicator, bias is the degree of systematic error present in the assessment or analysis process. When bias is present, the sampling result value will differ from the accepted, or true, value of the parameter being assessed.

Blind sample. A type of sample used for quality control purposes, a blind sample is a sample submitted to an analyst without their knowledge of its identity or composition. Blind samples are used to test the analyst's or laboratory's expertise in performing the sample analysis.

Comparability. A data quality indicator, comparability is the degree to which different methods, data sets, and/or decisions agree or are similar.

Completeness. A data quality indicator that is generally expressed as a percentage, completeness is the amount of valid data obtained compared to the amount of data planned.

Data users. The group(s) that will be applying the data results for some purpose. Data users can include the monitors themselves as well as government agencies, schools, universities, businesses, watershed organizations, and community groups.

Data quality indicators (DQIs). DQIs are attributes of samples that allow for assessment of data quality. These include precision, accuracy, bias, sensitivity, comparability, representativeness and completeness.

Data quality objectives (DQOs). Data quality objectives are quantitative and qualitative statements describing the degree of the data's acceptability or utility to the data user(s). They include data quality indicators (DQIs) such as accuracy, precision, representativeness, comparability, and completeness. DQOs specify the quality of the data needed in order to meet the monitoring project's goals. The planning process for ensuring environmental data are of the type, quality, and quantity needed for decision making is called the DQO process. Madison Stream Team Sampling and Analysis Plan Page 23

Detection limit. Applied to both methods and equipment, detection limits are the lowest concentration of a target analyte that a given method or piece of equipment can reliably ascertain and report as greater than zero.

Duplicate sample. Used for quality control purposes, duplicate samples are an additional sample taken at the same time from, and representative of, the same site that are carried through all assessment and analytical procedures in an identical manner. Duplicate samples are used to measure natural variability as well as the precision of a method, monitor, and/or analyst. More than two duplicate samples are referred to as replicate samples.

Environmental sample. An environmental sample is a specimen of any material collected from an environmental source, such as water or macroinvertebrates collected from a stream, lake, or estuary.

Field blank. Used for quality control purposes, a field blank is a "clean" sample (e.g., distilled water) that is otherwise treated the same as other samples taken from the field. Field blanks are submitted to the analyst along with all other samples and are used to detect any contaminants that may be introduced during sample collection, storage, analysis, and transport.

Instrument detection limit. The instrument detection limit is the lowest concentration of a given substance or analyte that can be reliably detected by analytical equipment or instruments (see detection limit).

Matrix. A matrix is a specific type of medium, such as surface water or sediment, in which the analyte of interest may be contained.

Measurement Range. The measurement range is the extent of reliable readings of an instrument or measuring device, as specified by the manufacturer.

Method detection limit (MDL). The MDL is the lowest concentration of a given substance or analyte that can be reliably detected by an analytical procedure (see detection limit).

Precision. A data quality indicator, precision measures the level of agreement or variability among a set of repeated measurements, obtained under similar conditions. Relative percent difference (RPD) is an example of a way to calculate precision by looking at the difference between results for two duplicate samples.

Protocols. Protocols are detailed, written, standardized procedures for field and/or laboratory operations.

Quality assurance (QA). QA is the process of ensuring quality in data collection including: developing a plan, using established procedures, documenting field activities, implementing planned activities, assessing and improving the data collection process and assessing data quality by evaluating field and lab quality control (QC) samples.

Quality assurance project plan (QAPP). A QAPP is a formal written document describing the detailed quality control procedures that will be used to achieve a specific project's data quality requirements. This is an overarching document that might cover a number of smaller projects a group is working on. A QAPP may have a number of sample analysis plans (SAPs) that operate underneath it.

Quality control (QC). QC samples are the blank, duplicate and spike samples that are collected in the field and/or created in the lab for analysis to ensure the integrity of samples and the quality of the data produced by the lab.

Relative percent difference (RPD). RPD is an alternative to standard deviation, expressed as a percentage and used to determine precision when only two measurement values are available. Calculated with the following formula: RPD as % = ((D1 – D2)/((D1 + D2)/2)) x 100 Where: D1 is first replicate result D2 is second replicate result

Replicate samples. See duplicate samples.

Representativeness. A data quality indicator, representativeness is the degree to which data accurately and precisely portray the actual or true environmental condition measured.

Sampling and Analysis Plan (SAP). A SAP is a document outlining objectives, data collection schedule, methods and data quality assurance measures for a project.

Sensitivity. Related to detection limits, sensitivity refers to the capability of a method or instrument to discriminate between measurement responses representing different levels of a variable of interest. The more sensitive a method is, the better able it is to detect lower concentrations of a variable.

Spiked samples. Used for quality control purposes, a spiked sample is a sample to which a known concentration of the target analyte has been added. When analyzed, the difference between an environmental sample and the analyte's concentration in a spiked sample should be equivalent to the amount added to the spiked sample.

Standard operating procedures (SOPs). An SOP is a written document detailing the prescribed and established methods used for performing project operations, analyses, or actions.

Appendix C – Quality Control Checklist

Laboratory QC

___ Condition of samples upon receipt

___ Cooler/sample temperature within required range

___ Proper collection containers

___ All containers intact

___ Sufficient sample volume for analysis

___ Sample pH of acidified samples <2

___ All field documentation complete. If incomplete areas cannot be completed, document the issue.

___ Holding times met

___ Field duplicates collected at the proper frequency (specified in SAP)

___ Field blanks collected at the proper frequency (specified in SAP)

___ All sample IDs match those provided in the SAP. Field duplicates are clearly noted as such in lab results.

___ Analyses carried out as described in the SAP (e.g., analytical methods, photo documentation, field protocols)

___ Reporting detection limits met the project-required detection limit

___ All blanks were less than the project-required detection limit.

___ If any blanks exceeded the project-required detection limit, associated data is flagged.

___ Laboratory blanks/duplicates/matrix spikes/lab control samples were all within the required control limits defined within the SAP

___ Project DQOs and DQIs were met (as described in SAP)

___ Summary of results of OC analysis, issues encountered, and how issues were resolved addressed (corrective action)

___ Completed QC checklist before upload into DEQ's EQuIS (or other) database.

Appendix D – Data Qualifiers (Flags)

Result Qualifier	Result Qualifier Description
B	Detection in field and/or trip blank
D	Reporting limit (RL) increased due to sample matrix interference (sample dilution)
H	EPA Holding Time Exceeded
J	Estimated: The analyte was positively identified and the associated numerical value is the approximate concentration of the analyte in the sample.
R	Rejected: The sample results are unusable due to the quality of the data generated because certain criteria were not met. The analyte may or may not be present in the sample.
D	Not Detected: The analyte was analyzed for, but was not detected at a level greater than or equal to the level of the adjusted Contract Required Quantitation Limit (CRQL) for sample and method.
UJ	Not Detected/Estimated: The analyte was not detected at a level greater than or equal to the adjusted CRQL or the reported adjusted CRQL is approximate and may be inaccurate or imprecise.

Appendix E – Field Protocols

(1) Grab Sample Collection

Site Selection

Chose a sample site that is (a) fully within the body of water listed in the site description, (b) not influenced by nearby bodies of water (i.e., > 10' above the stream's mouth, away from water entering the stream from a tributary), (c) in flowing current (not an eddy or backwater), and (d) is as close as possible to additional site description information provided (e.g., photos, maps, narrative descriptions). If you have previously visited the site, try to collect data from the same spot.

Grab Samples (see MTDEQ 2012, 5.2.1)

Unfiltered Grab Samples

The following samples will be collected using unfiltered grab sampling techniques:

- Total Persulfate Nitrogen (TPN): 250 ml square bottle with white cap
- Total Phosphorus (TP) **and** Nitrite plus Nitrate (NPN): 250 ml bottle with yellow cap

1. Triple-rinse the bottle and lid: Facing upstream into the direction of the flow, collect a small amount of water in the bottle, replace the lid, and shake gently. Discard this rinse water behind you. Repeat this process three times to triple-rinse the bottle.
2. Collect the sample: Facing upstream into the direction of the flow, submerge the sample bottle deep enough so that the mouth of the bottle is below the water surface but not so deep that you scoop river bottom sediments. Fill the bottle up to the shoulder, leaving a small amount of "head space," and securely tighten the lid.
3. Add the vial of sulfuric acid preservative to the TP, NPN sample: Put on rubber gloves, carefully unscrew the cap of the TP, NO_{2+3} sample bottle and sulfuric acid preservative vial, dump the entire contents of the acid vial into the TP, NO_{2+3} sample bottle, securely tighten the cap on the sample bottle, discard the empty vial, and gently invert the sample bottle three times to mix the preservative into the sample.
4. Store the samples upright in a cooler on regular ice (≤ 6°C) until delivery to the analytical laboratory.

Filtered Grab Samples

The following sample will be collecting using filtered grab sampling techniques:

- Orthophosphate: 250 ml round bottle with white cap

1. Open the new 60 cc syringe package, remove the syringe, and discard the packaging. Triple-rinse the syringe by drawing water into the syringe, gently shaking, and compressing the syringe to force the water out three times.

Figure 3. Syringe used to filter water samples.

2. Fill the syringe with ambient water.
3. Open a new 0.45 µm filter package by gripping the blue ring and peeling the cover open. Screw the filter onto the syringe and discard the packaging. Pass a small amount of water through the filter to "prime" it.

Figure 4. Disposable 0.45 µm filters used with syringe when filtering water samples.

Note: Avoid contaminating the filter before and during sample collection by not touching the filter tip anywhere besides the blue ring.

4. Triple-rinse the sample bottle with filtered water. Draw water into the syringe from below the water surface. Plunge a small amount of water (approximately 10-20ml) from the syringe through the filter into the sample bottle. Replace the lid and shake gently. Discard this rinse water behind you. Repeat this process three times to triple-rinse the bottle with filtered water. When finished rinsing, unscrew and discard the filter used for rinsing.
5. Refill the syringe with ambient stream water, open and attach a new filter, and pass a small amount of water through the filter to "prime" it.
6. Once the bottle has been rinsed, fill the bottle with filtered water. Since the bottle is 250 ml and the syringe holds only 60ml, filling the bottle will require approximately 4 refills of the syringe. When the syringe is empty, grip the filter's blue ring, unscrew the filter and refill the syringe, taking care not to contaminate the filter. If the filter is not clogged, screw the filter back onto the syringe and continue filtering until the bottle is sufficiently full. If the filter clogs mid-way throughout filtering, unscrew and discard the clogged filter, refill the syringe, screw on a new filter, pass a small amount of water through the new filter, and continue filtering. Repeat this process until the sample bottle is full.

   Note: Be sure to leave enough headspace in this sample bottle so it can expand when frozen without breaking, about ¼" below the shoulder of the bottle.

7. Store the samples upright in a cooler frozen on dry ice (≤ 6°C) until delivery to the analytical laboratory.

Duplicates and Field Blanks

Samples to be sent to an independent lab will include two duplicate samples for each parameter during each sampling event. These will be drawn from randomly selected sites from a defined list of sites, and prepared in the same manner as routine samples. In addition, we will prepare one field blank for each parameter during each sampling event. These will be processed in the field and labeled like any other sample, but will contain deionized water instead of an actual stream sample.

(2) Manually Recorded Data

Temperature and pH will be recorded from the same sites where grab samples are collected, using handheld instruments and following the manufacturer's protocols. We will also take photographs of the banks on either side of the sample site, and conduct an aquatic vegetation assessment (see MTDEQ 2012, Attachment H) at each sample site, using the observer's viewshed (looking downwards) as the sampling frame. Some sites will also have stream gauge data to be collected.

Aquatic Vegetation Assessment:

1. Stand at the sample collection site, face upstream, and look down: the area within your viewshed will be your "sampling frame".
2. Identify the (a) **microalgae**, (b) **filamentous algae**, (c) **macrophytes**, and (d) **moss** within your sampling frame.
3. Visually estimate the amount of area covered by each vegetative group, and record the estimate categorically as: **0** (absent, 0%), **1** (sparse, <10%), **2** (moderate, 10-40%), **3** (heavy, 40-70%), **4** (very heavy, >75%)
4. Record the predominant color for each group as: **G** (green), **GLB** (green/light brown), **LB** (light brown), **BR** (brown/reddish), or **DBB** (dark brown/black).
5. Record the condition for each group: **Gr** (growing), **M** (mature), or **D** (decaying).
6. For microalgae, record the **thickness** in mm.
7. For filamentous algae, record the **length** in cm.

Stream Gauge Data

1. For sites with an Onset MX2001:
    a. Download the HoboMobile app, open the Settings page and enable HoboLink and click the wifi-only box, and enable the Bluetooth feature on your smartphone.
    b. Open the app, click on a sensor in range (one must be within 100m of the sensor), and click Readout.
    c. Open the new data file, download it as a .CSV, and email it to rivernet@yellowstoneresearch.org.
2. For sites with a staff gauge, read the value in feet (to the nearest 1/100th of a foot) at the meniscus (the bottom part of the "U" when viewing water at the level) of the average water level.

(3) Stream Gauge Establishment

Purpose: As part of the Yellowstone Ecological Research Center's RiverNET project objective to increase the resolution of stream flow and temperature data by increasing the density of stream gauge sensors, we will establish ~20 new stream gauge sites on the Yellowstone River and its tributaries between Gardiner, MT, and Greycliff, MT. We will locate sites that are suitable for stream gauges, monument them with a staff gauge, and produce a rating curve for each site to convert depth measurements to stream flow. These data will be made publicly available so any entity (e.g., conservation district, agency, university, NGO, private landowner/business) can install monitoring equipment there: we only ask that the sensors be maintained to our protocols and the data be contributed to our network. These protocols will be suitable for establishing new stream gauge sites in other locations as well.

Equipment: *Site Selection* equipment only needs to be included when new sites are being established, while *Rating Curve Data Collection* equipment needs to be included for every site visit, including installation, rating curve data collection, and validation/maintenance.

Site Selection

- Staff gauge (1/site)
- Steel T-post (1/site)
- Staff gauge mounting hardware (2 #8 roundhead bolts/site, nuts if attaching to T-post or epoxy if attaching to rock)
- Rebar stakes (2/site)
- Post pounder and hand sledge hammer
- Drill with full batteries (x2) and 8mm carbide bits (x4)
- GPS
- Camera
- Data sheets, clipboard, pens
- Waders, boots, wader belt, PFD
- Safety goggles

Rating Curve Data Collection

- Flowmeter
- Depth measuring rod
- 50m transect tape
- Data sheets, clipboard, pens
- Waders, boots, wader belt, PFD

Site Selection: Main stem sites will be located behind bridge piers, while tributary sites will be located near the mouth of the tributary unless otherwise noted (e.g., upstream of major diversions). A thorough reconnaissance of the area and sound judgment that considers how a stream will change over a season is necessary for selecting suitable sites, which should ideally meet the following qualifications:

- Close to the main current (thalweg) that should remain submerged during low flow periods, yet downstream from a permanent object that will protect the stream gauge from floating debris (e.g., bridge pier, boulder)
- When available, choose a site with a concrete control (i.e., bridge, culvert, etc.) that will both protect the stream and staff gauge and offer a predictable and permanent stream channel width.
- In a reach where the flow is restricted to a single channel with relatively stable geomorphology (permanent banks; large, heavy substrate free from scouring and excessive vegetative growth), unaffected by incoming

streams or natural or man-made features causing seasonal backwaters (e.g., log jams, dams), and with a straight flow line and consistent gradient ~100m upstream and downstream of the site (see also Rantz et al. 1982, Chapter 2)

- Accessible for continuous site visits (installation, data collection, and maintenance) keeping in mind ease of access, safety, and private property restrictions
- Minimal visual disturbance for river users, inhabitants of nearby dwellings, etc.
- Outside of trout spawning habitat, characterized by pools or eddies with fine gravel substrates where trout may be seen congregating in spring/early summer. Make sure no such habitat is present at the stream gauge site itself or within a 6' wide area between it and either bank

Once a suitable site is selected:

1. **Install** the staff gauge in a protected, continuously submerged, accessible, and minimally visible location. Either pound in a steel T-post with the flanges perpendicular to the flow line until the flanges are completely buried, drill holes through the T-post that align with the holes on the staff gauge, and attach with bolts and nuts; or drill holes into a boulder that align with the holes on the staff gauge, fill the holes with epoxy, and press the bolts through the staff gauge and into the epoxy-filled holes (see Site Restoration below to uninstall).
2. **Zero** out the staff gauge at the winter base flow for the stream and estimate the water flow at time of installation to the nearest 1/100th of a foot.
3. **Record** the GPS coordinates (lat/long decimal degrees) for the site on its data sheet, and **photograph** the site from multiple angles as well as its parking, access routes, and other landmarks that will help with locating the site.
4. At the edge of the high water mark of both banks on either side of the staff gauge, **install** the rebar stakes: these will be used to align the transect tape while recording discharge data (below), so the stakes and staff gauge must be aligned perpendicular to the flow line. **Record** the distance between the stakes as the max channel width.

Rating Curve Data Collection: We will collect two types of data – stream stage and discharge – over at least 10 data collection intervals between low- and high-water in order to calculate the stage-discharge relationship, or rating curve, for each site.

Average Cloud Cover

Record an estimate of the average cloud cover using the following key:

Key
P = precipitating
PC = partly cloudy (25-75%)
MC = mostly cloudy (>= 75%)
S = sunny (<25% clouds)

Total Precipitation

Record the total inches of precipitation received for the previous 7-day period using data from the nearest NOAA weather station which should be recorded by station name or ID.

Stream Stage

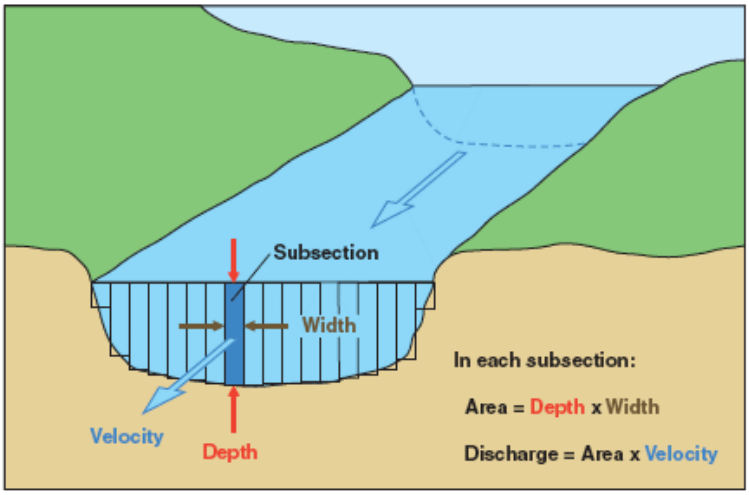
Simply **record** the depth observed on the staff gauge (in feet, to the 1/100th of a foot).

Discharge

Discharge is the product of the stream's cross-sectional area and its velocity (Turnipseed and Sauer 2010). To calculate discharge, we will use one of two methods depending on our ability to safely wade across the stream: for low water

conditions, we will use the **subsection method**, and for high water conditions, we will use a modified **float-area method** that uses a current meter instead of a float to measure surface velocity. We will use the velocity-area method to account for a non-uniform streambed, **calculating discharge** for subsections across the channel, and averaging these to estimate that of the entire channel:

Discharge: Subsection Method (Low Water)



USGS Water Science School

1. **Run** the transect tape between the two rebar posts, making sure it is both **taut** and **perpendicular** to the flow line. You will use the transect tape to define your data collection points, which should be spaced **every ½ foot** for channels that are <10' wide, or **every foot** for channels that are >10' wide (Michaud and Wierenga 2005).
2. Starting on one end of the channel, **establish** the first observation point (Point 0) at the edge of the water on one side of the channel, and **record** the distance between this point and the nearest rebar stake (the **"initial point"**), and the depth and velocity (both of which should be 0 for observation Point 0)
    a. Record the orientation of the rebar stake used as the **initial point** as N, S, E or W of the river channel
3. **Move** to the next observation point (Point 1; either ½ foot away from Point 0 for channels <10' wide or 1 foot away from Point 0 for channels >10' wide), and **record** the distance from the initial point, the depth (in feet, to the nearest 1/100th of a foot), and 1-2 velocity measurements (Turnipseed and Sauer 2010):
    a. If the depth is <2', **record** one velocity measurement at a depth of 0.6 * total depth, and **enter** this SAME observation in BOTH velocity fields ("Velocity1", "Velocity2")
    b. If the depth is >2', **record** one velocity measurement at a depth of 0.2 * total depth, **enter** it under "Velocity1", **record** another velocity measurement at a depth of 0.8 * total depth, and **enter** it under "Velocity2".
    c. See Appendix II for approximate velocity measurement depths.
    d. When measuring velocity, make sure that the observer is standing ~1-3' DOWNSTREAM of the transect tape, and ~1.5' TO THE SIDE of the flow line so as not to influence the velocity measurement.
4. **Repeat** Step 3, **recording** observation points (Point *n*), distances from the initial point, depths, and velocity measurements up to the last possible flooded observation point near the opposite bank.
5. **Record** any additional observations in the "Notes" section (e.g., observed changes/disturbances since the previous data collection period, relative water clarity, staff gauge condition, aquatic vegetative growth, spawning trout observed, problems/obstacles that hampered data collection, etc.). Also **record** the stream name, site number, date (mm/dd/yyyy), data collection interval sequence number (1-10+), time (24-hr) of the first observation, observer name, recorder name, names of other crew members present, current weather (sunny, partly cloudy, mostly cloudy, overcast, light precipitation, heavy precipitation), and water temperature on the datasheet.

6. **Enter** the data in the digital database as soon as possible following data collection, and **file** the hardcopy datasheet in the "Rating Curve Data 2019" file folder.
7. **Repeat** Steps 1-6 on at least 10 intervals distributed between low- and high-flow stream conditions, filling out a separate datasheet for each data collection interval. For consistency, it is best to have the same technician acting as "observer" as well as that the same technician acts as "recorder" for each interval.

Discharge: Modified Float-Area Method (High Water)

1. **Establish** the cross-sectional area of the channel, reference the current river width against the wetted cross-sectional area from the last measurement to establish if any new sections have become submerged. This will require preliminary reference either form the google docs uploaded data (2019 datasheet photos), or the physical data sheets themselves, before heading into the field.
2. **Calculate** the new area by adding the current stage height to the most recent stage measurement(also preliminarily noted) from the subsection method. Recalculate the new square footage with the addition of any wetted sections.
3. To measure velocity, use the velocimeter to record a **minimum** of one velocity measurement from a safely accessible section of the current that is representative of the average of the channel current. Measurements will be taken as close to the surface as possible, allowing for full submersion of the propellor blades. If possible two or more velocity measurements will be taken(from other side or accessible parts of channel), these numbers will be **combined** to create a more accurate average.
4. Based on current water depth **select** the appropriate roughness coefficient(c) from table.

Coefficients for Converting Float Velocity to Mean Channel	
Avg. Depth (ft)	Coeff.
1	0.66
2	0.68
3	0.7
4	0.72
5	0.74
12	0.78
Source: USBR Water Measurement Manual (1997)	

5. Take the updated area, velocity average, and the roughness coefficient to **calculate** discharge using the formula Q=A*V*c.