Final Report
Headwaters Project – FWP Contract # FWP19-0148

Completed by Yellowstone Ecological Research Center (on behalf of Sweet Grass Conservation District)
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Robert Crabtree -- executive director, chief scientist

July 30, 2019

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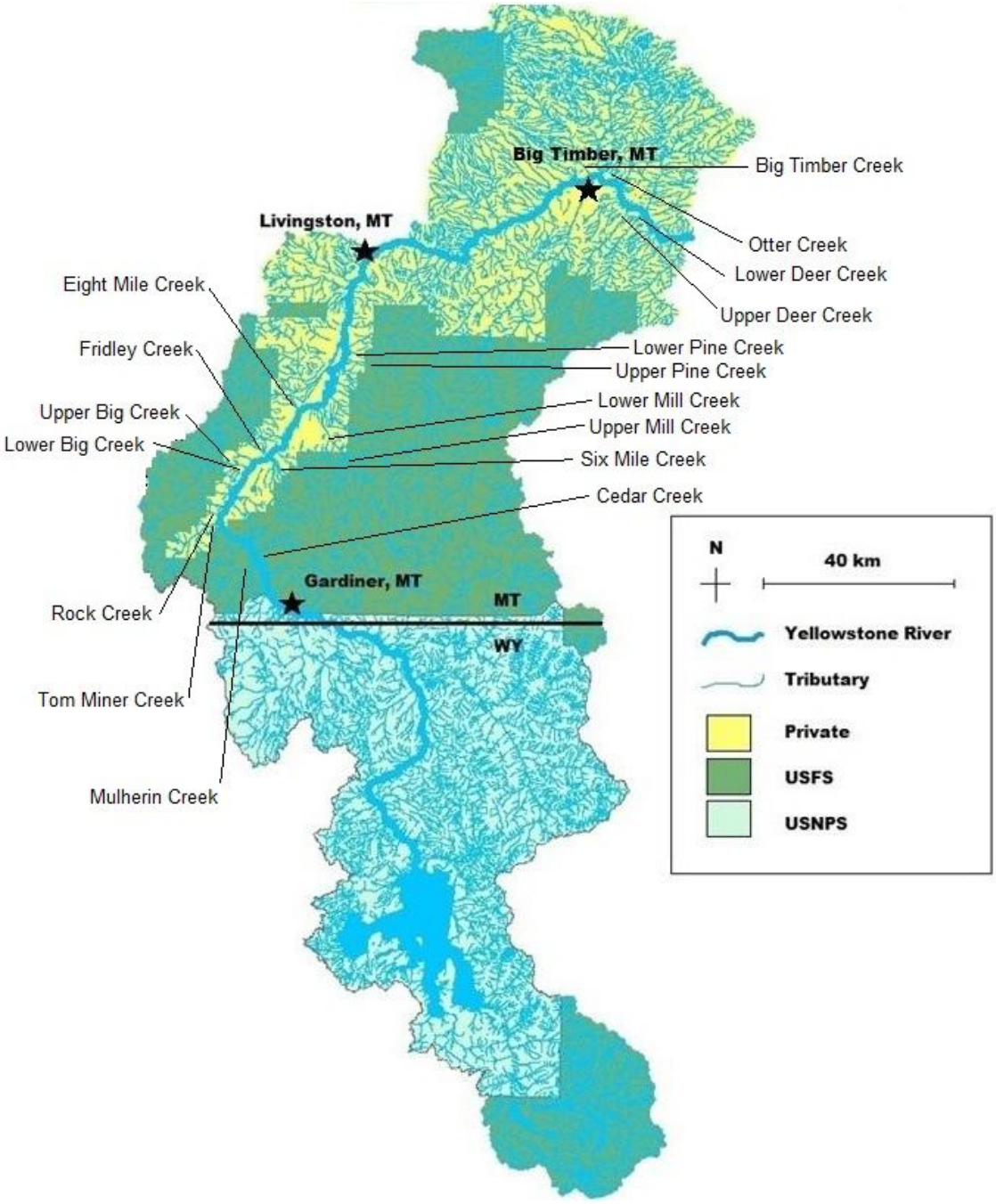
Cover Photo: Yellowstone Ecological Research Center field technicians collecting stage and discharge data for calculating a rating curve on Mill Creek near Pray, Montana, in April 2019.

Figure 1: Upper Yellowstone River Watershed (HUCs 10070001 & 10070002) study area, showing streams, land ownership, and the stream gauge sites established during this project.



Project Summary

Responding to the need for better data on the environmental conditions behind the 2016 Prolific Kidney Disease outbreak and subsequent fish kill on the Upper Yellowstone River, the Yellowstone Ecological Research Center (YERC) launched its *RiverNET* water quality monitoring program in 2018. *RiverNET*'s objectives include increasing the density of stream gauge stations in the Upper Yellowstone River Watershed (UYRW; **Figure 1**). That summer, we identified priority stream gauge sites – predominantly on tributaries as well as one main stem site on the Mill Creek Road Bridge halfway between existing USGS stream gauges at Corwin Springs (USGS 06191500) and near Livingston (USGS 06192500) – and tested sensor systems (Onset MX2001; Hydrolab DS5X) to record stream *depth*.

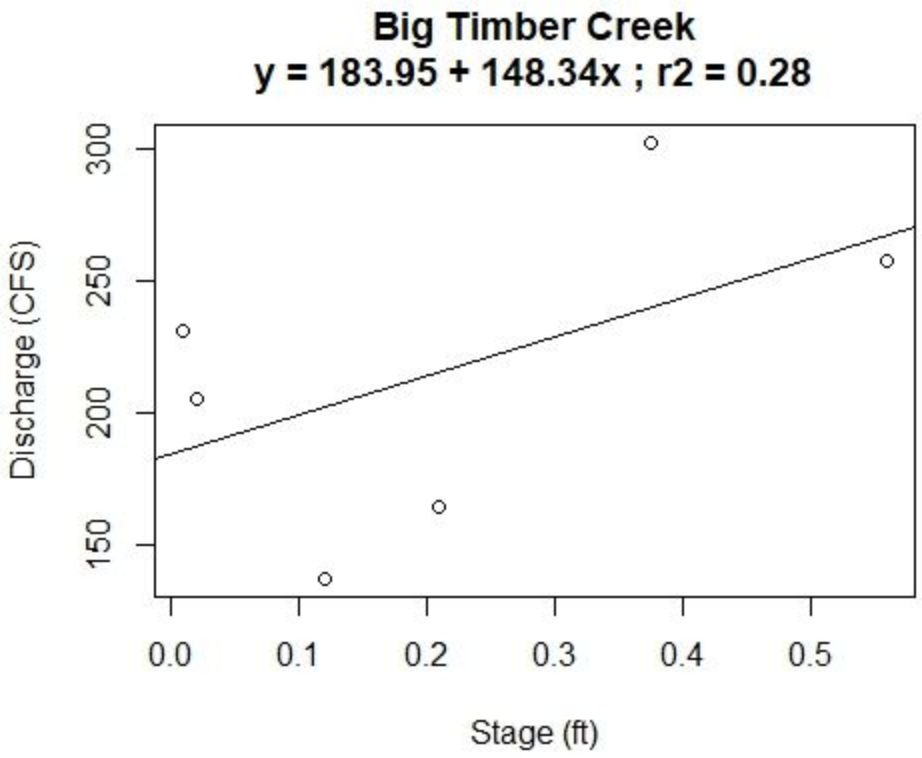
In December 2018, YERC signed a memorandum of understanding with Sweet Grass Conservation District (SGCD; **Appendix II**) to apply for funding from Montana Fish, Wildlife & Parks' (FWP) Drought Management Planning Program to calculate depth-to-discharge rating curves for stream gauges in the Upper Yellowstone Watershed. Such rating curves are necessary to convert the sensors' depth observations into *discharge* (i.e., flow) estimates. In March 2019, FWP approved a contract with SGCD (**Appendix III**), working through YERC as a subcontractor, to (1) Identify up to 20 potential stream gauge sites in the UYRW between Gardiner and Big Timber, (2) Calculate depth-to-discharge rating curves for each site, (3) Make the information publicly available on YERC's website and on the Montana State Library's Yellowstone River Clearinghouse, and (4) Complete the work by June 30, 2019.Below average temperatures and above average precipitation in Spring 2019 delayed both ice-off and run-off about a month later than expected, consequently pushing back the timeframe when YERC was able to conduct the work and the number of site visits YERC was able to complete in that time. Nevertheless, we established 17 stream gauge sites (4 in Sweet Grass County and 13 in Park County), and calculated rating curves for each site with an average of 8.53 depth:discharge ratings for each rating curve.

It is important to note that these rating curves are only applicable with high confidence for the range of stages reported for each site: estimates of discharge using these rating curves at stages greater than those reported should be interpreted with less confidence. This limitation is due to the discharge calculating methods we employed, which generally required wading across the stream (see **Appendix I**), so crew safety precluded the application of these methods when depth and velocity made the stream unwadable. We did collect additional data during these high water periods, including stage, stream width and representative velocity measurements, which we will use to attempt to estimate discharge and refine these rating curves later this summer; alternate methods that could be employed in high water conditions include contracting a towable Acoustic Dopler Current Profiler to collect these data. Also, even though we attempted to select sites with stable stream morphology characteristic, selecting sites with concrete control structures (e.g., weirs, bridge piers) when available, these rating curves are only applicable with high confidence for the 2019 water year without their being additional rating data for validation and calibration in subsequent years. This is because intraannual and interannual changes in stream morphology can affect the cross-sectional area relative to stage compared to the data we collected in 2019. With these caveats in mind, we have high confidence in the results we are reporting here considering the high goodness-of-fit between the rating curves we calculated through linear regression and the coupled stage and discharge data used to fit those models.

One rating curve (Big Timber Creek) failed to meet our goodness-of-fit acceptance standards ($r^2 > 0.50$), probably due to damage to the staff gauge and nearby bank stabilization work that occurred during data collection. All other sites had acceptable goodness of fit ($0.64 < r^2 < 0.97$). This report summarizes the results for each site, including the rating curve formula and r^2 value, a plot of the rating curve and data points, and the rating table. Appendices to this report include protocols YERC staff used to establish sites and collect and analyze data, and the Memorandum of Understanding and contracts entered into by the collaborating parties.

A copy of this report, as well as discharge estimates using these rating curves at sites where sensors have already been installed, can be found at https://yellowstoneresearch.org/rivernet. For questions, contact Patrick Cross at cross@yellowstoneresearch.org.

Site: Big Timber Creek
Latitude, Longitude: 45.8544, -109.9334
Formula, r^2 Value, Plot:



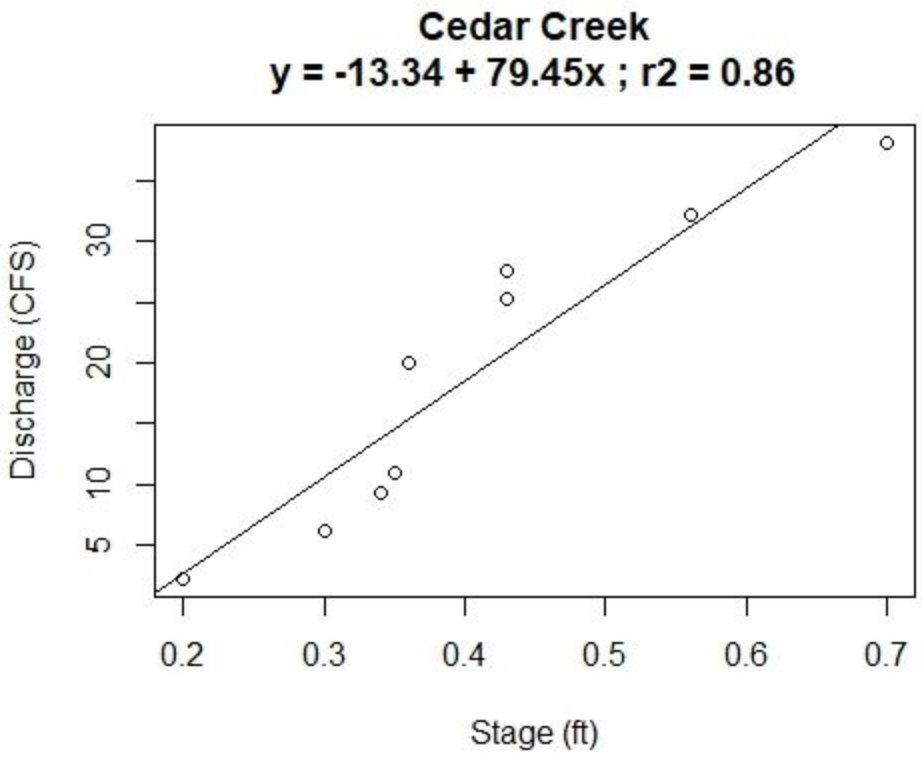
Rating Table:

Site	Date	Stage	Discharge
Big Timber Creek	5/21/2019	0.01	231.015
Big Timber Creek	5/24/2019	0.02	205.225
Big Timber Creek	5/10/2019	0.12	136.85
Big Timber Creek	5/1/2019	0.21	163.82
Big Timber Creek	6/18/2019	0.375	301.99
Big Timber Creek	5/15/2019	0.56	256.895

Stage Zero Level (ft.) [+ Stage = True Depth]: 1.49

Notes: Wide scatter in the stage:discharge data and a poor fitting rating curve indicate there were problems with data collection at this site. Technicians reported that (a) the staff gauge was damaged and repaired, and (b) stream bank stabilization work (rip rap) occurred just downstream from the site during data collection. It also had less than the minimum of 8 data points required for this assessment. For these reasons, we reject this rating curve for Big Timber Creek, and recommend reestablishing the site and recalculating the rating curve at a later season.

Site: Cedar Creek
Latitude, Longitude: 45.1433, -110.8130
Formula, r^2 Value, Plot:

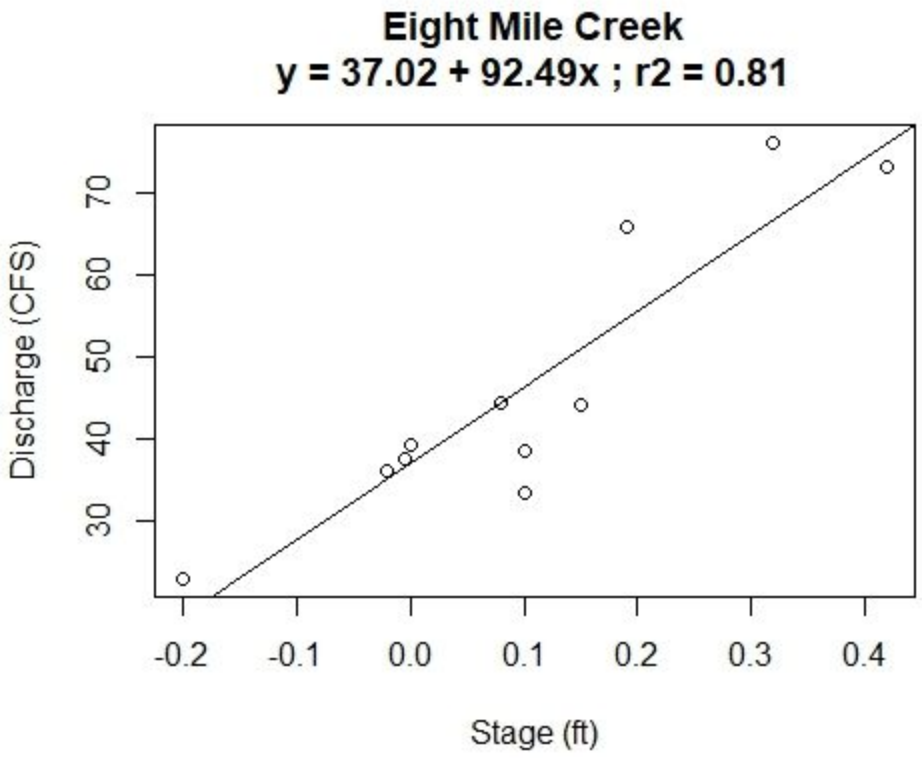


Rating Table:

Site	Date	Stage	Discharge
Cedar Creek	4/12/2019	0.2	2.21
Cedar Creek	5/6/2019	0.3	6.1
Cedar Creek	5/9/2019	0.34	9.34
Cedar Creek	4/26/2019	0.35	10.945
Cedar Creek	5/27/2019	0.36	19.93
Cedar Creek	5/23/2019	0.43	25.18
Cedar Creek	5/30/2019	0.43	27.59
Cedar Creek	5/14/2019	0.56	32.15
Cedar Creek	5/17/2019	0.7	38.11

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.3

Site: Eight Mile Creek
Latitude, Longitude: 45.4091, -110.6996
Formula, r^2 Value, Plot:

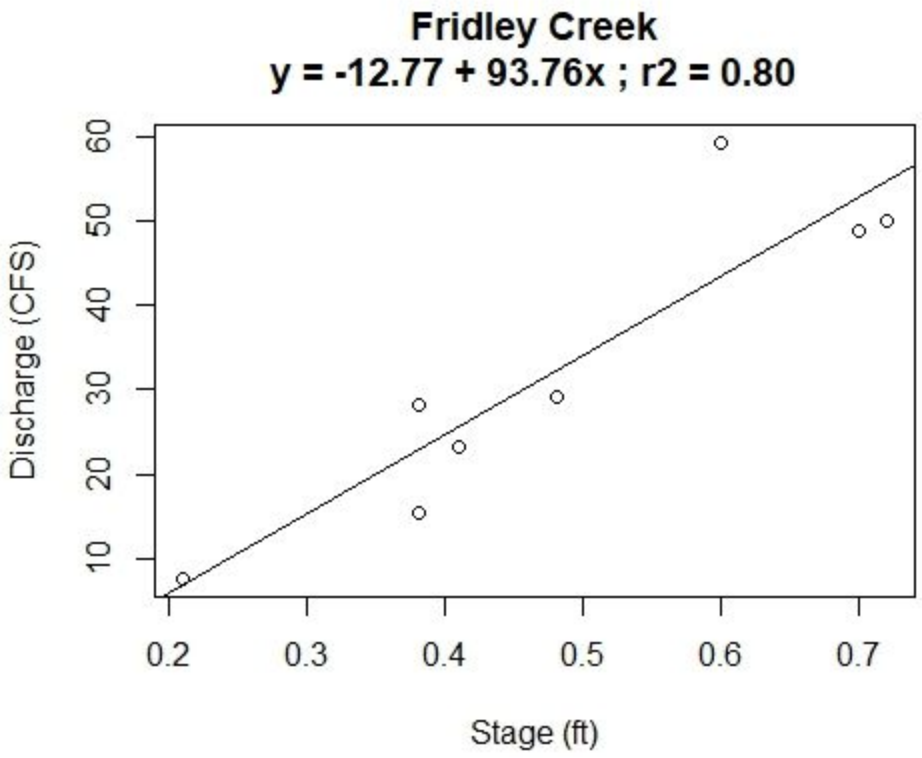


Rating Table:

Site	Date	Stage	Discharge
Eight Mile Creek	4/12/2019	-0.2	23.1
Eight Mile Creek	4/30/2019	-0.02	36.23
Eight Mile Creek	5/7/2019	-0.005	37.63
Eight Mile Creek	5/28/2019	0	39.345
Eight Mile Creek	6/3/2019	0.08	44.39
Eight Mile Creek	5/13/2019	0.1	33.6
Eight Mile Creek	5/23/2019	0.1	38.68
Eight Mile Creek	4/24/2019	0.15	44.31
Eight Mile Creek	6/13/2019	0.19	65.88
Eight Mile Creek	6/17/2019	0.32	76.03
Eight Mile Creek	5/16/2019	0.42	73.01

Stage Zero Level (ft.) [+ Stage = True Depth]: 1.4

Site: Fridley Creek
Latitude, Longitude: 45.3428, -110.7570
Formula, r^2 Value, Plot:

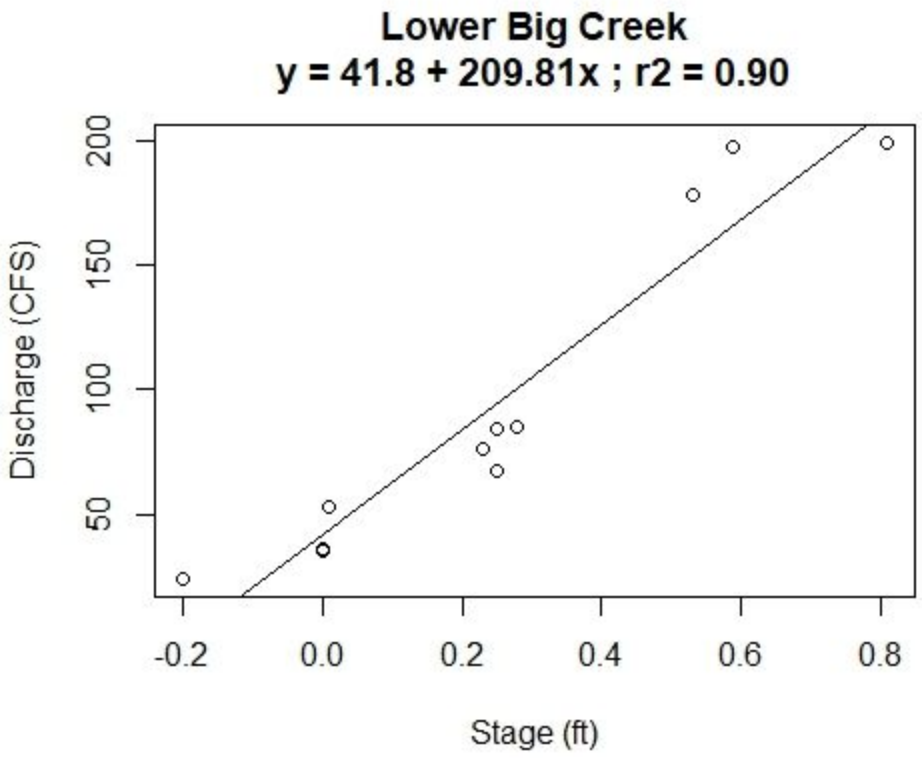


Rating Table:

Site	Date	Stage	Discharge
Fridley Creek	4/17/2019	0.21	7.6275
Fridley Creek	4/30/2019	0.38	15.49
Fridley Creek	5/7/2019	0.38	28.28
Fridley Creek	5/23/2019	0.41	23.18
Fridley Creek	5/28/2019	0.48	29.23
Fridley Creek	5/13/2019	0.6	59.19
Fridley Creek	4/24/2019	0.7	48.745
Fridley Creek	5/16/2019	0.72	49.92

Stage Zero Level (ft.) [+ Stage = True Depth]: 1.34

Site: Lower Big Creek
Latitude, Longitude: 45.3992, -110.8315
Formula, r^2 Value, Plot:

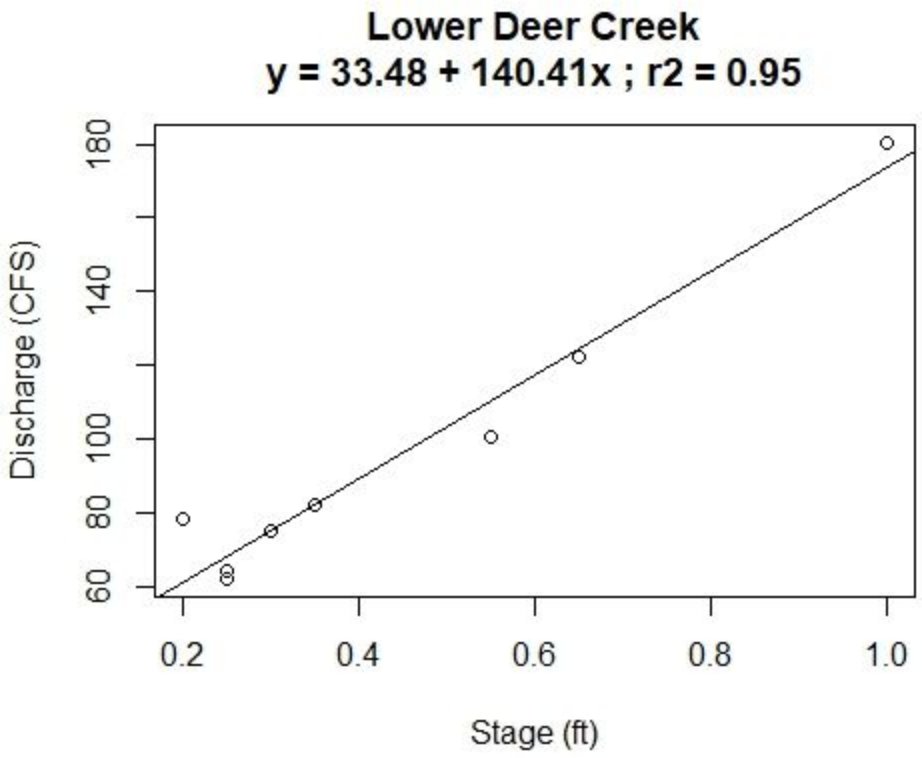


Rating Table:

Site	Date	Stage	Discharge
Lower Big Creek	4/17/2019	-0.2	24.455
Lower Big Creek	4/11/2019	0	36.5
Lower Big Creek	5/7/2019	0	35.35
Lower Big Creek	4/30/2019	0.01	53.11
Lower Big Creek	5/28/2019	0.23	76.315
Lower Big Creek	5/13/2019	0.25	67.735
Lower Big Creek	5/22/2019	0.25	84.195
Lower Big Creek	4/24/2019	0.28	84.965
Lower Big Creek	6/13/2019	0.53	178.2
Lower Big Creek	6/17/2019	0.59	197.03
Lower Big Creek	6/4/2019	0.81	198.89

Stage Zero Level (ft.) [+ Stage = True Depth]: 1.7

Site: Lower Deer Creek
Latitude, Longitude: 45.7817, -109.7916
Formula, r^2 Value, Plot:

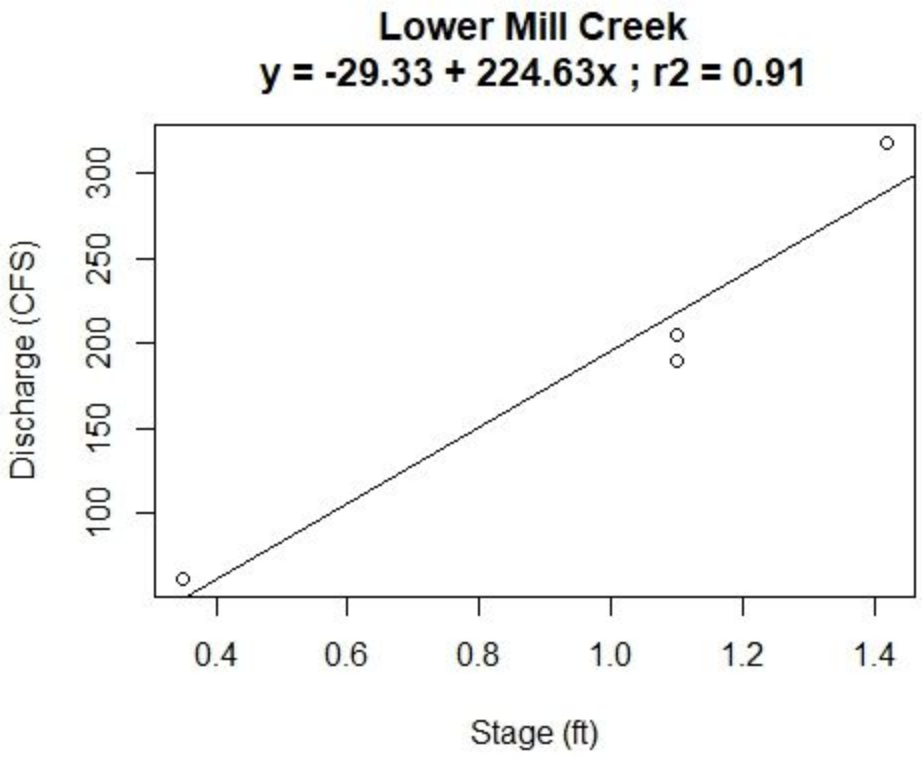


Rating Table:

Site	Date	Stage	Discharge
Lower Deer Creek	5/10/2019	0.2	78.32
Lower Deer Creek	5/1/2019	0.25	62.39
Lower Deer Creek	6/18/2019	0.25	64.54
Lower Deer Creek	5/15/2019	0.3	75.185
Lower Deer Creek	6/12/2019	0.35	82.46
Lower Deer Creek	5/21/2019	0.55	100.615
Lower Deer Creek	6/5/2019	0.65	122.44
Lower Deer Creek	5/24/2019	1	180.3175

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.8

Site: Lower Mill Creek
Latitude, Longitude: 45.3947, -110.6399
Formula, r^2 Value, Plot:



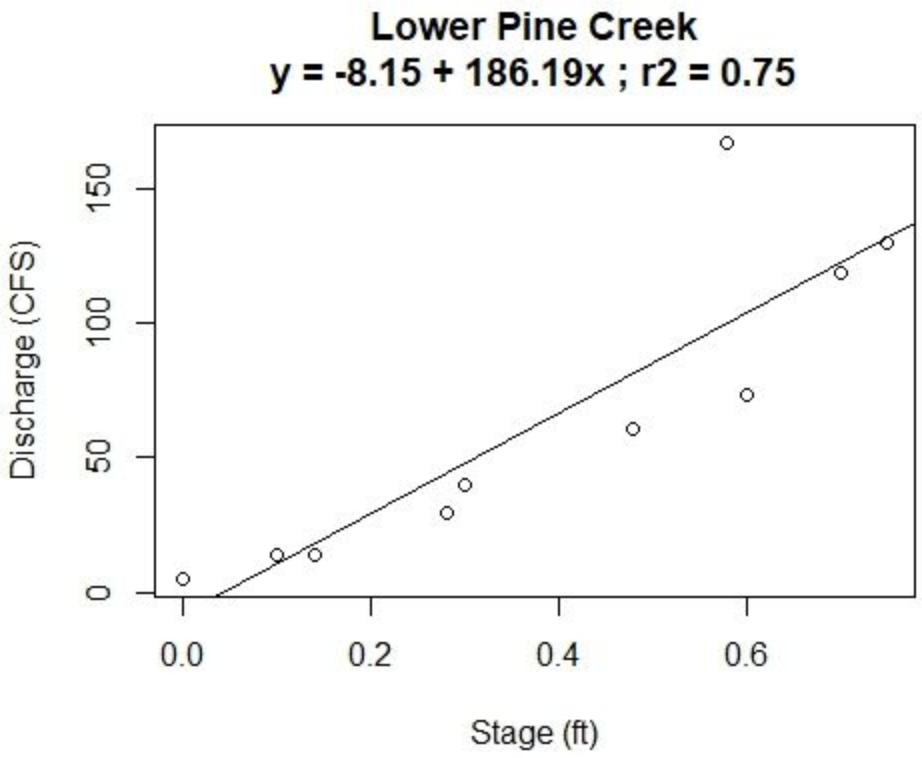
Rating Table:

Site	Date	Stage	Discharge
Lower Mill Creek	4/15/2019	0.35	61.42
Lower Mill Creek	4/23/2019	1.1	190.205
Lower Mill Creek	5/8/2019	1.1	204.79
Lower Mill Creek	5/13/2019	1.42	318.07

Stage Zero Level (ft.) [+ Stage = True Depth]: 0

Notes: This dataset has less than the minimum of 8 data points required for this assessment. However, the data points have a good distribution across a range of stages, and the rating curve has a good fit to the data: we will therefore accept this rating curve for Lower Mill Creek. We did collect partial data during other site visits when high water precluded completion of the transect, and will use these to add qualified data points later; otherwise we recommend collecting additional data to supplement this dataset.

Site: Lower Pine Creek
Latitude, Longitude: 45.5047, -110.5679
Formula, r^2 Value, Plot:

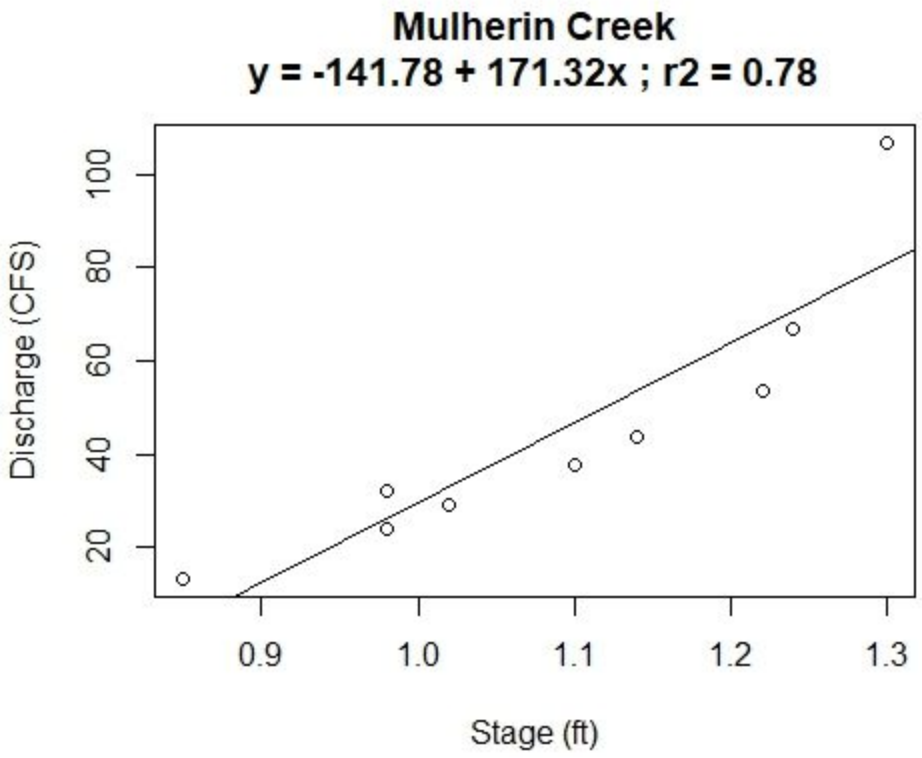


Rating Table:

Site	Date	Stage	Discharge
Lower Pine Creek	4/11/2019	0	5.03
Lower Pine Creek	5/6/2019	0.1	13.6
Lower Pine Creek	5/9/2019	0.14	13.48
Lower Pine Creek	5/22/2019	0.28	29.79
Lower Pine Creek	4/23/2019	0.3	39.67
Lower Pine Creek	5/27/2019	0.48	60.72
Lower Pine Creek	6/3/2019	0.58	166.815
Lower Pine Creek	5/30/2019	0.6	73.065
Lower Pine Creek	5/17/2019	0.7	118.295
Lower Pine Creek	6/13/2019	0.75	129.79

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.9

Site: Mulherin Creek
Latitude, Longitude: 45.1276, -110.8058
Formula, r^2 Value, Plot:

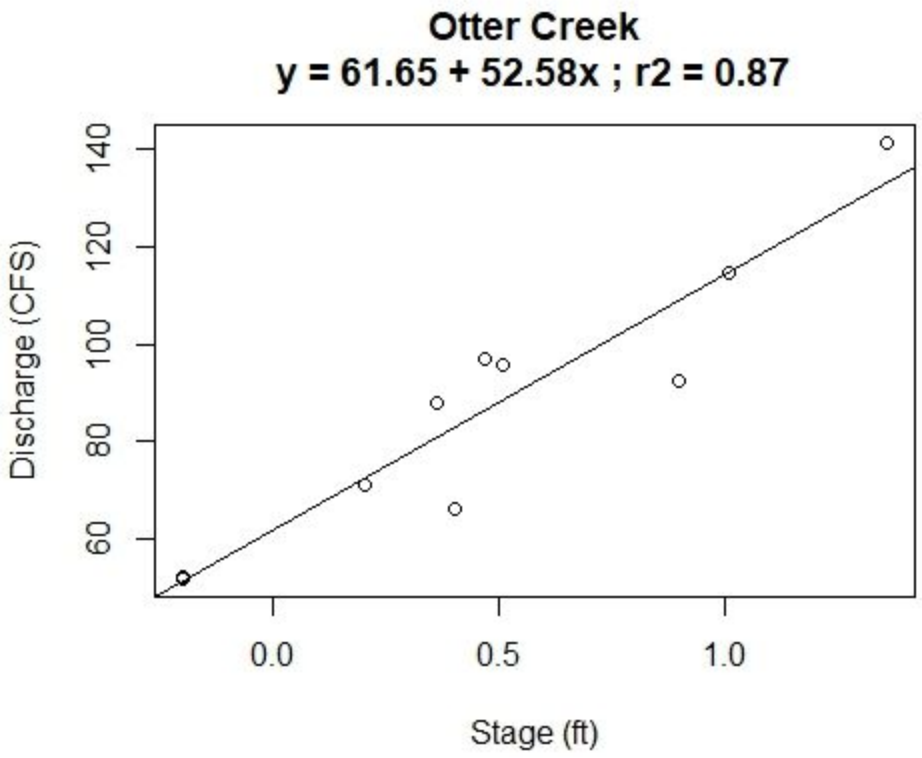


Rating Table:

Site	Date	Stage	Discharge
Mulherin Creek	4/17/2019	0.85	13.415
Mulherin Creek	5/2/2019	0.98	32.19
Mulherin Creek	5/6/2019	0.98	24.205
Mulherin Creek	5/9/2019	1.02	29.42
Mulherin Creek	4/26/2019	1.1	37.86
Mulherin Creek	5/27/2019	1.14	43.705
Mulherin Creek	5/14/2019	1.22	53.50625
Mulherin Creek	5/30/2019	1.24	66.9
Mulherin Creek	5/17/2019	1.3	106.81

Stage Zero Level (ft.) [+ Stage = True Depth]: 0

Site: Otter Creek
Latitude, Longitude: 45.8571, -109.9033
Formula, r^2 Value, Plot:

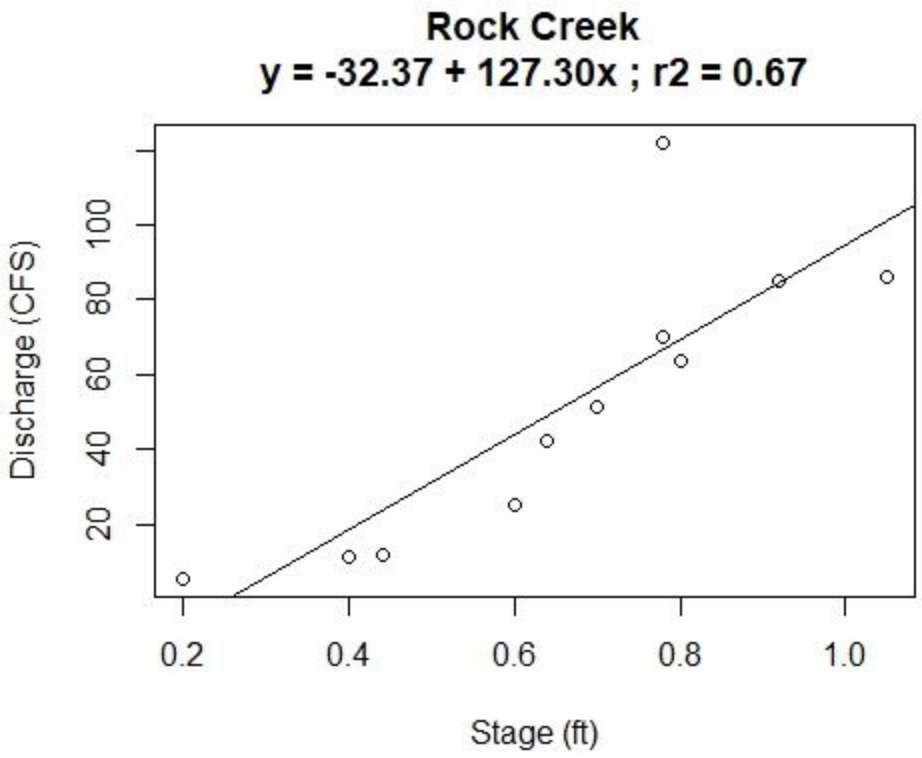


Rating Table:

Site	Date	Stage	Discharge
Otter Creek	5/10/2019	-0.2	51.71
Otter Creek	5/15/2019	-0.2	52.04
Otter Creek	5/1/2019	0.2	70.845
Otter Creek	5/21/2019	0.36	87.87
Otter Creek	5/24/2019	0.4	66.22
Otter Creek	6/18/2019	0.47	96.77
Otter Creek	6/12/2019	0.51	95.83
Otter Creek	4/22/2019	0.9	92.22
Otter Creek	6/5/2019	1.01	114.535
Otter Creek	5/31/2019	1.36	141.3875

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.85

Site: Rock Creek
Latitude, Longitude: 45.2109, -110.9039
Formula, r^2 Value, Plot:

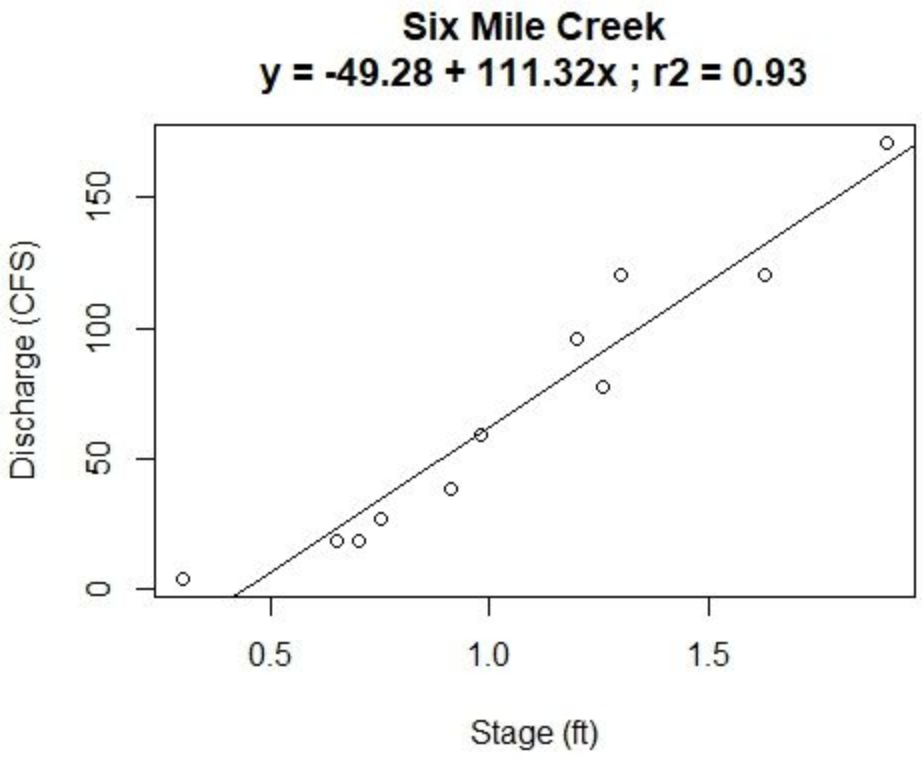


Rating Table:

Site	Date	Stage	Discharge
Rock Creek	4/25/2019	0.2	5.59
Rock Creek	5/6/2019	0.4	11.24
Rock Creek	5/9/2019	0.44	12.02
Rock Creek	4/26/2019	0.6	25.45
Rock Creek	5/27/2019	0.64	42.14
Rock Creek	5/20/2019	0.7	51.28
Rock Creek	5/30/2019	0.78	70.28
Rock Creek	6/17/2019	0.78	121.94
Rock Creek	5/14/2019	0.8	63.66
Rock Creek	5/17/2019	0.92	84.885
Rock Creek	6/6/2019	1.05	85.99

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.5

Site: Six Mile Creek
Latitude, Longitude: 45.3214, -110.7716
Formula, r^2 Value, Plot:

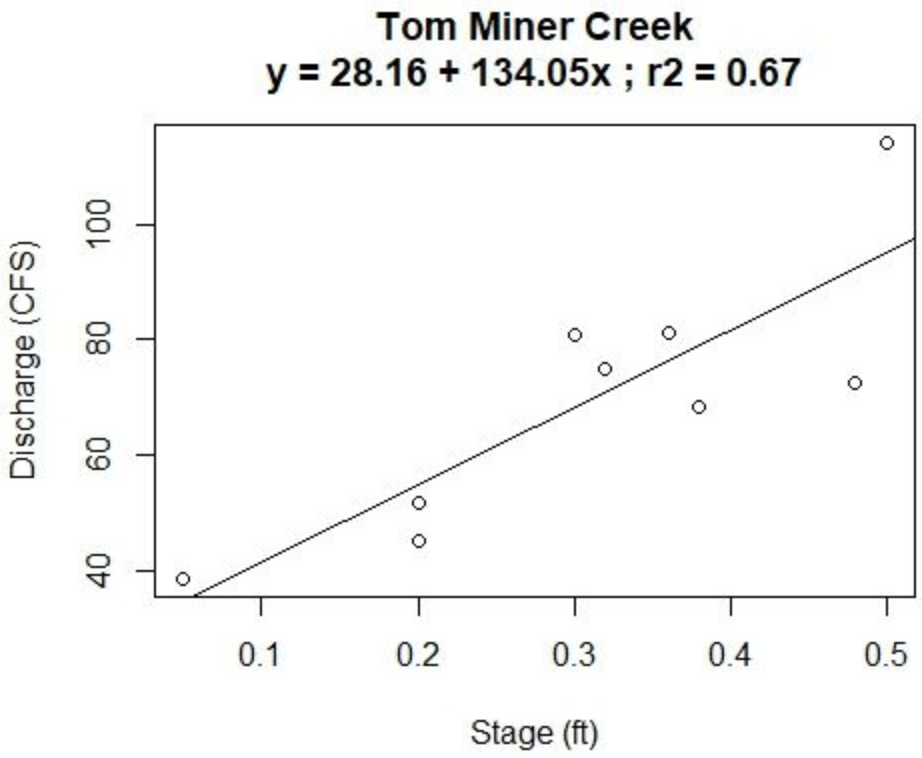


Rating Table:

Site	Date	Stage	Discharge
Six Mile Creek	4/18/2019	0.3	3.85
Six Mile Creek	5/6/2019	0.65	17.96
Six Mile Creek	5/8/2019	0.7	18.1
Six Mile Creek	4/26/2019	0.75	26.79
Six Mile Creek	5/23/2019	0.91	38.04
Six Mile Creek	5/27/2019	0.98	58.62
Six Mile Creek	5/30/2019	1.2	95.61
Six Mile Creek	5/14/2019	1.26	77.73
Six Mile Creek	6/17/2019	1.3	120.19
Six Mile Creek	6/14/2019	1.63	120.305
Six Mile Creek	6/6/2019	1.91	170.99875

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.7

Site: Tom Miner Creek
Latitude, Longitude: 45.1982, -110.9086
Formula, r^2 Value, Plot:

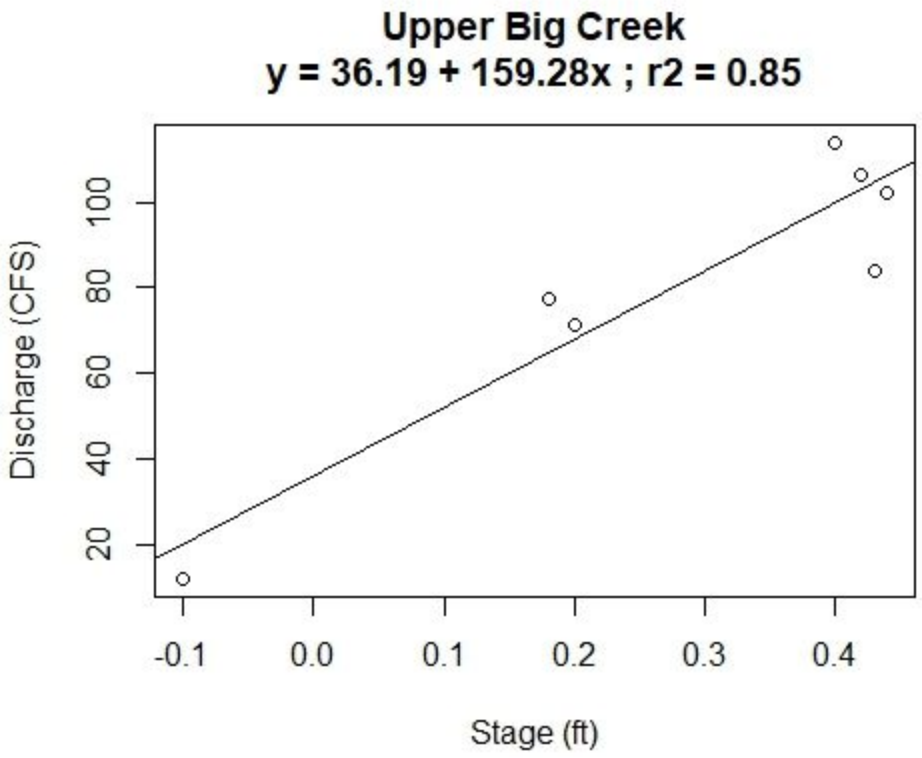


Rating Table:

Site	Date	Stage	Discharge
Tom Miner Creek	4/16/2019	0.05	38.605
Tom Miner Creek	5/6/2019	0.2	51.85
Tom Miner Creek	5/9/2019	0.2	45.31
Tom Miner Creek	4/26/2019	0.3	80.78
Tom Miner Creek	5/23/2019	0.32	74.99
Tom Miner Creek	5/27/2019	0.36	81.02
Tom Miner Creek	5/14/2019	0.38	68.35
Tom Miner Creek	5/30/2019	0.48	72.39
Tom Miner Creek	5/17/2019	0.5	114.095

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.65

Site: Upper Big Creek
Latitude, Longitude: 45.3055, -110.8667
Formula, r^2 Value, Plot:



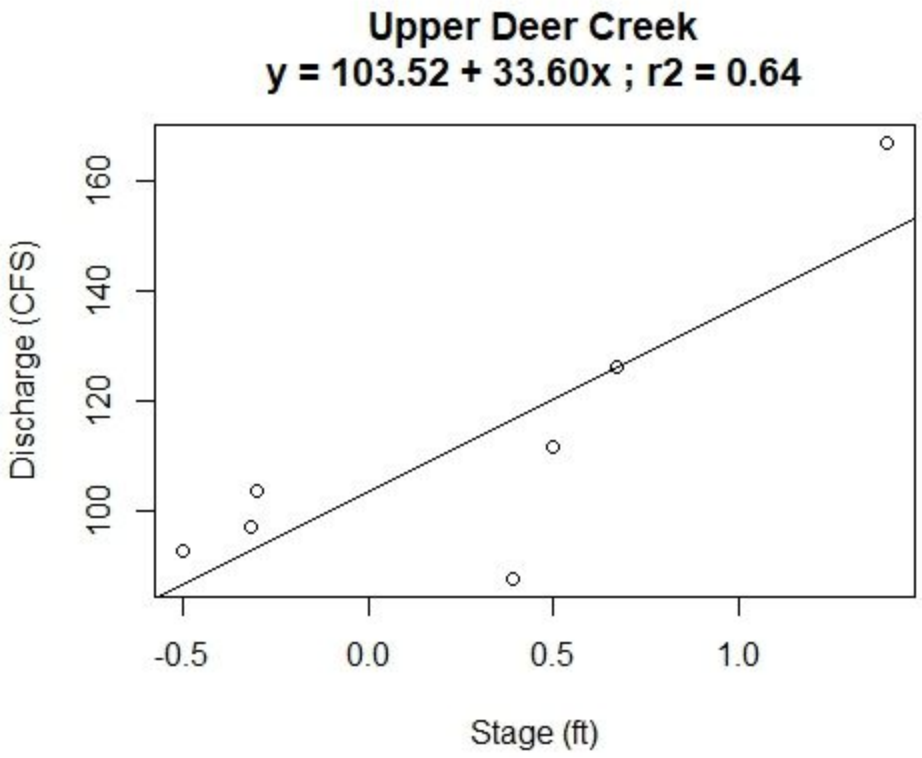
Rating Table:

Site	Date	Stage	Discharge
Upper Big Creek	4/16/2019	-0.1	11.985
Upper Big Creek	5/7/2019	0.18	77.48
Upper Big Creek	4/30/2019	0.2	71.261
Upper Big Creek	4/24/2019	0.4	113.91
Upper Big Creek	5/13/2019	0.42	106.24
Upper Big Creek	5/22/2019	0.43	83.86
Upper Big Creek	5/28/2019	0.44	102.36

Stage Zero Level (ft.) [+ Stage = True Depth]: 2.2

Notes: This dataset has less than the minimum of 8 data points required for this assessment. However, the data points have a good distribution across a range of stages, and the rating curve has a good fit to the data: we will therefore accept this rating curve for Upper Big Creek. We did collect partial data during other site visits when high water precluded completion of the transect, and will use these to add qualified data points later; otherwise we recommend collecting additional data to supplement this dataset.

Site: Upper Deer Creek
Latitude, Longitude: 45.7934, -110.8329
Formula, r^2 Value, Plot:



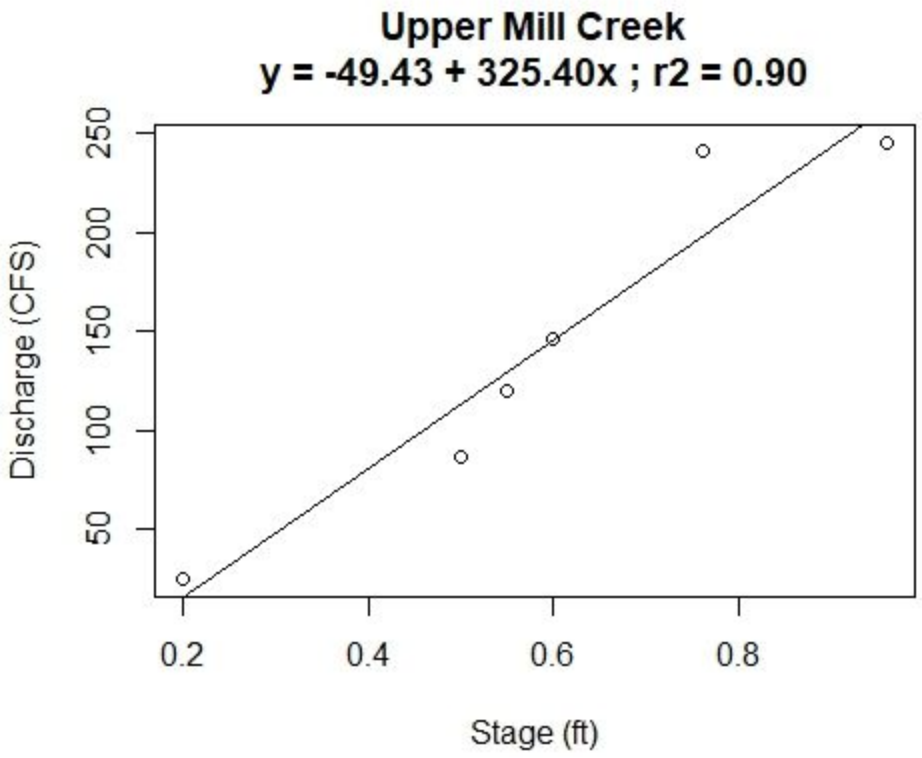
Rating Table:

Site	Date	Stage	Discharge
Upper Deer Creek	5/10/2019	-0.5	92.73
Upper Deer Creek	5/15/2019	-0.32	97.08
Upper Deer Creek	5/1/2019	-0.3	103.91
Upper Deer Creek	6/12/2019	0.39	87.87
Upper Deer Creek	6/5/2019	0.5	111.69
Upper Deer Creek	5/21/2019	0.67	126.26
Upper Deer Creek	5/24/2019	1.4	166.905

Stage Zero Level (ft.) [+ Stage = True Depth]: 1.4

Notes: This dataset has less than the minimum of 8 data points required for this assessment. However, the data points have a good distribution across a range of stages, and the rating curve has a good fit to the data: we will therefore accept this rating curve for Upper Deer Creek. We did collect partial data during other site visits when high water precluded completion of the transect, and will use these to add qualified data points later; otherwise we recommend collecting additional data to supplement this dataset.

Site: Upper Mill Creek
Latitude, Longitude: 45.2924, -110.5555
Formula, r^2 Value, Plot:



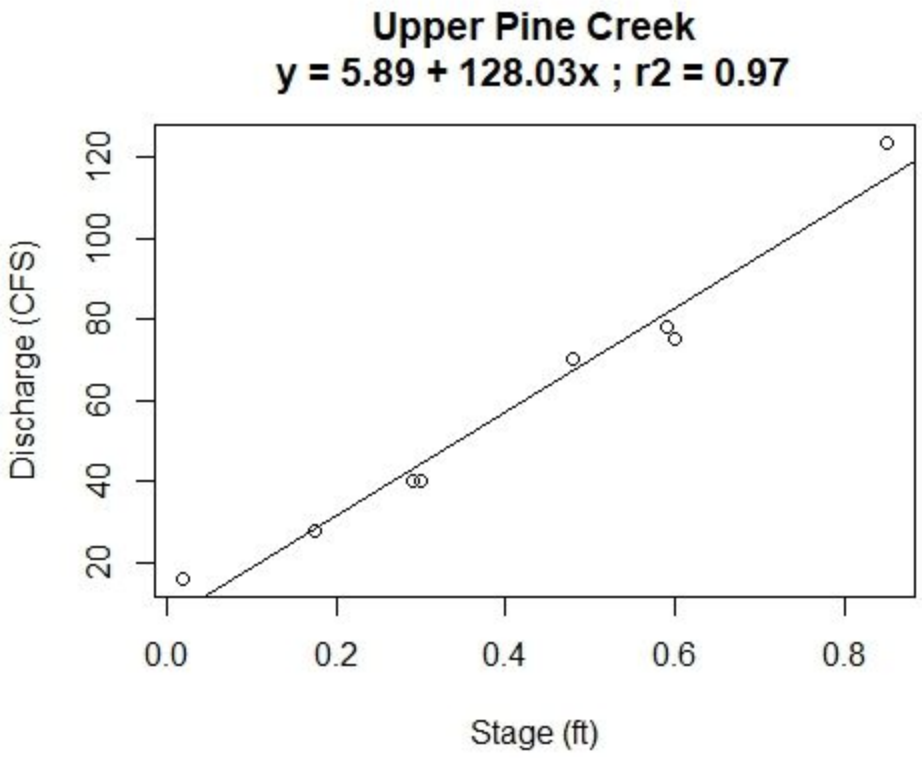
Rating Table:

Site	Date	Stage	Discharge
Upper Mill Creek	4/15/2019	0.2	25.225
Upper Mill Creek	4/30/2019	0.5	86.33
Upper Mill Creek	4/23/2019	0.55	120.46
Upper Mill Creek	5/8/2019	0.6	146.18
Upper Mill Creek	5/13/2019	0.76	241.455
Upper Mill Creek	6/13/2019	0.96	245.48

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.5

Notes: This dataset has less than the minimum of 8 data points required for this assessment. However, the data points have a good distribution across a range of stages, and the rating curve has a good fit to the data: we will therefore accept this rating curve for Upper Mill Creek. We did collect partial data during other site visits when high water precluded completion of the transect, and will use these to add qualified data points later; otherwise we recommend collecting additional data to supplement this dataset.

Site: Upper Pine Creek
Latitude, Longitude: 45.4997, -110.5217
Formula, r^2 Value, Plot:



Rating Table:

Site	Date	Stage	Discharge
Upper Pine Creek	5/6/2019	0.02	16.05
Upper Pine Creek	5/9/2019	0.175	27.62
Upper Pine Creek	5/23/2019	0.29	40.02
Upper Pine Creek	4/23/2019	0.3	40
Upper Pine Creek	5/27/2019	0.48	70.04
Upper Pine Creek	5/14/2019	0.59	78.01
Upper Pine Creek	5/30/2019	0.6	75.08
Upper Pine Creek	6/3/2019	0.85	123.46

Stage Zero Level (ft.) [+ Stage = True Depth]: 0.9

Appendix I

Stream Gauge Establishment and Rating Curve Calculation Protocols
Yellowstone Ecological Research Center, February 2019

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

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

Site Selection

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

Rating Curve Data Collection

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

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

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

flow line and consistent gradient ~100m upstream and downstream of the site (see also Rantz et al. 1982, Chapter 2)

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

Once a suitable site is selected:

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

Rating Curve Data Collection: We will collect two types of data – stream stage and discharge – over approximately 8-10 data collection events between low- and high-water in order to calculate the stage-discharge relationship, or rating curve, for each site. Below are the data to be recorded (**Appendix III**) during each collection event.

1. ***Site Name & Site Location:*** Each site is given a unique name and the location of the sensor and transect are recorded using **Latitude** and **Longitude** (recorded in decimal degrees).
2. ***Date and Collection Time:*** The date of collection is recorded using the format MM/DD/YYYY as well as the start/end time (24:00) of data collection.
3. ***Sample #:*** The Sample # is correlated with the date of collection with the first collection date being assigned "A" and each subsequent collection assigned the next consecutive alphabetical letter.
4. ***Observer/Recorder/Visitors:*** First and Last Initials are used to distinguish field technicians. The observer is the technician assessing the measurements while the recorder is the technician recording the measurements onto the data sheet while in the field. Any visitors at the site during data collection are also recorded.
5. ***H_2O Temperature:*** Water temperature is measured and using the Flowmeter and recorded to the nearest 1/100th of a degree (F).
6. ***Average Cloud Cover:*** **Record** an estimate of the average cloud cover using the following key:

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

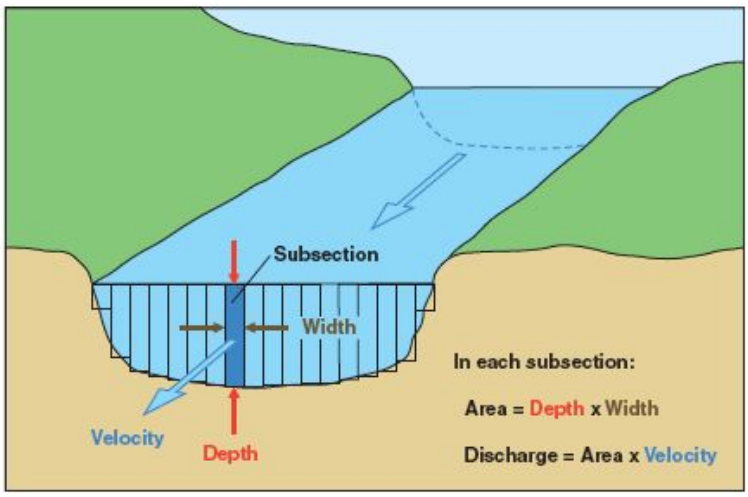
7. ***Stream Stage:*** Simply **record** the depth observed on the staff gauge (in feet, to the 1/100th of a foot).

8. ***Depth at Gauge:*** The water depth at the location of the stream gauge is recorded during each site visit using the depth stick. This offers a reference water depth level over the season and is recorded to the nearest 1/10th of a foot.
9. ***Sample Protocol:*** **Low H_20 protocol** versus **High H_20 protocol** can be simply checked off according to whether the stream is wadeable and a complete transect is being sampled (Low H_20 protocol) or if the high water conditions exist making it unsafe to wade the stream and only representative depths and velocities are recorded (High H_20 protocol).
10. ***Subsection Data:*** Once the site information is completed in the top portion of the data sheet, the following rows should be used to record data for each measured **point** along the transect. Each point correlates with a 1ft wide subsection of the stream and should include the distance to the "initial point" of orientation (see *Site Selection* above), a depth measurement (ft), 1-2 velocity measurements (ft/s) and any notes for the subsection.
11. The same data sheet can be used for both **High H_20 protocol** and **Low H_20 protocol** events. During **High H_20 protocol** events, simply check the appropriate box for protocol type, record all site data, and use the top row to record a representative depth and velocity. The notes section should be used to describe where in the channel the representative depth and velocities were measured.
12. The ***Additional Notes*** section at the bottom of the datasheet should be used for any general site observations including stream channel obstructions or changes, major weather events, or other observations that may have an impact on data collection.
13. ***Data Entry:*** There is a section at the top of the data sheet to record the initials and of the technician who enters the data electronically as well as the date on which the data is entered.
14. ***Data Quality Control:*** There is a section at the top of the data sheet to record the initials of the technician who performs quality control of the data electronically as well as the date on which quality control takes place.

Discharge:

Discharge is the product of the stream's cross-sectional area and its velocity (Turnipseed and Sauer 2010). To calculate discharge, we will use one of two methods depending on our ability to safely wade across the stream: for low water conditions, we will use the **subsection method**, and for high water conditions, we will use an abbreviated method using a single representative velocity measurement.

Discharge: Subsection Method (Low Water)



USGS Water Science School

1. **Run** the transect tape between the two rebar posts, making sure it is both **taut** and **perpendicular** to the flow line. You will use the transect tape to define your data collection points (subsections), spaced **every foot** for channels (Michaud and Wierenga 2005).
2. **Measure** the stream width from high water mark to stream edge to stream edge using the transect tape and record to the 1/10th of a foot on the datasheet.

3. Starting on one end of the channel, **establish** the first observation point (Point 0) at the edge of the water at the "initial point" of orientation established during transect setup and gauge installation. R**ecord** the distance between **Point 0** and the nearest rebar stake (the **"initial point"**). Using the Flowmeter, measure and record the depth in feet to the nearest 1/100th of a foot and 1-2 velocity measurements as detailed below (Turnipseed and Sauer 2010):
    a. If the depth is < 2', **record** one velocity measurement at a depth of 0.6 * total depth (**Appendix II**), and **enter** this SAME observation in BOTH velocity fields ("Velocity1", "Velocity2")
    b. If the depth is > 2', **record** one velocity measurement at a depth of 0.2 * total depth, **enter** it under "Velocity1", **record** another velocity measurement at a depth of 0.8 * total depth, and **enter** it under "Velocity2".
    c. See Appendix II for approximate velocity measurement depths.
    d. When measuring velocity, make sure that the observer is standing ~1-3' DOWNSTREAM of the transect tape, and ~1.5' TO THE SIDE of the flow line so as not to influence the velocity measurement.
4. **Move** to the next observation point (Point 1; 1 foot away from Point 0 for channels), and **record** the distance from the initial point, the depth (in feet, to the nearest 1/100th of a foot), **Repeat** Step 3, **recording** observation points (Point *n*), distances from the initial point, depths, and velocity measurements up to the last possible observation point at the stream edge on the opposite bank.
5. **Record** any additional observations in the "Notes" column for each subsection (e.g., observed changes/disturbances since the previous data collection period, relative water clarity, staff gauge condition, aquatic vegetative growth, spawning trout observed, problems/obstacles that hampered data collection, etc.).
6. **Repeat** Steps 1-6 for subsequent data collection events (approximately 10 in total) distributed between low- and high-flow stream conditions, filling out a separate datasheet for each data collection interval. For consistency, it is best to have the same technician acting as "observer" as well as that the same technician acts as "recorder" for each interval.
7. **Enter** the data in the digital database as soon as possible following data collection along with a symbol indicating which method was used ("L" for Low Water), and **file** the hardcopy datasheet in the "Rating Curve Data 2019" file folder.
8. **Calculate** the area of each subsection by simply multiplying the depth(ft) measurement recorded at each subsection by the subsectional width (1ft for all subsections).
9. **Determine** the discharge for each subsection by multiplying the calculated area(ft^2) for a subsection by the velocity(ft/s) measurement recorded for the same subsection. When 2 velocity measurements are taken for a subsection, the calculated average is used to determine subsectional discharge.
10. **Sum** all subsectional discharges together to determine the **Total Discharge** for the transect for each data collection event.

Discharge: Modified Float-Area Method (High Water)

When the stream is too deep/swift to safely wade and conduct the Subsection Method (Low Water) for calculating discharge, employ the following method instead:

1. **Reference** the width and subsectional data from the last data collected under the Subsection Method (Low Water) to establish (a) whether there are new wetted subsections on either side of the channel, and (b) the previous cross-sectional area.
2. **Calculate** the **new cross-sectional area** [A] of the channel by **(a)** calculating the areas of the new subsections following the standard method (depth * subsection width), **(b)** calculating the ***difference*** between the current stage height and the previous stage height **(c)** multiplying that difference by the previous channel width, and then adding that product to the previous cross-sectional area, and **(d)** summing all these areas together.
3. For velocity, use the Flowmeter to record a **representative velocity** measurement [V] from a safely accessible section of the current that is representative of the average of the channel current. Measurements will be taken as close to the surface as possible, allowing for full submersion of the propellor blades.
4. Based on the average water depth (the new cross-sectional area from Step 2 above divided by the number of subsections) **select** the appropriate roughness coefficient [c] from this table:

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

5. **Calculate** the discharge [Q] by multiplying the new cross-sectional area, the representative velocity, and the roughness coefficient (Q=A*V*c). Record this discharge value, along with a symbol indicating which method was used ("H" for High Water), the calculated average depth, and the roughness coefficient used in the appropriate columns on the database.

Data Analysis:

Evaluate the stage:discharge relationship through linear regression in R (R Core Team 2013) using the attached code (**Appendix IV**), reporting (a) the linear model formula (Discharge = $\beta_0 + \beta_1$ * Stage), and (b) the adjusted r^2 value. Start with a simple linear regression model. We expect high precision for data collected under the Subsection Method (Low Water), but considering (a) the addition of less-precise data collected under the Modified Float-Area Method (High Water), (b) the naturally inconsistent relationship between time and stage caused by variable discharge events (e.g., precipitation, extreme temperature changes), and (c) natural variation in the channel morphology throughout the data collection period caused by scouring, aquatic vegetation grown, etc., we consider models with $r^2 > 0.50$ (i.e., those that explain more than 50% of the model variance) to have an acceptable goodness-of-fit. A visual inspection of plotted data and curves with moderate r^2 values ($0.50 < r^2 < 0.75$) showing linear relationships and reasonable deviation among data points, plus one or two outliers besides an otherwise well fit dataset, supports this acceptance criteria. For those with a poor goodness-of-fit ($r^2 < 0.50$) but otherwise did not have any reported problems during data collection, use multiple linear regression models with polynomial terms to attempt to find a better fitting model. If there were problems during data collection that may explain the poor fit, record those in the notes.

***Data Archiving*:**

1. **Hard Copy** datasheets will be filed and stored at the YERC office. Each site will have its own folder and data will be organized by date (sample #).
2. A **Database** will be used to electronically store all data and used to produce calculations of average velocity, area, and discharge for each subsection and site visit. The database will hold permanent location and descriptive information for each site as well as data and notes from site visits and data collection.
3. **Data Quality Control** will take place after data has been electronically entered and by a different technician than the data enterer to assure the quality of the data and correct any data entry mistakes. Quality Control is done by simply comparing hard copy datasheets to the electronic database.
4. Electronic versions of the datasheet, database, site photos, and associated documents are saved within a **Google Drive** accessible by biologists and technicians involved with data collection and analysis.

***Maintenance*:**

1. The **Flowmeter** should be kept dry and out of direct heat. The batteries should be periodically checked to make sure it is working condition and the screen brightness is easily read in the field. Should the flowmeter get wet or take on any humidity inside the casing, the battery should be removed immediately and the unit should be allowed to dry completely before subsequent use.

2. The **Propeller** used to determine velocity should be kept clear of river rocks and handled so that it is not bent or broken. It should also be periodically assessed for debris that can get caught in the propeller, obstructing its spinning and therefore leading to inaccurate velocity measurements.
3. The **Depth Measuring Rod or Depth Stick** should be periodically evaluated for easiness in reading the increment markings as they can fade with repeated use. The increments can be re-established using permanent markers (different colors for each distance increment) using a staff gauge as the reference ruler.
4. The **datasheets** are best printed on rite-in-the-rain paper to keep them from disintegrating with wetness. They should be kept in a protective hard plastic clipboard while in the field and in the YERC office once the data has been entered electronically.

***Site Restoration*:**
Once all data collection has been completed, each site will be visited a final time to remove the rebar stakes and restore any rocks, natural vegetation or other natural features that had been manipulated for the ease of data collection. When a natural boulder or bridge pier have been used to install a stream or staff gauge, removal of the gauges will include filling in any unnatural holes, removing any hardware, and restoring the site to its natural form. Site photos taken during transect setup and gauge installation will be referenced to help restore the site. Any needed communications with landowners for sites on private land will take place at this time.

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

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

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

***References*:**
Michaud JP, Wierenga M. 2005. Estimating discharge and stream flows: a guide for sand and gravel operators. Washington State Department of Ecology publication number 05-10-070. Available at: https://fortress.wa.gov/ecy/publications/documents/0510070.pdf (February 2019).

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: http://www.R-project.org/ (February 2019).

Rantz SE, et al. 1982. Measurement and computation of streamflow: volume 1. Measurement of stage and discharge. United States Geological Survey water-supply paper 2175. Available at: https:// pubs.usgs.gov/wsp/wsp2175/pdf/WSP2175_vol1a.pdf (February 2019).

Turnipseed DP, Sauer VB. 2010. Discharge measurements at gaging stations. United States Geological Survey Techniques and Methods book 3, chapter A8. Available at: https://pubs.usgs.gov/tm/tm3-a8/ (February 2019).

Glossary:

Cross-sectional Area: the two-dimensional area of the entire stream channel from along the transect line. It is delineated by stream edge to stream edge and water surface to stream bed across the transect. The cross-sectional area is comprised of multiple subsectional areas described below (see subsectional area).

Data Quality Control: refers to comparing hard copy datasheets and notes to the electronic database and correcting and data entry mistakes using the hard copy data sheets as the reference.

Depth: Distance between streambed and water surface, used here for subsection data

Depth Measuring Rod: synonymous with depth stick used to take water depth measurements. The rod is a 5' long PVC pipe delineated with $1/10^{th}$ of a foot, ½ foot, and foot increments using differentiating colors.

Discharge: volume of water flowing past a given point, measured in cubic feet per second, used here for subsection data

Flow: synonymous with discharge

Flowmeter: consists of a display unit, probe and propeller and records H_20 temperature and water flow velocity. Measurements can be set to display average, maximum, and/or minimum.

Google Drive: a cloud storage service from Google that lets users store and synchronize digital content across computers, laptops and mobile devices, including Android-powered tablet and smartphone devices.

High Water Mark: the point on a stream bank reached at maximum water capacity for the channel.

Initial Point of Orientation: Start of transect where subsectional data is collected.

Max Channel Width: the width of the stream channel at maximum capacity, or high water to high water mark on each bank.

Rating Curve: A formula describing the depth:discharge relationship at a given point on a given stream, used to convert depth observations from stream gauge equipment to discharge estimates.

Representative Velocity: A single velocity measurement taken in a section of stream that is safely accessible and representative of the average velocity of the stream, used during high water.

Staff Gauge: Metal measuring device with 1/100th foot graduations, used to monument stream gauge site and record stage.

Stage: Water level as measured on the staff gauge (a relative measure, different from actual depth).

Stream Gauge: Location and equipment where water quantity information is collected.

Stream Width: Distance across wetted area of channel during a given data collection event.

Subsection: Unit of the channel with a set width for which area and velocity are measured, summed for total channel area and discharge.

Subsectional Area: Width by depth of a given subsection.

Total Discharge: Discharge um of subsectional discharge.

T-post: Steel fencing post used to anchor staff gauges.

Winter Base Flow Conditions: Annual low water depth recorded at staff gauge during installation in early spring.

[Protocols] Appendix I: Site Locations

Site Name	Sensor (Y/N)	Latitude	Longitude
Big Timber Creek	N	45.85436	-109.93336
Cedar Creek	N	45.14328	-110.81295
Eight Mile Creek	Y	45.40911	-110.69962
Fridley Creek	N	45.34283	-110.75693
Lower Big Creek	Y	45.39916	-110.8315
Lower Deer Creek	N	45.78173	-109.79162
Lower Mill Creek	Y	45.39466	-110.63986
Lower Pine Creek	N	45.50474	-110.56789
Mulherin Creek	N	45.12757	-110.80582
Otter Creek	N	45.85708	-109.90333
Rock Creek	Y	45.21087	-110.9039
Six Mile Creek	Y	45.32144	-110.77164
Tom Miner Creek	N	45.198197	-110.9086
Upper Big Creek	Y	45.30552	-110.86668
Upper Deer Creek	N	45.7934	-109.83289
Upper Mill Creek	Y	45.29237	-110.55551
Upper Pine Creek	N	45.49973	-110.5217

[Protocols] Appendix II: Depth Table for Velocity Measurements

Depths (in $1/10^{th}$ ft) at which to record velocity measurements considering the total depth at the observation point, based on the six-tenths method for total depths <2' and the two-point method (two-tenths for "Velocity 1", eight-tenths for "Velocity 2") for depths >2' (Turnipseed and Sauers 2010).

Total Depth	Velocity 1	Velocity 2
0.5	0.3	NA
1	0.6	NA
1.5	0.9	NA
2	1.2	NA
2.5	0.5	2
3	0.6	2.4
3.5	0.7	2.8
4	0.8	3.2
4.5	0.9	3.6
5	1	4

[Protocols] Appendix III: Data Sheet

Entered by _____ on _____QC BY _____ on_____

Site Name:			Lat:	Long:
Date:	Sample #:	Start Time (24:00):	End Time (24:00):	Observer:
Stream Width (ft):	**Stream Stage (ft):**	Depth at Gauge (ft):	Cloud Cover Code:	Recorder:
Low H_2O Protocol) _____ High H_2O Protocol _____			H_2O temp (ºF):	Visitors:

Point #	Distance (ft)	Total Depth (ft)	Velocity A (ft/s)	Velocity B (ft/s)	Notes

ADDITIONAL NOTES:

Page _____ of _____

[Protocols] Appendix IV: Analysis R Code

```
##### RATING CURVES #####

##### setup #####
### load data
setwd("C:/Users/USER/Desktop/RatingCurve_FINAL")
RatingCurve<-read.csv("RatingCurve_FINAL.csv", header=T)
# this .CSV can be replicated by amalgamating the rating tables included in the Final Report for FWP19-0148
### subset by site
BTC<-RatingCurve[RatingCurve$Site=="Big Timber Creek",]
CC<-RatingCurve[RatingCurve$Site=="Cedar Creek",]
EMC<-RatingCurve[RatingCurve$Site=="Eight Mile Creek",]
FC<-RatingCurve[RatingCurve$Site=="Fridley Creek",]
LBC<-RatingCurve[RatingCurve$Site=="Lower Big Creek",]
LDC<-RatingCurve[RatingCurve$Site=="Lower Deer Creek",]
LMC<-RatingCurve[RatingCurve$Site=="Lower Mill Creek",]
LPC<-RatingCurve[RatingCurve$Site=="Lower Pine Creek",]
MC<-RatingCurve[RatingCurve$Site=="Mulherin Creek",]
OC<-RatingCurve[RatingCurve$Site=="Otter Creek",]
RC<-RatingCurve[RatingCurve$Site=="Rock Creek",]
SMC<-RatingCurve[RatingCurve$Site=="Six Mile Creek",]
TMC<-RatingCurve[RatingCurve$Site=="Tom Miner Creek",]
UBC<-RatingCurve[RatingCurve$Site=="Upper Big Creek",]
UDC<-RatingCurve[RatingCurve$Site=="Upper Deer Creek",]
UMC<-RatingCurve[RatingCurve$Site=="Upper Mill Creek",]
UPC<-RatingCurve[RatingCurve$Site=="Upper Pine Creek",]

##### simple linear regression #####
BTClm<-lm(Discharge~Stage, BTC)
summary(BTClm)
# BTC wide scatter/poor fit - staff gauge was damaged and nearby stream bank stabilization work happened during data collection
CClm<-lm(Discharge~Stage, CC)
summary(CClm)
EMClm<-lm(Discharge~Stage, EMC)
summary(EMClm)
FClm<-lm(Discharge~Stage, FC)
summary(FClm)
LBClm<-lm(Discharge~Stage, LBC)
summary(LBClm)
LDClm<-lm(Discharge~Stage, LDC)
summary(LDClm)
LMClm<-lm(Discharge~Stage, LMC)
summary(LMClm)
LPClm<-lm(Discharge~Stage, LPC)
summary(LPClm)
MClm<-lm(Discharge~Stage, MC)
summary(MClm)
OClm<-lm(Discharge~Stage, OC)
summary(OClm)
RClm<-lm(Discharge~Stage, RC)
summary(RClm)
SMClm<-lm(Discharge~Stage, SMC)
summary(SMClm)
TMClm<-lm(Discharge~Stage, TMC)
summary(TMClm)
UBClm<-lm(Discharge~Stage, UBC)
summary(UBClm)
UDClm<-lm(Discharge~Stage, UDC)
summary(UDClm)
UMClm<-lm(Discharge~Stage, UMC)
```

```
summary(UMClm)
UPClm<-lm(Discharge~Stage, UPC)
summary(UPClm)

##### plots #####
plot(BTC$Stage, BTC$Discharge, main="Big Timber Creek
y = 183.95 + 148.34x ; r2 = 0.28", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(BTClm)
plot(CC$Stage, CC$Discharge, main="Cedar Creek
y = -13.34 + 79.45x ; r2 = 0.86", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(CClm)
plot(EMC$Stage, EMC$Discharge, main="Eight Mile Creek
y = 37.02 + 92.49x ; r2 = 0.81", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(EMClm)
plot(FC$Stage, FC$Discharge, main="Fridley Creek
y = -12.77 + 93.76x ; r2 = 0.80", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(FClm)
plot(LBC$Stage, LBC$Discharge, main="Lower Big Creek
y = 41.8 + 209.81x ; r2 = 0.90", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(LBClm)
plot(LDC$Stage, LDC$Discharge, main="Lower Deer Creek
y = 33.48 + 140.41x ; r2 = 0.95", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(LDClm)
plot(LMC$Stage, LMC$Discharge, main="Lower Mill Creek
y = -29.33 + 224.63x ; r2 = 0.91", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(LMClm)
plot(LPC$Stage, LPC$Discharge, main="Lower Pine Creek
y = -8.15 + 186.19x ; r2 = 0.75", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(LPClm)
plot(MC$Stage, MC$Discharge, main="Mulherin Creek
y = -141.78 + 171.32x ; r2 = 0.78", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(MClm)
plot(OC$Stage, OC$Discharge, main="Otter Creek
y = 61.65 + 52.58x ; r2 = 0.87", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(OClm)
plot(RC$Stage, RC$Discharge, main="Rock Creek
y = -32.37 + 127.30x ; r2 = 0.67", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(RClm)
plot(SMC$Stage, SMC$Discharge, main="Six Mile Creek
y = -49.28 + 111.32x ; r2 = 0.93", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(SMClm)
plot(TMC$Stage, TMC$Discharge, main="Tom Miner Creek
y = 28.16 + 134.05x ; r2 = 0.67", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(TMClm)
plot(UBC$Stage, UBC$Discharge, main="Upper Big Creek
y = 36.19 + 159.28x ; r2 = 0.85", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(UBClm)
plot(UDC$Stage, UDC$Discharge, main="Upper Deer Creek
y = 103.52 + 33.60x ; r2 = 0.64", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(UDClm)
plot(UMC$Stage, UMC$Discharge, main="Upper Mill Creek
y = -49.43 + 325.40x ; r2 = 0.90", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(UMClm)
plot(UPC$Stage, UPC$Discharge, main="Upper Pine Creek
y = 5.89 + 128.03x ; r2 = 0.97", xlab="Stage (ft)", ylab="Discharge (CFS)")
abline(UPClm)
```

Appendix II - MOU

Memorandum of Understanding (MOU)

This MOU is made 12/14/2018 between Yellowstone Ecological Research Center (YERC; 2048 Analysis Drive Suite B, Bozeman, MT 59718) and Sweet Grass County Conservation District (SGCD; 225 Big Timber Loop Road, Big Timber, MT 59011), for the purpose of *applving for funding from Montana Fish, Wildlife. and Parks' Drought Management Planning Program to calculate depth-to-discharge rating curves for stream gauges in the Upper Yellowstone Watershed*. This MOU is valid until 06/30/2019, and is contingent on funding being awarded by Montana Fish. Wildlife. and Parks.

YERC will:

(1) Identify n=20 potential sites for stream gauges on tributaries of the Yellowstone River between Gardiner MT and Big Timber MT, selecting locations of local stakeholder interest that are as close as possible to the main channel (thalweg), protected from floating debris upstream, accessible for maintenance and data downloads, and have minimal visual impacts;

(2) Calculate a rating curve for each site to convert depth measurements to discharge (flow) by measuring the stream channel's cross section at the potential site, visiting the site 10 times between March (low flows) and June (high flows) to record depth and flow under different stream conditions, and then using this data to calculate the rating curve using established procedures;

(3) Make results publicly available on YERC's Website and the Yellowstone River Clearinghouse (part of the Montana State Library's Geographic Information Clearinghouse);

(4) Administer all grant program requirements, including drafting proposals and applications and complying with all reporting and other administrative tasks.

SGCD will:

(1) Sponsor the project for Montana Fish, Wildlife, and Parks' Drought Management Program's 2018 funding season;

(2) Distribute awarded funds to YERC, minus a $200 grant processing fee payable to SGCD.

12/14/2018

Yellowstone Ecological Research Center

By Patrick Cross, Ecologist/Lab Manager

Sweet Grass County Conservation District

By Kevin Dawe, Chairman

Appendix III - Contract

MONTANA FISH, WILDLIFE & PARKS
FWP# 19-0148

Headwaters Project

THIS CONTRACT is entered into by and between the State of Montana, Fish, Wildlife & Parks, (State or FWP), whose address and phone number are PO Box 200701, Helena, MT 59620-0701 and Sweet Grass Conservation District (Contractor or CD) whose address and phone number are USDA Building, 225 Big Timber Loop Road, PO Box 749, Big Timber, MT 59011, and (406) 932-5160 Ext. 3.

1. EFFECTIVE DATE, DURATION, AND RENEWAL

1.1 Contract Term. The Contract's initial term is upon all parties signing, through June 30, 2019. unless terminated earlier as provided in this Contract. In no event is this Contract binding on State unless State's authorized representative has signed it. The legal counsel signature approving legal content of the Contract and the procurement officer signature approving the form of the Contract do not constitute an authorized signature.

2. SERVICES AND OR SUPPLIES

Contractor shall provide State the agreed upon tasks and deliverables as described below.

1) Identify up to 20 potential stream gauge locations on tributaries of the Upper Yellowstone River between Gardiner, MT and Big Timber, MT.
- Selecting sites of interest for local stakeholders (e.g., conservation districts, fisheries biologists) that are near the main current (thalweg), protected from floating debris, accessible for maintenance and data collection, and have minimal visual impact;

2) Calculate a depth-to-discharge rating curve for each site by measuring the stream cross section during low flows, then visiting the site 10 times between April 1 (low flows) and June 1 (high flows. a) Measurement will record depth and flow at different water levels,
b) Calculating the rating curve following established procedures;
3) Make the information publicly available on YERC's website and on the Montana State Library's Yellowstone River Clearinghouse.
4) Work will begin upon the execution of the contract and end by June 30, 2019.

Project Tasks: Sweet Grass Conservation District, working through the Yellowstone Ecological Research Center, Montana Fish, Wildlife & Parks and other partners, will select stream discharge monitoring sites, establish staff gauges, monitor stream discharge at those sites, build rating curves and prepare a final report.

Task 1. Select Monitoring Sites
Estimated expenditure: $1,415 (equipment $915, admin $500) March 2019
- Select twenty appropriate stream flow monitoring sites on tributaries to the Yellowstone River in the river reach extending from Gardiner, MT to Big Timber, MT.
- CD will acquire permission from landowners to access select sites and install staff gauges, CD will acquire any necessary permits, such as a SPA 124.

Task 2. Establish Monitoring Sites
Estimated expenditure: $2,900 (labor $2,000, admin $400, mileage $250, lodging $250) March -April 2019
- Record stream geometry metrics, GPS coordinates
- Install staff gauge

Task 3. Stream Flow Monitoring
Estimated expenditure: $4,000 (labor $2,000, mileage $1,750, lodging $250) April -June 2019

- Conduct up to ten discharge measurements, approximately three monthly, for each station using USGS protocols. Measurement will focus upon the period from base flow and into the rising limbs of the hydrograph. (Due to risks and equipment limitation peak flow measurements are not expected.)

Task 4. Stream Flow Monitoring and Development Rating Curve
Estimated expenditure: $1,250 (labor $1,000, admin $250) June 2019

- Continue flow monitoring
- Build rating curves for each site

Task 5. Data Assembly and Report
Estimated expenditure: $1,250 (labor $1,000, admin $250)

- Prepare a report that includes measured data and calculated flow data based upon stage as record in transducers. If possible, discuss findings and conclusions subject to data limitations.
- Submit a digital file of measured flow, and a calculated discharge as determined by stage and rating curves.
- Make the information publicly available on YERC's website and on the Montana State Library's Yellowstone River Clearinghouse present measurement data and findings to FWP, DNRC.

Deliverables: Must provide a written report summarizing measured and calculated data; digital file of measured discharge, and calculated discharge; and Web-based date presentation.

The primary goals of this project are to deliver, through a sensor network, high spatial and temporal resolution hydrologic data, at near real-time. This will be a valuable tool for monitoring stream flows, identifying drought indicators, evaluating the effectiveness of voluntary drought response programs, and other drought management needs. This will augment existing sensor networks (i.e., USGS stream gauges) that have large

3. WARRANTIES

3.1 Warranty of Services. Contractor warrants that the services provided conform to the Contract requirements, including all descriptions, specifications and attachments made a part of this Contract. State's acceptance of services provided by Contractor shall not relieve Contractor from its obligations under this warranty. In addition to its other remedies under this Contract, at law, or in equity, State may, at Contractor's expense, require prompt correction of any services failing to meet Contractor's warranty herein. Services corrected by Contractor shall be subject to all the provisions of this Contract in the manner and to the same extent as services originally furnished.

4. CONSIDERATION/PAYMENT

4.1 Payment Schedule. In consideration of the services to be provided, State shall pay Contractor according to the following schedule: Compensation will be used to purchase and install flow monitoring equipment, and fund personnel to collect flow measurements, and conduct rating curve development.

Compensation not to exceed $10,815.00. Payments are made as reimbursable expenditures and paid upon invoice.

4.2 Withholding of Payment. In addition to its other remedies under this Contract, at law, or in equity, State may withhold payments to Contractor if Contractor has breached this Contract. Such withholding may not be greater than total value of the subject statement of work or applicable contract.

4.3 Payment Terms. Unless otherwise noted in the solicitation document, State has thirty (30) days to pay invoices, as allowed by 17-8-242, MCA.

4.4 Reference to Contract. The Contract number MUST appear on all invoices, packing lists, packages, and correspondence pertaining to the Contract. If the number is not provided, State is not obligated to pay the invoice.

5. ACCESS AND RETENTION OF RECORDS

5.1 Access to Records. Contractor shall provide State, Legislative Auditor, or their authorized agents access to any records necessary to determine Contract compliance. State may terminate this Contract under section 16, Contract Termination, without incurring liability, for Contractor's refusal to allow access as required by this section. (18-1-118, MCA.)

5.2 Retention Period. Contractor shall create and retain all records supporting the services for a period of eight years after either the completion date of this Contract or termination of the Contract.

6. ASSIGNMENT, TRANSFER. AND SUBCONTRACTING

Contractor may not assign, transfer, or subcontract any portion of this Contract without State's prior written consent. (18-4-141, MCA) Contractor is responsible to State for the acts and omissions of all subcontractors or agents and of persons directly or indirectly employed by such subcontractors, and for the acts and omissions of persons employed directly by Contractor. No contractual relationships exist between any subcontractor and State under this Contract.

7. HOLD HARMLESS/INDEMNIFICATION

To the fullest extent permitted by law, Contractor shall indemnify and hold harmless State, its elected and appointed officials, officers, agents, directors, and employees from and against all claims, damages, losses and expenses, including the cost of defense thereof, to the extent caused by or arising out of Contractor's negligent acts, errors, or omissions in work or services performed under this Contract, including but not limited to, the negligent acts, errors, or omissions of any Subcontractor or anyone directly or indirectly employed by any Subcontractor for whose acts Subcontractor may be liable.

8. REQUIRED INSURANCE

8.1 General Requirements. Contractor shall maintain for the duration of this Contract, at its cost and expense, insurance against claims for injuries to persons or damages to property, including contractual liability, which may arise from or in connection with the performance of the work by Contractor, agents, employees, representatives, assigns, or subcontractors. This insurance shall cover such claims as may be caused by any negligent act or omission.

8.2 Primary Insurance. Contractor's insurance coverage shall be primary insurance with respect to State, its officers, officials, employees, and volunteers and shall apply separately to each project or location. Any insurance or self-insurance maintained by State, its officers, officials, employees, or volunteers shall be excess of Contractor's insurance and shall not contribute with it.

8.3 Specific Requirements for Commercial General Liability. Contractor shall purchase and maintain occurrence coverage with combined single limits for bodily injury, personal injury, and property damage of $500,000 per occurrence and $1,000,000 aggregate per year to cover such claims as may be caused by any act, omission, or negligence of Contractor or its officers, agents, representatives, assigns, or subcontractors.

State, its officers, officials, employees, and volunteers are to be covered and listed as additional insureds for liability arising out of activities performed by or on behalf of Contractor, including the insured's general supervision of Contractor, products, and completed operations, and the premises owned, leased, occupied, or used.

8.4 Deductibles and Self-Insured Retentions. Any deductible or self-insured retention must be declared to and approved by State. At the request of State either: (1) the insurer shall reduce or eliminate such deductibles or self-insured retentions as respects State, its officers, officials, employees, or volunteers; or (2) at the expense of Contractor, Contractor shall procure a bond guaranteeing payment of losses and related investigations, claims administration, and defense expenses.

8.5 Certificate of Insurance/Endorsements. A certificate of insurance from an insurer with a Best's rating of no less than A- indicating compliance with the required coverages has been received by Fish, Wildlife & Parks, P.O. Box 200701, Helena, MT 59620-0701. The certificates must name the State of Montana as certificate holder and Contractor shall provide copies of additional insured endorsements required by Contractor's commercial genera/liability and automobile liability policies. Contractor must notify State immediately of any material change in insurance coverage, such as changes in limits, coverages, change in status of policy, etc. State reserves the right to require complete copies of insurance policies at all times.

9. COMPLIANCE WITH WORKERS' COMPENSATION ACT

Contractor shall comply with the provisions of the Montana Workers' Compensation Act while performing work for State of Montana in accordance with 39-71-401, 39-71-405, and 39-71-417, MCA. Proof of compliance must be in the form of workers' compensation insurance, an independent contractor's exemption, or documentation of corporate officer status. Neither Contractor nor its employees are State employees. This insurance/exemption must be valid for the entire Contract term and any renewal. Upon expiration, a renewal document must be sent to Fish, Wildlife & Parks, P.O. Box 200701, Helena, MT 59620-0701.

10. COMPLIANCE WITH LAWS

Contractor shall, in performance of work under this Contract, fully comply with all applicable federal, state, or local laws, rules, regulations, and executive orders including but not limited to, the Montana Human Rights Act, the Equal Pay Act of 1963, the Civil Rights Act of 1964, the Age Discrimination Act of 1975, the Americans with Disabilities Act of 1990, and Section 504 of the Rehabilitation Act of 1973. Contractor is the employer for the purpose of providing healthcare benefits and paying any applicable penalties, fees and taxes under the Patient Protection and Affordable Care Act [P.I. 111-148, 124 Stat. 119]. Any subletting or subcontracting by
Contractor subject's subcontractors to the same provisions. In accordance with 49-3-207, MCA, and Executive Order No. 04-2016 Contractor agrees that the hiring of persons to perform this Contract will be made on the basis of merit and qualifications and there will be no discrimination based on race, color, sex, pregnancy, childbirth or medical conditions related to pregnancy or childbirth, political or religious affiliation or ideas, culture, creed, social origin or condition, genetic information, sexual orientation, gender identity or expression, national origin, ancestry, age, disability, military service or veteran status, or marital status by the persons performing this Contract.

11. DISABILITY ACCOMMODATIONS

State does not discriminate on the basis of disability in admission to, access to, or operations of its programs, services, or activities. Individuals who need aids, alternative document formats, or services for effective communications or other disability related accommodations in the programs and services offered are invited to make their needs and preferences known to this office. Interested parties should provide as much advance notice as possible.

12. REGISTRATION WITH THE SECRETARY OF STATE

Any business intending to transact business in Montana must register with the Secretary of State. Businesses that are incorporated in another state or country, but which are conducting activity in Montana, must determine whether they are transacting business in Montana in accordance with 35-1-1026 and 35-8-1001, MCA. Such businesses may want to

obtain the guidance of their attorney or accountant to determine whether their activity is considered transacting business.

If businesses determine that they are transacting business in Montana, they must register with the Secretary of State and obtain a certificate of authority to demonstrate that they are in good standing in Montana. To obtain registration materials, call the Office of the Secretary of State at (406) 444-3665, or visit their website at http://sos.mt.gov.

13. INTELLECTUAL PROPERTY/OWNERSHIP

13.1 Mutual Use. Contractor shall make available to State, on a royalty-free, non-exclusive basis, all patent and other legal rights in or to inventions first conceived and reduced to practice or created in whole or in part under this Contract, if such availability is necessary for State to receive the benefits of this Contract. Unless otherwise specified in a statement of work, both parties shall have a royalty-free, nonexclusive, and irrevocable right to reproduce, publish, or otherwise use copyrightable property created under this Contract. This mutual right includes (i) all deliverables and other materials, products, modifications that Contractor has developed or prepared for State under this Contract; (ii) any program code, or site- related program code that Contractor has created, developed, or prepared under or primarily in support of the performance of its specific obligations under this Contract; and (iii) manuals, training materials, and documentation. All information described in (i), (ii), and (iii) is collectively called the "Work Product".

13.2 Title and Ownership Rights. State retains title to and all ownership rights in all data and content, including but not limited to multimedia or images (graphics, audio, and video), text, and the like provided by State (the "Content"), but grants Contractor the right to access and use Content for the purpose of complying with its obligations under this Contract and any applicable statement of work.

13.3 Ownership of Work Product. Contractor shall execute any documents or take any other actions as may reasonably be necessary, or as State may reasonably request, to perfect State's ownership of any Work Product.
13.4 Copy of Work Product. Contractor shall, at no cost to State, deliver to State, upon State's request during the term of this Contract or at its expiration or termination, a current copy of all Work Product in the form and on the media in use as of the date of State's request, or such expiration or termination.

14. PATENT AND COPYRIGHT PROTECTION

14.1 Third-Party Claim. If a third party makes a claim against State that the products furnished under this Contract infringe upon or violate any patent or copyright, State shall promptly notify Contractor. Contractor shall defend such claim in State's name or its own name, as appropriate, but at Contractor's expense. Contractor shall indemnify State against all costs, damages, attorney fees, and all other costs and

expenses of litigation that accrue as a result of such claim. If State reasonably concludes that its interests are not being properly protected, or if principles of governmental or public law are involved, it may enter any action.

14.2 Product Subject of Claim. If any product furnished is likely to or does become the subject of a claim of infringement of a patent or copyright, then Contractor may, at its option, procure for State the right to continue using the alleged infringing product, or modify the product so that it becomes non-infringing. If none of the above options can be accomplished, or if the use of such product by State shall be prevented by injunction, State will determine whether the Contract has been breached.

15. CONTRACT TERMINATION

15.1 Termination for Cause with Notice to Cure Requirement. State may terminate this Contract in whole or in part for Contractor's failure to materially perform any of the services, duties, terms, or conditions contained in this Contract after giving Contractor written notice of the stated failure. The written notice must demand performance of the stated

failure within a specified period of time of not less than 30 days. If the demanded performance is not completed within the specified period, the termination is effective at the end of the specified period.

15.2 Reduction of Funding. State must by law terminate this Contract if funds are not appropriated or otherwise made available to support State's continuation of performance of this Contract in a subsequent fiscal period. (18-4-313(4), MCA) If state or federal government funds are not appropriated or otherwise made available through the state budgeting process to support continued performance of this Contract (whether at an initial contract payment level or any contract increases to that initial level) in subsequent fiscal periods, State shall terminate this Contract as required by law. State shall provide Contractor the date State's termination
shall take effect. State shall not be liable to Contractor for any payment that would have been payable had the Contract not been terminated under this provision. As stated above, State shall be liable to Contractor only for the payment, or prorated portion of that payment, owed to Contractor up to the date State's termination takes effect. This is Contractor's sole remedy. State shall not be liable to Contractor for any other payments or damages arising from termination under this section, including but not limited to general, special, or consequential damages such as lost profits or revenues.

16. EVENT OF BREACH- REMEDIES

16.1 Event of Breach by Contractor. Any one or more of the following Contractor acts or omissions constitute an event of material breach under this Contract:

- Products or services furnished fail to conform to any requirement;
- Failure to submit any report required by this Contract;
- Failure to perform any of the other terms and conditions of this Contract, including but not limited to beginning work under this Contract without prior State approval or breaching section 21.1, Technical or Contractual Problems, obligations; or
- Voluntary or involuntary bankruptcy or receivership.

16.2 Actions in Event of Breach. Upon Contractor's material breach, State may:

- Terminate this Contract under Section 15.1, Termination for Cause and pursue any of its remedies under this Contract, at law, or in equity; or
- Treat this Contract as materially breached and pursue any of its remedies under this Contract, at law, or in equity.

17. FORCE MAJEURE

Neither party is responsible for failure to fulfill its obligations due to causes beyond its reasonable control, including without limitation, acts or omissions of government or military authority, acts of God, materials

shortages, transportation delays, fires, floods, labor disturbances, riots, wars, terrorist acts, or any other causes, directly or indirectly beyond the reasonable control of the nonperforming party, so long as such party uses its best efforts to remedy such failure or delays. A party affected by a force majeure condition shall provide written notice to the other party within a reasonable time of the onset of the condition. In no event, however, shall the notice be provided later than five working days after the onset. If the notice is not provided
within the five-day period, then a party may not claim a force majeure event. A force majeure condition suspends a party's obligations under this Contract, unless the parties mutually agree that the obligation is excused because of the condition.

18. WAIVER OF BREACH

Either party's failure to enforce any contract provisions after any event of breach is not a waiver of its right to enforce the provisions and exercise appropriate remedies if the breach occurs again. Neither party may assert the defense of waiver in these situations.

19. CONFORMANCE WITH CONTRACT

No alteration of the terms, conditions, delivery, price, quality, quantities, or specifications of the Contract shall be granted without the Montana Fish, Wildlife & Parks prior written consent. Product or services provided that do not conform to the Contract terms, conditions, and specifications may be rejected and returned at Contractor's expense.

20. LIAISONS AND SERVICE OF NOTICES

20.1 Contract Liaisons. All project management and coordination on State's behalf must be through a single point of contact designated as State's liaison. Contractor shall designate a liaison that will provide the single point of contact for management and coordination of Contractor's work. All work performed under this Contract must be coordinated between State's liaison and Contractor's liaison.

Michael Mclane is State's liaison
PO Box 200701
Helena, MT 59620-0701
Telephone: 406-444-1563
Cell Phone: Fax:
E-mail: mmclane@mt.gov

Kevin Dawes is Contractor's liaison
Chair
USDA Building, 225 Big Timber Loop Rd
PO Box 749
Big Timber, MT 59011
Phone: 406-932-6860 or 406-930-0001 (C) E-mail: kdawyrlngs@gmail.com

Guelda Halverson, District Administrator USDA Building, 225 Big Timber Loop Rd PO Box 749
Big Timber, MT 59011
Phone: 406-932-5160 Ext. 3
E-mail: guelda.halverson@mt.nacdnet.net

20.2 Notifications. State's liaison and Contractor's liaison may be changed by written notice to the other party. Written notices, requests, or complaints must first be directed to the liaison. Notice may be provided by personal service, mail, or facsimile. If notice is provided by personal service or facsimile, the notice is effective upon receipt; if notice is provided by mail, the notice is effective within three business days of mailing. A signed and dated acknowledgement of the notice is required of both parties.

20.3 Identification/Substitution of Personnel. The personnel identified or described in Contractor's proposal shall perform the services provided for State under this Contract. Contractor agrees that any personnel substituted during the term of this Contract must be able to conduct the required work to industry

standards and be equally or better qualified than the personnel originally assigned. State reserves the right to approve Contractor personnel assigned to work under this Contract and any changes or substitutions to such personnel. State's approval of a substitution will not be unreasonably withheld. This approval or disapproval shall not relieve Contractor to perform and be responsible for its obligations under this Contract. State reserves the right to require Contractor personnel replacement. If Contractor personnel become unavailable, Contractor shall provide an equally qualified replacement in time to avoid delays to the work plan.

21. MEETINGS

21.1 Technical or Contractual Problems. Contractor shall meet with State's personnel, or designated representatives, to resolve technical or contractual problems occurring during the Contract term or to discuss the progress made by Contractor and State in the performance of their respective obligations, at no additional cost to the State. State may request the meetings as problems arise and will be coordinated by State. State shall provide Contractor a minimum of three full working days' notice of meeting date, time, and location. Face-to-face meetings are desired; however, at Contractor's option and expense, a conference call meeting may be substituted. Contractor's consistent failure to participate in problem resolution meetings, Contractor missing or rescheduling two consecutive meetings, or Contractor's failure to make a good faith effort to resolve problems may result in termination of the Contract.

21.2 Progress Meetings. During the term of this Contract, State's Project Manager shall plan and schedule progress meetings with Contractor to discuss Contractor's and State's progress in the performance of their respective obligations. These progress meetings will include State's Project Manager, Contractor's Project Manager, and any other additional personnel involved in the performance of this Contract as required. At each meeting, Contractor shall provide State with a written status report that identifies any problem or circumstance encountered by Contractor, or of which Contractor gained knowledge during the period since the last such status report, which may prevent Contractor from completing any of its obligations or may generate charges in excess of those previously agreed to by the parties. This may include the failure or inadequacy of State to perform its obligation under this Contract. Contractor shall identify the amount of excess charges, if any, and
the cause of any identified problem or circumstance and the steps taken to remedy the same.

22. TRANSITION ASSISTANCE

If this Contract is not renewed at the end of this term, if the Contract is otherwise terminated before project completion, or if particular work on a project is terminated for any reason, Contractor shall provide transition assistance for a reasonable, mutually agreed period of time after the expiration or termination of this Contract or particular work under this Contract. The purpose of this assistance is to allow for the expired or terminated portion of the services to continue without interruption or adverse effect, and to facilitate the orderly transfer of such services to State or its designees. The parties agree that such transition assistance is governed by the
terms and conditions of this Contract, except for those terms or conditions that do not reasonably apply to such transition assistance. State shall pay Contractor for any resources utilized in performing such transition assistance at the most current Contract rates. If State terminates a project or this Contract for cause, then State may offset the cost of paying Contractor for the additional resources Contractor utilized in providing transition assistance with any damages State may have sustained as a result of Contractor's breach.

23. CHOICE OF LAW AND VENUE

Montana law governs this Contract. The parties agree that any litigation concerning this bid, proposal, or this Contract must be brought in the First Judicial District in and for the County of Lewis and Clark, State of Montana, and each party shall pay its own costs and attorney fees.

24. TAX EXEMPTION

State of Montana is exempt from Federal Excise Taxes (#81-0302402).

25. AUTHORITY

This Contract is issued under authority of Title 18, Montana Code Annotated, and the Administrative Rules of Montana, Title 2, chapter 5.

26. SEVERABILITY

A declaration by any court or any other binding legal source that any provision of the Contract is illegal, and void shall not affect the legality and enforceability of any other provision of the Contract, unless the provisions are mutually and materially dependent.

27. SCOPE, ENTIRE AGREEMENT, AND AMENDMENT

27.1 Contract. This Contract consists of ten (10) numbered pages. In the case of dispute or ambiguity arising between or among the documents, the order of precedence of document interpretation is the same.

27.2 Entire Agreement. These documents are the entire agreement of the parties. They supersede all prior agreements, representations, and understandings. Any amendment or modification must be in a written agreement signed by the parties.

28. WAIVER

State's waiver of any Contractor obligation or responsibility in a specific situation is not a waiver in a future similar situation or is not a waiver of any other Contractor obligation or responsibility.

29. EXECUTION

The parties through their authorized agents have executed this Contract on the dates set out below.

STATE OF MONTANA Fish, Wildlife, & Parks PO Box 200701
Helena, MT 59620-0701

Sweet Grass Conversation District
USDA Building, 225 Big Timber Loop Road
Big Timber, MT 59011
FEDERAL ID #: 81-0404453