MUSSELSHELL SEDIMENT SAMPLING - 2015

Sampling and Analysis Plan

Prepared for:

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY
Water Quality Monitoring and Assessment and Water Quality Management Sections, Water Quality Planning Bureau
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1.0 Introduction and Background Information

The Musselshell watershed is located in central-eastern Montana and includes five major (4th level) basins; Upper Musselshell, Middle Musselshell, Lower Musselshell, Flatwillow Creek and Box Elder Creek. The watershed spans 11 counties including; Meagher, Wheatland, Golden Valley, Musselshell, Fergus, Petroleum, Sweetgrass, Stillwaterm Yellowstone, Rosebud, and Garfield. The majority of the watershed is within the Northwestern Great Plains Level III Ecoregion, with some waterbodies originating in the Middle Rockies Level III Ecoregion. Most waterbodies are designated as C-3 use classes, with several B-1 and B-2 use classes within the Upper Musselshell Basin. The watershed consists of 53 sub-basins (5th level) and 68 waterbodies (including all segments of the mainstem, all streams and lakes/reservoirs – see Attachments A and B).

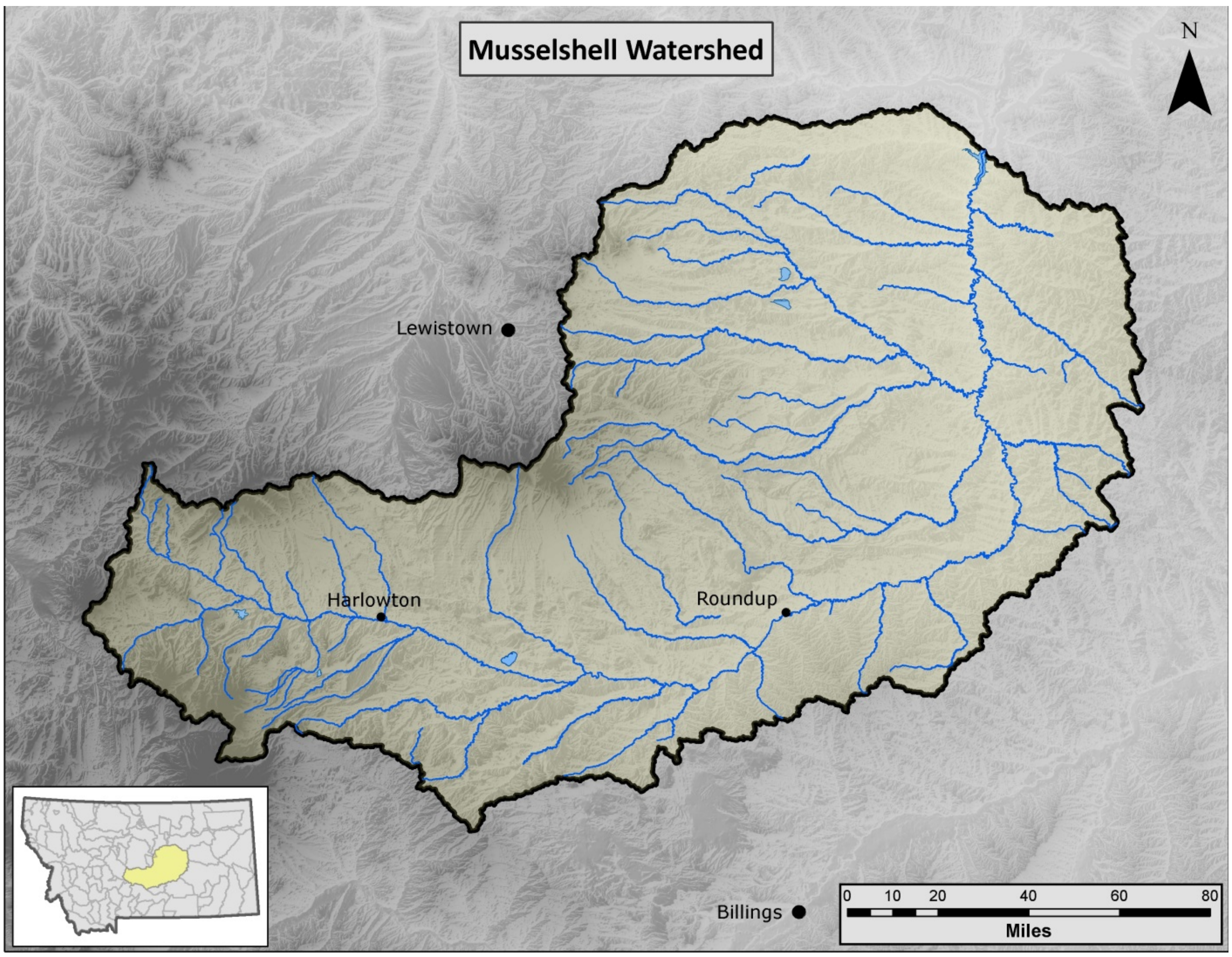

Figure 1-1. Location Map of the Musselshell Watershed

The Musselshell Watershed is being monitored as part of a rotating watershed basin approach developed by the Montana Department of Environmental Quality (DEQ) to inform watershed condition reporting and beneficial use support assessment throughout the state. DEQ has developed a watershed risk assessment process to guide watershed planning efforts as part of the rotating basin approach. This process will be used for water program integration across DEQ, as well as with external entities including other agencies and local/regional stakeholders.

This Sampling and Analysis Plan is designed to address the sediment monitoring that will occur in the Musselshell Watershed in 2015. Due to the large size of the watershed, 2015 sediment monitoring will be confined to the Upper and Middle Musselshell Basins. Sediment monitoring will support water quality assessment and total maximum daily load (TMDL) development, if necessary.

2.0 Sampling Design, Project Objectives And Goals

This section describes the project objectives and specific monitoring goals for 2015 sediment monitoring in the Upper and Middle Musselshell Basins, as well as the principles used to develop the sampling design.

2.1 Sampling Planning and Site Selection

2.1.1 Selecting Monitoring Waterbodies

Before monitoring sites were selected, all potential streams to be monitored went through the stratification process (DEQ, 2015a), and subsequent risk assessment and ranking. The stratification process is a GIS-based approach that uses hard breaks to divide waterbodies into comparable reaches, based on level IV ecoregion, Strahler stream order, valley gradient, and valley confinement. Using these breaks, each individual reach is further broken into subreaches using soft breaks. Soft breaks are determined by characteristics such as land use and land cover, tributary confluences, beaver activity, etc. The reaches are classified into reach types, which display the specific ecoregion, valley gradient, stream order, and confinement for that individual reach. For example MR-0-3-U is the reach type that represents the Middle Rockies ecoregion (**MR**-0-3-U), 0-<2% gradient (MR-**0**-3-U), stream order 3, (MR-0-**3**-U), and unconfined channel (MR-0-3-**U**).

This process also identifies low gradient, depositional areas ideal for monitoring sediment parameters. Additionally the process includes an aerial riparian assessment for each subreach, which identifies riparian vegetation and condition, changes in land use and land cover, and potential anthropogenic sediment sources and their severity of effect. Once the riparian assessment is complete, a risk evaluation based on aerial condition is completed to identify waterbodies of high priority to be monitored. Each reach receives a risk rank from 1-5, with 1 being in reference condition and 5 being severely at risk for impairment. The aerial assessment and risk evaluation are then combined with a resource appraisal to inform monitoring decisions.

Due to the limited resources of the Monitoring and Assessment Section (MAS) to monitor all potential waterbodies for sediment and habitat in the Upper and Middle Musselshell Basins, the risk evaluation, aerial riparian assessment, and resource value appraisal allow MAS to determine which waterbodies to monitor in 2015. Criteria for monitoring included the following:

- Mainstem segment (highest resource value)
- Major tributaries or other waters with high resource value
- Existing 303(d) sediment or habitat listings
- High local interest in restoration or protection
- Highest risk (most in need of restoration)

- Lowest risk (most in need of protection)

Table 2-1 shows the decision rationale behind each waterbody selected for monitoring.

Table 2-1. Waterbodies selected for sediment and habitat monitoring during the 2015 field season

Waterbody	Waterbody Classification	AUID	Sediment Listing	Habitat Listing	Overall Risk Rank	Monitoring Rationale
North Fork Musselshell River, upper	B-3	MT40A002_010	No	No	2.3	Major tributary to the Musselshell
North Fork Musselshell River, lower	B-3	MT40A002_010	No	No	2.3	Major tributary to the Musselshell
Mill Creek	B-3	MT40A002_040	Yes	Yes	1.5	Listed for sediment and habitat
Trail Creek	B-3	MT40A002_030	Yes	No	2.5	Listed for sediment
South Fork Musselshell River	B-3	NA	No	No	2.7	Major tributary to the Musselshell
Cottonwood Creek	B-3	NA	No	No	2.2	Major tributary to South Fork Musselshell River
Miller Creek	B-3	NA	No	No	2.8	Major tributary that makes up most water entering the Musselshell from Little Elk Creek
Big Elk Creek	B-3	NA	No	No	2.7	Major tributary
American Fork	B-3	NA	No	No	2.41	Major tributary
Musselshell River, North and South Fork confluence to Deadman's Basin Diversion Canal	B-3	MT40A001_010	Yes	Yes	2.8	Mainstem, sediment and habitat listing
*Fish Creek	C-3	MT40A002_070	No	Yes	4.38	Major tributary, habitat listing and high risk
Careless Creek, upper	C-3	NA	No	No	3.34	Major tributary, habitat listing in lower segment
Careless Creek, lower	C-3	MT40A002_050	No	Yes	3.34	Major tributary, habitat listing
*Big Coulee Creek	C-3	NA	No	No	4.63	Major tributary; high risk
*Painted Robe Creek	C-3	MT40A002_080	No	Yes	3.9	Major tributary; habitat listing
*Currant Creek	C-3	NA	No	No	3.9	Major tributary
*Half Breed Creek	C-3	MT40A002_090	No	No	4.4	Major tributary; high risk
North Willow Creek	C-3	MT40C002_010	Yes	No	3.3	Major tributary, listed for sediment

*These waterbodies will be monitored in 2015 if time allows, if not they will be monitored in 2016. Sites have not been selected for these waterbodies at this time. If sites are planned for 2015, an addendum will be written to this Sampling and Analysis Plan.

2.1.2 Selecting Monitoring Sites

Once the stratification process and risk assessment was completed for the Upper and Middle Musselshell Basins, sites were selected. When possible, sites were chosen to represent the varying degrees of riparian condition and risk score. Low gradient sites with a Strahler stream order of 2 or greater were selected as the effects of excess sediment are most apparent in low gradient, unconfined streams larger than 1st order. Sites selected for monitoring will be contained within a single reach.

In addition to monitoring sites determined to be at risk for sediment and habitat impairment, sites have also been selected to represent potential best management practices within the watershed. These sites may serve as good examples of sediment and habitat conditions in the watershed when all land, soil and water conservation practices are in place.

Table 2-2. Sediment monitoring site names and locations

Waterbody	Reach ID	AUID	Latitude	Longitude	Reach Type	Site Rationale
North Fork Musselshell River- above Bair Reservoir	NMLS 05-01	MT40A002_010	46.64007	-110.5736	GRP-0-2-U	Site is easily accessed from ranch road off Jamison Trail Rd. and access permission is shared with lower Mill Creek
North Fork Musselshell River – above Bair Reservoir	NMSL 06-01	MT40A002_010	46.61455	-110.577	GRP-2-3-C	Site is easily accessed from ranch road off Jamison Trail Rd. and represents unique reach type
North Fork Musselshell River – below Bair Reservoir	NMSL 08-01 (1)	MT40A002_010	46.56288	-110.5107	GRP-0-4-C	Site is easily accessed from ranch road off Hwy 12 and shares access with lower Trail Creek
North Fork Musselshell River – below Bair Reservoir	NMSL 08-01 (2)	MT40A002_010	46.57269	-110.5365	GRP-0-4-C	Alternate to NMSL 08-01 (1)
North Fork Musselshell River – below Bair Reservoir	NMSL 12-10 (1)	MT40A002_010	46.48146	-110.275	GRP-0-4-U	Site captures condition at mouth and represents high risk for sediment and habitat impairment.
North Fork Musselshell River – below Bair Reservoir	NMSL 12-09 (2)	MT40A002_010	46.48642	-110.3008	GRP-0-4-U	Alternate to NMSL 12-10
Mill Creek – mid segment	MILL 03-01	MT40A002_040	46.65864	-110.5612	MR-2-1-C	Waterbody is listed for sediment; site is easily accessed from Lion Camp Creek Rd.
Mill Creek - lower	MILL 04-02	MT40A002_040	46.6422	-110.5729	GRP-2-1-U	Waterbody is listed for sediment; site shares access with NMSL 05-01
Trail Creek – mid segment	TRLC 06-01	MT40A002_030	46.60449	-110.5181	GRP-2-2-C	Waterbody is listed for sediment; site is easily accessed from ranch road off Spring Creek Road

Trail Creek - lower	TRLC 06-04	MT40A002_030	46.56459	-110.5123	GRP-2-2-C	Waterbody is listed for sediment; site shares access with NMSL 08-01
South Fork Musselshell River	SFMR 05-07	NA	46.45305	-110.3557	GRP-0-5-U	Site is easily accessed on public land from Hwy 294
South Fork Musselshell River	SFMR 04-01	NA	46.4132	-110.5441	GRP-0-4-U	Site is easily accessed from Hwy 294 near Lennep
Cottonwood Creek	COTN 03-01	NA	46.43379	-110.4079	GRP-0-4-U	Site is easily accessed from Hwy 294 near mouth of waterbody. Site may be potential reference condition
Cottonwood Creek	COTN 02-02	NA	46.38385	-110.3934	GRP-0-4-U	Site is easily accessed off Cottonwood Creek Road
Big Elk Creek	BELK 09-02	NA	46.42529	-110.0594	GRP-0-4-U	Site is near mouth and is easily accessed from Two Dot Hwy
Big Elk Creek	BELK 08-16	NA	46.32846	-110.0359	GRP-0-4-U	Site represents high risk for sediment and habitat impairment
American Fork	AMER 03-02	NA	46.39211	-109.7583	GRP-0-4-U	Site is near mouth and captures conditions after Lebo Creek enters waterbody
American Fork	AMER 02-09	NA	46.28742	-109.8823	GRP-0-3-U	Site is easily accesses off Hwy 191 and may represent near reference condition
Miller Creek	MILR 04-03	NA	46.4096	-110.163	GRP-0-3-U	Site is easily accessed off Miller Creek Road and captures risk for sediment and habitat impairment due to land use
Miller Creek	MILR 03-03	NA	46.38459	-110.1937	GRP-0-2-U	Reach was included during reconnaissance work and is easily accessed off Moore Byway Road
Careless Creek (Lower)	CARE 11-05	MT40A002_050	46.33485	-109.2169	GRP-0-4-U	Waterbody is listed for habitat; site represents high risk for sediment and habitat impairment
Careless Creek (Lower)	CARE 11-06	MT40A002_050	46.31618	-109.1872	GRP-0-4-U	Waterbody is listed for habitat; site captures conditions at the mouth
Careless Creek (Upper 3)	CARE 11-01	NA	46.37374	-109.2915	GRP-0-4-U	Lower part of waterbody is listed for habitat; site is easily accessed off Jessie Road
Careless Creek (Upper 4)	CARE 11-01	NA	46.40736	-109.3792	GRP-0-4-U	Lower part of waterbody is listed for habitat; site is easily accessed on public land off Wallum Road
North Willow Creek	NWLW 06-04	MT40C002_010	46.72121	-107.9994	GRP-0-4-U	Waterbody is listed for sediment; site is on public land and captures conditions near the mouth
North Willow Creek	NWLW 05-01	MT40C002_010	46.64943	-108.6031	GRP-0-3-U	Waterbody is listed for sediment; site is on public land and represents high risk for sediment and habitat impairment
Upper Musselshell River	MUSL 01-01	MT40A001_010	46.47693	-110.2489	GRP-0-5-U	Waterbody is listed for habitat; site captures conditions as the North and South Fork Musselshell

						Rivers come together
Upper Musselshell River	MUSL 01-03 (1)	MT40A001_010	46.43965	-110.029	GRP-0-5-U	Waterbody is listed for habitat; site captures conditions after several large tributaries enter the Musselshell
Upper Musselshell River	MUSL 01-05 (2)	MT40A001_010	46.42885	-109.8406	GRP-0-5-U	Waterbody is listed for habitat; site is an alternate location for MUSL 01-03
Upper Musselshell River	MUSL 01-10	MT40A001_010	46.40875	-109.6979	GRP-0-5-U	Waterbody is listed for habitat; site captures conditions near the end of the waterbody segment

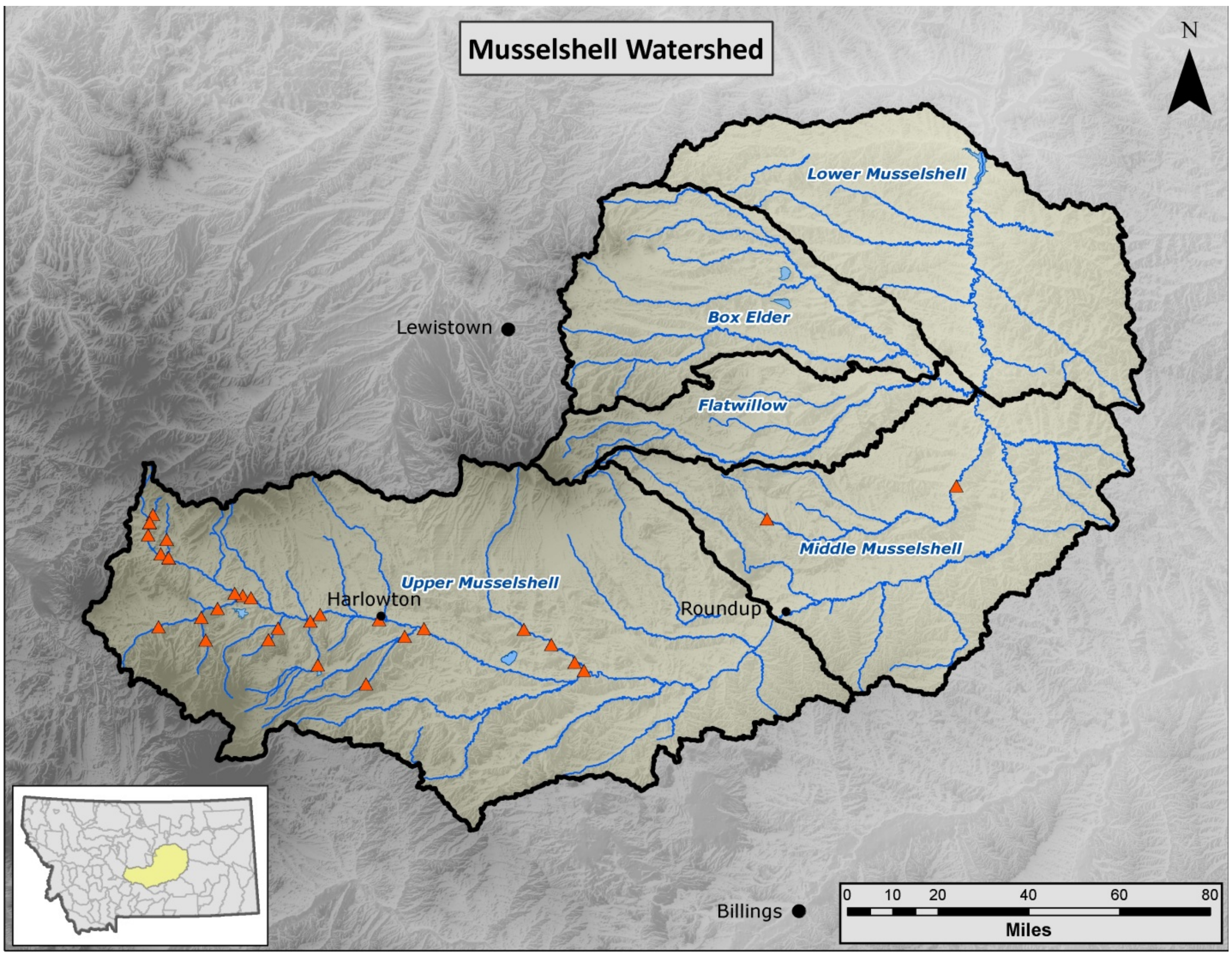

Figure 2-1. Proposed 2015 Monitoring Locations

2.2 Project Objectives and Goals

The primary objectives of this project are:

1. to collect water quality data to facilitate assessment of current sediment condition and beneficial use support of the Upper and Middle Musselshell Basins, and

2. to support the development of a sediment TMDL for assessed waterbodies, if required.

Data will be collected according to the Sediment and Habitat Field Method for Wadeable Streams (DEQ, 2015b). DEQ assessment methods for sediment (Kusnierz *et al.*, 2013) will guide the analysis of the resulting dataset. These methods define the data quality requirements for sediment and guide impairment decisions.

Specific data collection goals for this monitoring project are as follows and will be applicable to all sites in the Upper and Middle Musselshell Basins, with the exception of C-3 streams. Modifications to data collection for these streams are noted in the data collection goals below:

- Identify feature/habitat types throughout each site
- Collect periphyton samples at each monitoring site
- Collect pool-tail grid tosses, and residual pool depth in all pools within the site (C-3 streams may not have classic pool/riffle habitat, or visible substrate, which would preclude pool data collection unless cold water species are identified in MFISH)
- Collect 100 pebble counts in four evenly distributed, yet random riffles for a total of 400 pebbles/site (C-3 streams may not have gravel substrate appropriate for pebble counts. If riffles are present on C-3 streams, collect 100 pebble counts per site)
- Collect RSI (riffle stability index) at the depositional feature downstream of each riffle sampled for a pebble count (C-3 streams may not have riffle habitat, which would preclude RSI collection)
- Collect width to depth (W/D) measurements at each sampled riffle (C-3 streams may not have riffle habitat. If not, use measuring rod to determine the shallowest 4 areas of the site and collect width to depth measurements)
- Collect flood-prone width measurements at width to depth measurement location
- Measure slope from the top of the reach to the bottom using a clinometer
- Perform Rosgen Channel Type measurements and calculations at each W/D measurement location
    - Bankfull width
    - Mean depth
    - Width/Depth Ratio
    - Maximum Depth
    - Width of Flood-prone Area
    - Entrenchment Ratio
    - Water Surface Slope
    - Channel sinuosity (this may be done upon return to the office using GIS)

3.0 FIELD PROCEDURES

All field procedures described throughout this Sampling and Analysis Plan are documented in DEQ's Sediment and Habitat Field Method for Wadeable Streams (DEQ, 2015b).

3.0.1 General Sampling Sequence

To minimize site disturbance and avoid biasing results, parameters most sensitive to disturbance will be collected before parameters less sensitive. All sampling activities are assuming a crew of three for sediment monitoring parameters and an additional two team members for greenline and bank erosion hazard index (BEHI) monitoring. The following sequence of activities will be followed at each sediment monitoring site (**Table 2-2**):

1. Georeference and photograph the site start. Determine site length by measuring bankfull height and width. (This step may be omitted if bankfull width is obviously less than 26 ft.) While moving upstream from the start, 2 people will flag, map, and record all habitat features and EMAP reaches.
2. The third team member will follow the mapping/flagging team and begin collecting periphyton at each flagged transect.
3. Once the flagging/mapping team reaches the minimum site length, they will georeference and photograph the end point. The third team member should be done sampling periphyton before moving on.
4. Once periphyton collection is complete, the team will move downstream collecting residual pool depth and pool tail grid tosses. The team will also ensure all mapping and flagging is correct.
5. Greenline and BEHI data collection can begin at this time as long as both teams leave riffle habitat undisturbed until riffle data is collected. Tapes will be strung along the streambank from downstream to upstream.
6. Once pool data is collected, the sediment team will move back upstream collecting riffle cross section, pebble counts, riffle stability index, and flood-prone width measurements.
7. At this point, the greenline and BEHI teams may collect data anywhere within the site.
8. The sediment team will collect slope from upstream to downstream.
9. Finally the sediment team will complete the Rosgen channel type field forms and the entire crew will complete a site summary.

3.1 BIOLOGY SAMPLES

3.1.1 Periphyton

Periphyton samples will be collected at all sites (**Table 2-2**). Periphyton will be collected with the EMAP sitewide approach using the PERI-1mod method (DEQ 2012b). It is a single composite sample representing a miniature replica of the stand of algae which are present at the study site. Micro- and macroalgae will be collected using this protocol. Periphyton data will be used as a diagnostic for sediment impairment when physical parameters fail to yield a clear result.

3.2 SEDIMENT MONITORING PARAMETERS

All sediment monitoring parameters will be collected at each monitoring site according to stream classification (**Table 2-2**).

3.2.1 Determine Site Length

Identify bankfull height using the following indicators (all may not be present):

- **Examine streambanks for an active floodplain.** This is a relatively flat, depositional area commonly vegetated and above the current water level, unless there is a large amount of spring runoff or there has been a substantial rain event (i.e., stream running at bankfull stage).
- **Examine depositional features such as point bars.** The highest elevation of a point bar usually indicates the lowest possible elevation for bankfull stage. However, depositional features can form both above and below the bankfull elevation when unusual flows occur during years preceding the survey. Large floods can form bars that extend above bankfull whereas several years of low flows can result in bars forming below bankfull elevation.
- **A break in slope of the banks and / or change in the particle size distribution** from coarser bed load particles to finer particles deposited during bank overflow conditions.

- **Define an elevation where mature key riparian woody vegetation exists**. The lowest elevation of birch, alder, and dogwood can be useful, whereas willows are often found below the bankfull elevation.
- **Examine the ceiling of undercut banks.** This elevation is normally below the bankfull elevation.
- **Stream channels actively attempt to reform bankfull features such as floodplains after shifts or down cutting in the channel.** Be careful not to confuse old floodplains and terraces with the present indicators.

Use bankfull height to measure bankfull width. Bankfull width will be measured at five locations. The 1st bankfull width measurement will be taken at the downstream start location of the site. The 2nd-5th bankfull width measurements will be taken upstream from the 1st measurement at 53 foot intervals following the thalweg.

NOTE: If bankfull width is obviously less than 26 feet, skip these five measurements and continue to Section 3.2.2.

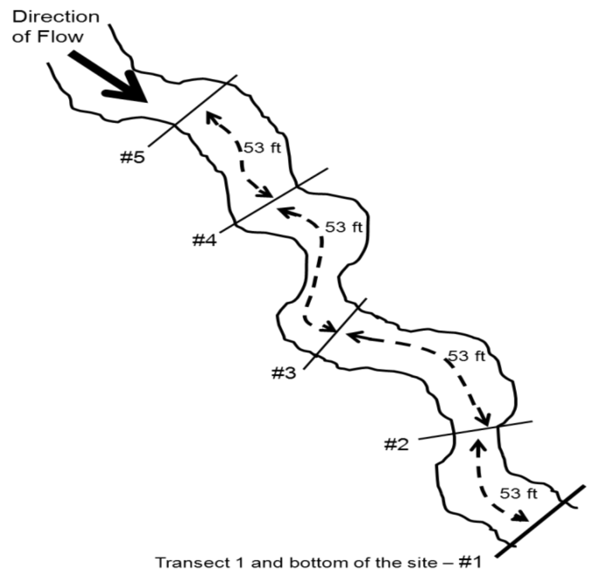

Figure 3-1. Bankfull measurements

These measurements will be recorded on the "**Assessment Location, Map and Slope**" form and averaged. The averaged value will be used to determine the width category and the minimum site length using **Table 3-1**.

Table 3-1. Width Categories for Determining Site Length

Average bankfull width (ft)	Width Category	Minimum site length (ft)
0 to 26	26	520
26.1 to 33	33	660
33.1 to 39	39	780
39.1 to 46	46	920
46.1 to 53	53	1060
53.1 to 59	59	1180
59.1 to 66	66	1320
66.1 to 72	72	1440
>72	79*	1580

* If a stream's average bankfull width is greater than 79 ft, the minimum site length will be 20 times the measured value.

3.2.2 Delineate Pools and Riffles and Map the Site

Each sediment monitoring site will begin at the downstream extent of a pool (pool tail). If no pools are present, the site will begin at the predetermined GPS start coordinates. GPS coordinates and photographs will be taken at the start of each site. The site will be measured using measuring tapes or a chain man. Features will be mapped on the "**Assessment Location, Map and Slope**" form. All pool and riffle features will be flagged and mapped moving upstream.

Pools and riffles will be labeled with a number and a distance from the downstream extent of the site, beginning downstream and working upstream. Only main channel pools where the thalweg runs through the pool will be considered. No backwater or side channel pools will be measured. Pools and riffles will be recorded on the "**Riffle and Pool Count**" form.

3.2.3 Measure Pool Data

Once all features are mapped, residual pool depth will be collected on all wadeable pools. Pool tail grid tosses will be collected on all scour pools meeting the depth requirement of at least 1.5 times the pool-tail depth along the pool's thalweg in all B-3 streams. Grid tosses will not be conducted in C-3 streams or where habitat does not make it possible. This data and pool size will be recorded on the "**Residual Pool Depth and Pool Tail Fines**" form.

Residual pool depth (d_r) will be calculated by measuring the deepest point in the pool along the thalweg (d_p) and subtracting the depth of the riffle crest (d_{rc}). See **Figure 3-2**.

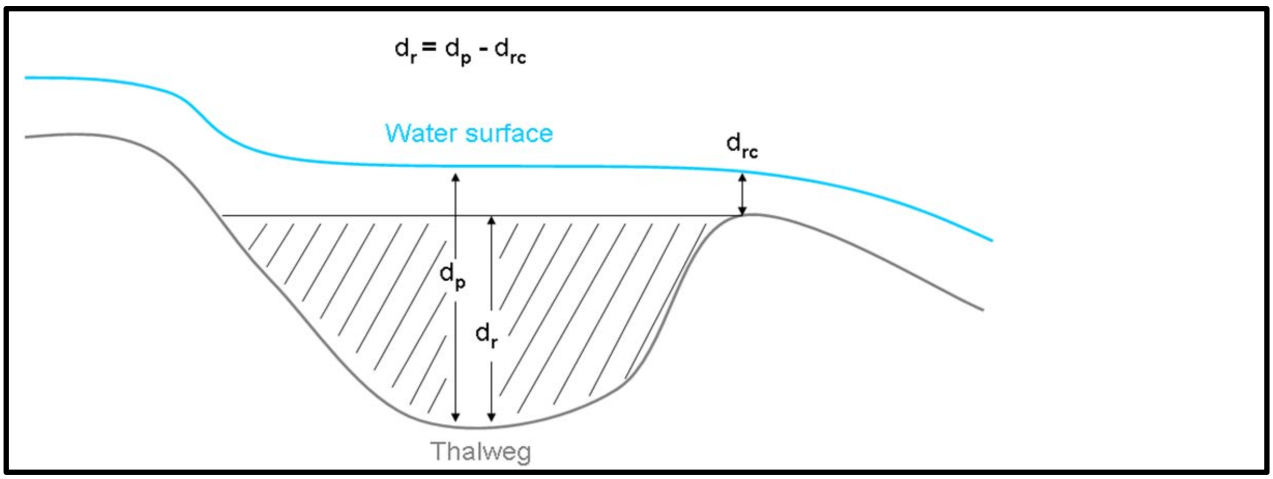

Figure 3-2. Residual Pool Depth

Grid tosses will occur at points 25%, 50%, and 75% across the pool's wetted width at a distance that is 10% of the pool's length or 1 m from the pool tail crest, whichever is less (**Figure 3-3**). The number of the internal intersections (49 total) completely covering particles will be counted and recorded. The median (i.e., D50) substrate size class of the substrate under the grid will be estimated for each grid toss and recorded as: s = sand (< 2 mm), g = gravel (2 mm - 64 mm), c = cobble (64 mm – 256 mm), b = boulder (256 mm - 2048 mm), and bd = bedrock (> 2048 mm). If the grid falls on a small boulder or larger particle, these intersections will not be assessed. The number of particles < 6mm out of the total number assessed will be recorded on the "**Residual Pool Depth and Pool Tail Fines**" form.

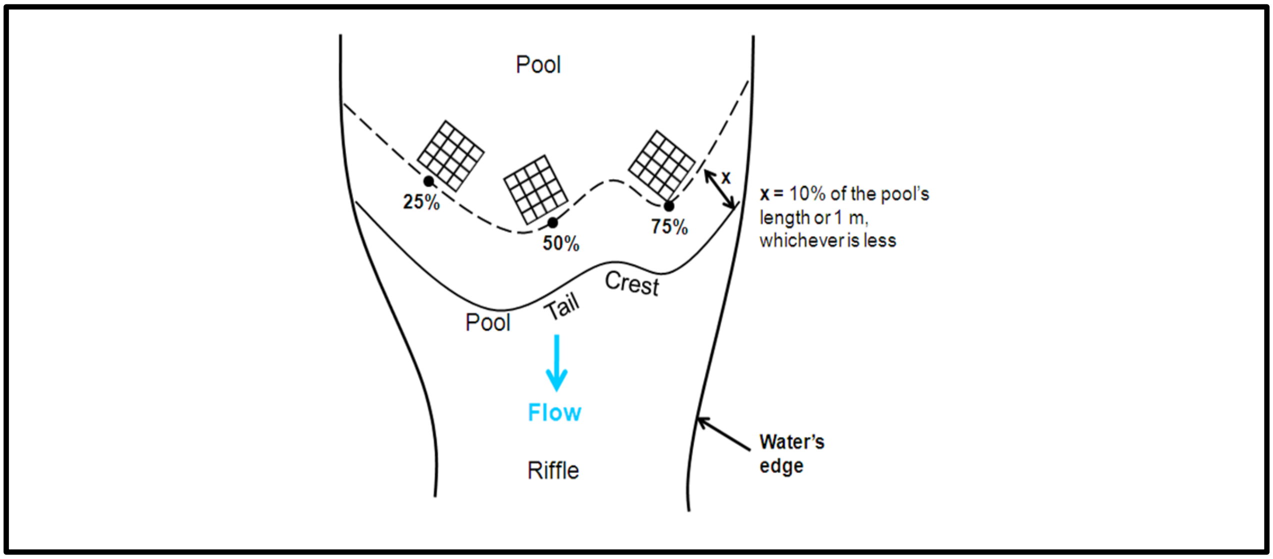

Figure 3-3. Pool-Tail Grid Tosses

NOTE: If waterbody substrate is composed 100% of fine sediment, and/or entire site consists of one pool (common on prairie streams), or if turbidity obstructs substrate observation, pool data will not be collected.

3.2.4 Riffle Pebble Count

Four random, yet evenly distributed riffles will be chosen from the "**Riffle and Pool Count**" form to collect riffle pebble counts, riffle stability index, cross sections, and flood-prone width measurements. A 100 pebble count will be collected at each selected riffle moving downstream to upstream. If fewer than four riffles are present, a total of 400 particles will be counted with the number of particles evenly distributed among the number of riffles samples. Within each riffle, the length will be measured, and four transects will be evenly distributed (from downstream to upstream) at 20, 40, 60, and 80% of the riffle length. Along each transect, 25 sampling locations will be evenly spaced within the bankfull width, so the maximum distance between each is 1/25 of the bankfull width.

Sampling will begin at the downstream transect from river left to river right, then will proceed to the next transect upstream and sample from river right to river left; this pattern will be repeated moving upstream to the final two transects. Each particle will be selected by pointing directly down of the tip of the sampler's boot at each sampling location along the transect. The particle directly below will be selected and measured using a gravelometer and recorded on the "**Riffle Pebble Count**" form. If a particle is too large to move, its size will be estimated.

Warm water streams (C-3) will have a modified riffle pebble count. If classic riffle habitat is not present at any point along the site, a riffle pebble count will not be collected, but the D_{50} will be recorded. If any riffle habitat is present, a 100 pebble count will be collected evenly throughout all available riffle habitat.

3.2.5 Riffle Stability Index

At each riffle sampled for the pebble count, the lateral bar or depositional area directly downstream will be identified. Fifteen dominant large particles that have been recently moved will be identified in this area. Recently moved particles are those brighter in color, not embedded, and lack staining algae, or attached moss. The B-axis of each of these particles (**Figure 3-4**) will be measured and recorded on the "**Riffle Pebble Count**" form.

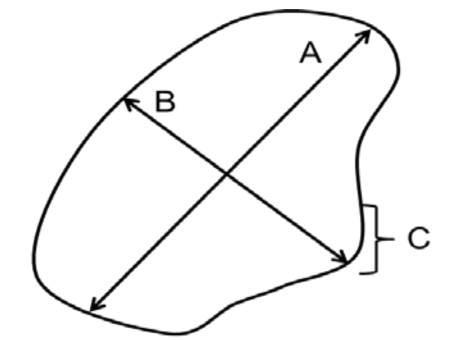

Figure 3-4. Measuring the B-axis

If no depositional feature is present, it will be recorded on the field form

3.2.6 Riffle Cross Section

The width/depth (W/D) ratio will be measured at each of the four riffles sampled for pebble counts. Near the center of each riffle, a cross section will be set up by tightly stretching a tape between pins placed at bankfull height. One of the middle riffle pebble count transects may be used for the cross section. Undercut banks, cattle crossings, old road crossings, former bridge crossings, islands, boulders, bars, brushy banks, logs and log jams, and uneven water surface will be avoided if possible. The bankfull width will be divided to 10 evenly spaced intervals and depth from the channel substrate surface to the tape will be measured. Width and depth measurements will be recorded on the "**Riffle W/D Ratio**" form.

Warm water (C-3) streams likely will not have classic riffle habitat to measure width/depth ratio. If this occurs, cross section measurements will be made at the four shallowest locations throughout the site.

3.2.7 Flood-Prone Width

During each width/depth ratio measurement, flood-prone width will be calculated. The cross section thalweg will be measured and multiplied by two to find the flood-prone elevation. The flood-prone width will be measured by placing the measuring rod on the left bank at the start of the measuring tape (0 ft), and placing a clinometer at the cross section thalweg height on the measuring rod. The clinometer will be balanced at zero while the distance from the rod to the zero point on the floodplain will be measured and recorded on the "**Riffle W/D Ratio**" form. This will be repeated on the right side of the channel and completed for each riffle sampled.

As with the riffle cross section, if riffle habitat is not present on C-3 streams, collect flood-prone measurements at the four shallowest points where cross section measurements are made.

3.2.8 Slope

Slope will be measured from the top of the site to the bottom. If there is not a clear path between these points, the angle will be measured between transects where there is visibility (**Figure 3-5**). One person will stand at the downstream transect holding a vertical measuring rod with flagging attached at a particular height with the bottom of the rod at the water's edge. A second person will stand at the upstream transect with a measuring rod held vertically on the same side of the stream with the bottom at the water's edge. The person at the upstream end will use a clinometer and hold it at the same height on the rod as the flagging on the downstream rod and aim it at the flagging. The percent slope will be recorded on the "**Assessment Location, Map and Slope**" form. This process will be repeated so the entire site is surveyed for slope, and the slope weighted average will be calculated in the office.

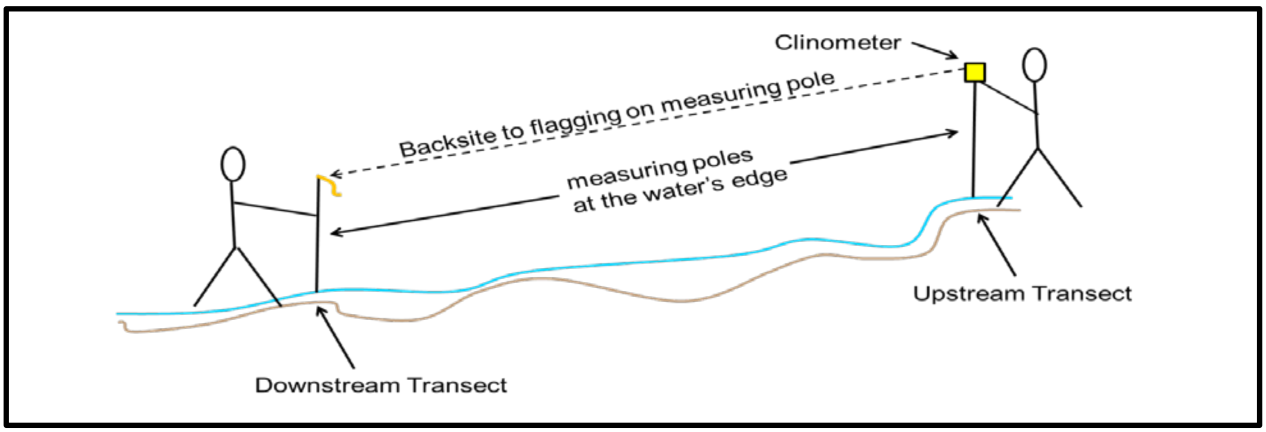

Figure 3-5. Measuring Slope

3.2.9 Rosgen Channel Type

Rosgen channel type (Rosgen 1994)will be estimated in the field at each riffle (or shallow area where width/depth was measured) and noted on the "**Rosgen Stream Classification**" form. If the sampling site is in an unstable condition, potential Rosgen channel type will be recorded as well. Rosgen channel type will be refined in the office where sinuosity will be calculated using GIS and applied. The following data will be used to determine Rosgen channel type:

- Bankfull width
- Mean depth
- Width/Depth ratio
- Maximum depth

- Flood-prone width
- Entrenchment ratio
- D_{50} Particle size index
- Channel sinuosity (stream length/valley length)

3.2.10 Riparian Greenline Data Collection

The greenline tasks categorize general riparian vegetation types along the ground cover, understory, and overstory for the length of the site. Greenline and BEHI data collection will have a different site length category than other sediment data collection. Site length will still be dependent on bankfull channel width, but will be based on the following width categories (**Table 3-2**):

Table 3-2. Survey Site and Survey Cell Lengths

Bankfull Channel Width (Feet)	Survey Site Length (Feet)	Length of Survey Cell (Feet)				
		Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
< 10	500	0-100	100-200	200-300	300-400	400-500
> 10 to < 50	1000	0-200	200-400	400-600	600-800	800-1000
> 50 to < 75	1500*	0-300	300-600	600-900	900-1200	1200-1500
>75	2000*	0-400	400-800	800-1200	1200-1600	1600-2000

* The selection of either a 1500 or 2000 foot survey site length at bankfull channel widths of > 50 will be determined on an individual basis.

Data collected during the riparian greenline assessment will be recorded on the "**Riparian Greenline**" form. The steps to perform the riparian greenline assessment are as follows:

1. Starting at the downstream end of the cell, collect measurements at 10-foot intervals progressing upstream along the greenline, which is located at approximately the bankfull channel margin (Winward 2000).
2. Every 10-feet, the ground cover (<1.5 feet tall), understory (1.5 to 15 feet tall) and overstory (>15 feet tall) riparian vegetation will be assessed (USEPA 2004).
3. The ground cover (<1.5 feet tall) vegetation will be described in the following categories:

   W = Wetland vegetation, such as sedges and rushes
   G = Grasses or forbs, rose, snowberry (vegetation lacking binding root structure)
   B = Disturbed/bare ground
   R = Rock, when a large cobble or boulder is encountered
   RR = Riprap

4. When the 10-foot interval falls at the base of a shrub or tree, place a dash (-) on the field form.
5. When pugging and hummocking due to the mechanical hoof action of grazing ungulates is observed, add "/H" to the field form (i.e. "G/H" indicates grass or forb ground cover with evidence of pugging and hummocking).
6. When Bare/Disturbed ground is observed, if the location appears to have the potential to support an herbaceous or woody vegetative community under "natural" circumstances, add "/D" to the field form.
7. If moss is encountered, simply choose the category that best describes the feature that the moss is associated with.

8. The understory vegetation (1.5 to 15 feet tall) and overstory vegetation (>15 feet tall) will be described in the following categories:

   C = Coniferous
   D = Deciduous, riparian shrubs and trees with sufficient rooting mass and depth to provide protection to the streambanks
   M = mixed coniferous and deciduous

9. When assessing understory and overstory vegetation along the greenline, envision an imaginary column about 5 feet or so in diameter extending up from the 10-foot interval at the bankfull margin. If this column intersects the canopy a shrub or tree, then record the data in the appropriate category. Only count vegetation originating from the side of study. Vegetation from the opposite bank that extends into the column is not to be recorded.
10. If no shrub or tree is encountered, place a dash (-) in the column on the field form.
11. When the bankfull channel margin is comprised of exposed sand or gravel due to streambank erosion, the greenline measurement should be made at the top of the bank.
12. When the channel margin is along a gravel bar, the greenline measurement should be made at the estimated bankfull elevation. When this is the case, place an “X” on the field form to denote the measurement was made along the bankfull channel margin at a gravel bar.
13. At 50-foot intervals, the field crew will estimate the vegetated buffer width along both sides of the stream. This can be accomplished with a tape measure in areas where the riparian zone is small or the vegetation is not dense. The buffer width can also be estimated by pacing, visual estimate or with the use of a range finder. This distance should generally correspond with the flood-prone area and, in many instances, will be bound by terraces or other distinct topographic features.
    a. The goal is to estimate the width of vegetation that is buffering the stream from adjacent land use. It is not defined as the actual width of the band of riparian vegetation. This is because both riparian and non-riparian vegetation can act in a buffering capacity.
14. When performing the greenline assessment on larger streams, 2 crew members should progress along opposite sides of the channel simultaneously. In this case, crew members will be responsible for performing the greenline assessment on their respective sides of the channel, though only one crew member will be responsible for recording the data. The crew member assessing the river left side of the channel that lacks the tape should estimate the location of each 10-foot interval based on the guidance of the crew member progressing along the tape measure.
15. Following the completion of greenline measurements, the total number of times each canopy type was observed is tallied in the box at the bottom of the field form.
16. Note that the greenline assessment is specifically designed for areas in which streambank erosion is influenced by riparian shrub coverage. This measurement is optional in situations where riparian shrubs do not play an important role in streambank stability, such as steep mountain streams in coniferous forests.

3.2.11 Bank Erosion Hazard Index (BEHI) Data Collection

The BEHI tasks include identifying slowly eroding and actively eroding streambanks and conducting measurements related to stream depths, bank dimensions, soil character, vegetation and root depths, and distinguishing potential forces of influence on the bank, including measurement or estimation of near-bank stress (NBS).

The steps to performing the streambank erosion assessment are outlined in the following sections.

Eroding Streambank "Type" Delineation:

1. The field crew member tasked with performing the eroding stream bank assessment will assess the various "types" of eroding streambanks as he/she moves through the assessment reach.
    a. For this assessment eroding streambanks will be delineated by "type" based on the eroding rate estimation, and BEHI and NBS characteristics, with each unique bank being described as an individual "type".
    b. When a bank is encountered that is similar to a bank already assessed, it is considered an "add bank" and it is assigned the "type" of the earlier bank.
2. Identify the upstream and downstream end of each unique eroding streambank, and record its type and stationing on the "**Streambank Erosion**" form.
    a. If the eroding streambank is an "add bank" this data is recorded on the "**Additional Streambank Erosion Measurements**" form.
3. Assess streambank erosion in one cell at a time, numbering streambanks in ascending order.
    a. Each individual eroding streambank regardless of "type" will be given a number per #3 above. If the eroding bank is an "add bank" in addition to the bank number, this eroding bank will be assigned the number of the similar bank "type", and this will be recorded on the "**Additional Streambank Erosion Measurements**" form.
4. If a cell lacks an eroding streambank, no streambanks will be assessed in that cell.
5. If an eroding streambank extends between two cells, include it in the downstream cell, which will be the first cell assessed in the upstream progression.
6. If an eroding streambank extends beyond the boundaries of the delineated stream survey site, do not include the portion of the streambank outside of the site.

Bank Erosion Hazard Index and Near Bank Stress:
This assessment will be performed on one bank for each bank "type". The data is recorded on the "**Streambank Erosion**" form.

1. Visually determine whether the eroding streambank is "Non-vegetated", or "Vegetated" and record on the field form. Non-vegetated stream banks appear to be obvious sources of sediment, and are typified by minimal to no vegetation and evidence of recent disturbance/erosional processes. Vegetated stream banks are likely contributing some minimal sediment over time, but at a very slow and gradual rate. They are typified by well vegetated and generally stable banks, often composed of erosion resistant streambank materials, and relatively small vertical scale.
2. Estimate the mean height of the eroding streambank from the toe of the bank to the top of the bank by making several measurements along the eroding streambank. The ***toe*** of the streambank is defined as the point where the streambank meets the channel bed. Note that the toe of the streambank will not necessarily be in the water during baseflow conditions.
3. Identify the most representative portion of the streambank and perform the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) estimates and/or measurements at this spot based on methods developed by Rosgen (1996, 2001, 2006) and adopted by the USEPA (2006). The measurements should be conducted in a location correspondent to the mean height of the eroding streambank.

4. The BEHI score is a metric derived from the following measurements which will be performed in the field: bank height, bankfull height, root depth, bank angle, and surface protection (**Figure 3-6**). For each bank, the BEHI score is then adjusted for bank materials and stratification.

   Bank height is measured from the toe of the bank to the top of the bank (note that this is labeled "study bank height" in **Figure 3-6**).

   Bankfull height is measured from the toe of the bank to the bankfull elevation. Unless the toe of the bank is at or above the surface water elevation, this height will be greater than the bankfull elevation identified along the survey site.

   Root depth is measured as the depth that the predominant roots extend into the soil from the top of the bank.

   Root density is estimated as a percent of the area assessed for root depth that is comprised of plant roots. Record estimates to the nearest 10%.

   Bank angle is measured from a horizontal plane in degrees from the toe of the bank to the top of the bank, with 90° being a vertical bank and >90° being an undercut bank. The angle of an undercut bank is determined by inserting the measuring rod into the deepest portion of the undercut and gently "prying" it back as close as it will go to vertical. Record measurements to the nearest 5°.

   Surface protection is measured as the percent of the streambank that is exposed to erosion. Surface protection can be provided by sod mats (i.e., vegetated slumps), large woody debris or boulders. Record measurements to the nearest 10%.

   The **bank material adjustment** is applied as follows:

   - Subtract 10 points if the bank is comprised of cobbles.
   - Add 5-10 points if the bank is comprised of gravel and sand, depending on the amount of sand.
   - Add 10 points if the bank is comprised of sand.
   - No adjustment is necessary for clay banks.

   The **stratification adjustment** is applied depending on the position of the layers in relation to the bankfull stage. A streambank should be considered stratified when a more erosive layer is situated or "sandwiched" between two less erosive layers within the bankfull zone.

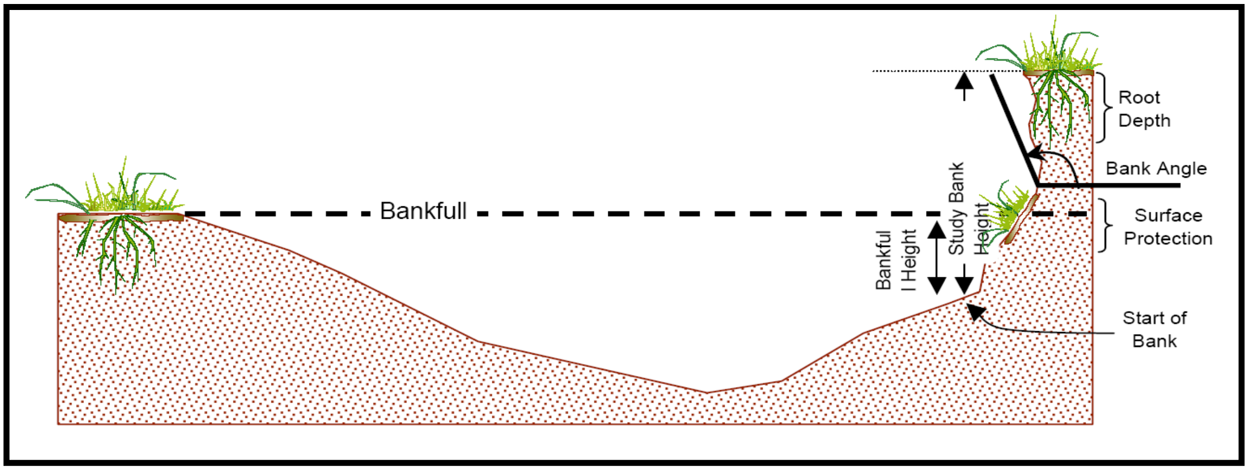

Figure 3-6. BEHI Measurement Variable (from EPA 2006).

1. Perform the NBS assessment and/or record estimate.
   a. To perform the NBS assessment, choose and apply the most appropriate method for NBS determination from the following choices:
      i. <u>Channel Pattern Estimate</u>: This method does not require any measurements but is appropriate for cases when obvious conditions affecting NBS are present and channel pattern features create a disproportionate energy distribution in the near-bank region. Chute cutoffs and split channels that converge against study banks will have NBS ratings from High to Extreme. In addition, depositional features including transverse bars and central bars also have NBS ratings of High to Extreme; in these areas, changes in slope and velocity are evident. The NBS will be estimated based on the channel pattern features.
         1. If transverse and/or central bars exist, and are short and/or discontinuous in nature, NBS will be recorded as High or Very High, dependent upon the judgment of the assessor.
         2. If *extensive* deposition is evident and is continuous and cross-channel, NBS will be recorded as Extreme.
         3. If chute cutoffs, down-valley meander migration, or converging flow are evident, NBS will be recorded as Extreme.
      ii. <u>Ratio of Near-Bank Maximum Depth top Bankfull Mean Depth (d_{nb}/d_{bkf})</u>: This method calculates the ratio of the near-bank maximum bankfull depth (d_{nb}) at study site to mean depth (d_{bkf}) from the study site or a nearby riffle cross-section. This method is generally most appropriate in relatively straight sections or gently turning bends.
         1. Perform approximately 5 bankfull depth measurements at roughly equal spacing across the bankfull width of the stream channel. Record these measurements in the *Bankfull mean depth calculations* box on the field form and calculate the mean bankfull depth. Use the d_{bkf} from one of the cell cross-sections if the cell cross-section occurs nearby and resembles the conditions of your study site.
         2. Measure the *near bank maximum depth*, which is the deepest bankfull channel depth (measured from the channel bed to the bankfull elevation) within the 1/3 of the channel closest to the eroding bank along the cross-section. Record this depth on the field form.

3. Calculate the ratio of near-bank maximum depth to bankfull mean depth (d_{nb}/d_{bkf}) and record this value and the subsequent NBS ratings (**Table 3-3**).

Table 3-3. Conversion Table of d_{nb}/d_{bkf} Values to NBS Ratings

d_{nb}/d_{bkf} ratio	NBS rating
< 1.00	Very Low
1.00 – 1.50	Low
1.51 – 1.80	Moderate
1.81 – 2.50	High
2.51 – 3.00	Very High
> 3.00	Extreme

iii. Ratio of Radius of Curvature to Bankfull Width (R_c/W_{bkf}): This method can be rapidly completed in the field or on an aerial photograph. This method is most appropriate for eroding banks at meander bend locations.

1. Measure the radius of curvature of the meander bend where your study site is located. Radius of curvature is the radius or distance from the center of the approximating circle that best fits a given meander bend. For a given meander bend, identify the beginning and end points of the arc of the meander bend and measure the distance from these points to the center of a circle that would best fit along that arc. (In theory, the distance from the center of the circle to the beginning and end points of the arc is the same, however, due to field variability and vegetation, measurements may slightly differ from one another. In that case, the average of the two measurements can be used for the radius of curvature determination.)
2. Measure the bankfull channel width at a close by riffle. Typically this riffle will occur in the reach leading to or away from the meander at the study site.
3. Calculate the ratio of radius of curvature to bankfull width (R_c/W_{bkf}) and record this value and the subsequent NBS rating (**Table 3-4**).

Table 3-4. Conversion Table of R_c/W_{bkf} Values to NBS Ratings

R_c/W_{bkf} ratio	NBS rating
> 3.00	Very Low
2.21 – 3.00	Low
2.01 – 2.20	Moderate
1.81 – 2.00	High
1.50 – 1.80	Very High
< 1.50	Extreme

2. Once the BEHI and NBS estimates and/or measurements have been made take one photo looking downstream at the eroding streambank and second photo facing the streambank at the site where the BEHI and NBS assessment was performed (**Figure 3-7**). Include the measuring rod and the line level in the photo for reference, with the base of the rod placed at the toe of the streambank. Provide a brief description in the "**Photo Log**" form (i.e. "d/s view at BEHI 1", "view toward bank at BEHI 1").
3. If the eroding streambank is "complex" and appears to have more than one BEHI value and/or more than one NBS value, then the streambank may need to be broken into two or more eroding streambank "types." If only the NBS changes along the streambank, then two separate

NBS measurements can be performed for one eroding bank so long as the length of eroding bank associated with each NBS measurement is recorded.

Figure 3-7. Example of Appropriate Photos of Eroding Streambanks

Streambank Composition and Erosion Source Assessment:

1. For each bank that undergoes the BEHI assessment, visually estimate the streambank material composition and identify the sources of streambank erosion.
2. When assessing the streambank composition, first estimate the percent comprised of coarse gravel, cobbles and boulders (>6mm). Next, evaluate the percent comprised of sands and clays (<2mm). Finally, assess the amount of streambank comprised of fine gravels (2mm-6mm). Assess each category to the nearest 10%.
3. Indicate if hoof shear is observed by circling either "present" or "absent" on the field form. If hoof shear is observed, document it with a photograph and provide a brief description in the "**Photo Log**" form.
4. For all eroding stream banks regardless of "type," identify sources of streambank instability and estimate a percent in the following categories:
   - Transportation
   - Riparian Grazing
   - Cropland
   - Mining
   - Silviculture
   - Irrigation-shifts in stream energy
   - Historical (provide a description of the source)
   - Natural Sources
   - Other (provide a description of the source)

5. If a source of streambank erosion is not observed, do not record a value. The exception is for natural sources, which must always be estimated, even if that value is 0%. Eroding streambanks at the outside of meander bends, for example, are likely due at least partially to natural sources, though human sources may be leading to increased instability and erosion.

6. Sources of streambank instability should be attributed to the factors most influential on the study bank. This does not necessarily equate to those factors most visible or directly adjacent to the study bank. For instance, historic practices may have denuded the riparian area and resulted in prolonged instability. Current riparian condition however may be that of early growth vegetation in a stage of recovery, although the full recovery of stream stability may still take years. In this case, some of the sources of instability should be accounted for as 'Historical', with a description of the practices that likely created the instability. As another example, the existence of placer mining and stream channelization may have occurred upstream of the study bank. The resultant changes in hydrology and stream power extend below the mining location and affects the erosional processes at the study bank. In this case, 'Mining' would receive a percentage of streambank instability sources even though no mining is actively present at the study bank.
7. The attribution of sources of streambank instability relates to the context of a given site within its watershed and should be conducted by a member or members of the team who are best qualified to make that determination. Knowledge should include history of the stream or reach, familiarity with hydrology and geomorphology principles, and understanding of the effects of many land use practices.

3.3 DATA ANALYSIS

Physical instream data and biological samples will be used in sediment assessment following the process outlined in the Sediment and Habitat Field Method for Wadeable Streams (DEQ 2015b). The determination of a reference dataset to compare physical data from Musselshell waterbodies will be undertaken after all Musselshell sediment data is collected. The reference dataset for physical measurements is typically derived from similar (Strahler order, slope, geology, ecoregion, stream type) streams meeting the water quality standard for sediment. Biological data will not be compared to a reference dataset, but will be use the thresholds described in DEQ (2011). Greenline and BEHI data will be used in source assessment in the event TMDL development is needed.

4.0 SAMPLE HANDLING PROCEDURES

Field samples will be collected and preserved according to **Section 3**. DEQ monitoring crews will be responsible for proper labeling, sample custody, documentation, and storage in accordance to the specifications in the Field Procedures Manual and QAPP (DEQ 2005, 2012b). Periphyton samples will be delivered to Rhithron, Inc. for analysis. Taxa presence will be recorded by Rhithron, Inc. and the Diatom Increaser (DEQ 2011) will be calculated.

Table 4-1. Sampling Volumes, Containers, Preservation and Holding Times

Analyte	Bottle Size	Container	Preservation	Storage	Holding time

Periphyton	50 cm^3	Centrifuge tube	Formalin	Cool, dark location	Up to one year

5.0 Quality Assurance and Quality Control Requirements

This project will follow the WQPB "internal process". All QA/QC requirements followed by MT DEQ will be instituted for this project. The QA/QC requirements are described in the QAPP (DEQ 2005).

6.0 Handling Sampling Records

Site Visit Forms, field forms, and digital photos will be processed by WQPB staff using QA/QC procedures described in the QAPP (DEQ 2005). Rhithron, Inc. will provide results to DEQ in the required EDD format. DEQ will perform the necessary data evaluations and will manage the data in accordance with the QAPP (DEQ 2005) and MT DEQ records management policies. Physical measurement data will be input to Sediment Habitat Data System.

7.0 Schedule

Sediment and periphyton sampling will occur from June to October, 2015.

8.0 Project Team and Responsibilities

Monitoring and Assessment Section staff will lead the monitoring component. Darrin Kron will oversee the Monitoring and Assessment section activities. Jessica Clarke will lead the sediment monitoring. Monitoring and Assessment Section, Watershed Management Section, and Watershed Protection Section staff will provide monitoring support in the field. Dean Yashan will oversee the TMDL source assessment activities (BEHI and greenline measures) for this project.

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