ANNUAL REPORT FOR MONITORING OF SUSPENDED SEDIMENT CONCENTRATIONS AND TURBIDITY DURING THE 2022 WATER YEAR IN MCCLOUD CREEK, HUMBOLDT COUNTY, CALIFORNIA

Pursuant to:
Monitoring and Reporting Program (MRP)
Order No. R1-2020-0001

Submitted:
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1.0 Introduction

Elk River is listed as an impaired water body under Section 303(d) of the Federal Clean Water Act (USEPA, 1999) due to high instream sediment loads and associated adverse impacts to the beneficial uses of water. In response to this, the North Coast Regional Water Quality Control Board (NCRWQCB) developed a Total Maximum Daily Load (TMDL) for sediment in Elk River. In May 2016 the NCRWQCB adopted the Action Plan for the Upper Elk River Sediment TMDL as an amendment to the Water Quality Control Plan for the North Coast. The TMDL Action Plan was approved by the State Water Resources Control Board in August 2017, the Office of Administrative Law in March 2018, and the US Environmental Protection Agency in April 2018.

To address the Elk River sediment impairment, the NCRWQCB has adopted and revised multiple Waste Discharge Requirements (WDRs) with Green Diamond Resource Company (GDRCo) over the years. These Orders have included Monitoring and Reporting Programs (MRPs), that includes the monitoring activities that GDRCo has been conducting in Elk River beginning in 2006. The current Order (R1-2020-0001) supersedes those portions of GDRCo's Forest Management WDR (Order R1-2012-0087) that apply to certain activities conducted by GDRCo on our timberlands in the Upper Elk River Watershed.

As part of the MRP in Order No. R1-2020-0001, GDRCo has agreed to continue to conduct water-quality trend monitoring in McCloud Creek, a tributary of SF Elk River. Using Turbidity Threshold Sampling (TTS), GDRCo measured stage, water velocity, turbidity and suspended sediment concentrations in McCloud Creek during the 2022 water year (WY). This annual report covers the period from October 1, 2021 through July 1, 2022, during which TTS monitoring occurred.

2.0 Data Collection and Analysis Activities

Data collection and analysis have been conducted as outlined in the MRP (Order No. R1-2020-0001), Standard Operating Procedures, and the Turbidity Threshold Sampling Quality Assurance Project Plan for McCloud Creek. See this document for further details on the monitoring parameters, protocols, and frequencies.

2.1 Station Installation and/or Adjustments

Equipment was installed at the McCloud Creek TTS station for the 2022 WY on September 22, 2021. The surface hydrology was disconnected at this time and the monitoring unit was dry. The station was turned online and stage and turbidity were monitored beginning on October 22nd when continuous flow was initiated, and the station remained powered on to monitor stage and turbidity throughout the water year.

2.2 Continuous Measurement Station

The TTS station was established in McCloud Creek on BLM property, approximately 400 feet upstream from the confluence with SF Elk River (Figure 1). The watershed area above the McCloud TTS monitoring site is approximately 1,482 acres (6.0 km^2). The specifications for the construction and operation of the TTS station are based on procedures developed by the United States Forest Service Redwood Science Laboratory (Lewis and Eads 2008). The station automatically records stage height and turbidity at 10-minute intervals and collects and stores automated grab samples of creek water, which are later transported to the lab and analyzed to quantify turbidity and suspended sediment concentration. Table 1 displays all the parameters and frequency of measurements collected at the McCloud Creek TTS station.

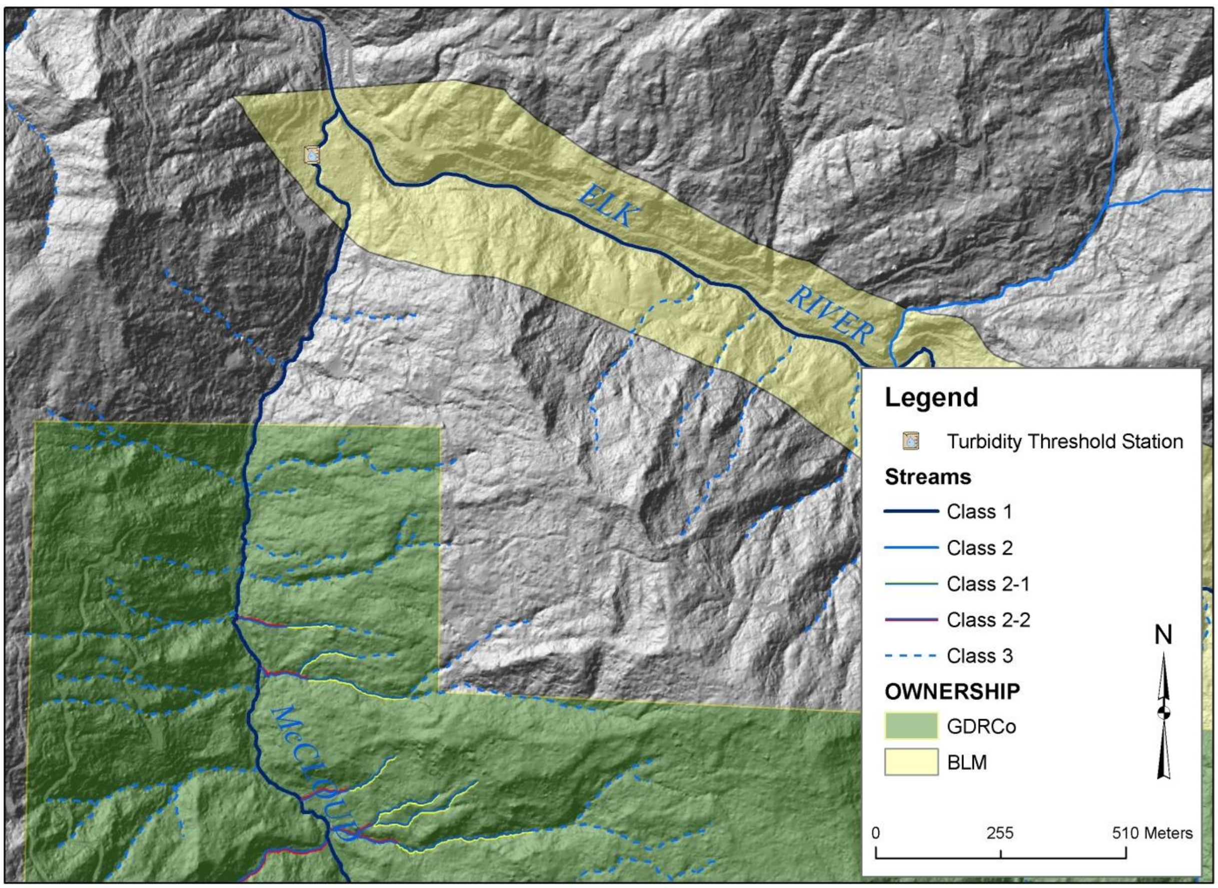

Figure 1. Location of the McCloud Creek TTS station.

Table 1. McCloud Creek TTS station parameters and specifications.

Parameter	Units	Sampling Method	Sampling Frequency
Turbidity	FNU	DTS-12 (turbidimeter, *in situ* measurement)	Continuous (10 minute interval)
Turbidity	NTRU	Manual ISCO sample	Weekly[1]
Suspended sediment	mg/L	Manual ISCO sample	Weekly[1]
Suspended sediment	mg/L	Automated ISCO sample	Event driven, based on turbidity thresholds
Discharge	cfs	Direct measurement	Weekly[1] and as needed for stage-discharge relationship
Stage	feet	Druck (pressure transducer, *in situ* measurement)	Continuous (10 minute interval)
Stage	feet	Stage plate	Weekly[1] and when present for stream flow measurements

[1] This frequency varies at times due to high flows during storm events, which restrict access to the McCloud Creek TTS station and low flow conditions where velocity is below minimum required for flow-meters.

2.2.1 Field Visits – Summary of Logs

A total of 39 field visits (frequency ≈ once weekly) were conducted during the 2022 WY. Visits were conducted to exchange bottles and batteries, download data, take flow measurements, or perform other storm-related maintenance activities. A summary of the activities conducted during the 2022 WY is provided in Table 2.

Table 2. Summary of field activities at the McCloud Creek TTS station during the 2022 WY. *Type: SI = Site installation, MO = Monitoring (data dumps, flow measurements, and grab samples), MA = Maintenance (sensor cleanings and site adjustments), CO = Construction, G/C = grab and control sample collected.

Date	Type*	Comments
9/22/2020	SI/CO	Monitoring equipment installed, station offline
10/22/2021	SI/MO	Station online for stage and turbidity, measured discharge
10/25/2021	MO/MA	Measured discharge, G/C
11/2/2021	MO/MA	Measured discharge, G/C
11/5/2021	MO/MA	Measured Discharge.
11/10/2021	MO/MA	Measured discharge, G/C
11/19/2021	MO/MA	Measured discharge, G/C
11/23/2021	MO	Discharge not measured, G/C
11/30/2021	MO	Discharge not measured, G/C
12/7/2021	MO	Discharge not measured, G/C
12/13/2021	MO/MA	Measured discharge, G/C, adjusted DTS
12/17/2021	MO	Discharge not measured, G/C
12/28/2021	MO	Measured discharge, G/C
1/5/2022	MO	Measured discharge, G/C
1/12/2022	MO/MA	Measured discharge, G/C, adjusted DTS
1/21/2022	MO/MA	Measured discharge, G/C, adjusted DTS
2/3/2022	MO	Discharge not measured, G/C
2/10/2022	MO	Discharge not measured, G/C
2/15/2022	MO	Discharge not measured, G/C
2/21/2022	MO	Discharge not measured, G/C
3/4/2022	MO	Discharge not measured, G/C
3/8/2022	MO	Discharge not measured, G/C
3/15/2022	MO	Discharge not measured, G/C
3/22/2022	MO	Discharge not measured, G/C
3/29/2022	MO	Discharge not measured, G/C
4/5/2022	MO	Discharge not measured, G/C
4/13/2022	MO/MA	Measured discharge, G/C, adjusted DTS
4/19/2022	MO	Measured discharge, G/C
4/28/2022	MO/MA	Measured discharge, G/C, adjusted DTS
5/4/2022	MO	Measured discharge, G/C
5/11/2022	MO	Measured discharge, G/C
5/18/2022	MO	Measured discharge, G/C
5/27/2022	MO	Discharge not measured, G/C
6/2/2022	MO	Discharge not measured, G/C
6/10/2022	MO	Discharge not measured, G/C
6/15/2022	MO	Discharge not measured
6/23/2022	MO	Discharge not measured
6/28/2022	MO	Discharge not measured
7/6/2022	MO/CO	Discharge not measured, Monitoring station taken offline and equipment removed

2.2.2 Site Observations

A summary of site observations was compiled for the 2022 WY (Table 3). These site visit observations included notable items, unrelated to the station status, but related to the site conditions. Observations for this WY included hydrologic conditions and discharge measurement quality.

Table 3. Summary of site observations collected at the McCloud Creek TTS station during the 2022 WY.

Comment Type	Start Date	End Date	Comment	Initials
Observation	09/20/21	10/22/21	Reach is dry and hydrologically disconnected. Station remains offline.	MRR/LJJ
Observation	09/22/21		Monitoring equipment installed, station offline.	MRR/LJJ
Observation	10/22/21		Monitoring unit became hydrologically connected at 910. Point of zero flow is estimated to be between 1.00-1.05'.	MRR
Observation	10/22/21		Station is online for both stage and turbidity.	MRR
Observation	10/22/21		Discharge measurement had four verticals >10% of total flow; graded as *poor data* in TTS.	MRR
Observation	10/25/21		Discharge measurement had three verticals >10% of total flow; graded as *poor data* in TTS.	MRR
Observation	11/02/21		Discharge measurement had three verticals >10% of total flow; graded as *poor data* in TTS.	LJJ
Observation	11/05/21		Discharge measurement had a low number of verticals; graded as *fair data* in TTS	LJJ
Observation	11/10/21		Discharge measurement had four verticals >10% of total flow; graded as *poor data* in TTS.	EML
Observation	11/19/21		Discharge measurement had only four verticals due to low flows; graded as *unusable data* in TTS.	LJJ
Observation	11/23/21	12/13/21	Station is hydrologically connected but streamflow is too low to obtain a discharge measurement.	LJJ
Observation	12/13/21		Discharge measured approximately 5 feet downstream of normal cross-section due to cross-flow conditions.	MRR
Observation	12/28/21		Discharge measurement graded as FAIR due to too few verticals measured and 6 of 11 were greater than 10% of the flow.	
Observation	01/12/22		Discharge measurement had two verticals >10% of total flow; graded as *fair data* in TTS.	EML
Observation	01/21/22		Discharge measurement had three verticals >10% of total flow; graded as *poor data* in TTS.	EML
Observation	02/03/22	04/13/22	Station is hydrologically connected but streamflow is too low to obtain a discharge measurement.	LJJ/EML/MRR
Observation	02/21/22		Reach is hydrologically connected at 0.92'	MRR
Observation	02/21/22		Sent new test datalogger program that changes "TtsTable" to "MC2_TtsTable" for use with the Fulcrum application	MRR
Observation	03/08/22		Reach is hydrologically connected at 0.90'	EML
Observation	05/27/22	07/06/22	Station is hydrologically connected but streamflow is too low to obtain a discharge measurement.	EML/MRR
Observation	07/06/22		Station was taken offline for water year and monitoring equipment removed.	EML

2.2.3 Download Data Summary

The data logger at the TTS station was downloaded to a field PC at least weekly when the station was online. The files were then transferred to the GDRCo server and compiled into a proprietary SQL database. Editing and analysis were performed using this database, Aquatic Informatics' AQUARIUS Time-Series©, and Microsoft Excel. The output data file for this report is labeled as "Appendix_A_MC2_All_Data_WY2022.xlsx" and was submitted with this annual report in accordance with the NCRWQCB 2014 electronic document submission guidelines.

2.2.3.1 Continuous Stage

A Druck pressure transducer (Druck Inc.) was used to measure continuous stage height (feet) at 10-minute intervals throughout the 2022 WY (Figure 2). Stage plate observation (accuracy +/- 0.01 feet) was used to validate the stage readings during each site visit. Where stage values were erroneous or missing due to stage drift, stage offset, or equipment failure, values were estimated using time-interpolated drift corrections, offset corrections, or interpolated using adjacent valid data in AQUARIUS. The type of estimates used for missing or erroneous data was noted and can be found in the 'Data Management' tab of the electronic data file (Appendix A).

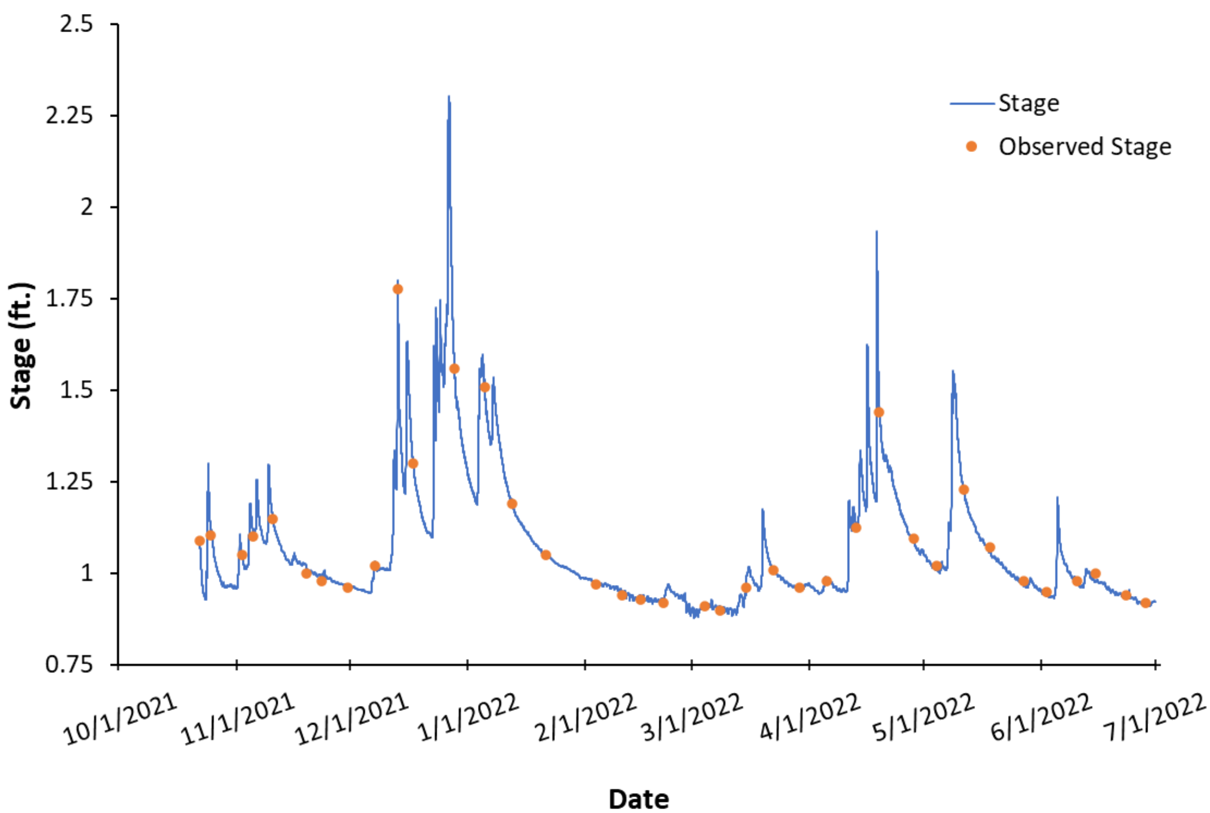

Figure 2. Continuous time-series of stage collected by the instream Druck pressure transducer sensor and stage plate observations at the McCloud Creek TTS station during the 2022 WY.

2.2.3.2 Stage-Discharge Relationship

During the 2022 WY, GDRCo personnel collected 17 water velocity measurements using the Price Pygmy flow meter. Using Aquatic Informatics' Rating Development Tool (Aquarius, 2016), coincidental stages were taken with discharge measurements and plotted to create a rating curve for the 2022 WY (Figure 3). Sixteen of the seventeen measurements were used to verify the stage-discharge relationship used during this water year, as one measurement was poor quality due to low-velocity conditions. The effective rating period begins on December 21,2015 in which the same relationship was used between stage and discharge during this time since there were no physical changes to the channel control of the monitoring unit.

Derived discharge values above the maximum measured stage of 2.12 ft for the rating period were extrapolated using the Flow Transference Method (FTM) with discharge data from the South Fork Elk River provided by Humboldt Redwood Company. Measuring a high-water discharge has been limited by technician's ability to cross the SF Elk River; which is unsafe at higher flows. Previous extrapolations of the rating curve simply extended the known curve to the maximum recorded stage value to produce a derived discharge. That extrapolation method yielded unusually high discharge values in excess of 1000 cfs which would begin to exceed discharge measurements from the Humboldt Redwood Company South Fork Elk River gaging station. The FTM yields a more realistic discharge value that is consistent with what would be expected of a watershed the size of McCloud Creek. These data should be used and viewed with caution without additional empirical support. However, they do provide a more realistic idea of flows in McCloud Creek. Furthermore, access was established for accessing the monitoring site at stages above 2.12 feet for the 2022 water year. This will allow for technicians to access the site and get discharge measurements to verify the current estimated discharges at greater stage values.

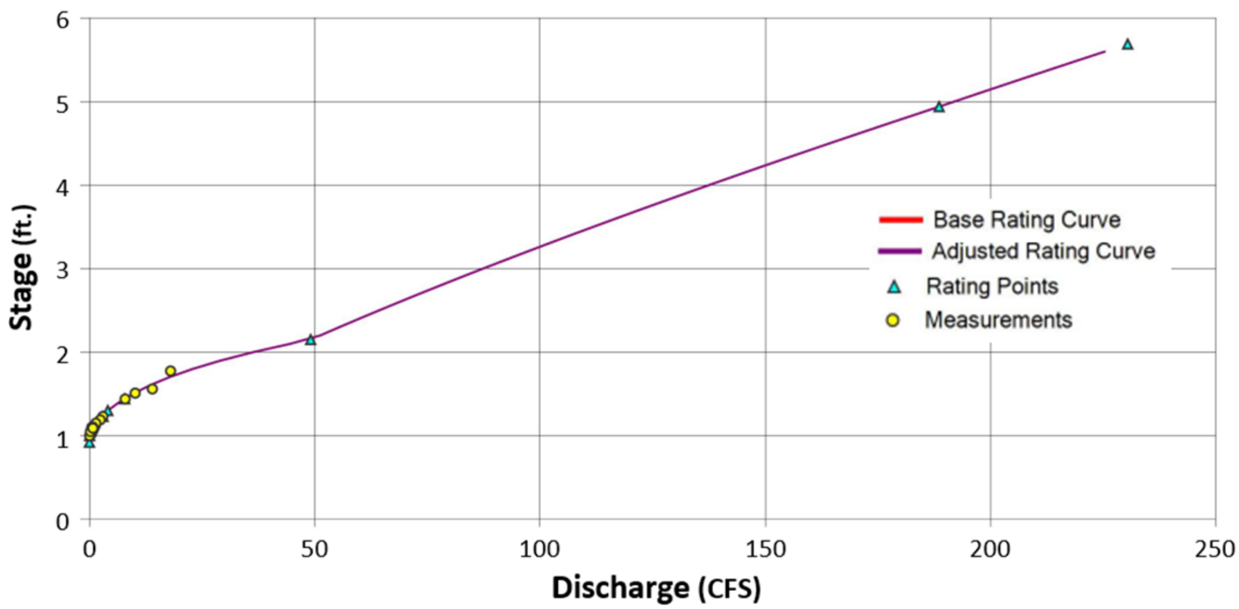

Figure 3. Discharge-stage relationship used for the 2022 WY.

2.2.3.3 Continuous Discharge

Continuous discharge for the 2022 WY (Figure 4) was derived using the rating curve and the continuous time series stage data in Aquarius. The estimated peak discharge for McCloud Creek during the 2022 WY occurred on December 27th and was ≈ 56 cfs (stage = 2.30 ft). Due to the safety limitations involved in wading across SF Elk River during storm events, discharge measurements at the McCloud TTS site have been limited to stages < 2.12 ft (≈ 48 cfs). Despite this limitation, 99.89% of the stage measurements recorded during the 2022 WY were within the range of measured discharges in the rating period. Considering the strong relationship between stage and discharge, interpolated discharges below ≈ 50 cfs have high confidence. The extrapolated discharge values that exceed the range of empirical values have a high uncertainty given the lack of discharge measurements for stages greater than 2.12 ft. A general rule of thumb is to not estimate over two times the max measured discharge stage value as it becomes exceedingly difficult to account for when channel controls take effect. For this reason, the Flow Transference Method was used in an attempt to better predict high end discharges.

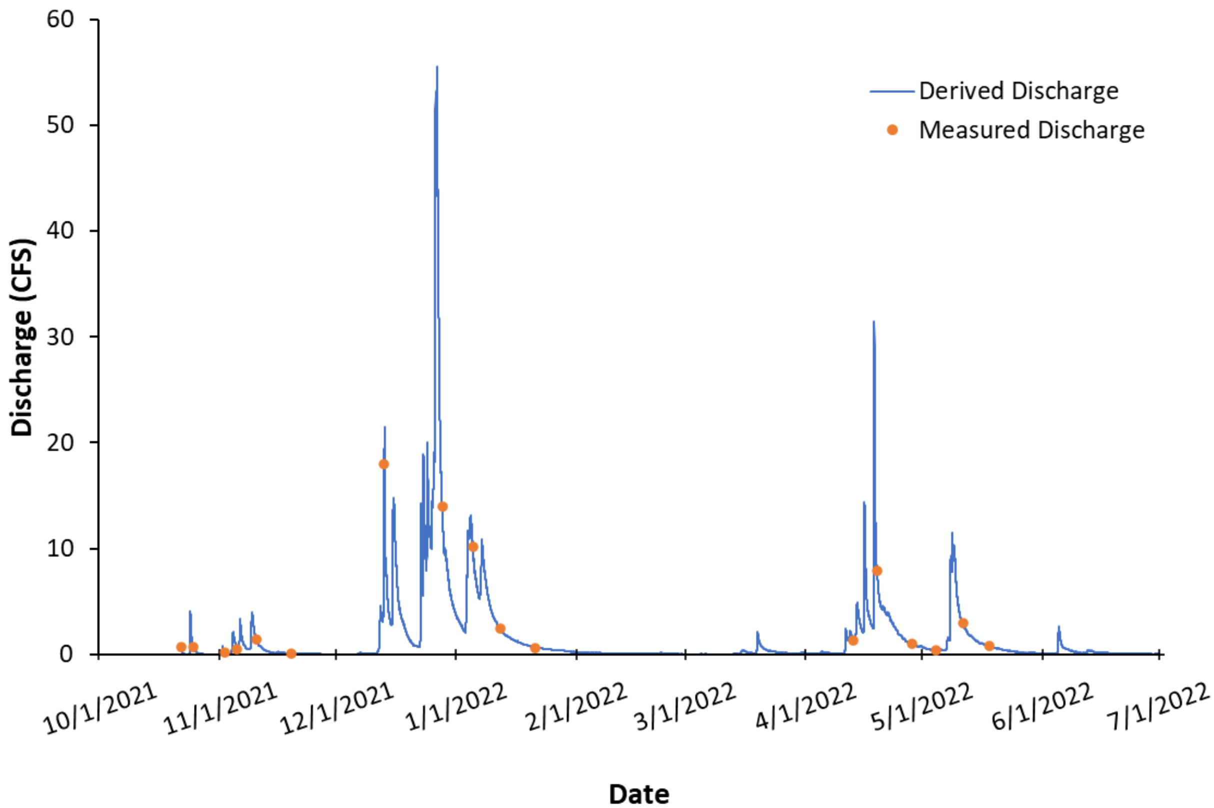

Figure 4. Continuous estimated discharge and measured discharge at the McCloud Creek TTS station during the 2022 WY.

2.2.3.4 Turbidity

Turbidity was measured simultaneously using two methodologies at the McCloud Creek TTS station during the 2022 WY. A DTS-12 turbidity sensor (Forest Technology Systems, LTD., Victoria, B.C., Canada) was used to measure water turbidity (Formazin Nephelometric Units [FNU]) in the field. Coincident water samples were collected using an ISCO 3700C water sampler (Teledyne ISCO, Lincoln, Nebraska) during each field visit and automatically based on established turbidity thresholds.

During the 2022 WY, 158 water samples were collected with the ISCO water sampler. Most of the water samples (59.5%) were collected by automated turbidity threshold sampling (n = 94) and the remainder were paired manual samples collected during site visits (n = 64 (32 pairs)). Low level turbidity samples (FNU <30) comprised a disproportionate amount of the total samples collected. Over processing of these samples can lead to bias in the low end of the FNU-NTRU relationship. To reduce this bias, a subsampling protocol was introduced, to process 50% of the samples in the lab with low turbidities (FNU <30). Water samples were brought to the laboratory and a Hach 2100N turbidimeter (Hach Company, Loveland, Colorado) was used to measure turbidity (Nephelometric Turbidity-Ratio Units [NTRU]). A total of 70 water samples collected via automated turbidity threshold sampling and 38 collected via manual collection were processed for turbidity in lab.

A relationship between the lab and field turbidity measurements was analyzed to develop a regression equation (Figure 5). This regression equation was then applied to lab sample turbidities to assist in reconstructing missing field turbidity, smoothing erratic values, or verifying turbidity spikes.

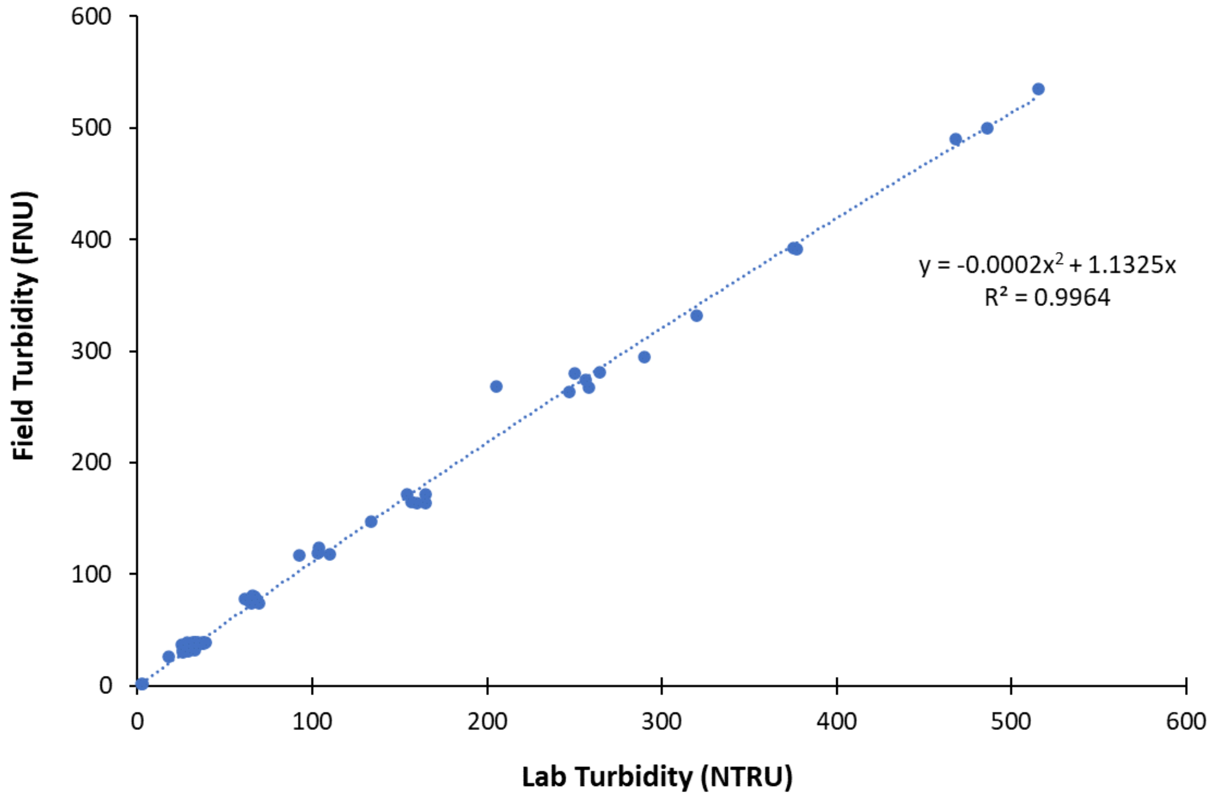

Figure 5. Relationship between coincident field turbidity measurements (FNU) and lab turbidity measurements (NTRU) collected at the McCloud Creek TTS station during the 2022 WY.

2.2.3.5 Continuous Turbidity

A DTS-12 sensor was used to measure continuous turbidity (FNU) at 10-minute intervals throughout the 2022 WY (Figure 6). Where turbidity values were missing or erroneous due to equipment failure or measurable range exceedance, values were estimated using stage-based regressions, values derived from ISCO samples (when possible), or interpolated using adjacent valid data. The type of estimates used for missing or erroneous data was noted and can be found in the 'Data Management' tab in the electronic data file (Appendix A).

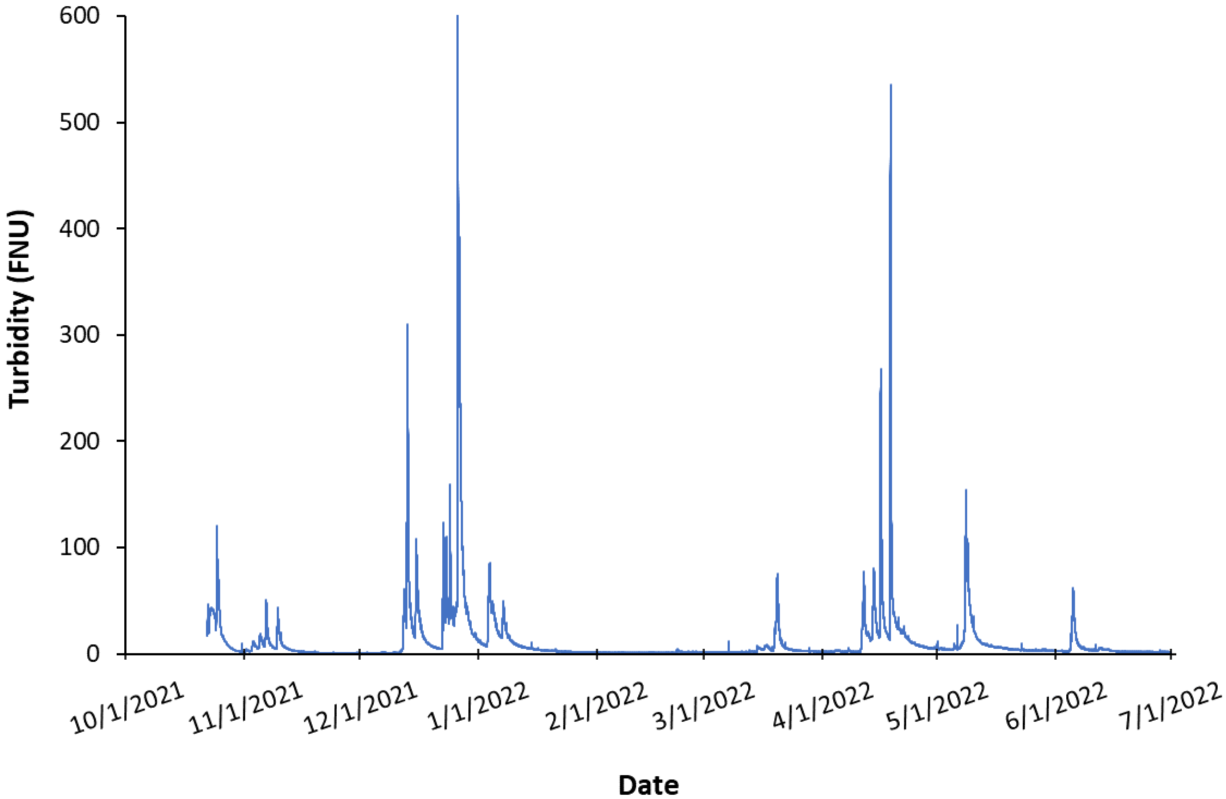

Figure 6. Continuous Time-Series of turbidity collected by the instream DTS-12 sensor at the McCloud Creek TTS station during the 2022 WY.

2.2.3.6 Grab Sample Data Summary

A total of 158 water samples were collected (94 automated and 64 manual) during the 2022 WY. Paired manual grab samples were always taken if the station turbidity read >30 FNU and taken opportunistically when FNU was <30 during a site visit. These were collected using the ISCO sampler with a manual override and were primarily used as laboratory quality control samples. The collection times for manual and automated (i.e., turbidity threshold) grab samples were compiled and overlaid on the continuous turbidity time series for the 2022 WY (Figure 7).

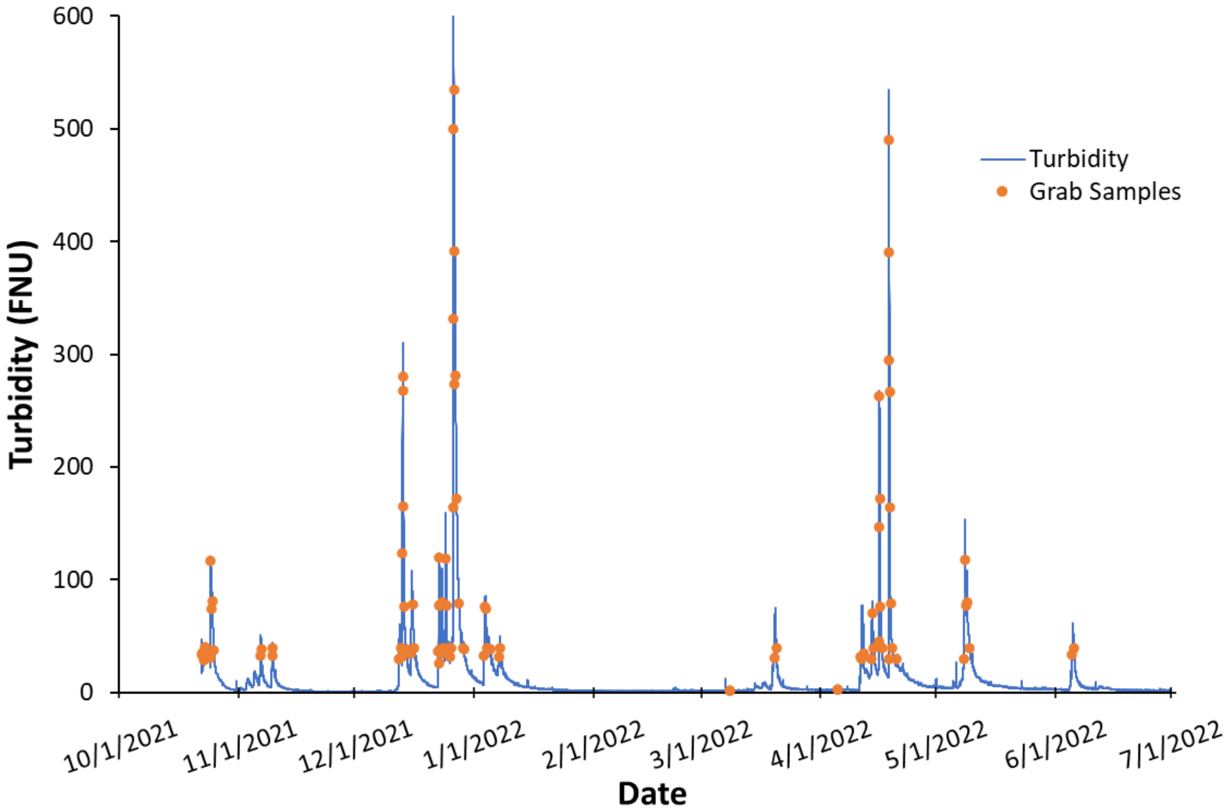

Figure 7. Continuous turbidity and timing of turbidity threshold grab samples at the McCloud Creek TTS station during the 2022 WY.

2.2.3.7 Comparative Analysis of Continuous Stage and Turbidity

A visual assessment comparing continuous stage and turbidity data was made to determine if there were any increases in continuous turbidity that were not associated with an increase in continuous stage. This would indicate additional sediment input into the system though such sources as localized landslides, nearby upstream tributaries, or roads for example. As expected, all increases in turbidity coincided with an increase in stage at the McCloud Creek TTS monitoring site for the 2022 WY, indicating that turbidity was discharge driven (Figure 8).

The two largest increases in turbidity coincided with the largest increases in stage and occurred on December 26th, 2021 and April 18th, 2022.

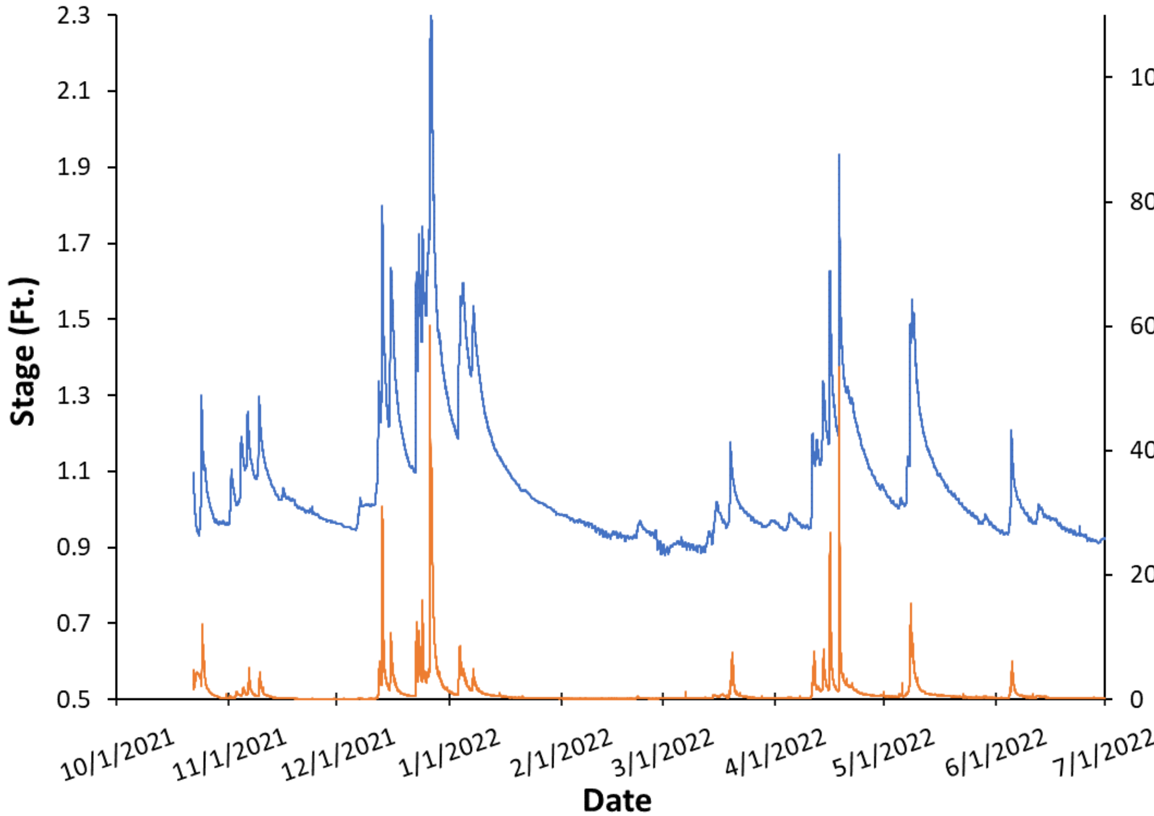

Figure 8. Continuous time-series of stage and turbidity at the McCloud Creek TTS station during the 2022 WY.

2.2.3.8 Suspended Sediment Concentration

The relationship between suspended sediment concentration (SSC, in mg/L) of the ISCO samples and the turbidity (FNU) from DTS-12 for the entire 2022 WY was established as a power curve (Figure 9). There was a total of 86 automated samples processed for suspended sediment concentration during the 2022 WY. The initial assessment of this relationship is relatively simplistic, and a better fit of these data may be possible through an assessment of additional relationships and variables.

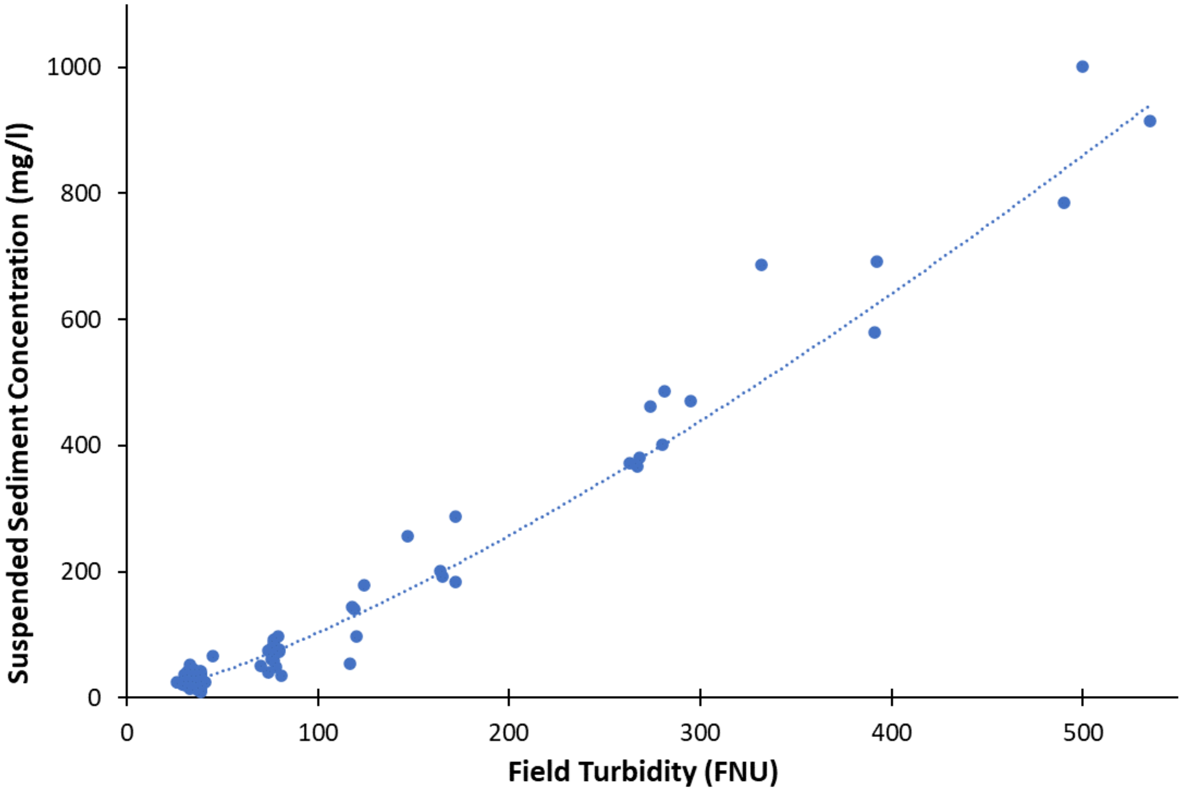

Figure 9. Relationship between turbidity and SSC for the McCloud Creek TTS station during the entire 2022 WY. This graph is an overview of the entire water year.

The relationship between SSC and turbidity can change over the course of the year either between or within storm events (Lewis 1996). We analyzed individual storm events to establish stronger relationships, and if possible, the relationships of individual rising and falling limbs of storms. SSC data was then paired with corresponding turbidity measurements using a set of procedures developed by Jack Lewis at Redwood Sciences Lab (Lewis 2007) for use within R, a free statistical software package (R Core Team 2018). This software allows for the construction of turbidity sediment rating curves where relationships between SSC and turbidity can be established on a storm-by-storm basis. Storm periods are defined for those rising and falling turbidities having at least four samples, and ideally 4 samples on the rising and 4 samples on the falling limbs. For those periods where the sample size was less than 4, they were combined with adjacent storm's samples. The best fit relationship for each storm period was determined after reviewing graphics, R-squared and residual standard error. The best fit relationship is determined to be either linear, power or log transformed variables. Once relationships are established, the software produces a derived SSC time-series data set using the turbidity time-series as the input (Figure 10). The derived SSC data set is then multiplied by the derived discharge data produced by a standard stage-discharge rating curve. The resulting data set gives instantaneous Suspended Sediment Load (iSSL) estimates for every 10-minute interval for the water year.

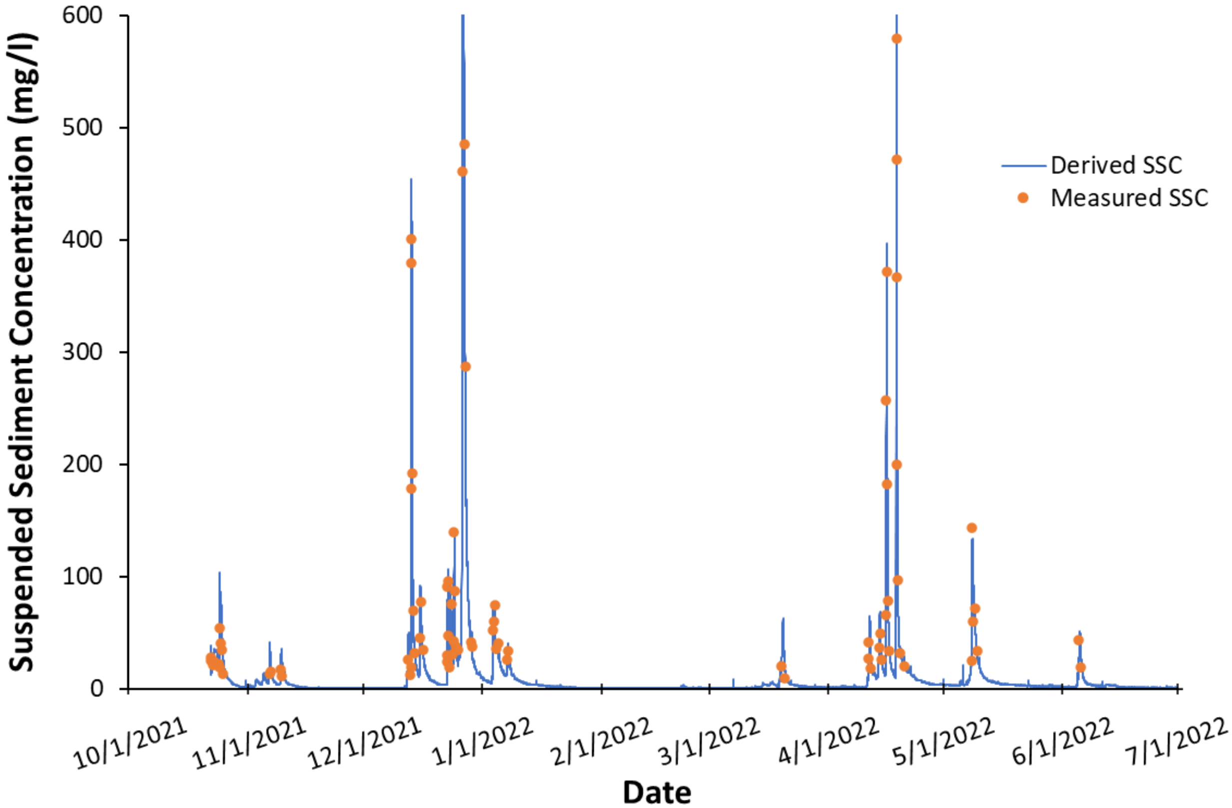

Figure 10. Derived Suspended Sediment Concentration (SSC) and based on individual storm's best-fit relationships during the 2022 WY.

2.2.3.9 Sediment Load and Yield

Sediment load was produced for the 2022 WY using a set of procedures developed by Jack Lewis at Redwood Sciences Lab (Lewis 2007) for use within R, a free statistical software package (R Core Team 2018). Sediment Load (kg) was estimated for the entire water year based on derived continuous sediment concentrations (mg/l). For the 2022 WY there was a total of 5 periods for which relationships were established between turbidity and SSC, including 4 storms (2 of which were separated by rising and falling limbs) and a base relationship (Table 4). This annual sediment load was adjusted by watershed area upstream of the TTS monitoring site (6.0 km^2) producing sediment yield in metric tons per km^2 per year (metric tons/km^2/year) and a coefficient of variation (CV). The estimated sediment load for the 2022 WY was 104,848 kg (104.85 metric tons, CV = 2.27%). The sediment load for storm 2 comprises 64.59% of the total annual sediment load. The annual sediment yield for the 2022 WY was 17.44 metric tons/km^2/year which is the lowest since beginning of monitoring in water year 2007. The average annual sediment yield is 253.82 metric tons/km^2/year for the entire monitoring period since the 2007 WY (Table 5).

Table 4. Summary of time periods and relationships used to estimate continuous suspended sediment concentration (mg/l) and sediment Loads (kg) for the 2022 WY. (logxy = log-transformed turbidity and SSC, mvue = bias correction method, n = sample size, CV% = coefficient of variation).

Period	Start	End	Relationship	n	Sediment Load (kg)	CV%	Percent of Annual Sediment Load
Storm 1	12/13/2021 09:20	12/15/2021 16:00	power	7	5859	3.4	5.59%
Storm 2	12/26/2021 15:10	12/29/2021 10:10	logxy:mvue	9	67723	3.3	64.59%
Storm 3 (rising) Storm 3 (falling)	4/16/2022 02:30 4/16/2022 17:00	4/16/2022 16:50 4/18/2022 14:50	power power	7	3930	6.4	3.75%
Storm 4 (rising) Storm 4 (falling)	4/18/2022 15:00 4/18/2022 19:40	4/18/2022 19:30 4/20/2022 20:20	power power	7	10260	2.0	9.79%
Base	10/22/2021 09:30 12/15/2021 16:10 12/29/2021 10:20 4/20/2022 20:30	12/13/2021 09:10 12/26/2021 15:00 4/16/2022 02:20 6/30/2022 23:50	logxy:mvue	56	17077	3.7	16.29%
			Total:	86	104848	2.27%	

Table 5. Annual sediment yield (metric tons/km^2/year) estimates and the coefficient of variation (CV%) for the McCloud TTS monitoring site for water years 2007 through 2022. Sediment yield was determined using the watershed area above the monitoring site (6.0 km^2).

WY	Sediment Yield metric tons/km^2/year	CV%
2007	298.53	0.59%
2008	208.71	0.57%
2009	43.71	0.98%
2010	157.16	0.93%
2011	429.96	0.85%
2012	430.58	0.73%
2013	209.46	1.03%
2014	24.34	1.75%
2015	611.87	1.27%
2016	516.83	0.67%
2017	499.79	0.47%
2018	75.85	0.64%
2019	468.75	1.82%
2020	42.54	1.88%
2021	25.56	1.28%
2022	17.44	2.27%
Average:	253.82	

3.0 Summary of Field Problems Encountered and Resolutions

A summary of problems encountered and resolutions were compiled for the 2022 WY (Table 6). Typical problems encountered included but were not limited to Druck offset adjustments, turbidimeter adjustments, stage plate observations, discharge measurement notes, and equipment maintenance.

Table 6. Summary of field problems encountered and resolutions at the McCloud Creek TTS station during the 2022 WY.

Comment Type	Start Date	End Date	Comment	Resolution	Resolution Date	Initials
Observation	10/25/21		Discharge measurement had three verticals >10% of total flow; graded as *poor data* in TTS.			MRR
Problem	10/25/21		Slight amount of water (approximately 25 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-9 and in manual Grab and Controls samples of DD #1. Checked tube in ISCO distributor arm and length was appropriate and tested with manual sample. Will monitor and adjust ISCO settings if necessary		MRR
Observation	11/02/21		Discharge measurement had three verticals >10% of total flow; graded as *poor data* in TTS.			LJJ
Problem	11/02/21		Slight amount of water (approximately 15 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1 and in manual Grab and Controls samples of DD #2. Will monitor and adjust ISCO settings if necessary		LJJ
Problem	11/10/21		Slight amount of water (approximately 25 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-4 and in manual Grab and Controls samples of DD #4. Will monitor and adjust ISCO settings if necessary		EML
Problem	11/23/21	11/30/21	E-stage does not match observed stage measurement, is off by +.02	Will monitor and re-calculate stage offset if necessary.	11/30/21	LJJ
Problem	12/13/21	12/13/21	DTS is sitting too low in the water column.	Raised DTS so that sensor is at standard 6/10 depth.	12/13/21	MRR
Problem	12/13/21		Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/- 0.02'). Will monitor future stage plate measurements and edit if necessary.		MRR
Problem	12/17/21		Slight amount of water (approximately 25 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-7 and in manual Grab and Controls samples of DD #10. Will monitor and adjust ISCO settings if necessary		EML
Problem	12/28/21		Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/- 0.04'). Will monitor future stage plate measurements and edit if necessary.		LJJ
Problem	01/05/22		Stage plate unable to be accurately read in fast flows.	Used e-stage value as observed stage measurement due to difficulty reading stage plate.		MRR
Problem	01/12/22	01/12/22	ISCO battery was dead upon arrival at site.	Replaced the dead ISCO battery with a new one. Was not able to change data logger battery at this site visit.	01/12/22	EML
Problem	01/12/22	01/12/22	DTS was sitting too high in the water column	Lowered DTS so that sensor is at standard 6/10 depth.	01/12/22	EML
Problem	01/21/22	01/21/22	DTS was sitting too high in the water column	Lowered DTS so that sensor is at standard 6/10 depth.	01/21/22	EML
Problem	04/13/22	04/13/22	DTS is sitting too low in the water column for anticipated storms.	Raised DTS so that sensor is at standard 6/10 depth.	04/13/22	MRR
Problem	04/19/22		Slight amount of water (approximately 25 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-17 and in manual Grab and Controls samples of DD #22. Checked tube in ISCO distributor arm and length was appropriate and tested with manual sample. Everything okay.		MRR
Problem	04/28/22	04/28/22	DTS is sitting too high in the water column	Lowered DTS so that sensor is at standard 6/10 depth.	04/28/22	EML
Problem	04/28/22		Slight amount of water (approximately 25 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-2 and in manual Grab and Control samples of DD #23. Will monitor and adjust ISCO settings if necessary.		EML
Problem	06/15/22	07/06/22	E-stage does not match observed stage measurement, is off by -0.02 to -0.03'.	Monitored and applied offset correction to data after removing equipment from site.	07/06/22	MRR / EML

4.0 Quality Assurance Summary

Special training is required for all GDRCo staff involved in the implementation of this project. During the 2022 WY, 5 individuals participated in some part of the implementation of field and lab standard operating procedures. All personnel were trained prior to performing assigned work tasks and responsibilities.

The Lead Watershed Technician was appointed by the Project Supervisor to perform the training and certification of the watershed staff during the 2022 WY (Table 7). Training was performed on all aspects of field work including cleaning and adjusting equipment, downloading of data, exchanging ISCO samples, and taking discharge measurements. Training in the laboratory included: preparing filters, taking turbidity measurements, filtering and weighing of suspended sediment, and recording data. Data management training included: data entry, QA/QC, and updating files. The chain-of-custody for all phases of project implementation was tracked.

Table 7. Summary of initial training dates for certifications completed by GDRCo staff involved in field and lab activities during the 2022 WY. Employees have annual refresher training before the beginning of each water year.

Personnel	Role	Lab Certification	Field Methods Certification	Data Management Certification
Matt Nannizzi	Project Supervisor	12/15/2011	10/1/2021	10/21/2021
Melissa Reneski	Hydrology Coordinator	10/1/2015	10/1/2015	10/1/2015
Lily Judevine	Hydrology Technician	1/1/2022	10/1/2021	1/26/2022
Eric LeBlanc	Hydrology Technician	1/1/2022	10/1/2021	1/26/2022

Among the turbidity samples collected and measured, no outliers were identified and excluded from the FNU-NTRU regression analysis. Potential outliers are identified empirically by graphing lab vs turbidity values. Generally there is a tight relationship (R^2 > 95%) between the two measurements, so errors and outliers tend to stand out.

To evaluate the consistency of laboratory processing for turbidity and SSC, GDRCo performed a QA/QC test using paired grab and control water samples collected during site visits. Grabs are taken back to be immediately processed in the lab while controls are stored in a refrigerator until the end of the water year. Hydrochloric acid is added to each control sample that is placed in the refrigerator to help preserve it for later processing. At the end of the water year a random subsample of grabs and paired controls are processed for turbidity and SSC to assess lab repeatability. This subsample resulted in 6 of the 21 paired manual samples from McCloud to be selected. These samples were collected during routine site visits, using the ISCO pump sampler. The relationships between the paired grab and control samples for turbidity and SSC were established (Figures 11 and 12, respectively) using data from 12 TTS sites that GDRCo operates including the McCloud Creek station. The relationship for lab turbidity was linear and strong (R^2= 0.993); and produced no outlier data, indicating that the turbidity laboratory process produced nearly identical values between paired water samples. The paired samples for SSC also produced a strong and linear relationship (R^2= 0.984) indicating that the SSC laboratory process was consistent between grab and control samples.

All equipment was maintained and calibrated within the frequency defined in Section B6 of the Turbidity Threshold Sampling QAPP submitted by GDRCo. The DTS-12 sensors were calibrated by FTS in August, 2021 prior to deployment. The Hach 2100N was calibrated every 3 months with Formazin StableCal® standards and weekly during the monitoring season using Gelex Secondary standards and receives yearly calibration and maintenance from HACH. The Druck pressure transducer was calibrated by the GDRCo watershed staff on August 16th and 17th, 2021 to ensure proper operation prior to deployment. Finally, current meters used during the monitoring season received calibrations at least weekly.

At times there can be complications regarding the DTS-12 turbidity sensor, resulting in missing, or “noisy”, data. When this happened, the “cleaning” of the data was applied conservatively. In the case of missing data, values were generated using the methods described in Section 2.2.3.5 and are noted in the ‘Data Management’ tab in the electronic data file (Appendix A).

Two different approaches were used to address “noisy” turbidity data where there was no association with fluctuations in stage. If the turbidity recordings prompted an ISCO sample that verified there was no increase in SSC, that turbidity value was interpolated from adjacent values. If there was no associated ISCO sample, which can happen when the turbidity increases didn’t cross set thresholds, the value was left and no “cleaning” took place.

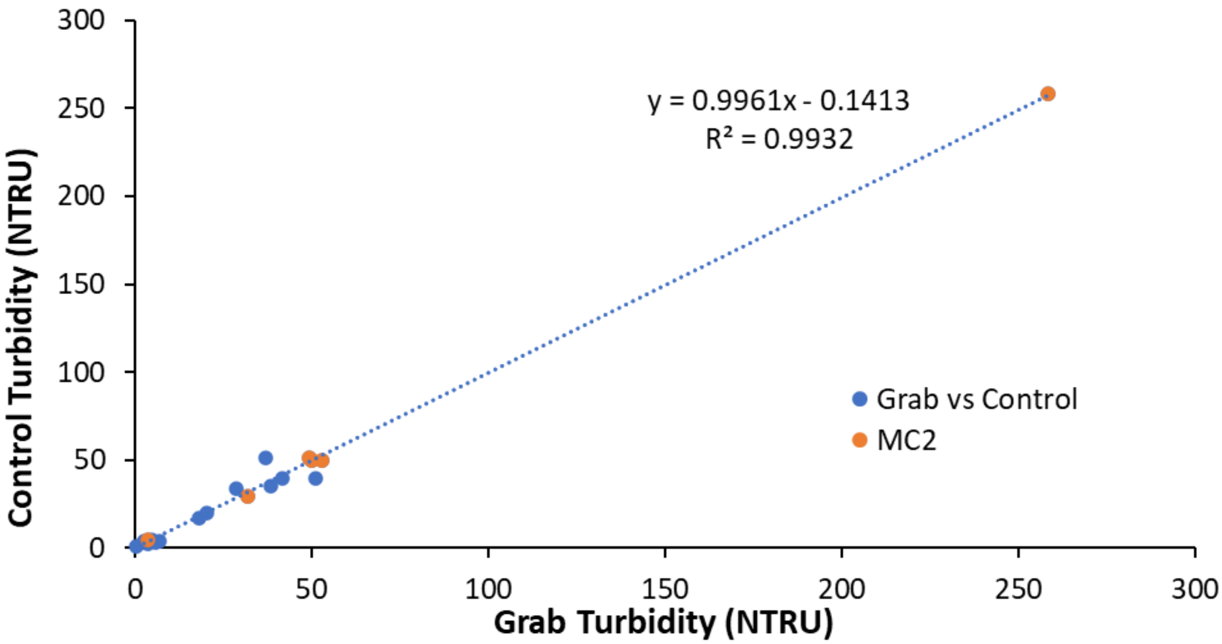

Figure 11. Relationship between turbidity (NTRU) of paired control and grab samples collected across 12 sites during the 2022 WY.

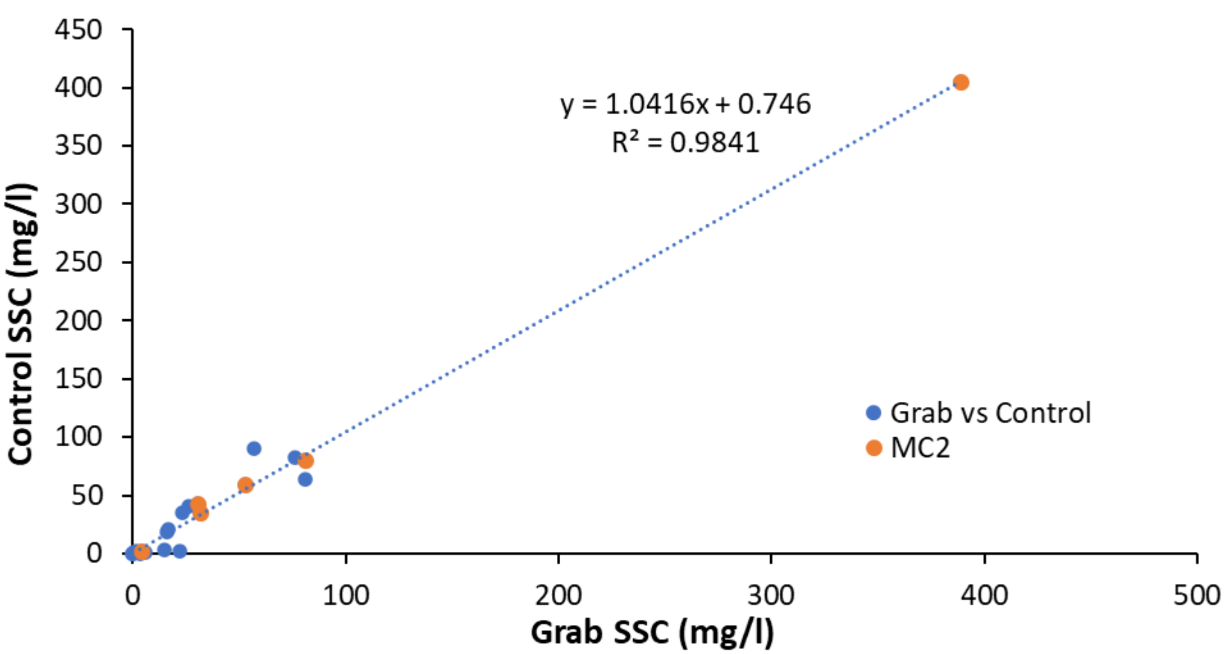

Figure 12. Relationship between suspended sediment concentration (SSC, mg/l) of paired control and grab samples collected across 12 sites during the 2022 WY.

5.0 Other Problems Encountered

During larger storm events, it is often unsafe to cross SF Elk River, preventing access to the McCloud Creek TTS site. In WY 2022, no site visits were missed due to unsafe conditions. However, this does not mean access to the monitoring site was possible during peak events. This can affect data quality with respect to discharge, turbidity, and SSC. The inability to obtain discharge measurements at higher stages is a limitation when estimating discharges above the measured values. Given that the channel geometry at the monitoring site is substantially different above the range of empirical discharge measurements, we assume that the actual relationship is likely different than that predicted here for discharges above this range.

Water sample data can also be affected when GDRCo staff cannot access the site during high flows to exchange ISCO bottles, because it leads to missed water samples during prolonged storm events. No samples were missed in the 2022 WY due to site inaccessibility. Large storm events are usually associated with higher sediment loads, and calculation of discharge and sediment load require extrapolation from relationships established at low to medium flow conditions, resulting in low confidence in the higher sediment load estimates. High water access has been established to access the TTS site at higher flows to measure discharge and verify or modify the existing stage-discharge rating curve.

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Appendix A

Electronic copy (file name = Appendix_A_MC2_All_Data_2022WY.xlsx) of data collected and data management notes for the McCloud TTS site during the 2022 WY. This file was submitted as an email attachment to the NCRQCB in accordance with the 2014 electronic document submission guidelines.