**Big Hole River Foundation**

**Water Quality Monitoring Program**

**Sampling and Analysis Plan**

April 2022

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Approved by:

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# Revision History

This section should be used to note any changes in protocols, who made the changes (initial when they occurred), and a description of the changes.

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Revision by – Date** | **Section(s) Revised** | **Revision Description** |
| 1 | 2/25/20 | Algae | BHRF Board voted not to pursue algal monitoring in 2020 due to cost and time associated with sampling as well as limited capacity of staff and volunteers.  This decision can be found in the corresponding meeting minutes, available upon request. References to algae sampling have been removed from this document. |
| 2 | 1/05/21 | Site Visit Form | Field forms were modified to be cleaner, less cluttered with unused data lines, and easier to read for purposes of data entry at the end of each season. Example from provided on page 43.  – Brian Wheeler, Program Director |
| 3 | 2/22/21 | Sampling Sites | After sample collection in 2020 uncovered excessive nutrient loading in the upper river, near Wisdom, BHRF is expanding the monitoring program to include additional sampling sites near the headwaters at Skinner Meadows and on the N. Fork Big Hole River to better understand these findings. Preliminary locations are noted in this document, however exact coordinates and river miles may change once sites become accessible in spring. – Brian Wheeler, Program Director |
| 4 | 2/01/22 | Algae Visual Assessment | In 2022, BHRF will begin to utilize an algae visual assessment form (provided by DEQ) to document the presence & coverage of algae, in addition to site photos. – Brian Wheeler, Program Director |
| 5 | 4/2/22 | Sampling Process | Macroinvertebrate sampling has been deemed a separate project that is funded independently, and sampling methods have been removed from this SAP. |
|  |  |  |  |

# 1.0 INTRODUCTION

## 1.1 Project Area Overview

The Big Hole River in Southwest Montana originates in the Beaverhead Mountains and flows without major impoundments for approximately 151 miles before its confluence with the Beaverhead River to form the Jefferson River. The watershed drains 2,800 sq. miles of evergreen forest, sagebrush steppe, and foothill valley grassland. The watershed spans four counties (Beaverhead, Anaconda-Deer Lodge, Madison, and Silver Bow) and several mountain ranges (Pioneer, Pintler, Beaverhead, and Anaconda).

The Department of Environmental Quality divided the Big Hole watershed into three planning areas during development of Total Daily Maximum Loads (TMDLs) that cumulated in two TMDL and water quality improvement plans in 2009. Table 1 provides information on the Assessment Units (AU), impairments, and TMDLs for each waterbody monitored in this project.

The Upper Big Hole watershed encompasses the area upstream from the confluence of the Big Hole River with Pintlar Creek (1,200 square miles), the Middle Big Hole extends 43.8 miles from the confluence of Pintler Creek downstream to the confluence with Divide Creek, and the Lower Big Hole extends 51.4 miles from Divide Creek downstream to the confluence with the Beaverhead River. Stream flow patterns are primarily driven by snowmelt throughout the watershed, with peak flow occurring in late May and early June and a general trend of peak flow coming earlier in the season.

**Table 1**. Project Assessment Units (AUs), impairments, and TMDLs.

| **Water Body & Location Description** | **Assessment Unit** | **Impairments** | **TMDL Completed** |
| --- | --- | --- | --- |
| Big Hole River, headwaters to Pintlar Creek | MT41D001\_030 | Alteration in stream-side or littoral vegetative covers (AL) | No |
| Sedimentation/Siltation (AL) | Yes |
| Temperature (AL) | Yes |
| Flow Regime Modification (AL) | No |
| Big Hole River, Pintlar Creek to Divide Creek | MT41D001\_020 | Alteration in stream-side or littoral vegetative covers (AL) | No |
| Copper (AL) | Yes |
| Lead (AL & DW) | Yes |
| Physical substrate habitat alterations (AL) | No |
| Sedimentation/Siltation (AL) | Yes |
| Temperature (AL) | Yes |
| Flow Regime Modification (AL) | No |
| Big Hole River, Divide Creek to mouth | MT41D001\_010 | Cadmium (AL & DW) | No |
| Copper (AL) | No |
| Lead (AL & DW) | No |
| Physical substrate habitat alterations (AL) | No |
| Temperature (AL) | Yes |
| Zinc (AL) | No |
| Flow Regime Modification (AL) | No |
| Deep Creek, headwaters to mouth | MT41D003\_040 | Alteration in stream-side or littoral vegetative covers (AL) | No |
| Sedimentation/Siltation (AL) | Yes |
| Flow Regime Modification (AL) | No |
| Wise River, headwaters to mouth | MT41D003\_200 | Alteration in stream-side or littoral vegetative covers (AL) | No |
| Cadmium (AL) | Yes |
| Copper (AL) | Yes |
| Lead (AL) | Yes |
| Physical substrate habitat alterations (AL) | No |
| Sedimentation/Siltation (AL) | Yes |
| Flow Regime Modification (AL) | No |
| North Fork Big Hole River, headwaters to mouth | MT41D004\_010 | Alteration in stream-side or littoral vegetative covers (AL) | No |
| Sedimentation/Siltation (AL) | Yes |
| Flow Regime Modification (AL) | No |

Notes: (AL) represents Aquatic Life impairment and (DW) represents Drinking Water impairment.

The primary impairments in the Big Hole watershed include sediment, nutrients, metals, and water temperature. The most significant sources of sediment loads include upland erosion associated with grazing, unpaved roads, natural sources, and streambank erosion related to riparian vegetation removal and grazing associated with agriculture. Significant sources of nutrients include natural and agricultural sources, which include livestock grazing and hay/alfalfa production. Metal impairments existed in all three planning areas, but metal TMDLs were only provided for the Middle and Lower watershed (DEQ 2009b). Significant sources of metals include atmospheric deposition from the Anaconda smelter and acid mine drainage from abandoned mines. Although the Anaconda smelter shut down in 1980 (began running in 1918), its effects on the environment are still being felt. The deleterious effects of atmospheric deposition of heavy metals are compounded by increased sediment erosion due to sulfur dioxide from the smelter killing the vegetation in the surrounding area. Impairments from the Anaconda smelter are particularly prevalent in the Mt Haggin Wilderness Area. Water temperature impairments have been attributed to agricultural practices that have increased erosion, leading to wider and shallower stream channels, decreased riparian vegetation, and shading from livestock grazing, and decreased stream flows from irrigation withdrawals.

The Big Hole provides critical habitat for several aquatic species of concern including Arctic Grayling, Westslope cutthroat, and Western Pearlshell mussels. The Big Hole is home to the last remaining populations of native fluvial Arctic grayling. The eligibility of Arctic grayling as endangered distinct population segment has been contested since 1982. Substantial monitoring and restoration efforts are undertaken in the Big Hole to protect Arctic grayling and other species of concern, including work done by US Fish and Wildlife Service (USFWS), Montana Fish Wildlife and Game (MFWP), Arctic Grayling Recovery Program, Montana Department of Natural Resources and Conservation (DNRC), Big Hole River Foundation (BHRF), Bureau of Land Management (BLM), Natural Resources Conservation Service (NRCS), US Forest Service (USFS), and the Big Hole Watershed Committee (BHWC).

## 1.2 Project Goals and Objectives

Here we establish­ clear goals and specific objectives to ensure our program has a clear direction, to allow us to gauge the progress/success of the program, and to obtain funding (Sigler and Wall 2017). These goals and objectives may change through time as the program evolves and new concerns arise.

Although substantial research, restoration work and associated pre- and post-monitoring occurs throughout the watershed, a holistic water quality monitoring program that examines the overall health of the system over multiple years is lacking. In 2020, the Big Hole River Foundation established a long-term water quality monitoring program. The program was designed to complement existing work while limiting replication. For that reason, the program focuses on sediment and nutrient monitoring, which are not commonly monitored in the watershed.

The water quality monitoring goals, objectives, and analyses are summarized in table 2.

**Table 2.** Project goals, objectives, and analyses

| **Goal** | **Objective** | **Data Analysis** |
| --- | --- | --- |
| Evaluate current nutrient, sediment, and aquatic plant conditions throughout the Big Hole watershed and establish a baseline for future comparisons. | * To collect nutrient (TN, TP and NO2+3) and sediment samples (turbidity, TDS, TSS) and visual assessments of aquatic plants at seven sites spanning the length of the Big Hole River and three sites on major tributaries and examine spatial trends. * Develop waterbody specific relationships between TDS and specific conductivity (SC) to allow the calculation of TDS from SC measurements. * Increase sampling effort in reaches with the highest loads of pollutants to assess pollutant sources. | Compare nutrient concentrations against the recommended ranges of nitrogen and phosphorus that protect beneficial uses. |
| Graph nutrient and TSS concentrations from upstream to downstream and observe spatial patterns among sites. |
| Graph TDS and SC and use least squares regression to estimate relationship. |
| * Continue monitoring of the watershed in perpetuity to build a long-term data set to evaluate intra- and inter-year trends for nutrient (TN, TP and NO2+3) and sediment (turbidity, TDS, and TSS) concentrations, assess environmental changes, and inform proactive management and research in the watershed. * Continue visual inspections of aquatic plants to assess the health and productivity of the aquatic ecosystem, record nuisance aquatic plant problems, and document temporal changes in the plant community. * Adapt program to provide pre- and post- monitoring data for any major land use changes or developments within the watershed. * Conduct biweekly sampling during the spring (April-June) when most nutrients and sediment enter the system and monthly sampling during the summertime growing season from July 1 - September 30, when protective ranges of nutrients apply. Sample once in October. Increased sampling in the spring will help better quantify variability during this period and identify areas contributing the largest loads of pollutants * Compare collected data to any available historic data to assess long term changes | Graph temporal trends (by sampling event and year) for each parameter of interest. |

## 1.3 Project Budget

The budget includes laboratory costs of water sample analysis. Equipment costs, calibration solutions, sensor membrane replacements, and other additional contracted work are not included. An itemized project budget is included in appendix A.

# 2.0 SAMPLING PROCESS

## 2.1 Study Design

### Sampling Locations

Sites were selected based on their accessibility, impairment status of the waterbodies considered for study, geographic location, and presence of historic and current water quality data. Discharge was monitored at all long-term sample sites by other agencies (USGS, DRNC) and real-time flow data is available for all sites except Deep Creek. Staff gauge readings near the mouth of Deep Creek are recorded directly after each Deep Creek sampling event and associated discharges are provided by the DNRC hydrologist at the end of the sampling season. Temperature data is also available for all mainstem sites except the headwaters site. The seven mainstem sites span the majority of the length of the Big Hole; providing a consistent spatial distribution while also being located above or below major differences in geology, land use, and groundwater inputs (Figure 1). Site locations and measured parameters are provided in Table 3 and more detailed descriptions of sites are provided in appendix D.

**Table 3.** Sampling locations and descriptions

| **Site Name** | **Site Description** | **Latitude\*** | **Longitude\*** | **Parameters to Collect** | **River Mile\*\*** | **Waterbody ID** | **County** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| BHTW | Big Hole near Twin Bridges | 45.549705 | -112.36064 | Nutrients\*\*\*, field parameters\*\*\*\*, physical parameters\*\*\*\*\*, macroinvertebrates, aquatic plants visual assessment (AQPVA) | 1.9 | MT41D001\_010 | Madison |
| BHKA | Big Hole at Kalsta Bridge | 45.525341 | -112.701475 | Nutrients, field parameters, physical parameters, macroinvertebrates,  AQPVA | 29.7 | MT41D001\_010 | Beaverhead |
|  |  |  |  |  |  |  |  |
| ­­BHMR | Big Hole at Maiden Rock | 45.702308 | -112.735628 | Nutrients, field parameters, physical parameters, AQPVA | 48.1 | MT41D001\_010 | Beaverhead |
| WS | Wise River nr confluence | 45.797401 | -112.949816 | Nutrients, field parameters, physical parameters, macroinvertebrates, AQPVA | 1.0 | MT41D003\_200 | Beaverhead |
| BHMUD | Big Hole at Mudd Creek Bridge | 45.806526 | -113.310866 | Nutrients, field parameters, physical parameters, AQPVA | 87.9 | MT41D001\_020 | Beaverhead |
| DC | Deep Creek on BLM land | 45.903339 | -113.110046 | Nutrients, field parameters, physical parameters, macroinvertebrates, AQPVA | 2.1 | MT41D003\_040 | Deer Lodge |
| BHW | Big Hole at Wisdom | 45.620710 | -113.454946 | Nutrients, field parameters, physical parameters, macroinvertebrates, AQPVA | 109.1 | MT41D001\_030 | Beaverhead |
| NFBH | N. Fork Big Hole near Wisdom | 45.70503 | -113.46013 | Nutrients, field parameters, physical parameters, AQPVA | 5.6 | MT41D004\_010 | Beaverhead |
| BHJ | Big Hole at Jackson | 45.361639 | -113.440727 | Nutrients, field parameters, physical parameters, macroinvertebrates, AQPVA | 131.4 | MT41D004\_010 | Beaverhead |
| BHSK | Big Hole at Skinner Meadows | 45.18425 | -113.51698 | Nutrients, field parameters, physical parameters, AQPVA | 150.2 | MT41D004\_010 | Beaverhead |

\*GPS coordinates are NAD\_1983 UTM Zone 12N.

\*\*River miles calculated with the “Trace Downstream” feature of ArcGIS

\*\*\*Nutrients: Total persulfate nitrogen, nitrite+nitrate, and total phosphorus

\*\*\*\*Field parameters: Dissolved oxygen, pH, specific conductivity, and temperature

\*\*\*\*\*Physical parameters: Total suspended solids, total dissolved solids, and turbidity

**Figure 1.** Map of sampling locations.

**Map

Description automatically generated**

### Sampling Timing

Sampling will occur from April-October. Chemical sampling will occur at all sites on an approximately biweekly schedule in May-June and monthly from July-October and in April. The increased sampling effort in May-June should include measures on the ascending and descending limbs of the hydrograph, as well as the peak(s) if possible (Figure 2). The majority of sediment and nutrients enter the watershed during this spring runoff period. Nutrients measured include: total nitrogen (TN), total phosphorous (TP), and Nitrite+Nitrate (NO2+3). Physical parameters include: total suspended solids (TSS), total dissolved solids (TDS), and turbidity. Field parameters include: dissolved oxygen, pH, specific conductivity, and temperature. One set of field blanks will be prepared per sampling event and submitted to the lab with the field samples. A handheld YSI ProDSS (YSI, Yellow Springs, OH) is used for field measurements of temperature, dissolved oxygen, pH, turbidity, and specific conductance for all site visits. Specifications of the sensors are present in Table 4. Aquatic plant visual assessments (AQPVA) will occur for all sampling events during the months of July-October. Nutrient, physical, AQPVA and field measurements should occur at approximately the same time at each sampling location if possible, to limit variability associated with diel fluctuations of some parameters.

**Table 4.** YSI ProDSS system specifications.



**Table 5.** Sample collection timeframe

|  |  |  |
| --- | --- | --- |
| **Data** | **Parameters** | **Reason for Date Selection** |
| April | Nutrient, field, and physical parameters | Pre-runoff conditions |
| May-June | Nutrient, field, and physical parameters (bi-weekly) | Runoff expected, majority of sediment and nutrients enter system |
| July – September | Nutrient, field, AQPVA, and physical parameters (once per month) | Summer growing season |
| October | Nutrient, field, AQPVA, and physical parameters (once per month) | Primary brown trout spawning time. |

**Figure 2.** Hydrograph for the Big Hole at Melrose for 2021. This gage station has the longest historical record in the watershed, going back to 1923, and can be used when comparing water years.

Chart, line chart

Description automatically generated

## 2.2 Sampling Methods

Sampling protocols generally follow those outlined in MDEQ’s Standard Operating Procedure for Sample Collection for Chemistry Analysis: Water, Sediment, and Biological Tissue but have been modified to meet the needs of the program (Makarowski 2019, section 10.2). As these protocols are updated and replaced, this SAP will be modified to reflect those changes. A pre-sampling checklist is included in **Appendix E.**

Sampling sequence

Samples will be collected in sequence from most- to least- sensitive to disturbance: beginning with chemical sampling, then physical, then aquatic plant visual assessments (Makarowski 2019, section 10.1). The goal is to avoid contamination or biased results from physical disturbance of the sampling site. Thus, selected sites will be sampled from downstream to upstream to avoid contaminating successive samples. If sample sites are accessed from upstream, care should be taken to avoid walking in water. If this is unavoidable, chemical samples should be taken in currents that do not pass through the disturbed area and biological sampling should not occur in the disturbed areas.

1. Select and record initial sampling site

* Identify representative sampling sites within the reach
* Record latitude/longitude of sampling site “F” (middle site within sampling reach) using GPS receiver or Collector application and record on Site Visit Form. Always use the GPS coordinate system datum NAD 1983 and record coordinates in decimal degrees (DEG.DDDD) to a minimum of the fourth decimal. Take a photograph of the sample site.
* Utilize landmarks such as trees, fences, head gates, etc. to ensure sampling takes place in the same location each time.
* Avoid sampling in sluggish water, directly downstream from bridges, culverts, or dams/diversions, directly upstream or downstream of confluences (5 stream width downstream adequate; a shorter distance upstream is adequate, just want to avoid upstream backwater conditions -> site dependent)
* Complete vertical and lateral mixing within cross section is desirable

2. Set-up and collection of data with hand-held meter

* Using the YSI ProDSS probe, collect and record in situ chemistry measurements at sample site on Site Visit Form. Aerated/turbulent water should be avoided as it can result in inaccurate DO and turbidity measurements.
  + Temperature (water + air)
    - For air temperature, place thermometer in a location with adequate shade and air circulation and allow it to stabilize for several seconds
  + Dissolved oxygen
    - Submerge probe and shake vigorously to remove any air bubbles trapped near the probe, position it facing upstream into the flow and ensure there are no obstructions in front of the probe. If water is not flowing, gently move probe from side to side to circulated water around the probe. Aerated/turbulent water should be avoided
  + Turbidity
    - Submerge probe facing upstream, making sure there are no obstructions in front of probe. Be cautious not to disturb the substrate around the probe and allow the reading to stabilize for several moments. Also, avoid turbulent water when taking turbidity measurements.

3A. Monitoring Montana Waters/Freshwater Research Lab sample collection (April, May, June, October sampling events)

* Collect unfiltered ‘grab’ water samples for TP, TN, NO2+3, TSS and TDS.
  + Fill out the label on each bottle with the following information and cover it with clear packing tape.
    - Waterbody name/code
    - Sample type
    - Collection date and time
  + Rinse sample bottles three times with ambient stream water. After rinsing, submerge the bottles to fill them with fresh water upstream from any previous disturbances to avoid contaminating the sample. Submerge the bottle sufficiently to prevent particulates floating on the water surface or sediment from the stream bottom from entering the sample bottle. Samples should be collected facing upstream in well mixed area, preferably in the main flow.

TN and TP will be collected in a clear HDPE 60ml bottle with blue tape. No preservative is added and the sample is frozen.

TSS and TDS will be an unfiltered grab sample collected in a 1000ml bottle with white tape. No preservative is added and the sample is kept cold on ice at ≤ 6 degrees Celsius.

Nitrate + Nitrite will be collected in a clear HDPE 60ml bottle with red tape. No preservative is added and the sample is frozen.

Leave appropriate headspace:

For most samples, the bottle should be filled to the shoulder or line that denotes the target volume

If samples are to be frozen, leave sufficient head space to allow the sample to expand when it freezes without the bottle breaking.

3B. Energy Lab sample collection (July, August, September sampling events)

* Collect unfiltered ‘grab’ water samples for TP, TN, NO2+3, TSS, and TDS.
  + Fill out the label on each bottle with the following information and cover it with clear packing tape.
    - Waterbody name/code
    - Sample type
    - Collection date and time
* Rinse sample bottles three times with ambient stream water. After rinsing, submerge the bottles to fill them with fresh water upstream from any previous disturbances to avoid contaminating the sample. Submerge the bottle sufficiently to prevent particulates floating on the water surface or sediment from the stream bottom from entering the sample bottle. Samples should be collected facing upstream in well mixed area, preferably in the main flow.

TN will be an unfiltered grab sample collected in a 250ml bottle with a white cap. No preservative is added and the sample is kept on ice at ≤ 6degC.

TSS and TSS will be an unfiltered grab sample collected in a 1000ml bottle with a white cap. No preservative is added and the sample is kept on ice at ≤ 6degC.

TP and NO2+3 will be an unfiltered grab sample collected in a 250 ml bottle with a yellow cap. One vial of sulfuric acid (H2SO4) provided by the lab will be added to the sample bottle (wearing gloves, then gently inverted three times to mix), and the sample is kept on ice at ≤ 6degC.

Leave appropriate headspace:

• For most samples, the bottle should be filled to the shoulder or line that denotes the target volume; this will leave a small amount of head space, especially necessary if preservative will be added to the sample.

4. Collect Field Blanks and Duplicates (Makarowski 2019, section 12.0) for samples sent to both labs

* Field blanks and duplicates must be handled identically to the respective sampling parameter they are replicating/duplicating (e.g. preservation, holding time, etc.)
* Indicate on Field Visit Form that field duplicates and/or blanks were collected; a distinct Activity ID (ending in “FB” for blanks and “FD” for duplicates) should be used and write “Field Blanks” or “Duplicate Samples” in the “Site Visit Comments” field.
  + - Field blank
      * Rinse sample bottles (same bottles that were used for water samples) three times with laboratory-grade deionized water. Fill sample bottle with deionized water, add preservatives if necessary (e.g. for Energy Labs: sulfuric acid in TP and NO2+3 samples), and store on ice at ≤ 6 oC.
    - Field duplicate
      * Repeat all steps performed in collecting one sample so the two identical samples have been collected at the **same time**.
      * Store on ice at ≤ 6 oC.

5. Aquatic Plant Visual Assessment (AQPVA)

* The visual assessment form for wadeable streams is in **Appendix F**. For sample sites AQPVA will only be collected at transect “F” and will use only the “F” labeled transect in the **Appendix F** form (use one “F” site form per stream site).
* The form in **Appendix F** has four parts, any of which can be used depending upon the visibility in and degree of access to the medium river. There is a part for the Right side of the transect (i.e., river right), the Middle of the transect, the Left side of the transect, and—if the whole transect can be observed—the Entire transect. At a location, complete as many parts of the **Appendix F** form as possible; if the transect from right bank to left bank is clearly visible, just complete Entire for that transect. If assessing only parts of a transect (e.g., Right and Middle), record in the Comments the approximate fraction of the transect length each part represents (for example: Right is 30% of the entire transect length, Middle is 20%).
* At the transect, the assessor will evaluate the entire observable wetted stream bottom as it appears 5 m above and 5 m below the transect line (i.e., an evaluation zone comprising 10 longitudinal m of stream bottom, with 5 m of stream bottom downstream of the transect line and 5 m upstream).
  + **Actual Cover in Channel:** Refers to the area coverage of the stream bottom by the plant type in question, within the evaluation zone. Circle the percent coverage category that most closely fits what you see. It will be necessary to be able to generally identify aquatic flora to complete this section. It is recommended that a good aquatic plant identification guide (e.g., (DiTomaso and Healy, 2003) be taken to the field and consulted when filling out the form. Identified macrophytes can be listed (from most to least common) in the Comments.
  + **Predominant Color:** The colors of aquatic plants are clues to their identity, state of growth, and health of the aquatic ecosystem. Record the predominant color of the plants or algae from the pick list, using the letter codes. Be sure to lift up your sunglasses to record accurate color categories. **Note:** Color reference is to the actual colors observed, not the types of algae the assessor may identify.
  + **Condition**: Aquatic plants go through seasonal cycles of growth, maturity, and decay. The condition of a plant or algae will indicate the approximate stage of this seasonal cycle. It can also help explain cases where, for example, Ash-Free Dry Weight (AFDW) to chlorophyll *a* (Chl*a*) ratios are found to be unusually high. Growing plants and algae show new growth and bright colors. Mature plants and algae are larger but have more subdued colors because of age, epiphytes, and sediment deposits. Decaying plant and algae display a loss of both pigmentation and physical integrity. Record conditions as Growing, Mature, or Decaying on the form using the letter codes.
  + **Thickness Category for Microalgae**: Non-filamentous microalgae can be present on stones and fine sediment surfaces and can develop a wide array of Chl*a* levels depending upon the mat thickness. The categories (Thin, Medium, Thick) can help corroborate Chl*a* and AFDW measurements collected and document progression of algal growth at a site. Use a mm-scale ruler to measure the mat thickness and record the category on the left side of the applicable box; Thin includes rock coating that are too thin to measure but feel slippery. If a good measurement can be acquired, record the actual thickness in mm on the right of the same box.
  + **Length Category for Filamentous Algae**: Increasing length of filamentous algae has been associated with recreation impacts (Biggs, 2000; Suplee, et al., 2009). Highly enriched waters tend to grow long filaments, 1-2 meters or more in length at times. Record filamentous algae filament lengths as Short or Long on the left side of the box on the form. When filaments are >2 cm in length, record in the same box the length (cm) of the most representative filaments in the assessment zone. Maximum filament length should be recorded in the Comments section. If flow is good, filament lengths can be obtained by standing downstream and placing the tip of your cm-marked wading pole at the origin point of a group of filaments and observing where on the pole the filament ends waver back and forth.

6. Wrap Up

* Document sites with photographs
* Ensure all forms are correctly and completely filled out (Site Visit Forms and Chain of Custody forms)
* All samples should be completely surrounded with ice.
* All field equipment should be cleaned and properly stored after each use
* Field visit forms and Chain of Custody forms should be scanned and electronically stored
* Chain of Custody forms should be placed sealed inside a ziplock and taped to the inside cover of the cooler
* Before shipping, samples and cubed ice should be sealed in separate ziplock bags. Samples should be stored upright in the cooler. Cooler should be taped closed.
* Coolers should be shipped no later in the week than Wednesday to ensure arrival during business hours. If this is not possible, they should be hand delivered or remain properly preserved (refrigerated) through the weekend and shipped the following Monday.
* Field summaries should be completed after sampling that includes any relevant weather/flow data, field observations, and any deviations from protocols and the reasons for deviating.
* Field pictures should be labeled with site code and transect number and electronically stored.

## 2.3 Field Forms

A field visit form will be filled out during each site visit, and will include fields for site location, time, field measurement, chemical samples, and aquatic plant visual inspections (Appendix E). Electronic copies of field forms for each sampling location are provided in the “Data sheet – forms” folder. All samples collected in April, May, June, and October will be delivered to the Freshwater Research Lab (FRL) at the Flathead Lake Biological Station (FLBS) for chemistry analysis and recorded on FRL’s chain of custody (COC) form, and chain of custody will be tracked with signatures and date whenever samples are relinquished and received. All samples collected in July, August, and September will be delivered to Energy Lab for chemistry analysis and recorded on Energy Lab’s chain of custody (COC) form, and chain of custody will be tracked with signatures and date whenever samples are relinquished and received.

Field forms and COC forms will be scanned and electronically stored at the end of each sampling event. These forms will also be physically stored in a 3-ring binder designated for the monitoring year.

A summary of field conditions, prior weather and flow conditions, any interesting observations, and any mistakes or alterations made during sampling should be written after each sampling event.

## 2.4 Laboratory Methods and Sample Handling Procedures

Water samples collected in April, May, June, and October will be sent to the Flathead Lake Biological Station Freshwater Research Lab in Polson, MT. Water samples collected in July, August, September will be sent to Energy Lab in Helena, MT.

**Table 6.** Monitoring Parameter Suite, Sample Handling, Analysis & Preservation for Monitoring Montana Waters/Freshwater Research Lab.

| **Parameter** | **Required Method** | **Required Report Limit** (µg/L) | **Holding Time** (days) | **Required Bottles** | **Preservative** |
| --- | --- | --- | --- | --- | --- |
| Total Suspended Solids (TSS) | A2540 D | 200 | 7 | 1000 ml HDPE | Place on ice (≤6oC) |
| Total Dissolved Solids (TDS) | A2540 C | 500 |
| Total Nitrogen (TN) as N | USGS 03-4174, EPA 353.2 | 25 | 45 | 60 ml HDPE | Freeze |
| Total Phosphorus (TP) as P | USGS 03-4174, EPA 365.1 | 1.5 | 45 | 60 ml HDPE | Freeze |
| Nitrate-Nitrite as N | EPA 353.2 | 1.5 | 45 | 60 ml HDPE | Freeze |

**Table 7.** Monitoring Parameter Suite, Sample Handling, Analysis & Preservation for Energy Labs.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Required Method** | **Required Report Limit** (µg/L) | **Holding Time** (days) | **Required Bottles** | **Preservative** |
| Total Suspended Solids (TSS) | A2540 D | 4000 | 7 | 1000 ml HDPE | Place on ice (≤6oC) |
| Total Dissolved Solids (TDS) | A2540 C | 4000 |
| Total Persulfate Nitrogen (TPN) | A4500-N C | 40 | 28 | 250ml HDPE | Place on ice (≤6oC) |
| Total Phosphorus as P | EPA 365.1 | 3 | 28 | 250ml HDPE | Add provided H2SO4, then place on ice (≤6°C) |
| Nitrate-Nitrite as N | EPA 353.2 | 10 |

## 2.5 End of Season

Calibration records for the YSI ProDSS will be downloaded and stored using the KorDss program. Data will be entered into spreadsheets, flagged based on the results of quality control measures and result comments will be added to describe any irregularities. A report on the methods used, results, and discussion of inferences and historical comparisons will be completed after each field season. Any changes to protocols for the next year will be noted in the sampling and analysis plan. All data, forms, notes, and reports will be electronically backed up on multiple external hard drives. Any field equipment will be cleaned and stored according to manufacturer recommendations. An inventory of field supplies will be made and supplies needed for the following year will be noted and obtained.

# 3.0 QUALITY ASSURANCE / QUALITY CONTROL

## 3.1 Quality Assurance and Quality Control Overview

To inform water quality studies, data needs to accurately represent conditions in the watershed. Most projects require some degree of proper sample handling, processing, and data quality assessment, particularly when scientific or resource management questions are being investigated.

Quality Assurance (QA) is the overall management of a sampling program. It ensures the monitoring process, from the methods used to how data will be managed and analyzed, is adequate for the project to meet its objectives with a stated level of confidence. QA activities include developing a sampling and analysis plan, making sure that volunteers or staff is properly trained, and following standard operating procedures.

Quality control (QC) includes technical actions taken to detect and control errors. QC consists of developing measures and protocols to ensure sample collection and analyses are consistent and correct. If there is a problem, good QC will help to identify the problem. It also helps determine whether volunteer work is being performed correctly. QC activities may include collecting replicate samples for chemical analyses and the use of field blanks.

Data quality objectives (DQOs) are qualitative and quantitative statements that clarify the purpose of the study, define the most appropriate type of information to collect, determine the most appropriate conditions from which to collect that information, and specify tolerable levels of potential decision errors. Essentially, DQOs prompt monitoring project managers to determine what level of data quality is necessary to achieve the objectives of the project.

Data quality indicators (DQIs) are attributes of samples that allow for assessment of data quality. Because there are large sources of variability in streams and rivers, DQIs are used to evaluate the sources of variability and error and thereby increasing confidence in our data.

* A list of Data Quality Assurance and Quality Control terms and definitions is included in **Appendix B**.

## 3.2 Data Quality Indicators

This section describes for each data quality indicator (representativeness, comparability, completeness, sensitivity, precision, and accuracy) how the sampling and analysis plan and study design aims to achieve data quality. Data quality indicator criteria are specified, where appropriate. Quality assurance laboratory protocols can be accessed by contacting Energy Lab Inc.

Per the Professional Services Guide document available at : “ELI’s comprehensive QA/QC program follows the rigorous criteria established by USEPA, TNI, DOD and various State agencies. ELI maintains certification from The NELAC Institute (TNI) and DOD for the analysis of water and wastewater (NPDES), hazardous and solid wastes (RCRA) and drinking water (SDWA). ELI also maintains certification under various State Agencies and USEPA Regions. Samples received at ELI are tracked and monitored by a strict laboratory information management system (LIMS) from receipt to report. Samples are logged in upon receipt and immediately inspected to determine any special handling requirements. All analytical procedures, sample handling, and preservation techniques are USEPA approved (where applicable). QA/QC test samples including matrix spikes and duplicates comprise greater than 10% of ELI’s analytical load.”

### Representativeness

Representativeness refers to the extent to which measurements represent an environmental condition in time and space. This project follows a sampling design in which spatial and temporal considerations were used to help ensure representativeness.

Spatial representation

The sample set was selected to provide a representative sample of the entire watershed from the headwaters to the mouth. Factors that influenced site selection included impairment status, existing flow monitoring, land accessibility, historical data records, and land use changes. All sites were selected on the main-stem or on major tributaries. All sites have public access in the headwaters reaches of the waterbody to provide the opportunity to examine pollutant loading between upstream and downstream sites. An approximately equal number of sites were selected in each of the TMDL planning areas (Upper, Middle, and Lower Big Hole). Sites in the middle and lower watershed, where major tributaries are scarce, are strategically placed in areas that represent transitions in land use or geology/topography. Sites in the upper watershed will include mainstem locations upstream and downstream of currently inaccessible major tributaries and locations on major tributaries.

Future expansions of the sampling set will likely focus on the Upper Big Hole, pending land access, due to the high number of major tributaries that converge in this planning area. Sampling locations with proximate tributaries or irrigation returns in the upstream direction were avoided. Longitudinal and cross-sectional conductance surveys should be conducted at new/proposed sampling sites to ensure the sampling location is representative of the proximate river conditions. This is of particular importance at sites where groundwater inputs have been noted.

Temporal representation

The sampling design will use two different sampling schedules to achieve temporal representativeness during spring runoff and the growing season (July 1st- Sept. 30th). During spring runoff, sampling will occur on the ascending limb of the hydrograph, as close to the peak flow as possible, during the descending limb, and at any major secondary peaks. During the growing season, sampling will occur on a regimented monthly schedule. Biological parameters will be sampled as close as possible to the same date each year to minimize seasonal variation. All sampling will occur in the downstream to upstream direction to ensure that the same water is not re-sampled. Efforts will be made to sample the sites at approximately the same time of day throughout the year. Within a sampling event, all sites will be sampled in as short of a time as possible to limit temporal variation.

### Comparability

Comparability is the degree to which different methods, data sets, and/or decisions agree or are similar. Comparability allows data users to determine the applicability of data to certain projects or decisions.

The Big Hole River Foundation will follow DEQ standard operating procedures for water quality collection and data to allow comparability with existing DEQ data, unless otherwise noted (Makarowski 2019).

Protocols will be strictly followed year to year and site to site to allow comparability among years and sites. The selected parameters are common to water quality monitoring programs, allowing comparisons to other watersheds. Site selection took into account the availability of historical water quality records, many of which are contained in the TMDL development documents. The described sampling schedule will ensure that data is comparable among years.

### Completeness

Completeness is a measure, expressed as a percentage, of the amount of data *planned for collection* compared to the amount *actually collected*, expressed as a percentage:

Completeness (%) = (# Valid Data Points or Samples/ Total # Data Points or Samples) x 100

The overall project goal is 90% completeness. Sampling sites lost due to inaccessibility or environmental conditions beyond the control of the organization will reduce the total number of sites in the equation but not the completeness goal. Rejected data results will be qualified with “R” flags and will count against project completeness. Data with “B” (detection in field blank; see appendix D for result qualifier descriptions) and “J” (analyte result value estimated) will not affect completeness. Before packing sample bottles into the cooler, tightness of the lids will be double checked. Prior to leaving a sampling site, field forms will be filled out and checked for completeness; this will reduce the occurrence of empty data fields. Data fields that do not change over time, such as location, GPS coordinates, HUC, county, and contact information, will be built into the data sheets prior to field collections to promote efficiency and completeness. Field visit forms will be scanned and electronically backed up the day of the collection. Two external hard drives, ideally kept in separate locations, will be backed up with all data, site visit forms, calibration records, and field summaries on a monthly basis to prevent the loss of information. Lab reports will be reviewed upon receipt and any discrepancies will be inquired into. Dates and times should be checked against field sheets, and not taken directly from laboratory results sheet, as these may have errors. Because of the limited funding for laboratory analysis, collection of additional samples in the event of breakage of sample bottles en route to the laboratory is not planned. Any sampling events that must be cancelled for any reason will be rescheduled. Should 90% completeness not be achieved, it is expected that project goals will still be met using the subset of data collected.

### Sensitivity

Sensitivity refers to the limit of a measurement to reliably detect a characteristic of a sample. 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. For analytical methods, sensitivity is expressed as the method detection limit (MDL).

Laboratory Sensitivity

Laboratories determine their method detection limits (MDLs) annually, and routinely check each method’s ability to achieve this level of sensitivity using negative controls (e.g., method blanks, continuing calibration Blanks, and laboratory reagent blanks). Sensitivity quality controls for all laboratory methods will follow the frequency and criteria specified in the analytical method or as described in the analytical laboratory’s Laboratory Quality Assurance Plan (LQAP).

**Corrective Action:** If the analytical method controls fail the specified limit, check with the laboratory to see how they addressed the non-conformance and qualify data, as necessary. If Field Blanks fail, all associated project data with <10x the detected value will be qualified with “B” flags.

### Precision, Bias and Accuracy for Water Samples

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. Bias can occur either at sample collection or during measurement. 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. Precision measures the level of agreement or variability among a set of repeated measurements, obtained under similar conditions.

Evaluation of precision and accuracy for the water sampling portion of this project will consist of collecting and evaluating the results of field duplicates and field blank samples. Any flagging that occurs should be accompanied by a comment in the “Result comment” column.

Precision: Field Duplicates

Field duplicates will be collected during this project and used to determine field and laboratory precision. Field duplicates consist of two sets of sample containers filled with the same water from the same sampling site. Duplicate samples will be taken at one site per sampling event, resulting in duplicates for >10% of all samples. All duplicate samples will be collected at the same location and time, with duplicate bottles being filled immediately after the routine sample. Field duplicate samples will be collected, handled and stored in the same way as the routine samples for laboratory shipment. Duplicates are used to determine field and laboratory precision.

Field duplicates will be used to evaluate data precision by calculating their relative percent difference (RPD):

RPD as % = ((D1 – D2)/((D1 + D2)/2)) x 100

where:

D1 is first replicate result

D2 is second replicate result

Precision for field QC samples will be assessed by ensuring that relative percent difference (RPD) between duplicates is less than 25%. If the RPD of field duplicates is greater than 25% and the original and duplicate result values are >5x the lower reporting limit (or method detection level if LRL is not provided), the original and duplicate will be ‘J’ flagged. Check with the laboratory to see how they addressed or qualified the data and add additional qualifies and notes as needed. Only the result of the original will be used for reporting or analysis.

Accuracy: Field Blanks

Field blanks consist of laboratory-grade, certified inorganic free deionized (DI) water, transported to the field, and poured into a prepared sample container. Blanks are prepared in the field at the same time as the routine samples, and will be preserved, handled and analyzed in the same way as the routine samples. Field blanks will be prepared once per sampling event, resulting in field blanks for >10% of the total samples. Field blank samples are used to determine the integrity of the volunteer monitors’ handling of samples, the condition of the sample containers supplied by the laboratory, and the accuracy of the laboratory methods.

Accuracy for field QC samples will be assessed by ensuring that blank samples return values less than the method detection limit (shown in **Section 3**). If a blank sample returns a result greater than the threshold, all data for that parameter from that batch (sampling event) of samples will be qualified with a “B” flag. The exception is that data with a value greater than 10 times the detected value in the blank does not need to be qualified.

Accuracy: Laboratory

Accuracy of individual measurements will be assessed by reviewing the analytical method controls (i.e. Laboratory Control Sample, Continuing Calibration Verification, Laboratory Fortified Blank, Standard Reference Material) and the analytical batch controls (i.e. Matrix Spike and Matrix Spike Duplicate).

Other

All samples will be checked to verify that they were processed within their specified holding times. Sample results whose holding time was exceeded prior to being processed will be qualified with an “H” flag. Because of the limited funding for laboratory analysis, collection of additional samples in the event of data results that do not meet data quality objectives is not planned. If problems are linked to field crew sampling error, the data is either rejected or qualified, depending on the degree of the problem, and supplemental training will be provided prior to the next sampling event.

## 3.3 Training

All volunteers will be trained in all field methods, including field meters, sample collection and handling, prior to the initial sampling event. Sampling training will occur prior to the first sampling event in the spring or prior to sampling events if new volunteers are present. Volunteers will demonstrate understanding of and proficiency in field methods to volunteer monitoring program manager(s) prior to sampling. Volunteers will be required to bring a copy of this SAP as well as any supplemental documentation of detailed field methods and/or standard operating procedures and should be supervised by someone with experience with the protocols.

## 3.4 Data Management, Record Keeping & Reporting

The science advisor is responsible for data management and record keeping, including the following activities that occur during or after the sampling is completed:

* Draft a brief synopsis of any SAP methodology deviations that occurred.
* Store and backup all data generated during this project, including field forms, laboratory reports obtained from the laboratories, electronic copies of field photographs, calibration records and written field notes.
* Review field forms for completeness and accuracy, especially Site Visit and Chain of Custody forms
* Flag data if it does not meet quality control objectives
* Enter all laboratory data into program data sheets and MT-eWQX database.

Analytical laboratories will prepare and analyze the samples in accordance with the chain-of-custody forms and analytical methods specified in **Table 5**. The lab will then supply the project coordinator with laboratory analytical reports and Electronic Data Deliverable (EDD) spreadsheets.

If DEQ or MMW funding is received in support of the monitoring project (e.g., through DEQ’s Volunteer Monitoring Lab Analysis Support Program or other funding mechanism), all data collected must be entered by the project coordinator into DEQ’s MT-eWQX database (also known as EQuIS). Instructions for preparing, validating, and submitting the EDD to MT-eWQX must be followed (available at https://deq.mt.gov/water/Programs/sw). For example, steps include:

* Compiling data (including site information, field measurements and lab results),
* Transforming the data into the required format,
* Performing a thorough quality control check of the data to correct errors, qualify problematic sample result values with data flags, etc.,
* Validating the data, and
* Submitting EDDs to MT-eWQX.

## 3.5 Project Team Responsibilities

**Table 6.** Project Team Roles and Responsibilities

|  |  |  |  |
| --- | --- | --- | --- |
| **Person** | **Role** | **Contact Information** | **Responsibilities** |
| David Dockery | Science advisor | [REDACTED] | Data review, analysis, and reporting. Data quality assessment and identifying data qualifiers. |
| Brian Wheeler | Foundation Director | [brian@bhrf.org](about:blank);  (406) 925-3290 | Volunteer training, sample collection, ensuring field forms are complete and accurate, filling out chain of custody forms for the lab, shipping samples to the lab, lab coordination, data entry |
|  |  |  |  |

## 3.6 Data Routing

The Program Director will be responsible for all data management. All data will be backed up and scanned if necessary on the project computer and two external hard drives.

**Table 7.** Data Routing Process

| **Task** | **Information/Data** | **Primary Responsibility** |
| --- | --- | --- |
| Reviewing for completeness | field forms | Program Director |
| Scanning | field forms | Program Director |
| Upload and backup | digital site photos | Program Director |
| Lab coordination | sample chain of custody forms, electronic data deliverables | Program Director |
| Data entry into EQuIS | lab results, field measurements, site information | Program Director |

# 4.0 ASSESSMENT RESULTS

## 4.1 Data Analysis

Chemical data will be stored in a master data sheet in Excel and data exploration and analysis will occur in program R (R Core Team, Vienna, Austria). Spatial and temporal trends will be examined through coded scatterplots. Pairwise scatterplots will be used to explore relationships among metrics. Nutrient data will be compared to the recommended ranges of nitrogen and phosphorus that protect beneficial uses: 30 µg/L total phosphorus; 300 µg/L total nitrogen. Nitrite-Nitrate levels will be compared to interim numeric screening criteria developed for the Big Hole watershed (DEQ 2009b): 100 µg/L. Simple code built into the excel data base will indicate if the measurement passes or fails numeric thresholds. Student t-tests and binomial tests will be used to assess exceedance rates of numeric thresholds (Suplee and Sada 2016). Collected data will be compared to available historic data.

## 4.2 Data Communication

Data and results will be presented through public meetings, newsletters, and social media outreach. When funding becomes available, data and results will be provided on the Foundation’s website.

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# Appendix A - Project Budget

Based on tentative schedule of biweekly sampling during runoff period (May-June), and monthly sampling for April and July-October.



# 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 – Additional Background Information of Project Area

The Environmental Protection Agency (EPS), United States Geological Survey (USGS), and Commission for Environmental Cooperation have a hierarchy of classifications based on ecoregion: areas with similarities in biotic, abiotic, terrestrial, and aquatic ecosystem components. From most encompassing to least, the Big Hole is classified in the Northwestern forested mountains (Level 1), Western cordillera (level II), Middle Rockies (Level III), and the Big Hole watershed (Level IV; HUC 1002004). Ecoregions provide a spatial framework for research, assessment, and monitoring of ecosystems and ecosystem components. Certain numeric water quality thresholds vary by ecoregion (e.g., numeric nutrient thresholds applicable for the Big Hole have been developed for the Middle Rockies Level III ecoregion). With sufficient data, standards can be developed on a watershed basis, which has been done for some areas in the Clark Fork and Yellowstone River Basin (DEQ 2014).

The Upper Big Hole is characterized by a wide (valley area of ~32 x 52 miles) high elevation (>6,000 ft) valley. The valley bottom is almost entirely privately owned and agriculture is the dominant land use. Outside of the valley bottom, the surrounding foothills and mountains are primarily US Forest Service land with a limited amount of Bureau of Land Management land. The valley is bordered on the west by the Beaverhead Mountains, the Anaconda Range to the north, and the Pioneer mountains to the east. Much of the valley bottom consist of Quaternary alluvial and glacial deposits overlaying sedimentary rocks of the Bozeman Formation. Characteristics of these soils include low capacity to hold water, low clay content, and high permeability. These characteristics contribute to a limited ability of the soil to support substantial vegetative growth and a high level of groundwater-surface water connectivity. The channel bed material consists of highly mobile granite derived sand (grus) and reworked alluvium consisting of gravels and coarse rounded cobble and boulders. The relative immobility of the larger alluvium limits the ability of flow to deepen the channel and results in channel bed armoring, which limits channel entrenchment (deepening of the channel) but can contribute to channel widening. Numerous tributaries converge in the upper Big Hole, more than in any other section of Big Hole. Demand for water is high and numerous irrigation diversions exist on all major tributaries. Flood irrigation is widespread throughout the valley during late spring and summer. Flow analysis indicates substantial dewatering occurs on the Big Hole above Wisdom while dewatering is less severe in the North Fork drainage, the largest sub-watershed within the upper Big Hole watershed. Groundwater recharge through flood irrigation is offset almost equally by evapotranspiration losses during the summer and early fall (Abdo and Roberts 2008), but irrigation may enhance surface water flows after the growing season (October-February) through groundwater recharge. Large groundwater flow systems converge and intersect with the Big Hole alluvial aquifer, resulting in groundwater influx, near Fishtrap, LaMarche, Deep Creek, Wise River, and Glen. Geological valley controls, areas where subsurface flows are contracted at natural ‘pinches’ of the valley, also provide groundwater influx at Greenwood Bottoms (near Dewey), Maiden Rock Canyon, and Notch Bottom. Groundwater influx and topographic shading as the river enters the canyon contribute to a decrease in water temperature near the middle of the watershed and functionally separates the upper and middle/lower Big Hole. Reduced shading from vegetative loss in the riparian corridor is predicted to have the largest effect on increasing water temperature in the Upper Big Hole. Increasing vegetative shading is predicted to be an effective temperature restoration strategy in the Upper Big Hole but not in the Middle or Lower watershed (DEQ 2009a).

The Middle Big Hole watershed (Pintlar to Divide Creek) is characterized by a steep walled canyon with evergreen forest. Agriculture is more limited than in the Upper or Lower Big Hole due to the limited size of the valley bottom and the mountainous topography. Tributaries are less numerous in the Middle and Lower Big Hole than in the Upper but are still heavily diverted for irrigation. Major tributaries important for irrigation include Pintlar, Mudd, Fishtrap, LaMarche, Seymour, Deep, Bear, and Divide Creek (DEQ 2009b). Major irrigation ditches on the mainstem include Owsley Slough, Hamilton Ditch, and Pageville Canal; all of which are located near Twin Bridges and contribute to the significant amount of dewatering that occurs in the lower reaches between Notch Bottom and Twin Bridges. The most significant mining occurred in the Middle Big Hole watershed, with major operations in the late 19th and early 20th century in the Deep Creek, Canyon Creek, Trapper Creek, and Wise River watersheds.

As the river enters the Lower Big Hole watershed, the valley bottom expands and then contracts numerous times as it enters and exits smaller canyon section near Maiden Rock, Glen, and Notch Bottom. Evergreen forests largely disappear in the lower watershed and the primary land cover is grass rangeland. Cottonwoods become abundant in the riparian corridor along the Lower Big Hole.

Although the remoteness and harsh winters of the Big Hole Valley have deterred substantial growth and development, humans have still drastically altered the landscape of the valley. Historically, the Big Hole valley served as an important trade route and foraging area for Native Americans; but due to the harsh winters, year-round habituation did not occur until European-American settlement. Trappers were among the first European-Americans in the area in the early 19th century. Abundant beavers and a thriving national and international fur trade brought trappers to valley. However, extensive trapping led to the near extirpation of beavers in the area and the fur trapping was in decline by the 1840s (Davis 2015). The fluvial geomorphology of the valley is expected to have been drastically altered by the removal of beavers. The removal of beaver dams likely contributed to faster flows, increased erosion, incision and simplification of the stream channel, decreased retention of sediment, decreased riparian cover, decreased floodplain connectivity, lowered groundwater tables and summer base flow, and loss of habitat diversity (Pollock et al. 2014). Habitat suitability models have been developed to inform potential restoration efforts involved in relocating beavers to areas where they may have the greatest positive impacts in the Big Hole watershed (Carpenedo 2011).

Discovery of gold in the inter-mountain West in 1862 brought a new wave of European-Americans to the area. Compared to other areas in the region, relatively little mining occurred in the Big Hole watershed with most mining occurring in the 1860s to 1890 and the 1930s to 1940s. However, legacy mines have contributed to sediment and metal impairments in the watershed. Potential molybdenum mining and oil and gas extraction may pose threats to the watershed in the future.

Agriculture quickly followed mining and provided a means to support the mining boom towns in the area. The high quality of hay in the Big Hole valley quickly led to agriculture becoming the dominant industry in the valley, which remains true to this day. While the US Forest Service is the dominant landowner in the watershed, the vast majority of the land in the valley bottom is privately owned by a small number of large ranches.

Livestock are known to congregate along river corridors and contribute to the loss of riparian vegetation and bank erosion. Much of the recent restoration work in the watershed has focused on fencing and the revegetation of riparian corridors. Flood irrigation remains the primary method to grow hay in the region. A trend of converting hay meadows to irrigated pastures has been observed in the Upper Big Hole River (DEQ 2009a). This is associated with an increase demand for water as irrigation of hay meadows typically ceased after the first cutting in early summer whereas irrigation of pastures for forage production occurs throughout the summer. Irrigation withdrawals contribute to detrimental low flow and high-water temperatures in the summer. A drought management plan was adopted by the Big Hole Watershed Committee, Montana Department of Fish, Wildlife and Parks, Department of Natural Resources and Conservation, and the US Natural Resources Conservation Service in 1997 and is amended every 2 years to address these concerns.

Urban and residential development remains minimal in the Big Hole watershed. Jackson, Wisdom, Wise River, Dewey, and Melrose represent the major towns in the watershed, with the majority of these with populations less than 100. Although no substantial growth has been observed, it is unlikely that the area will indefinitely avoid the high levels of growth being experienced throughout Southwest Montana.

**Primary Impairments – Sediment, Nutrients, Metals, Temperature**

The most significant sources of sediment loads include upland erosion associated with grazing, streambank erosion related to roads and riparian vegetation removal associated with agriculture, unpaved roads, and natural sources. Significant sources of nutrients included natural and agricultural sources, which include livestock grazing and hay/alfalfa production. Metal impairments were limited to the Middle and Lower watershed, with significant sources including atmospheric deposition from the Anaconda smelter and acid mine drainage from abandoned mines. Although the Anaconda smelter shut down in 1980 (began running in 1918), its effects on the environment are still being felt. The deleterious effects of atmospheric deposition of heavy metals are compounded by increased sediment erosion due to sulfur dioxide from the smelter killing the vegetation in the surrounding area. Impairments from the Anaconda smelter are particularly prevalent in the Mt Haggin Wilderness Area. Water temperature impairments have been attributed to agricultural practices that have increased erosion, leading to wider and shallower stream channels, decreased riparian vegetation, and shading from livestock grazing, and decreased stream flows from irrigation withdrawals.

**Middle & Lower River TMDL Report**: [http://deq.mt.gov/Portals/112/water/wqpb/CWAIC/TMDL/M03-TMDL-02a.pdf](about:blank)

**Upper River & North Fork Big Hole TMDL Report:**

[http://deq.mt.gov/Portals/112/water/wqpb/CWAIC/TMDL/M03-TMDL-01a.pdf](about:blank)

**Final 2018 Water Quality Integrated Report:**

[http://deq.mt.gov/Portals/112/Water/WQPB/CWAIC/Reports/IRs/2018/2018\_IR\_Final.pdf](about:blank)

**Lower River:** Reporting Cycle 2018

([http://svc.mt.gov/deq/dst/#/app/cwaic/report/cycle/2018/auid/MT41D001\_010](about:blank#/app/cwaic/report/cycle/2018/auid/MT41D001_010))

**Detailed Assessment Report & Overall Condition of Segment:**

([http://deq.mt.gov/Portals/112/Water/WQPB/CWAIC/Reports/2018/MT41D001\_010.pdf](about:blank) )

“Aquatic Life & Cold Water Fishery: BIOLOGY - moderate impairment: increased brown trout mortality rates, decreased Age IV+ numbers, decreased YOY survival and recruitment have been correlated with low flows and high temperatures associated with low water years and exacerbated by irrigation withdrawls; trout populations are also affected by angling pressure, implementation of special regulations, stocking efforts, interspecies competition, available habitat, spawning areas and the Divide dam barrier; macroinvertebrate & periphyton sampled in 1978 do not indicate impairment, but these 1977 samples may not be representative of the biologic community's response to low flow conditions; CHEMISTRY - severe impairment due to > 150% chronic standard exceedence for Lead & Cadmium; < 150% chronic standard exceedence for Cu & Zn exceedences and numerous, well-documented temperature standard exceedences. HABITAT - moderate impairment due to dewatering which is well documented in MFWP reports & substantiated by USGS gaging at Melrose and Twin Bridges; channel alteration via stabilization structures,irrigation diversions & road encroachment; management, development of alternative water sources & drought plan have and will mitigate dewatering impacts, but additional data should be collected to document long term effects on biota. Agriculture: no excessively high salinity and toxicant levels noted in water chemistry data. Industrial: no excessively high salinity and turbidity levels noted in water chemistry data. Drinking Water: Lead and Cadmium human health standard exceedences.”

**Middle River:** Reporting Cycle 2018

([http://svc.mt.gov/deq/dst/#/app/cwaic/report/cycle/2018/auid/MT41D001\_020](about:blank" \l "/app/cwaic/report/cycle/2018/auid/MT41D001_020) )

**Detailed Assessment Report & Overall Condition of Segment:**

([http://deq.mt.gov/Portals/112/Water/WQPB/CWAIC/Reports/2018/MT41D001\_020.pdf](about:blank))

“Aquatic Life & Cold Water Fishery: BIOLOGY -moderate impairment: periodic dewatering which occurs during low water years and exacerbated by irrigation withdrawls limits full potential of grayling and rainbow populations; trout populations are also affected by angling pressure, implementation of special regulations, stocking efforts, interspecies competition,available habitat, spawning areas and the Divide dam barrier; macroinvertebrates sampled in 1990 indicate slight impairment; CHEMISTRY - severe impairment due to Lead and Copper aquatic life standard exceedences (> 150% of chronic std). These single data points for Cu and Pb are over 21 years old at the time of this assessment update(11/03). More recent water chemistry data is needed for the Big Hole. Temperature standard exceedences associated with low flows; (Continued below. Comments pertain to both beneficial uses. HABITAT moderate impairment due to periodic dewatering. The lowest flows are about 100 cfs. The low streamflow and temperature problems persist as evidenced by the angling closures in 2002 and 2003; documented habitat degradation in the form of bank trampling & riparian vegetation degradation due to grazing; management, development of alternative water sources & drought plan have and will mitigate dewatering impacts, but additional data should be collected to document long term effects on biota. Agriculture: no high salinity or toxicant levels noted in water chemistry data. Industrial: no high salinity or turbidity levels noted in water chemistry data. Drinking Water: Lead human health standard exceedence.”

**Upper River:** Reporting Cycle 2018

([http://svc.mt.gov/deq/dst/#/app/cwaic/report/cycle/2018/auid/MT41D001\_030](about:blank" \l "/app/cwaic/report/cycle/2018/auid/MT41D001_030))

**Detailed Assessment Report & Overall Condition of Segment**:

([http://deq.mt.gov/Portals/112/Water/WQPB/CWAIC/Reports/2018/MT41D001\_030.pdf](about:blank))

“Aquatic Life & Cold Water Fishery: BIOLOGY - moderate impairment: grayling population is severely depleted relative to historical levels due to the following combination of stressors: dewatering, high water temperatures, non-native species competition, habitat degradation & angling pressure, although populations appear to rebounding over the past the several years, the fishery is still periodically diminished by adverse temperature and flow conditions; CHEMISTRY - moderate impairment: temperature standard exceedences commonly occur during periods of drought when low flows are further reduced by irrigation withdrawls. HABITAT - moderate impairment due to dewatering (commonly below the 60 cfs recommended instream flow and periodically below the 20 cfs recommended minimum survival flow for grayling) has been documented in numerous water years for prolonged periods of time; riparian veg removal, channel instability noted; road encroachment; management, development of alternative water sources & drought plan have and will mitigate dewatering impacts, but additional data should be collected to document long term effects on biota. Agriculture: no high salinity or toxicant levels noted which would preclude use for agricultural purposes. Industrial: no high salinity or turbidity levels noted which would precluded use for industrial purposes. Drinking Water: no human health standard exceedences noted.”

**CCAA**

([https://www.fws.gov/mountain-prairie/es/species/fish/grayling/CCAA\_June2006.pdf](about:blank))

With regard to grayling recovery efforts, work has focused on riparian fencing, increasing stream flows, removing fish barriers and providing fish passageways around irrigation diversions, and stream and riparian restoration. In 2009, MFWP in partnership with USFWS, DNRC, and the NRCS established a Candidate Conservation Agreement with Assurances (CCAA). Landowners are encouraged to enroll in the program and site-specific plans to maintain and/or restore stream and riparian habitat are developed for each property. Participating landowners are assured that no additional regulatory requirements will be applied if Arctic grayling do become listed. A drought management plan was put in place in 1997 through a partnership between the BHWC, MFWP, DNRC, and NRCS and is updated approximately every two years. The purpose of the plan is to mitigate the effects of low stream flows and high-water temperatures through voluntary efforts by landowners to divert less water for irrigation.

# Appendix D – Additional information on sampling sites

**Big Hole near Twin Bridges** (Waterbody #: MT41D001\_010; Monitoring station ID:M03BGHLR21): This site was chosen due to its location near the mouth of the river providing information on what pollutant loads are exiting the river, the presence of a real-time USGS flow and temperature monitoring station, public access, and presence of good macroinvertebrate sampling reaches.

The bridge access on Melrose-Twin Bridges County Road represents the lowest public access point on the Big Hole, approximately 2 miles from where the Big Hole meets the Beaverhead and forms the Jefferson. A side channel forms below the bridge with a diversion that supplies Hamilton Ditch. A USGS flow site is located just below this diversion, approximately a quarter mile below the bridge. The side channel is relatively straight and could provide a good location for macroinvetebrate sampling if flows on the mainstem are too high to safely sample (1000 cfs is the upper limit). During high water, sampling can occur upstream of the bridge from the riprap boulders (side channel is difficult to cross at high flows). Sampling during summer will occur at least a quarter mile below the bridge close to the USGS site.

The Big Hole between Twin Bridges and Divide was listed on the 303(d) list for cadmium, copper, lead, zinc, and temperature. TMDLs were not completed for any heavy metals but were completed for temperature. The Big Hole in this reach was still listed as impaired for cadmium, copper, lead, and zinc on the 2018 303(d) list.

Pennington bridge, located ~5 miles upstream, was also considered as the lowermost sampling site due to macroinvertebrate sampling occurring here at the end of August in 1960 and 2011 (Stagliano and Petersen 2016). However, we feel the macroinvertebrate community at the Twin Bridges access will be comparable to the community at the Pennington Bridge due to proximity and the advantages of real-time flow monitoring outweigh the benefits of sampling replication at Pennington. At least two major irrigation diversions occur between Twin Bridges and Pennington.

Reach between sampling locations: Approximately 27.8 river miles exist between the Twin Bridges site and the next site upstream, Kalsta Bridge. Notable access points in this stretch include Pennington Bridge, Notch Bottom, and Glen Fishing access. The river is highly braided with healthy stands of cottonwoods providing shade and bank stabilization. A natural topographical pinch in the valley bottom occurs at Notch Bottom, which is associated with upwellings of ground water. Valley bottoms have been converted to pastureland while the drainage area consist mostly of arid grass and brush rangeland. A limited area of evergreen forest exists on the higher elevations of McCartney Mountain and the surrounding mountains. Tributaries are rare, small, and mostly intermittent within this reach while irrigation common. Major irrigation outflows in this area include Stevens Slough, Owsley Slough, and Third Slough. Consequently, a large portion of the dewatering occurs in this reach. DEQ 2009b identified the reach around Twin Bridges to be an area of concern for temperature impairments due to the cumulative effects of dewatering. A channel migration zone mapping effort identified the largest avulsion and erosion hazard zones in the watershed occurring in the valley bottom just above Notch Bottom (mapping stopped at Wisdom). Erosion hazard is also naturally high in this reach with large unstable bluffs existing along the banks.

The drainage surrounding this reach includes some of the highest concentrations of abandoned mines in the watershed, especially in the Rochester Creek drainage. New claims to rework the Rochester tailings were noted to have been submitted (DEQ 2009b). Mining began in the 1880s for silver and gold but was generally short-lived. Rock phosphate deposits were mined in the region beginning in the 1950s but were also short lived as they were not sufficiently thick to warrant further production.

Comparing Kalsta to Twin Bridges could provide inferences into pollution loads contributed by the large agricultural operations occurring in the valley bottom between Kalsta and Twin Bridges, and the following tributaries: Lost Creek, Willow Creek, Birch Creek, Nez Perce Creek, Sassman gulch, and Rochester Creek. Willow creek was considered as a sampling location due to the presence of historic data, running through BLM land near its confluence, substantial flow observed in the spring of 2019, and a sediment impairment. However, access on BLM land was fenced and approach to creek would be difficult. Additionally, the stream is highly diverted and complex, with Birch creek appearing to be entirely diverted into Willow Creek.

**Big Hole at Kalsta Bridge** (Waterbody #: MT41D001\_010; Monitoring station ID: M03BGHLR15): The Big Hole at Kalsta was chosen due to public access, real-time USGS flow and temperature monitoring, good sampling habitat, and position downstream of the town of Melrose and associated agriculture in the valley.

Sampling will occur at the Montana Fish Wildlife and Parks (MFWP) fishing access at least a quarter mile below the HW 91 N bridge crossing. The interstate (I-15 S) crosses the river another quarter mile upstream and Rock creek enters at this point as well. The river is confined to a single, relatively straight channel that provides good sampling opportunities. However, the channel on the river left becomes deep and swift and alterations to sampling protocol may be needed.

Melrose is located 8 miles upstream and Glen fishing access is located 5 miles downstream. Macroinvertebrate sampling occurred at Melrose (Salmonfly fishing access) in 1960 and 2011, which may be close enough to allow some comparisons. The site occurs just downstream of a pinch in the valley, with the valley bottom expanding both upstream and downstream. Agriculture is the predominant land use in the valley bottom. Rock creek also has an agricultural operation near its confluence with the Big Hole.

Glen was considered as an alternative to this site but was not chosen due to the USGS flow site at Glen being located on private land and Birch and Willow creek meeting the Big Hole below the Glen fishing access but above the Glen USGS site.

A channel manipulation project was completed below Glen after high water in 1995 changed the river course and left it stranded behind a series of dikes. Three miles of channel were altered/created to re-establish flow into the main channel.

Intervening reach: Approximately 18.4 river miles separate the Kalsta and Maiden Rock sampling locations. A natural pinch in the floodplain occurs near the Kalsta sampling site, with the valley bottom expanding for an approximately 9-mile reach through Melrose before Maiden Rock Canyon. Agriculture is dominant in the valley bottom. A single agriculture operation exists in the Moose Creek drainage near its confluence. The river is mostly one or two channels through this section. Cottonwoods are still common up until Maiden Rock canyon. This section drains the east side of Pioneer mountains, which has large areas of evergreen forest. On the east side of the river are the Highland mountains. Irrigation withdrawals in the watershed are highest downstream of Melrose (DEQ 2009b) and temperature modeling indicates that the stretch between Melrose and Glen are an area of concern for temperature impairments.

Comparing the Kalsta site to Maiden Rock may provide inferences into pollution loads contributed by the town of Melrose, the surrounding agriculture in the valley bottom, and the following tributaries: Rock creek, Browns Creek, Trapper Creek, Grose creek, Camp Creek, Soap Creek and Moose Creek.

The lower Big Hole (Divide to Jefferson) is described as a properly functioning river system, with naturally migrating channel, healthy sediment transport abilities, high pool frequency, healthy riparian zones, and reestablishment of cottonwoods on point bars, and floodplain connectivity (DEQ 2009b). Channel width to depth ratios are lower in this section than in the middle section. DEQ identified rangeland grazing as the primary anthropogenic source of sediment in this area.

**Big Hole at Maiden Rock** (Waterbody #: MT41D001\_010 Monitoring Station ID: M03BGHLR16): Maiden rock was chosen due to the public access, USGS flow and temperature monitoring, river accessibility, and major land form/use change occurring downstream.

The sampling site is just upstream of the Maiden Rock bridge. Moose Creek runs in just below the bridge crossing and USGS flow site while Canyon Creek runs in just above the bridge. The effects of groundwater influx and Canyon Creek on water chemistry at the site should be examined with specific conductance cross sections. Additional sample sites exist upstream (Maiden Rock BLM put in) if major differences exist among cross-sections. Maiden Rock is located at the at mouth of a two-mile canyon. Significant agriculture operations exist upstream of the canyon to Divide, where the river exits a much longer canyon that extends almost to Mudd Creek bridge upstream. Historic phosphorous mines were located at Maiden Rock and in the Canyon Creek drainage. DEQ’s interactive map does not present any historic monitoring sites in this reach.

Intervening reach:

Approximately 24.3 river miles separate the Maiden Rock and the Dickie Bridge sampling locations. The river is mostly confined to a steep canyon between Maiden Rock and Dickie Bridge, with notable exceptions around Divide and Wise River where the floodplain expands briefly. Cottonwoods are present in the expanded floodplain around Divide and up to Wise River but become rare upstream of this point. Above Wise River the riparian vegetation switches to shrubs, primarily willow and conifers, which are primarily located on the south side on the river. The channel is primarily bedrock and large boulders in the canyon, with the floodplain confined within the channel, contributing to high velocities and depths. Channel migration is limited due to the confines of the canyon and a single channel is dominant. Natural shading and large groundwater inputs around Wise River, Greenwood Bottoms, and Maiden Rock Canyon help to decrease water temperatures in this region and offset the thermal warming that occurs in the upper watershed. DEQ 2009b and Lamothe and Magee 2004 note that pool habitat was of poor quality in this reach.

Major tributaries entering between Maiden Rock and Dickie Bridge include Divide Creek, Jerry Creek, and Wise River. The Big Hole from Divide Creek to Pintlar Creek was listed for copper, lead, temperature, and sediment on the 2006 303(d) list and the Big Hole between Divide Creek and the mouth is listed for cadmium, copper, lead, zinc, and temperature.

The Butte-Silver Bow Water Utility Company pumps water from the South Fork of Divide Creek at their Feely plant at Divide; average pumping was 13.4 cfs during July of 2006 (DEQ 2009b). The plant has the capacity to treat 16 million gallons of water/day (2018 Annual Drinking Water Quality Report)

All 2006 303(d) listed streams are assigned an A-1 water quality standard, except Seymour Creek (B-1), above the Butte Water Company intake at Divide and B-1 downstream of Divide. DEQ identified 34 mainstem irrigation diversions between Maiden Rock Canyon and the confluence with the Jefferson.

**Wise River** (Waterbody # MT41D003\_200; Station ID: M03WISE04): The Wise River was chosen as a primary tributary site. The Wise River is the largest tributary of the Big Hole and DRNC flow and temperature monitoring occurs at the site. The Wise River flows 25.7 miles from headwaters to mouth.

Sampling will occur downstream of the town of Wise River on private land owned by Pete Campensure (406-832-3334), who should be called before sampling. Sampling occurs near the location of USGS flow site. The Wise River is not listed for any impairments on the 2018 303(d) list but was listed for sediment and heavy metals on the 2006 303(d) list. The Wise River passes through private land in its lower reaches but is predominantly on public USFS land above the confluence of Deno Creek (~river mile 5). Agriculture and human development is limited above this point as well. A dam failure on Pattengaill Creek in 1927 drastically altered the stream channel and substrate. This led to scouring of the channel and deposition of large cobble/boulder substrate, which is a primary substrate below Pattengaill Creek, and large cutslopes.

Wise river drains a large part of the Pioneer Mountains, including much of the West Pioneer Wilderness Study Area (WPWSA) – the largest remaining roadless area in Southwest Montana (148,150 acres). Wilderness study areas are federal lands without permanent improvements or human habitation that are managed to preserve its natural condition. Initially, the goal of wilderness study areas was to study them for 5 years and use this information to determine if the area should be designated as wilderness. The WPWSA was first proposed for wilderness protections in 1977. Sen. Daines proposed a bill that would release the WPWSA from its wilderness protections, allowing road construction, hunting, mechanical transportation, and potentially opening up these areas to mining. A mineral-resource study identified 8 areas with molybdenum potential, four areas with gold-silver potential, one area with tungsten potential, and one area with barite potential (Berger and Benham 1984). This issue should be followed closely and monitoring on the tributaries arising in the WPWSA should be monitored before any changes in designation occur.

Pioneer Mountain Scenic Byway closely follows the river for the majority of it length. Historic mines, including the abandoned Elkhorn silver mine, are present in the watershed but no active mining occurs. A number of dirt forest service roads exist that likely contribute sediment. However, rangeland grazing has been identified as the primary anthropogenic source of sediment within the watershed. Additionally, the granitic geology of the watershed likely contributes to naturally elevated levels of fine sediment (DEQ 2009b).

Tributaries listed as impaired on the 2006 303(d) list include Gold Creek (sediment), Pattengail creek (sediment), and Elkhorn Creek (sediment, arsenic, cadmium, copper, lead, and zinc). A high priority abandoned mine site exists on Elkhorn Creek (Old Elkhorn Mine) and additional tributaries with abandoned mines include Wyman, Lacy, Gold, Sheep, Adson, and Swamp Creeks. Only Gold creek remains on the 2018 303(d) list, as listed for phosphorus impairment.

**Deep Creek** (Waterbody #: MT41D003\_040): Deep creek was chosen due to it being a large tributary of the Big Hole, public land access, flow monitoring, historical water quality data, and the ability to assess the effects of restoration work.

Deep Creek begins at the confluence of Sevenmile Creek and Tenmile Creek and flows 7.9 miles before its confluence with the Big Hole River. Deep creek is listed on the 2006 303(d) list as impaired due to alteration in stream-side or littoral vegetative covers, flow regime modification, and sedimentation/siltation. Several tributaries of Deep creek, including California, Corral, French, Oregon, Sevenmile, Twelvemile, and Sixmile Creek are also listed for sediment impairments. Additionally, heavy metal impairments (Copper, Arsenic, Lead, Iron) exist on French, California, and Oregon Creek from atmospheric deposition associated with the Anaconda and Washoe smelters, contaminated sediments from acid mine drainage and impacts from abandoned mines.

Gold mining began in the 1860s and logging quickly followed to feed the nearby Washoe smelter. Atmospheric deposition from the Anaconda Smelter has negatively affected vegetation and accelerated upland erosion in the upper portions of Mt. Haggin. Sediment loads are also associated with historic timber harvest in the watershed and livestock grazing, with the Mt Haggin Livestock Company holding a grazing lease within the Mt. Haggin Wildlife Management Area. The volcanic tuff in the area, which is highly erodible, exacerbates sedimentation issues. In the DEQ 2009 TMDL assessment, Deep creek had the second highest sediment loads associated with streambank erosion after the Wise River (correlated with stream discharge) in the Middle and Lower Big Hole. Highway 569 follows the drainage, crosses the continental divide, and connects to Highway 1 near Anaconda. Residential development exists in the drainage but is minimal.

DEQ assessed two monitoring section along Deep Creek in 2005. The upper stretch, Deep 1, is located in the Mt. Haggin Wildlife Management Area downstream of the former roadbed and upstream from the French Creek confluence. The lower stretch, Deep 2, is located in the lower mile of Deep Creek, approximately mid-way between Conner Gulch and the confluence with the Big Hole River.

Much of the Big Hole Watershed Committee’s (BHWC) work has focused on the Deep creek drainage. Projects included removing placer tailings from the floodplain, re-establishing natural stream meanders and reconnecting floodplain and wetlands in French Creek; sediment trapping, upland vegetation restoration, culvert restorations, riparian and floodplain restoration on California Creek, and sediment trapping and upland vegetation restoration on the Mt. Haggin uplands. BHWC is also developing stream, wetland, and riparian restoration projects in mining-impacted stretches of Oregon Creek. Groundwater upwellings and springs occur near the mouth of the river.

**Big Hole at Mudd Creek** (Waterbody #: MT41D001\_020) Mudd Creek bridge was chosen due to the public access, USGS flow and temperature monitoring, river accessibility, and its location near the downstream end of upper Big Hole Valley. The Upper Big Hole planning area begins just upstream of the Mudd Creek site.

The sampling site is located approximately 1000 feet below the Mudd Creek Bridge in a channel wide riffle. Public access becomes more limited above this site. The river is accessible on the North side at a few roadside locations along the Lower North Fork Road, relatively close to Mudd Creek Bridge, and at a few locations along the highway on the South side. A small BLM access area is located just upstream of the confluence with Pintlar Creek.

Intervening Reach:

Approximately 21.2 river miles exist between sampling sites at Mudd Creek bridge and Wisdom. Major tributaries that enter in this stretch include the North Fork of the Big Hole, Swamp creek, Steel creek, Plimpton creek, and Pintler Creek. Upstream of Mudd Creek bridge the Big Hole valley expands. With an area of 32 x 52 miles and elevation greater than 6,000 feet, the upper Big Hole Valley is the widest and highest elevation valley in western Montana. Channel slope is low within the valley. Wetland areas are common around the confluence with the North Fork of the upper Big Hole. The valley is bordered by the Beaverhead Mountains to the west, the Pioneer mountains to the east, and the Anaconda Range to the North. The large valley bottom is primarily privately owned and used for agriculture and ranching. Flood irrigation is the primary method for irrigation in the Big Hole Valley.

The river is a single channel from Mudd Creek Bridge upstream to the confluence of Pintlar Creek. The river is relatively wide and minimal riparian vegetation exists both upstream and downstream of Mudd Creek Bridge. Upstream of Pintlar Creek, the river becomes highly braided all the way to Wisdom. This change is attributed to an increase in the sediment load relative to the carrying capacity of the river, resulting in the deposition of sediment which from sand bars and islands (BHWC 2013). Comparisons to historical photos (1940s) indicate significant reductions in riparian shrub cover and reductions in channel braiding. These factors are attributed to increased erosion, over widening of the channel, decrease in habitat diversity, and increased temperature. Areas where historic aerial photos are available indicate an 81 percent reduction in riparian shrub cover (DEQ 2009a). The carrying capacity of the river in this stretch is likely decreased by water seeping into the groundwater (losing reach; Berger 2007).

Public access is very limited in the intervening stretch, with no bridges and only a single small chunk of BLM land just upstream of the Pintlar Creek confluence.

**North Fork Big Hole (Waterbody #: MT41D004\_010):**

The N. Fork was chosen in an effort to better understand upper river nutrient loading at the Wisdom and Mudd Creek sites found in 2020. The N. Fork enters the Big Hole River between the Wisdom and Mudd Creek sites and flows through and multiple cattle operations. The N. Fork has multiple bridge crossings, the furthest downstream of which was chosen as the sampling site due to its proximity to the confluence with the Big Hole.

**Big Hole at Wisdom (Waterbody #: MT41D001\_030)**:

Wisdom was chosen due to the USGS flow monitoring site, river accessibility, and strategic location within the upper Big Hole Valley. The sampling site is located approximately 0.5 miles below the bridge in the town of Wisdom. This stretch of river was listed for temperature impairment in 2006; a temperature TMDL was completed and the reach has since been removed from the 303(d) list. The site is accessed across land owned by Stanley Rasmussen (406-689-3270) but is leased by Mark and Sherry Raymond (406-689-3184) who own the Wisdom Marketplace. Owners and leasers approve of the program and the Raymond’s enjoy hearing about the progress of the program. Large cattle and ranching operations exist both upstream and downstream of the sampling site and riparian fencing appears uncommon.

Intervening Reach:

Approximately 22.3 river miles exist between the Wisdom and Jackson sampling site. A number of substantial tributaries merge within this reach, including Rock Creek, Big Lake Creek, Big Swamp Creek, Miner Creek, and Governor creek. Wetland areas become common upstream of the Big Lake Creek Road crossing. An additional USGS flow monitoring station exists at the confluence of Miner Creek with the Big Hole on private land. Large cattle and agricultural operations exist within this reach and the land bordering the river is entirely privately owned by Dick Hirschy. Access is limited to bridge crossings.

Confluence consulting and MFWP worked together to restore connectivity between the Big Hole and Rock Creek, which had previously been fragmented by a large irrigation ditch that intercepted the entire flow of Rock Creek. Almost a mile of the channel was relocated, eroding banks were stabilized, and pool habitat was restored on an additional 10,000 feet of channel. Project was completed in the spring of 2007. This change may have contributed to increased erosion at the sample site due to increased flow (Mark Raymond, *pers. comm*.).

**Big Hole at Jackson** (Waterbody #: MT41D001\_030):

The Jackson site was selected for accessibility, USGS flow monitoring, and position at the upstream end of valley. The site is located approximately 3 miles upstream from the town of Jackson at the bridge crossing of Miner Lakes Road. The sampling site is located ~1/4 mile below the bridge crossing. The land is owned by Jackson Ranches, which we have been unable to contact. The location of the site just downstream of the bridge, private land ownership, and the density of the riparian vegetation makes it difficult to access the sampling site without entering the water and potentially contaminating water samples or disturbing macroinvertebrate samples. Given these issues, moving a sampling site further upstream into public land may be beneficial. Moving the sample site to public land in the headwaters is suggested. This stretch was listed for temperature impairment in 2006, a temperature TMDL was completed it has since been removed from the 303(d) list.

Upstream Reach:

Approximately 8 miles exist between the sampling site and the next USGS flow gage located at Skinner Meadows. Wetland areas are common in this intervening stretch. Around Skinner Meadows, the river exits the forested foothills and enters the valley bottom. A small section of National Forest Land exists below the USGS flow site at the Saginaw Bridge Crossing. This is an appealing sample site but the contamination issues present at the Jackson site are also present here, as public access is only available downstream of the bridge. A ranching operation also occurs just upstream this site. Numerous sampling opportunities occur upstream in public USFS land.

**Big Hole at Skinner Meadows (Waterbody #:** MT41D001\_030)**:**

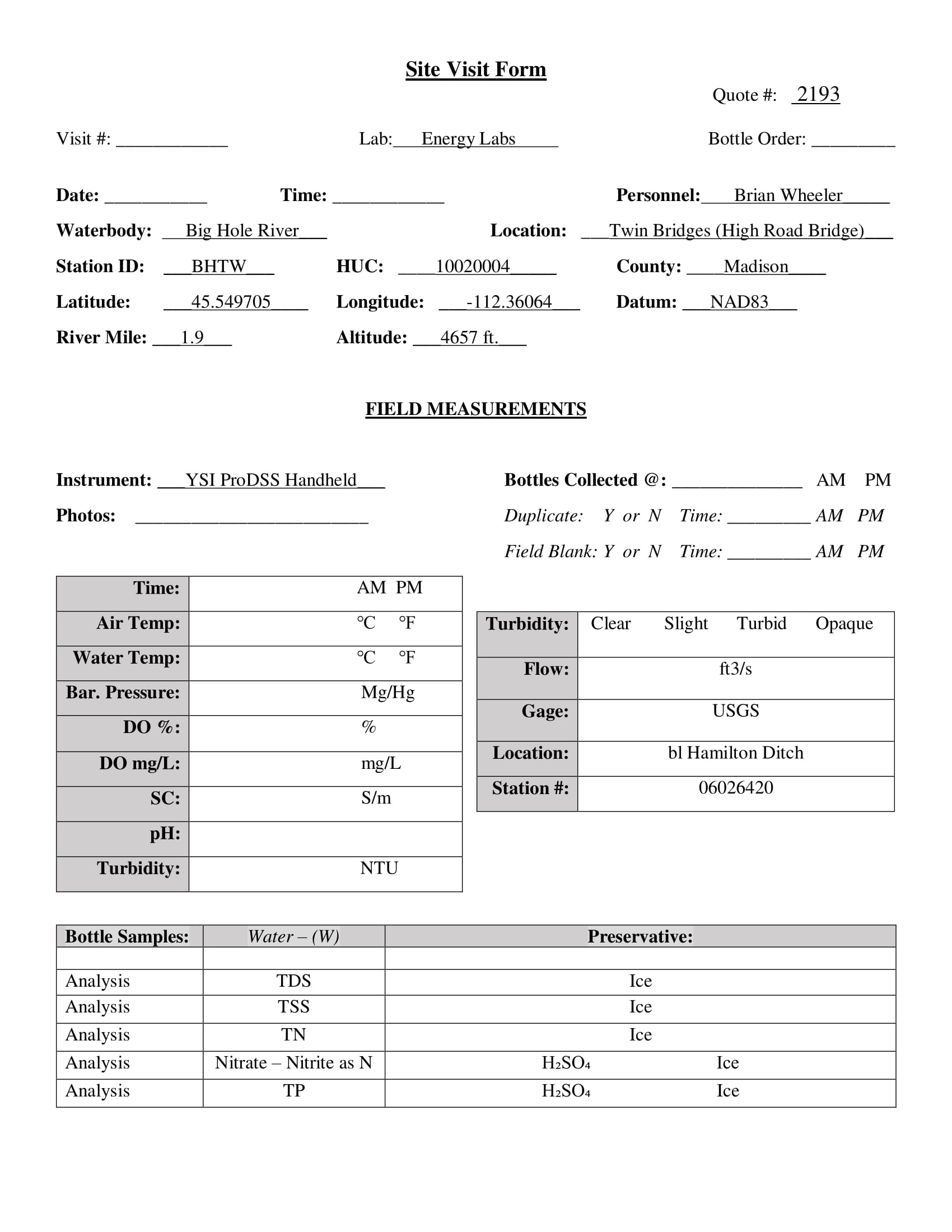
This site was chosen as the headwaters site, at the lower end of Skinner Meadows, to gain insight into the chemical health of the Big Hole upstream of cattle operations. This site is on public USFS land.

# Appendix E – Pre-sampling Checklist

* Check equipment list and ensure all necessary equipment is packed and organized
  + Print off the appropriate number of Field Visit Forms. Extra forms should be printed in case forms are damaged or lost
  + Count the number of sample bottles and ensure the correct number
  + Call landowners if necessary
  + [REDACTED] wishes to be contacted prior to accessing the Wise River across his land. He will want to know when you are sampling and what car you are driving.
  + Complete calibration of YSI ProDSS handheld meter
    - If possible, calibration should be conducted in the same environment the probe is stored in (i.e. indoors); large swings in temperatures during/before calibration should be avoided
    - Conductivity/temperature sensor should be cleaned with the supplied pipe brush daily
    - Calibration of turbidity, pH, and conductivity can be conducted the day before sampling to allow for time for any troubleshooting. Dissolved oxygen calibration should occur the day of sampling.
      * Instrument-specific operations and maintenance manuals are kept with the instrument
      * Calibration results should be recorded in the calibration log kept with the instrument
      * Expiration dates of calibration solutions should be checked before calibration
      * Never accept calibrations with error messages, follow troubleshooting tips in the “YSI-ProDSS User-Manual” if error messages arise
      * If sensors readings are slow to respond to calibration solutions, the sensors may need to be reconditioned (see “YSI-ProDSS User-Manual”)
  + Fill Yeti cooler with two bags of block ice and three bags of cubed ice the morning of sampling
    - Cubed ice can be split into 1-gallon ziplock bags
  + Check hydrograph ([https://waterdata.usgs.gov/mt/nwis/current?type=flow](about:blank)) and ([StAGE (mt.gov)](https://gis.dnrc.mt.gov/apps/stage/gage-report/location/4dc712150dbf41acbcabe289f3383b0c?msclkid=25298457b45611ecb7017732bb038273) and weather and make adjustments to sampling plan if necessary
    - High flows that are sufficiently powerful to mobilize bed sediments can lead to the burial, scour or export of benthic producers and organic matter. Such events can warrant the rescheduling of sampling. Additionally, high flows can inundate areas that were previously dry. This should be considered when selecting macroinvertebrate sampling sites, as newly wetted sites will not have had sufficient time to be colonized.

# Appendix F – Field forms

**Site Visit Form**



**Aquatic Plant Visual Assessment Form (wadeable streams)**

