BEFORE THE COLORADO WATER CONSERVATION BOARD

STATE OF COLORADO

Prehearing Statement of the United States of America, Department of the Interior, Bureau of Land Management

---

IN THE MATTER OF STAFF'S RECOMMENDATIONS FOR AN INSTREAM FLOW APPROPRIATION ON EAST MUDDY CREEK BETWEEN THE CONFLUENCE WITH LEE CREEK AND THE CONFLUENCE WITH MUDDY CREEK, WATER DIVISION 4

Pursuant to Rule 5n(2) of the Rules Concerning the Colorado Instream Flow and Natural Lake Level Program ("ISF Rules"), the Bureau of Land Management ("BLM") hereby submits its prehearing statement in support of the Colorado Water Conservation Board ("CWCB") staff's recommendations for an instream flow ("ISF") appropriation on East Muddy Creek between the confluence with Lee Creek and the confluence with Muddy Creek. BLM supports the appropriation on the reach in the locations, timing, and amounts adopted by the CWCB at its March 2025 regularly scheduled board meeting. The CWCB adopted the locations, timing, and amount set forth in the CWCB staff recommendation report made available to the CWCB and the public at the March 2025 CWCB board meeting. An executive summary of this recommendation is available for review on the CWCB's website at 2025 ISF Recommendations | DNR CWCB).

A. FACTUAL CLAIMS

1. There is a natural environment that can be preserved on the subject reach of East Muddy Creek. The finding of a natural environment is based upon fish surveys included in the Colorado Parks and Wildlife ("CPW") aquatic species database and fish surveys conducted by BLM. The natural environment:

> **a)** includes native and introduced fishes, aquatic macroinvertebrates, and riparian communities. The natural environment supports bluehead suckers, flannelmouth suckers, sculpin, and speckled dace, which are native species. The natural environment also supports brook trout, northern pike, fathead minnow, and white sucker, which are introduced species. The natural environment supports riparian communities and species, including narrowleaf cottonwood, willow, alder, and blue spruce.
> **b)** can be preserved with an instream flow appropriation that is based upon the flow needs of the fish species, because those species are indicator species for other elements of the natural environment.
> **c)** will be preserved to a reasonable degree with the proposed ISF water right.

d) can exist without material injury to existing water rights, including conditional surface water rights and conditional storage rights.

2. The instream flow location, amount and timing originally recommended by the CWCB staff at the March 2025 board meeting:

- **a)** is based upon standard field, office, and modeling procedures that are used to identify flow rates necessary to support water-dependent natural resource values. The standard procedures include collecting hydraulic and biologic data, surveying stream channel geometry, and modeling instream hydraulic parameters.
- **b)** is based upon accurate application of R2Cross hydraulic modeling procedures, which is the standard scientific modeling methodology utilized by the CWCB for identifying the flow rates needed to support fish populations.
- **c)** is a reasonable selection of protective flow rates, based on standard instream flow criteria used by the CWCB, and based on results from the R2Cross modeling effort that display the relationship between various flow rates and hydraulic parameters.
- **d)** is required to preserve the natural environment to a reasonable degree, given the dimensions of the East Muddy Creek stream channel, as well as the habitat needs, life histories, and population composition of the species found in this stream segment.

3. The water availability analysis conducted by the CWCB in support of the March 2025 instream flow appropriation:

- **a)** is based upon scientifically accepted hydrologic analysis procedures.
- **b)** relies upon multiple sources of data, all of which demonstrate that sufficient water is available for the proposed appropriation.
- **c)** reflects the amount of water that is available for appropriation as an ISF right, utilizing procedures employed by the CWCB. This analysis includes a range of hydrologic year types.
- **d)** includes measured flow data a location near the proposed lower terminus that reflects the operations, depletions, and return flows associated with ditches and reservoirs both within the proposed instream flow reach.
- **e)** includes measured flow data that reflects the operations and depletions associated with appropriations that may be presently undecreed, such as new junior appropriations, exchanges, and substitutions of supply between ditches.
- **f)** demonstrates that the proposed instream flow water right will not appropriate all available water for instream use but instead leaves a sizable volume of water available for future use and development, including future exchanges and storage projects.

5. BLM supports the staff recommendations as set forth in the CWCB Staff Report and Recommendation on the subject reach of the East Muddy Creek.

6. BLM hereby adopts the factual claims set forth in the CWCB staff's Prehearing Statement.

B. LEGAL CLAIMS

1. BLM is a party to these proceedings pursuant to Rule 5l (4) of the ISF Rules.

2. Because ISF water rights are non-consumptive and do not divert water from the stream, the CWCB can appropriate an ISF right, even if that water will be diverted downstream by a senior water right.

3. Even though the proposed ISF will be junior to existing water rights on the stream system, the CWCB can make appropriations based on water availability at the time of the proposed appropriation, without subtracting flow rates or volumes that have been adjudicated to conditional or presently undecreed appropriations.

4. The proposed instream flow water right will not deprive the people of the State of Colorado of their right to develop the volume of water allocated to the State of Colorado under the Colorado River Compact. The proposed ISF water right leaves substantial water volume available for new junior water rights and future water development.

5. In determining the amount of water available for an ISF appropriation, the CWCB is not limited to the amount of water available during drought years.

6. The CWCB has the exclusive authority to determine the amount and timing of water necessary to preserve the natural environment to a reasonable degree.

7. CWCB staff's ISF recommendation for the subject reach of East Muddy Creek meets all substantive and procedural requirements outlined in the ISF Rules.

8. The CWCB's appropriation of an instream flow water right on the subject reach of East Muddy Creek would further the express intent of Section 37-92-103(3), C.R.S. to "correlate the activities of mankind with some reasonable preservation of the natural environment."

9. BLM hereby adopts the legal claims set forth in the CWCB staff's Prehearing Statement.

C. EXHIBITS TO BE INTRODUCED AT HEARING

1. March 2025 CWCB Executive Summary on the subject reach of East Muddy Creek. This report, along with its appendices, contains maps of the proposed reach, proposed ISF amounts and timing, and water availability calculations. This report and supporting appendices are available for review on the CWCB's website at 2025 ISF

Recommendations | DNR CWCB In the hearing, BLM will refer to this report and its appendices as **Exhibit 1**.

2. Recommendation letter from the BLM and supporting data. At the hearing BLM will refer to this document as **Exhibit 2**.

3. BLM fish sampling report from July 2025. At the hearing, BLM will refer to this document as **Exhibit 3.**

4. CWCB R2Cross Field Manual dated July 2024. In the hearing, BLM will refer to this manual as **Exhibit 4**.

5. BLM may introduce demonstrative, rebuttal, or other exhibits as allowed by the CWCB or agreed upon by the Parties.

6. BLM hereby adopts all Exhibits listed in the CWCB staff's Prehearing Statement.

7. BLM may rely upon exhibits introduced or disclosed by any other party to this hearing.

D. WITNESSES

The following witnesses may testify at the hearing as described below, may give rebuttal testimony, and may be available at the hearing to answer questions from the CWCB.

1. Roy Smith, water rights and instream flow coordinator for the BLM (resume available upon request). Mr. Smith may testify about data collection methods, channel morphology, riparian characteristics, selection of data collection sites, R2Cross modeling efforts, how the BLM formulates ISF recommendations, and specifically how he worked to formulate BLM's recommendation for the subject reach of Creek.

2. Tom Fresques, BLM Colorado fisheries biologist (resume available upon request**)**. Mr. Fresques may testify concerning the fishery composition of Trout Creek, the life history and habitat needs of the various fish species found in Trout Creek, the relationship between riparian habitat and fish habitat, channel morphology, riparian characteristics, and standard data collection methods for the fishery surveys.

4. The BLM may call any witness declared by any other party to this hearing.

E. WRITTEN TESTIMONY

BLM does not seek to enter any written testimony at this time. BLM hereby adopts any written testimony listed in the CWCB staff's Prehearing Statement.

F. LEGAL MEMORANDA

BLM does not seek to enter any legal memoranda at this time. BLM hereby adopts any legal memoranda listed in the CWCB staff's Prehearing Statement.

Respectfully submitted this 3rd day of September 2025.

ROY SMITH Digitally signed by ROY SMITH Date: 2025.09.03 07:01:39 -06'00'

Roy E. Smith
Water Rights and Instream Flow Coordinator
Bureau of Land Management
Colorado State Office
Building 40
Denver Federal Center
Lakewood, CO 80225
Telephone: 303-239-3940
E-Mail: r20smith@blm.gov

East Muddy Creek Executive Summary

CWCB STAFF INSTREAM FLOW RECOMMENDATION
March 19-20, 2025

UPPER TERMINUS:	confluence Lee Creek at UTM North: 4327742.52 UTM East: 295050.07
LOWER TERMINUS:	confluence Muddy Creek at UTM North: 4319399.06 UTM East: 295770.58
WATER DIVISION/DISTRICT:	4/40
COUNTY:	Gunnison
WATERSHED:	North Fork Gunnison
CWCB ID:	21/4/A-005
RECOMMENDER:	Bureau of Land Management (BLM)
LENGTH:	6.32 miles
FLOW RECOMMENDATION:	11.2 cfs (11/01 - 02/29) 20 cfs (03/01 - 03/31) 23 cfs (04/01 - 07/31) 14.5 cfs (08/01 - 10/31)

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

BACKGROUND

Colorado's General Assembly created the Instream Flow and Natural Lake Level Program in 1973, recognizing "the need to correlate the activities of mankind with some reasonable preservation of the natural environment" (see 37-92-102 (3), C.R.S.). The statute vests the Colorado Water Conservation Board (CWCB or Board) with the exclusive authority to appropriate and acquire instream flow (ISF) and natural lake level water rights (NLL). Before initiating a water right filing, the Board must determine that: 1) there is a natural environment that can be preserved to a reasonable degree with the Board's water right if granted, 2) the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made, and 3) such environment can exist without material injury to water rights.

The information contained in this Executive Summary and the associated supporting data and analyses form the basis for staff's ISF recommendation to be considered by the Board. This Executive Summary provides sufficient information to support the CWCB findings required by ISF Rule 5i on natural environment, water availability, and material injury. Additional supporting information is located at: https://cwcb.colorado.gov/2025-isf-recommendations.

RECOMMENDED ISF REACH

The BLM recommended that the CWCB appropriate an ISF water right on a reach of East Muddy Creek. East Muddy Creek is located within Gunnison County and is approximately 14.5 miles northeast of the town of Paonia (See Vicinity Map). The stream originates at the confluence of Little Muddy Creek and Clear Fork and flows south until it reaches the confluence with Muddy Creek above Paonia Reservoir. Muddy creek is a tributary to the North Fork Gunnison River, which is tributary to the Gunnison River.

The proposed ISF reach extends from the confluence with Lee Creek downstream to the confluence with Muddy Creek for a total of 6.32 miles. Approximately 19% of the proposed reach is managed by the BLM, while 81% is managed under private ownership. (See Land Ownership Map). BLM's management goals include maintaining and enhancing habitat that supports fish species and functional riparian and wetland systems. Establishing an ISF water right will assist in meeting these BLM objectives.

OUTREACH

Stakeholder input is a valued part of the CWCB staff's analysis of ISF recommendations. Currently, more than 1,100 people subscribe to the ISF mailing list. Notice of the potential appropriation of an ISF water right on East Muddy Creek was sent to the mailing list in November 2024, March 2024, January 2024, November 2023, March 2023, March 2022, March 2021, and March 2020. Staff sent letters to identified landowners adjacent to East Muddy Creek based on information from the county assessor's website. Public notices about this recommendation were published in the Crested Butte News on January 5, 2024 and December 20, 2024 and the Delta County Independent on December 12, 2024.

Staff presented information about the ISF program and this recommendation to the Gunnison County Board of County Commissioners on November 10, 2020, September 13, 2022, October 24, 2023 and October 8, 2024. Staff met with Luke Reschke, District 40 Lead Water Commissioner, and Doug Christner, District 40 Water Commissioner, on September 26, 2023 to better understand the administration on West Muddy Creek and its tributaries. CWCB and CPW staff met with members of the North Fork Gunnison Water Users Association and Raquel Flinker from the Colorado River District on November 28, 2023 about the East Muddy Creek and West Muddy Creek ISF recommendations. CWCB and CPW staff also met with members of the Ragged Mountain Water Users Association and Raquel Flinker to discuss the recommendations on April 13, 2024. These stakeholder meetings included a presentation on the ISF recommendations and included discussions and questions about the purpose of ISF protection, stock uses, water availablity, and other concerns.

NATURAL ENVIRONMENT

CWCB staff relies on the recommending entity to provide information about the natural environment. In addition, staff reviews information and conducts site visits for each recommended ISF appropriation. This information provides the Board with a basis for determining that a natural environment exists.

East Muddy Creek is a cold-water, low to moderate gradient stream. It flows through a mountain valley approximately 0.5 miles in width. The stream cuts through alluvial deposits in some locations and is constrained by bedrock in locations where the stream comes close to valley walls. The stream generally has medium-sized substrate consisting of gravels, cobbles, and small boulders. The stream has a good mix of pool and riffle habitat for supporting introduced trout species as well as native fish species.

Fisheries surveys have revealed self-sustaining populations of speckled dace, sculpin, bluehead sucker, rainbow trout, fathead minnow, and white sucker (Table 1). Speckled dace, sculpin, and bluehead suckers are native species. Bluehead sucker appears on BLM's sensitive species list and BLM is a signatory to a multi-party, multi-state conservation agreement for that species that is designed to prevent a listing of bluehead suckers under the Endangered Species Act. Since Paonia Reservoir prevents migration of fish between East Muddy Creek and the Gunnison River, it is likely that East Muddy Creek provides year-round habitat for bluehead sucker.

Table 1. List of species identified in East Muddy Creek.

Species Name	Scientific Name	Status
brook trout	*Salvelinus fontinalis*	None
white-blue sucker hybrid	*Catostomus commersoni x discobolus*	None
white-flannelmouth hybrid	*Catostomus commersoni x latipinnis*	None
bluehead sucker	*Catostomus discobolus*	State - Species of Greatest Conservation Need
flannelmouth sucker	*Catostomus latipinnis*	State - Species of Greatest Conservation Need
fathead minnow	*Pimephales promelas*	None
sculpin	*Cottus bairdii*	None
speckled dace	*Rhinichthys osculus*	None
white sucker	*Catostomus commersonii*	None

The riparian community in this part of East Muddy Creek is generally comprised of willow species, alder, spruce, and narrowleaf cottonwood. In general, the riparian community is in good condition, provides some shading and cover for fish habitat, and provides stream stability during flood events.

ISF QUANTIFICATION

CWCB staff relies on the biological expertise of the recommending entity to quantify the amount of water required to preserve the natural environment to a reasonable degree. CWCB staff performs a thorough review of the quantification analyses completed by the recommending entity to ensure consistency with accepted standards.

Quantification Methodology

BLM staff used the R2Cross method to develop the initial ISF recommendation. The R2Cross method is based on a hydraulic model and uses field data collected in a stream riffle (Espegren, 1996; CWCB, 2022). Riffles are the stream habitat type that are most vulnerable to dry if streamflow ceases. The data collected consists of a streamflow measurement, a survey of channel geometry and features at a cross-section, and a survey of the longitudinal slope of the water surface.

The R2Cross model uses Ferguson's Variable-Power Equation (VPE) to estimate roughness and hydraulic conditions at different water stages at the measured cross-section (Ferguson 2007, 2001). This approach is based on calibrating the model as described in Ferguson (2021). The model is used to evaluate three hydraulic criteria: average depth, average velocity, and percent wetted perimeter. Maintaining these hydraulic parameters at adequate levels across riffle habitat types also will maintain aquatic habitat in pools and runs for most life stages of fish and aquatic macro-invertebrates (Nehring, 1979). BLM staff use the model results to develop an initial recommendation for summer and winter flows. The summer flow recommendation is based on the flow that meets all three hydraulic criteria. The winter flow recommendation is based on the flow that meets two of the three hydraulic criteria.

The R2Cross method estimates the biological amount of water needed for summer and winter periods. The recommending entity uses the R2Cross results and its biological expertise to develop an initial ISF recommendation. CWCB staff then evaluates water availability for the reach typically based on median hydrology (see the Water Availability section below for more details). The water availability analysis may indicate less water is available than the initial recommendation. In that case, the recommending entity either modifies the magnitude and/or duration of the recommended ISF rates if the available flows will preserve the natural environment to a reasonable degree or withdraws the recommendation.

Data Collection and Analysis

BLM collected R2Cross data at four transects for this proposed ISF reach (Table 2 and Site Map). Results obtained at more than one transect are averaged to determine the R2Cross flow rate for the stream reach. The R2Cross model results in a winter flow of 11.2 cfs and a summer flow of 23.3 cfs. R2Cross field data and model results can be found in the appendix to this report.

Table 2. Summary of R2Cross transect measurements and results for East Muddy Creek.

Date, XS #	Top Width (feet)	Streamflow (cfs)	Winter Rate (cfs)	Summer Rate (cfs)
06/01/2018, 1	49.90	45.34	15.16	32.41
06/01/2018, 2	42.37	43.24	6.80	15.59
09/24/2019, 1	50.54	11.58	13.42	17.19
09/24/2019, 2	44.45	12.17	9.48	27.91
			11.22	23.28

ISF Recommendation

The BLM recommends the following flows based on R2Cross modeling analyses, biological expertise, and staff's water availability analysis.

11.2 cfs is recommended from November 1 to February 29. This recommended flow rate meets two of three hydraulic criteria during the winter. This flow rate either meets or comes close to meeting the average depth and average velocity criteria in cross sections analyzed and should prevent icing in pools.

20.0 cfs is recommended from March 1 to March 31. This flow rate does not meet three of three criteria; it mimics spring flow initiation of snowmelt runoff.

23.0 cfs is recommended from April 1 to July 31. This flow rate meets three of three hydraulic criteria during the peak flow and snowmelt runoff period. The recommended flow rate is driven by the wetted perimeter criteria in most of the cross-section data collected. Wetting 50 to 60 percent of the channel, as recommended by the R2Cross manual for streams 40 to 60 feet in width, will provide important physical habitat during a time of year when the fish population is completing key life cycle functions.

14.5 cfs is recommended from August 1 to October 31; this flow rate is reduced due to limited water availability. This flow rate will generally meet the average velocity and average depth criteria in the cross-sections analyzed, while providing approximately 50% wetted perimeter in the wider cross sections.

WATER AVAILABILITY

CWCB staff conducts hydrologic analyses for each recommended ISF appropriation to provide the Board with a basis for determining that water is available.

Water Availability Methodology

Each recommended ISF reach has a unique flow regime that depends on variables such as the timing, magnitude, and location of water inputs (such as rain, snow, and snowmelt) and water losses (such as diversions, reservoirs, evaporation and transpiration, groundwater recharge, etc.). This approach focuses on streamflow and the influence of flow alterations, such as diversions, to understand how much water is physically available in the recommended reach.

Staff's hydrologic analysis is data-driven, meaning that staff gathers and evaluates the best available data and uses the best available analysis method for that data. Whenever possible, long-term stream gage data (period of record 20 or more years) are used to evaluate streamflow. Other streamflow information such as short-term gages, temporary gages, spot streamflow measurements, diversion records, and regression-based models are used when long-term gage data is not available. CSUFlow18 is a multiple regression model developed by Colorado State University researchers using streamflow gage data collected between 2001 and 2018 (Eurich et al. 2021). This model estimates mean-monthly streamflow based on drainage basin area, basin terrain variables, and average basin precipitation and snow persistence. Diversion records are used to evaluate the effect of surface water diversions when necessary. Interviews with water commissioners, landowners, and ditch or reservoir operators can provide additional information. A range of analytical techniques may be employed to extend gage records, estimate streamflow in ungaged locations, and estimate the effects of diversions. The goal is to obtain the most detailed and reliable estimate of hydrology using the most efficient analysis technique.

The final product of the hydrologic analysis used to determine water availability is a hydrograph, which shows streamflow and the proposed ISF rate over the course of one year. The hydrograph will show median daily values when daily data is available from gage records; otherwise, it will present mean-monthly streamflow values. Staff will calculate 95% confidence intervals for the median streamflow if there is sufficient data. Statistically, there is 95% confidence that the true value of the median streamflow is located within the confidence interval.

Basin Characteristics

The drainage basin of the proposed ISF on East Muddy Creek is 135.4 square miles, with an average elevation of 8,673 feet and average annual precipitation of 27.3 inches. East Muddy Creek is a cold-water, moderate gradient snowmelt driven hydrologic system with influence from mid-season monsoonal periods. Higher flows typically initiate in early April and generally reach peak flow conditions by early to mid-May. Baseflow conditions are generally lowest in August and September when irrigation practices combine with late summer climate conditions. Streamflow increases slightly when upstream irrigation ends each season.

Water Rights Assessment

There are 94 active water rights on East Muddy Creek and its tributaries. These include up to 290 cfs of direct flow ditch diversions, 376 acre-feet of reservoir storage, and four ISF water rights: Clear Fork of East Muddy Creek (case number 09CW0077), Spring Creek (case number 05CW0245A) and two reaches of Little Spring Creek (case numbers 09CW0072 and 09CW0073). There is one transbasin diversion high up in the Clear Fork contributing basin, a tributary to East Muddy Creek, that exports water to West Divide Creek in Division 5. Diversion records are consistently reported from 2004 to present and show high variability in exported water volumes for the Clear Fork Feeder Ditch (station ID CLFOFDCO) from nothing in 2005 to just under 1,624 acre feet in 2023. Within the extent of the recommended reach, there is one direct diversion water right, the Old Placer Ditch (WDID 4001737), which has a 1922 appropriation date for 0.5 cfs. This structure is listed as inactive and no records are maintained, however Luke Reschke indicated that new owners intend to rehabilitate this structure (personal communication, 2/05/2025).

The North Fork Gunnison River is often under administration with calls extending up both West and East Muddy Creek. The priority calling dates are typically in the late 1800s to early 1900's, but the exact priority can shift through the season. Typically, the call is on by late-July, but some calls have occurred as early as June. North Fork Water Conservancy District was decreed multiple points of exchange upstream of Paonia Reservoir in case number 05CW0236, with up to a volumetric limit of 2,000 acre feet. According to Water Commissioner Luke Reschke, in most years this exchange starts towards the end of July and the seasonal limit is reached by early to mid-September (personal communication, 9/26/2023 and 1/03/2024).

Data Collection and Analysis

Representative Gage Analysis

No current or long-term gages exist within the reach for the ISF recommendation on East Muddy Creek. There is one historic gage, East Muddy Creek Near Bardine, CO (BARDINE, USGS ID 9130500) that monitored streamflow conditions from 1934-1953 at a point approximately 1 mile above the confluence of West and East Muddy Creek. Streamflow at the Bardine gage was analyzed at a median daily timestep as well as calculated to mean monthly streamflow. Due to data limitations on West Muddy Creek, CWCB staff opted to install a temporary gage at the lower terminus of the current recommended ISF reach on West Muddy Creek. No suitable gage locations were identified for a temporary gage on East Muddy Creek. Staff used this data in conjunction with a downstream gage on Muddy Creek above Paonia Reservoir CO (MUDAPRCO, DWR WDID: 4003152) to estimate streamflow on East Muddy Creek.

West Muddy Temporary Gage Analysis

CWCB installed a temporary gage (West Muddy gage) near the lower terminus of the West Muddy ISF reach 500 feet above the point where West Muddy and East Muddy combine to create Muddy Creek. West Muddy Creek is monitored by Hobo MX2001 pressure transducer at a 15-minute interval that was installed on May 19, 2021; gaged West Muddy discharge data is analyzed through October 8, 2024 (period of record, POR: 5/19/2021 – 10/8/2024). There are periods when the gage was ice affected each winter, and the pressure transducer failed for two weeks during the rising limb of 2022. Water year 2023 received the most precipitation during the gage record and this is reflected in the hydrographs for each year. 2024 snowmelt peaked at the earliest date in late April and lowest streamflow at 125 cfs. By comparison, streamflow in 2023 reached over 400 cfs 10 days later than 2024 and maintained high flows longer than the other two water years.

Staff analyzed total streamflow from the MUDAPRCO gage during its POR from 1985 to present to contextualize gaged data on West Muddy gage. MUDAPRCO is located approximately 2,300 ft downstream from the confluence of East and West Muddy Creek. Annual streamflow yield during the previous 30-year record (1995-2024) show that the three years monitored represent a year that is slightly above median yield, a wet year and a dry year for 2022 through 2024, respectively. Therefore, the three years monitored during the POR, represent variability in patterns of streamflow generation and timing.

Estimated East Muddy Creek Streamflow

The West Muddy daily gaged streamflow, as described above, was subtracted from MUDAPRCO daily gaged streamflow to calculate streamflow in East Muddy Creek from 2021-2024. The estimated daily data for East Muddy Creek was compared to daily median streamflow from the East Muddy Bardine gage. The shape and timing of peak flows were similar, and the estimated streamflow based on the West Muddy gage and MUDAPRCO was lower than the Bardine gage during the higher streamflow months. Daily average East Muddy Creek streamflow was calculated as mean monthly streamflow (See Complete Hydrograph). Due to missing data from ice at the MUDAPRCO gage, the final estimated streamflow for East Muddy Creek includes mean-monthly streamflow from the Bardine gage from December through February.

The East Muddy reach is affected by within basin diversions. For a summary, please see existing water rights assessment section above. Given that the impacts of diversions are reflected in gage records at the West Muddy gage and at MUDAPRCO, no further adjustments were made to assess the impact on water available for the ISF reach. Staff also considered streamflow from Dugout Creek, a tributary below the East Muddy Creek and above MUDAPRCO and determined it to be negligible and no further adjustments were necessary

Site Visit Data
CWCB staff made one streamflow measurement on the proposed reach of East Muddy Creek as summarized in Table 3.

Table 3. Summary of streamflow measurements for East Muddy Creek.

Visit Date	Flow (cfs)	Collector
11/06/2023	16.9	CWCB

Water Availability Summary
The hydrograph shows estimated mean-monthly streamflow on East Muddy Creek, as described in the Data Collection and Analysis section above, along with the proposed ISF rate. The proposed ISF flow rate is below the mean-monthly streamflow. Staff has concluded that water is available for appropriation.

MATERIAL INJURY
If decreed, the proposed ISF on East Muddy Creek would be a new junior water right. This ISF water right can exist without material injury to other senior water rights. Under the provisions of section 37-92-102(3)(b), C.R.S., the CWCB will recognize any uses or exchanges of water in existence on the date this ISF water right is appropriated.

ADDITIONAL INFORMATION

Common Acronyms and Abbreviations

Term	Definition
af	acre feet
BLM	Bureau of land management
cfs	cubic feet per second
CWCB	Colorado Water Conservation Board
CPW	Colorado Parks and Wildlife
DWR	Division of Water Resources
HCCA	High Country Conservation Advocates
ISF	Instream Flow
NLL	Natural Lake Level
USGS	United States Geological Survey
USFS	United States Forest Service
XS	Cross section

Citations

Colorado Water Conservation Board, 2022, R2Cross model- User's manual and technical guide. Retrieve from URL: https://r2cross.erams.com/

Colorado Water Conservation Board, 2024, R2Cross field manual. Retrieve from URL: https://dnrweblink.state.co.us/cwcbsearch/0/edoc/224685/R2Cross%20Field%20Manual%202024.pdf

Eurich, A., Kampf, S.K., Hammond, J.C., Ross, M., Willi, K., Vorster, A.G. and Pulver, B., 2021, Predicting mean annual and mean monthly streamflow in Colorado ungauged basins, River Research and Applications, 37(4), 569-578.

Ferguson, R.I., 2007. Flow resistance equations for gravel- and boulder-bed streams. Water Resources Research 43. https://doi.org/10.1029/2006WR005422

Ferguson, R.I., 2021. Roughness calibration to improve flow predictions in coarse-bed streams. Water Res 57. https://doi.org/10.1029/2021WR029979

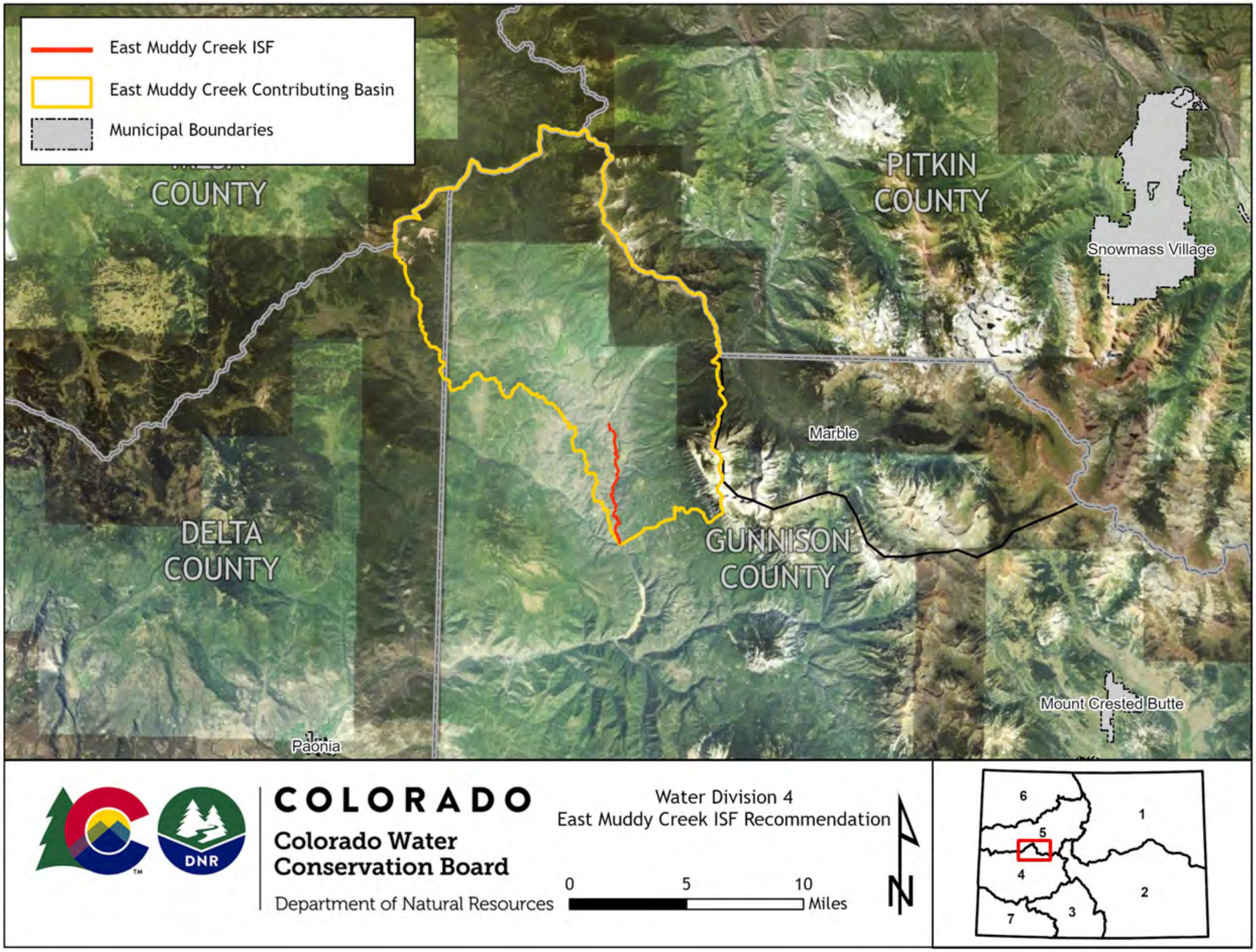
Nehring, B.R., 1979, Evaluation of instream flow methods and determination of water quantity needs for streams in the state of Colorado, Colorado Division of Wildlife.

Metadata Descriptions

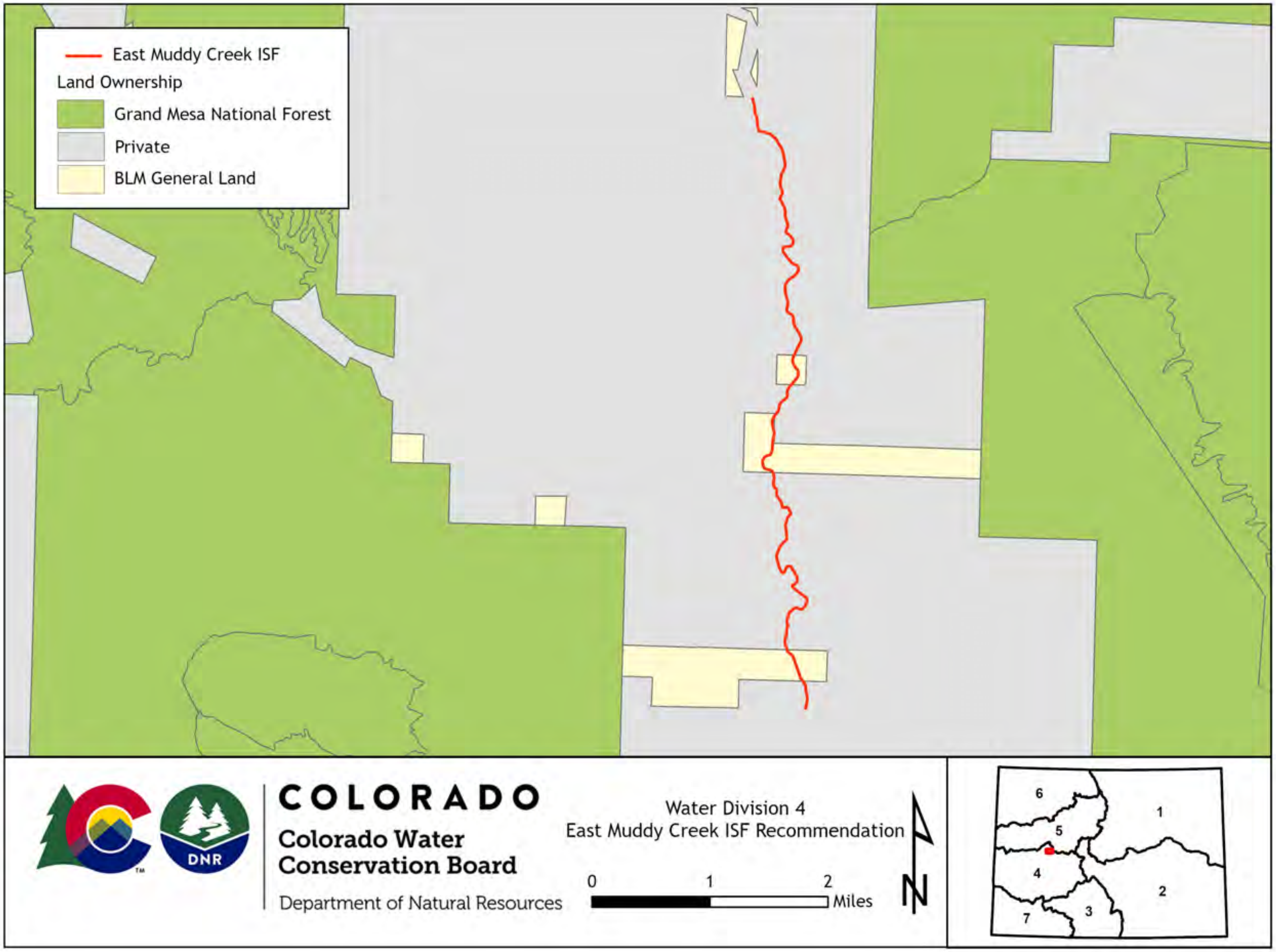
The UTM locations for the upstream and downstream termini were derived from CWCB GIS using the National Hydrography Dataset (NHD).

Projected Coordinate System: NAD 1983 UTM Zone 13N.

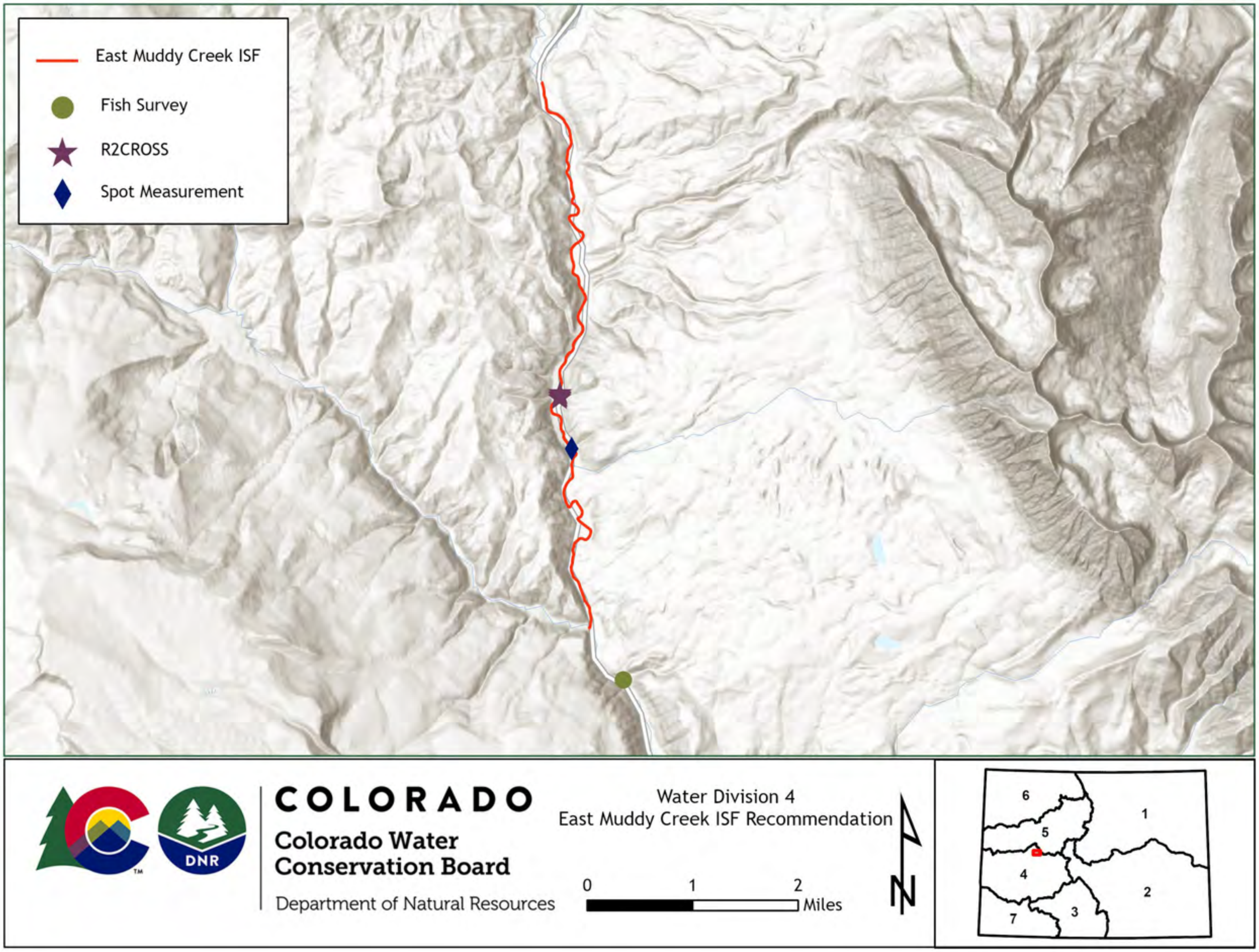
VICINITY MAP



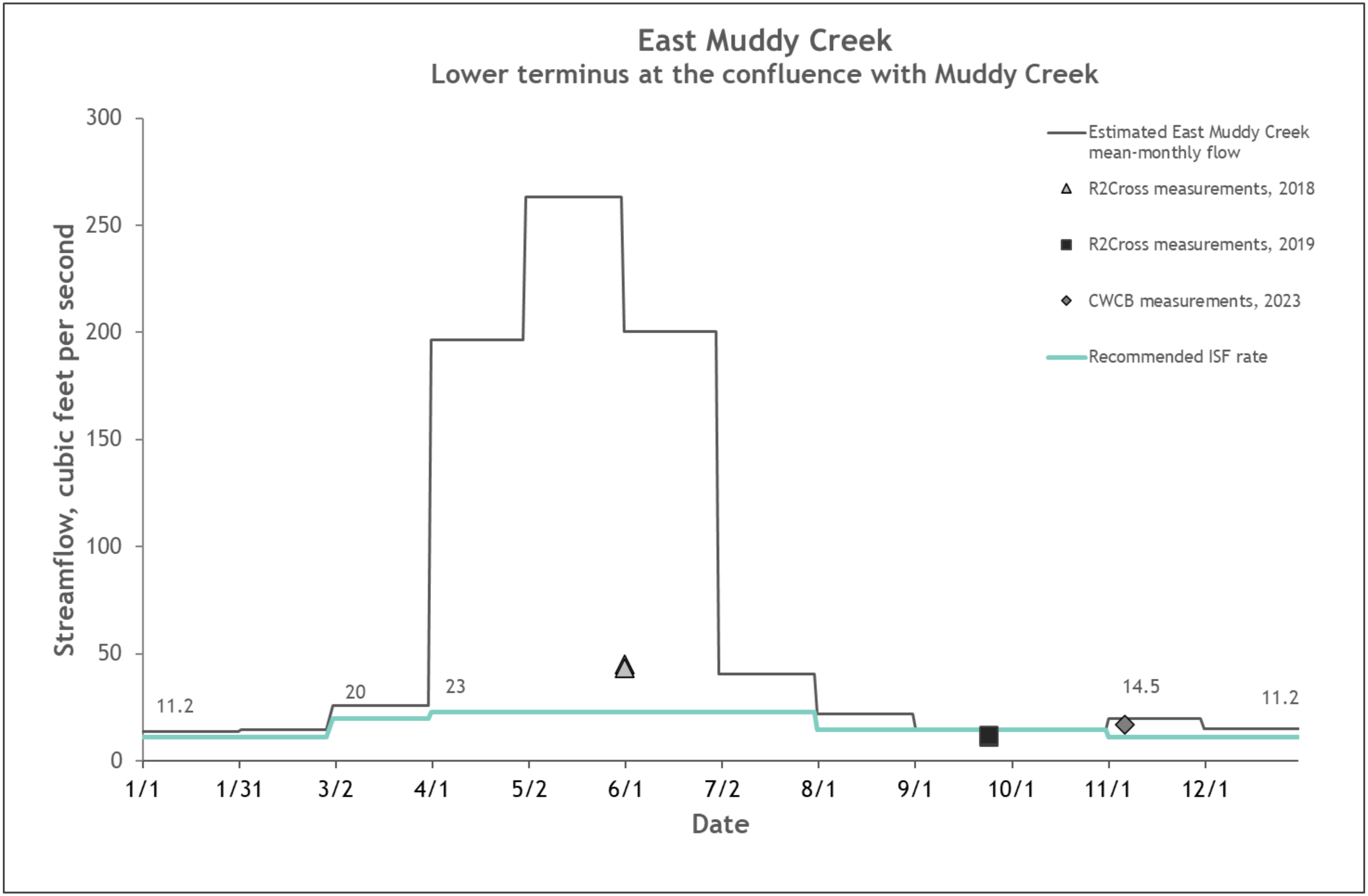
LAND OWNERSHIP MAP



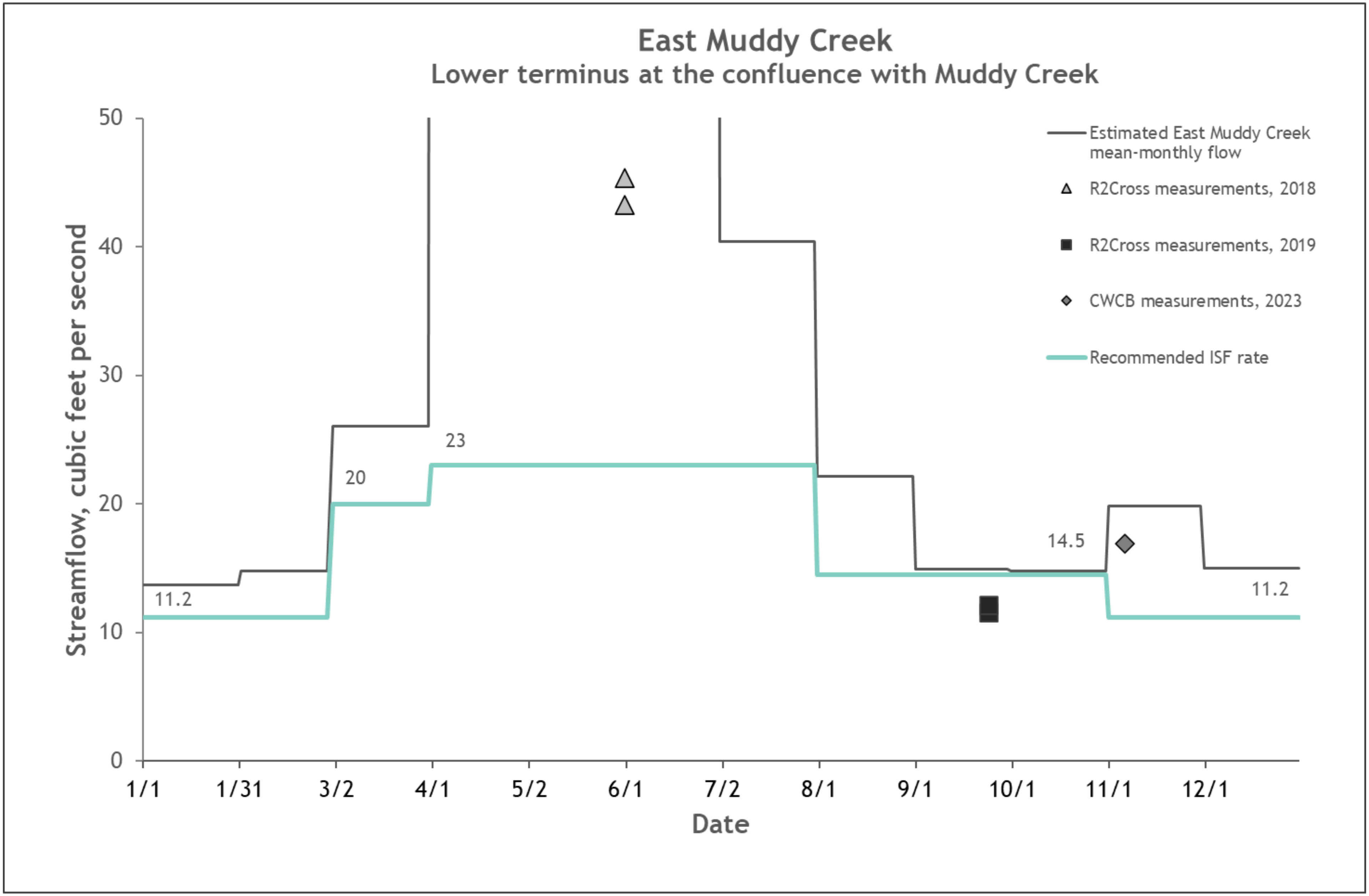
SITE MAP


East Muddy Creek ISF
Fish Survey
R2CROSS
Spot Measurement
COLORADO
Colorado Water Conservation Board
Department of Natural Resources
DNR
Water Division 4
East Muddy Creek ISF Recommendation
0
1
2
Miles
N
6
5
1
4
2
7
3

COMPLETE HYDROGRAPH



DETAILED HYDROGRAPH



United States Department of the Interior
BUREAU OF LAND MANAGEMENT

Colorado State Office
Denver Federal Center, Building 40
Lakewood, Colorado 80225
www.blm.gov/colorado

In Reply Refer To:
CO-932 (7250)

Mr. Rob Viehl
Colorado Water Conservation Board
1313 Sherman Street, Room 721
Denver, Colorado 80203

Dear Mr. Viehl:

The Bureau of Land Management (BLM) is writing this letter to formally communicate its recommendation for an instream flow water right on East Muddy Creek, located in Water Division 4.

Location and Land Status. East Muddy Creek originates at the confluence of Little Muddy Creek and Clear Fork, approximately 14.5 miles northeast of Paonia. The creek flows into Paonia Reservoir. This recommendation covers a reach that starts at the confluence with Lee Creek and extends to the confluence with West Muddy Creek. This stream reach covers a distance of approximately 6.36 miles. The BLM manages approximately 0.85 miles of this stream reach, while 5.51 miles are in private ownership.

Biological Summary. East Muddy Creek is a cold-water, low to moderate gradient stream. It flows through a mountain valley approximately 0.5 miles in width. The stream cuts through alluvial deposits in some locations and is constrained by bedrock in locations where the stream comes close to valley walls. The stream generally has medium-sized substrate, consisting of gravels, cobbles, and small boulders. The stream has a good mix of pool and riffle habitat for supporting introduced trout species as well as native fish species.

Fisheries surveys have revealed self-sustaining populations of speckled dace, mottled sculpin, bluehead sucker, rainbow trout, fathead minnow and white sucker. Speckled dace, mottled sculpin and bluehead suckers are native species, and the bluehead sucker appears on BLM's sensitive species list. Since Paonia Reservoir prevents migration of fishes between East Muddy Creek and the Gunnison River, it is likely that East Muddy Creek provides year-round habitat for bluehead sucker.

The riparian community in this part of East Muddy Creek is generally comprised of willow species, alder, spruce and narrowleaf cottonwood. In general, the riparian community is in good condition, provides some shading and cover for fish habitat, and provides stream stability during flood events.

R2Cross Analysis. BLM collected the following R2Cross data from East Fork Muddy Creek:

Cross Section Date	Discharge Rate	Top Width	Winter Flow Recommendation (meets 2 of 3 hydraulic criteria)	Summer Flow Recommendation (meets 3 of 3 hydraulic criteria)
06/01/2018 #1	45.34 cfs	49.9 feet	15.16 cfs	32.41 cfs
06/01/2018 #2	43.24 cfs	42.4 feet	6.80 cfs	15.59 cfs
09/24/2019 #1	11.58 cfs	50.5 feet	13.42 cfs	17.19 cfs
09/24/2019 #2	12.17 cfs	44.5 feet	9.48 cfs	27.91 cfs
		Averages:	11.22 cfs	23.28 cfs

BLM's analysis of this data indicates that the following flows are needed to protect the fishery and natural environment to a reasonable degree.

> 23.00 cubic feet per second is recommended for the snowmelt runoff period from April 1 through July 31. This recommendation is driven by the wetted perimeter criteria in a majority of the cross-section data collected. Wetting 50 to 60 percent of the channel, as recommended by the R2Cross manual for streams 40 to 60 feet in width, will provide important physical habitat during a time of year when the fish population is completing key life cycle functions.
>
> 14.5 cubic feet per second is recommended for the late summer and early fall period between August 1 and October 31. This recommendation is driven by limited water availability during this period. This flow rate will generally meet the average velocity and average depth criteria in the cross sections analyzed, while providing approximately 50% wetted perimeter in the wider cross sections.
>
> 11.20 cubic feet per second is recommended during the winter period between November 1 and February 29. This recommendation is driven by limited water availability during the winter. This flow rate either meets or comes close to meeting the average depth and average velocity criteria in cross sections analyzed and should prevent icing in pools.
>
> 20.0 cubic feet per second is recommending from March 1 to March 31. This period is when lower elevation snowmelt runoff begins. Sufficient water is available to significantly exceed the winter flow recommendation and provide additional habitat before large scale snowmelt runoff occurs.

Water Availability. The BLM recommends relying upon two data sources to confirm water availability. The first information source is USGS Gage 09130500 (East Muddy Creek Near Bardine, CO). This gage was operated between 1934 and 1953, reflecting a 20-year period of record. The gage records will have to be adjusted to account for new diversions below the gage that have commenced since 1953. In addition, the gage data will need be adjusted to reflect the fact that some tributaries enter the creek downstream of the gage. The second data source is comprised of reservoir content records for Paonia Reservoir, located downstream. Daily fill volumes can be converted to incoming flow rates from East Muddy Creek. If this data source is used, any inflow to the reservoir from West Muddy Creek would have to be subtracted out to accurately reflect water availability in the recommended instream flow reach.

The BLM is aware of only one active surface water right in the proposed reach, the John Medved Ditch 4, which is decreed for 1.5 cfs. Upstream from the proposed instream reach, BLM is aware of at least 25 active surface water rights, totaling just under 100 cfs in decreed diversion rates. BLM is also aware of multiple exchanges between Paonia Reservoir and upstream points of diversion.

Relationship to Land Management Plans. The BLM land use plan for this area calls for actions to maintain and enhance riparian and fisheries habitat. In general, any proposed new land use, such as right-of-way corridors or mineral development, must be implemented with no surface occupancy to avoid impacts to the creek. Any proposed land uses along this creek are also carefully reviewed and mitigated to prevent impacts to sensitive aquatic species which appear on BLM's sensitive species list. Establishing an instream flow water right would assist in meeting these objectives.

Data sheets, R2Cross output, fishery survey information, and photographs of the cross section were included with BLM's draft recommendation in February 2020. BLM thanks both Colorado Parks and Wildlife and the Colorado Water Conservation Board for their cooperation in this effort.

If you have any questions regarding our instream flow recommendation, please contact Roy Smith at 303-239-3940.

Sincerely,

JOEL HUMPHRIES Digitally signed by JOEL HUMPHRIES Date: 2024.11.27 09:06:37 -07'00' for

Alan Bittner
Deputy State Director
Resources

Cc: Kevin Hyatt, Uncompahgre FO
Dan Ben-Horin, Uncompahgre FO
Stephanie McCormick, Southwest District

Combined Summaries

Water **41741** **Muddy Creek** Date **7/17/2012**

Station **GU0040** **ABV Dugout Creek (EM-1)**

Drainage **Gunnison River** UtmX **296304** UtmY **4318625** Elevation **6478 ft**

Length **722 ft** Width **41.60 ft** Area **0.69 acre**

Surveyors **K. Thompson, S. Sherman, P. Jones, N. Thompson**

Gear **BPEF** Effort **2.00** Metric **PASS** Protocol **FULL HABITAT**

Proportional Stocking Density and Catch/Unit Effort

Species	Total Catch	Min Cut inch	Max Cut inch	Total used	Proportional Stock Density (%)	Percent Stock Size	Percent Quality Size	Percent Preferred Size	Percent Memorable Size	Percent Trophy Size	Max Length inches
BLUEHEAD SUCKER	112	5.91		112							9.49
BROOK TROUT	2	5.12		2	0.00	100.00					8.86
FLANNELMOUTH SUCKER	2	5.91		2							5.28
FATHEAD MINNOW	60			60							2.20
MOTTLED SCULPIN	102			102							4.80
NORTHERN PIKE	5	3.94		5							6.77
SPECKLED DACE	187			187							5.04
SUCKER (S.U.)	5			5							0.00
WHITE SUCKER	60	5.91		60	0.00	100.00					9.57
WHITE-BLUEHEAD SUCKER HYBRID	11			11							11.26
WHITE-FLANNELMOUTH HYBRID	1			1							0.00

Combined Summaries

Water **41741** **Muddy Creek** Date **7/17/2012**

Station **GU0040** **ABV Dugout Creek (EM-1)**

Mean, Minimum and Maximum Length and Weight

Species	Total Catch	Min cut inch	Max cut inch	Total Used	Length (inches) Mean	Length (inches) Minimum	Length (inches) Maximum	Weight (lb) Mean	Weight (lb) Minimum	Weight (lb) Maximum
BLUEHEAD SUCKER	112	5.91		112	3.85	2.44	9.49	0.04	0.00	0.33
BROOK TROUT	2	5.12		2	8.33	7.80	8.86	0.27	0.24	0.31
FLANNELMOUTH SUCKER	2	5.91		2	5.28	5.28	5.28	0.05	0.05	0.05
FATHEAD MINNOW	60			60	1.99	1.73	2.20	0.00	0.00	0.01
MOTTLED SCULPIN	102			102	3.53	2.40	4.80	0.03	0.01	0.07
NORTHERN PIKE	5	3.94		5	6.09	5.59	6.77	0.06	0.03	0.07
SPECKLED DACE	187			187	3.48	1.97	5.04	0.02	0.00	0.07
SUCKER (S.U.)	5			5		0.00	0.00		0.00	0.00
WHITE SUCKER	60	5.91		60	4.77	2.83	9.57	0.06	0.01	0.26
WHITE-BLUEHEAD SUCKER HYBRID	11			11	8.31	3.82	11.26	0.25	0.01	0.46
WHITE-FLANNELMOUTH HYBRID	1			1		0.00	0.00		0.00	0.00

Combined Summaries

Water **41741** **Muddy Creek** Date **7/17/2012**

Station **GU0040** **ABV Dugout Creek (EM-1)**

Relative Abundance and Catch/Unit Effort

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total used	Weight Lbs	Percent Number	Percent Weight	Catch per Unit Effort Number/Effort	Catch per Unit Effort Lbs/Effort
BLUEHEAD SUCKER	112	5.91		112	2.88	20.48	27.13	56.00	1.44
BROOK TROUT	2	5.12		2	0.55	0.37	5.14	1.00	0.27
FLANNELMOUTH SUCKER	2	5.91		2	0.05	0.37	0.46	1.00	0.02
FATHEAD MINNOW	60			60	0.01	10.97	0.14	30.00	0.01
MOTTLED SCULPIN	102			102	1.15	18.65	10.85	51.00	0.58
NORTHERN PIKE	5	3.94		5	0.28	0.91	2.59	2.50	0.14
SPECKLED DACE	187			187	1.67	34.19	15.71	93.50	0.84
SUCKER (S.U.)	5			5	0.00	0.91	0.00	2.50	0.00
WHITE SUCKER	60	5.91		60	1.81	10.97	17.00	30.00	0.90
WHITE-BLUEHEAD SUCKER HYBRID	11			11	2.23	2.01	21.00	5.50	1.12
WHITE-FLANNELMOUTH HYBRID	1			1	0.00	0.18	0.00	0.50	0.00

Combined Summaries

Water **41741** **Muddy Creek** Date **7/17/2012**

Station **GU0040** **ABV Dugout Creek (EM-1)**

Abundance and Biomass

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total Used	Population estimate	Biomass Lbs	Percent Number	Percent Weight	Density estimates Lb/Acre	Density estimates Fish/Acre	Density estimates Fish/Mile
BLUEHEAD SUCKER	112	5.91		112		2.88	20.48	27.13	4.18	162.48	819.29
BROOK TROUT	2	5.12		2		0.55	0.37	5.14	0.79	2.90	14.63
FLANNELMOUTH SUCKER	2	5.91		2		0.05	0.37	0.46	0.07	2.90	14.63
FATHEAD MINNOW	60			60		0.01	10.97	0.14	0.02	87.04	438.90
MOTTLED SCULPIN	102			102		1.15	18.65	10.85	1.67	147.97	746.13
NORTHERN PIKE	5	3.94		5		0.28	0.91	2.59	0.40	7.25	36.58
SPECKLED DACE	187			187		1.67	34.19	15.71	2.42	271.28	1,367.91
SUCKER (S.U.)	5			5		0.00	0.91	0.00	0.00	7.25	36.58
WHITE SUCKER	60	5.91		60		1.81	10.97	17.00	2.62	87.04	438.90
WHITE-BLUEHEAD SUCKER HYBRID	11			11		2.23	2.01	21.00	3.24	15.96	80.47
WHITE-FLANNELMOUTH HYBRID	1			1		0.00	0.18	0.00	0.00	1.45	7.32

Notes: 2x LR-24 BPEF; Primary purpose of survey is three species occupancy. Often no more than 40 specimens of individual species were weighed and measured and the remainder were counted. Therefore population estimates are not completely accurate. Leopard Frog.

COLORADO
Department of Natural Resources

Date	6/1/2018
Observer	R. Smith, J. Sondergard
Cross-section#	1
System	UTM Zone 13
X (easting)	295335
Y (northing)	4322956

R2CROSS CROSS-SECTION NOTES

Stream Name	Stream Location	Slope
East Muddy Creek	Approx 1.0 mile upstream from confluence with Spring Creek	0.0056

Feature	Distance From Initial Point (ft)	Rod Height (ft)	Water Depth (ft)	Velocity (ft/s)
Bankfull	0	3.5		
	4	4.17		
	8	4.65		
Waterline	11.9	4.95	0	0
	13	5.15	0.2	0.33
	14	5.35	0.4	1.19
	15	5.45	0.5	2.19
	16	5.75	0.8	1.68
	17	5.85	0.9	2.3
	18	5.75	0.8	1.92
	19	5.75	0.8	2.43
	20	5.85	0.9	1.89
	21	5.75	0.8	2.48
	22	5.95	1	2.53
	23	5.85	0.9	2.86
	24	5.85	0.9	2.64
	25	5.75	0.8	2.58
	26	5.85	0.9	2.56
	27	5.95	1	2.34
	28	5.95	1	2.42
	29	5.85	0.9	1.65
	30	5.95	1	1.71
	31	5.85	0.9	1.57
	32	6.05	1.1	1.63
	33	6.05	1.1	1.46
	34	5.95	1	1.81
	35	5.95	1	2
	36	5.75	0.8	1.73
	37	5.75	0.8	1.64
	38	5.7	0.75	1.65
	39	5.4	0.45	1.46
	40	5.1	0.2	0.54
Waterline	40.9	4.9	0	0
	44	4.36		
	48	3.9		
Bankfull	50.2	3.55		

COLORADO
Department of Natural Resources

Date	6/1/2018
Observer	R. Smith, J Sondergard
Cross-section#	2
System	UTM Zone 13
X (easting)	295345
Y (northing)	4323005

R2CROSS CROSS-SECTION NOTES

Stream Name	Stream Location	Slope
East Muddy Creek	Approx. 1.0 mile upstream from confluence with Spring Creek	0.0048

Feature	Distance From Initial Point (ft)	Rod Height (ft)	Water Depth (ft)	Velocity (ft/s)
	0	2.94		
Bankfull	4	3.43		
	8	3.86		
Waterline	12	4.15		
	14.5	4.4	0	0
	15	4.5	0.1	0.13
	16	5	0.6	0.81
	17	5.1	0.7	1.56
	18	5.2	0.8	1.7
	19	5.3	0.9	1.99
	20	5.3	0.9	1.09
	21	5.4	1	1.88
	22	5.4	1	2.01
	23	5.3	0.9	1.58
	24	5.4	1	2.03
	25	5.5	1.1	2.86
	26	5.4	1	2.14
	27	5.5	1.1	2.06
	28	5.5	1.1	1.9
	29	5.4	1	1.52
	30	5.5	1.1	2.38
	31	5.6	1.2	1.51
	32	5.5	1.1	1.99
	33	5.6	1.2	2.19
	34	5.6	1.2	1.6
	35	5.3	0.9	2.29
	36	5.6	1.2	1.54
	37	5.5	1.1	1.41
	38	4.8	0.4	0.98
	39	5.4	1	1.06
	40	5.4	1	0.69
	41	5.2	0.8	0.31
	42	4.6	0.2	0
Waterline	42.6	4.4	0	0
	44	3.98		
Bankfull	46.5	3.4		

COLORADO
Department of Natural Resources

Date	9/24/2019
Observer	J. Sondergard
Cross-section#	1

System	UTM Zone 13
X (easting)	295348.2
Y (northing)	4322971.9

R2CROSS CROSS-SECTION NOTES

Stream Name	Stream Location	Slope
East Muddy Creek	Approx 1.57 miles upstream from Paonia Reservoir	0.009

Feature	Distance From Initial Point (ft)	Rod Height (ft)	Water Depth (ft)	Velocity (ft/s)
	2.9	1.79		
Bankfull	5.3	2.74		
	17.25	3.96		
Waterline	20.45	4.64	0	0
	21.4	4.85	0.2	0
	22	5.1	0.45	0.63
	23	5.15	0.5	1.23
	24	5.1	0.45	0.6
	25	5	0.35	1.05
	26	5.15	0.5	1.34
	27	5.05	0.4	1.68
	28	5.15	0.5	1.4
	29	5.15	0.5	0.67
	30	5.05	0.4	1.52
	31	5.15	0.5	2.11
	32	5.05	0.4	1.78
	33	4.95	0.3	2.26
	34	5.05	0.4	1.55
	35	4.95	0.3	1.09
	36	5.05	0.4	0.48
	37	4.9	0.25	0.86
	38	4.85	0.2	0.69
	39	5.15	0.5	0.01
	40	5.15	0.5	0.31
	41	5.25	0.6	0.1
	42	5.05	0.4	0.24
	43	4.95	0.3	1.07
	44	5.05	0.4	1.4
	45	5.2	0.55	0.6
	46	5.15	0.5	0.55
	47	5.35	0.7	0.76
	48	5.5	0.85	0.9
	49	5.15	0.5	0.22
Waterline	49.5	4.65	0	0
	54.2	3.18		
Bankfull	56.25	2.63		
	56.85	2.12		

COLORADO
Department of Natural Resources

Date	9/24/2019
Observer	J. Sondergard
Cross-section#	2

Coordinate	Lat/Long
X (easting)	-107.364728
Y (northing)	39.03145

R2CROSS CROSS-SECTION NOTES

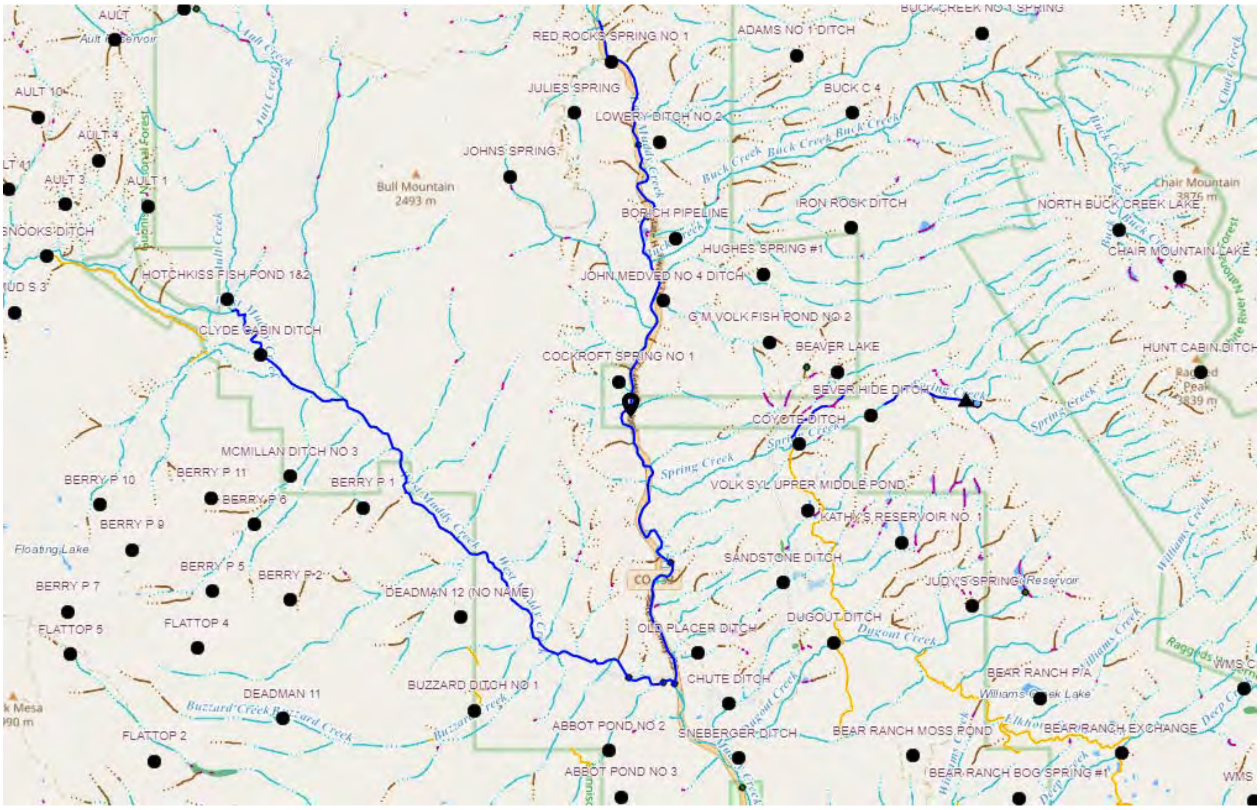
Stream Name	Stream Location	Slope
East Muddy Creek	Approx. 1.75 miles upstream from Paonia Reservoir	0.003

Feature	Distance From Initial Point (ft)	Rod Height (ft)	Water Depth (ft)	Velocity (ft/s)
	1	2.75		
Bankfull	3.65	3.55		
	8.05	4.62		
Waterline	10.1	5.14	0	0
	11	5.45	0.3	0.55
	12	5.55	0.4	0.07
	13	5.7	0.55	1.23
	14	5.75	0.6	1.5
	15	5.75	0.6	1.36
	16	5.65	0.5	1.45
	17	5.75	0.6	0.65
	18	5.95	0.8	1.43
	19	5.95	0.8	1.72
	20	5.85	0.7	1.65
	21	5.95	0.8	1.57
	22	5.95	0.8	1.24
	23	5.5	0.35	1.53
	24	5.55	0.4	1.22
	25	5.65	0.5	1.27
	26	5.6	0.45	1.31
	27	5.4	0.25	0.71
	28	5.35	0.2	0.17
	29	5.45	0.3	0.33
	30	5.15	0	0
Waterline	31.4	5.15	0	0
	33.5	4.42		
Bankfull	58.5	2.93		
	65.6	1.96		

R2Cross RESULTS

Stream Name: East Muddy Creek
Stream Locations: Approx. 1.75 miles upstream from Paonia Reservoir
Fieldwork Date: 09/24/2019
Cross-section: 2
Observers: J. Sondergard
Coordinate System: Lat/Long
X (easting): -107.364728
Y (northing): 39.03145
Date Processed: 05/29/2023
Slope: 0.003
Discharge: R2Cross data file: 12.17 (cfs)
Computation method: Ferguson VPE
R2Cross data filename: East Muddy Creek 9-24-19 #2.xlsx
R2Cross version: 2.0.2

LOCATION



ANALYSIS RESULTS

Habitat Criteria Results

Bankfull top width (ft) = 44.45

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft)	0.4	9.48
Percent Wetted Perimeter (%)	52.2	27.91
Mean Velocity (ft/s)	1.0	7.91

STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (sq ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Manning's n	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	3.55	44.45	1.3	2.4	57.98	45.07	100.0	1.29	0.03	3.0	173.98
	3.6	43.41	1.29	2.35	55.8	44.02	97.68	1.27	0.03	2.96	165.42
	3.65	42.36	1.27	2.3	53.65	42.97	95.34	1.25	0.03	2.93	157.16
	3.7	41.32	1.25	2.25	51.56	41.92	93.01	1.23	0.03	2.89	149.22
	3.75	40.27	1.23	2.2	49.52	40.87	90.67	1.21	0.03	2.86	141.59
	3.8	39.23	1.21	2.15	47.53	39.82	88.34	1.19	0.03	2.82	134.27
	3.85	38.18	1.19	2.1	45.6	38.76	86.0	1.18	0.03	2.79	127.26
	3.9	37.14	1.18	2.05	43.71	37.71	83.67	1.16	0.03	2.76	120.55
	3.95	36.1	1.16	2.0	41.88	36.66	81.34	1.14	0.03	2.73	114.13
	4.0	35.05	1.14	1.95	40.11	35.61	79.0	1.13	0.03	2.69	108.01
	4.05	34.01	1.13	1.9	38.38	34.56	76.67	1.11	0.03	2.66	102.17
	4.1	32.96	1.11	1.85	36.7	33.5	74.33	1.1	0.03	2.63	96.61
	4.15	31.92	1.1	1.8	35.08	32.45	72.0	1.08	0.03	2.6	91.32
	4.2	30.87	1.09	1.75	33.51	31.4	69.67	1.07	0.03	2.58	86.3
	4.25	29.83	1.07	1.7	32.0	30.35	67.33	1.05	0.03	2.55	81.55
	4.3	28.78	1.06	1.65	30.53	29.3	65.0	1.04	0.03	2.52	77.06
	4.35	27.74	1.05	1.6	29.12	28.24	62.66	1.03	0.03	2.5	72.82
	4.4	26.69	1.04	1.55	27.76	27.19	60.33	1.02	0.03	2.48	68.84
	4.45	26.06	1.01	1.5	26.44	26.55	58.91	1.0	0.03	2.43	64.22
	4.5	25.71	0.98	1.45	25.15	26.19	58.1	0.96	0.03	2.35	59.2
	4.55	25.37	0.94	1.4	23.87	25.82	57.29	0.92	0.03	2.28	54.36
	4.6	25.02	0.9	1.35	22.61	25.46	56.48	0.89	0.03	2.2	49.71
	4.65	24.67	0.87	1.3	21.37	25.1	55.69	0.85	0.03	2.12	45.25
	4.7	24.33	0.83	1.25	20.14	24.74	54.9	0.81	0.03	2.03	40.97
	4.75	23.99	0.79	1.2	18.94	24.39	54.11	0.78	0.04	1.95	36.88

	4.8	23.65	0.75	1.15	17.74	24.03	53.32	0.74	0.04	1.86	32.98
	4.85	23.31	0.71	1.1	16.57	23.68	52.53	0.7	0.04	1.77	29.28
	4.9	22.97	0.67	1.05	15.41	23.32	51.74	0.66	0.04	1.67	25.78
	4.95	22.63	0.63	1.0	14.27	22.97	50.95	0.62	0.04	1.57	22.47
	5.0	22.28	0.59	0.95	13.15	22.61	50.17	0.58	0.04	1.47	19.37
	5.05	21.94	0.55	0.9	12.05	22.26	49.38	0.54	0.04	1.37	16.48
	5.1	21.6	0.51	0.85	10.96	21.9	48.59	0.5	0.04	1.26	13.8
Waterline	5.15	19.87	0.5	0.8	9.88	20.15	44.71	0.49	0.04	1.23	12.19
	5.2	19.56	0.45	0.75	8.9	19.83	43.99	0.45	0.04	1.12	9.97
	5.25	19.25	0.41	0.7	7.93	19.5	43.26	0.41	0.04	1.0	7.95
	5.3	18.94	0.37	0.65	6.97	19.17	42.53	0.36	0.05	0.88	6.15
	5.35	18.63	0.32	0.6	6.03	18.85	41.82	0.32	0.05	0.76	4.57
	5.4	16.82	0.31	0.55	5.15	17.02	37.75	0.3	0.05	0.71	3.64
	5.45	15.75	0.28	0.5	4.33	15.93	35.34	0.27	0.06	0.62	2.68
	5.5	15.01	0.24	0.45	3.57	15.18	33.67	0.23	0.06	0.51	1.83
	5.55	13.14	0.22	0.4	2.86	13.29	29.49	0.22	0.06	0.46	1.31
	5.6	11.95	0.19	0.35	2.23	12.08	26.8	0.18	0.07	0.37	0.83
	5.65	10.01	0.17	0.3	1.69	10.11	22.44	0.17	0.08	0.32	0.54
	5.7	8.56	0.14	0.25	1.22	8.65	19.2	0.14	0.09	0.26	0.31
	5.75	5.45	0.16	0.2	0.85	5.52	12.24	0.15	0.08	0.29	0.24
	5.8	5.08	0.11	0.15	0.58	5.14	11.41	0.11	0.1	0.19	0.11
	5.85	4.73	0.07	0.1	0.34	4.77	10.58	0.07	0.15	0.09	0.03
	5.9	3.37	0.04	0.05	0.13	3.39	7.51	0.04	0.23	0.04	0.01
	5.93	2.41	0.01	0.01	0.03	2.41	5.36	0.01	0.57	0.01	0.0

This Manning's roughness coefficient was calculated based on velocity estimates from the Ferguson VPE method

MODEL SUMMARY

Measured Flow (Qm) =	12.17	(cfs)
Calculated Flow (Qc) =	12.19	(cfs)
(Qm-Qc)/Qm * 100 =	-0.09%	
Measured Waterline (WLm) =	5.14	(ft)
Calculated Waterline (WLc) =	5.15	(ft)
(WLm-WLc)/WLm * 100 =	-0.09%	
Max Measured Depth (Dm) =	0.8	(ft)
Max Calculated Depth (Dc) =	0.8	(ft)
(Dm-Dc)/Dm * 100 =	-0.02%	
Mean Velocity =	1.23	(ft/s)
Manning's n =	0.041	
0.4 * Qm =	4.87	(cfs)
2.5 * Qm =	30.43	(cfs)

FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
	1	2.75		
Bankfull	3.65	3.55		
	8.05	4.62		
Waterline	10.1	5.14	0	0
	11	5.45	0.3	0.55
	12	5.55	0.4	0.07
	13	5.7	0.55	1.23
	14	5.75	0.6	1.5
	15	5.75	0.6	1.36
	16	5.65	0.5	1.45
	17	5.75	0.6	0.65
	18	5.95	0.8	1.43
	19	5.95	0.8	1.72
	20	5.85	0.7	1.65
	21	5.95	0.8	1.57
	22	5.95	0.8	1.24
	23	5.5	0.35	1.53
	24	5.55	0.4	1.22
	25	5.65	0.5	1.27
	26	5.6	0.45	1.31
	27	5.4	0.25	0.71
	28	5.35	0.2	0.17
	29	5.45	0.3	0.33
	30	5.15	0	0
Waterline	31.4	5.15	0	0
	33.5	4.42		
Bankfull	58.5	2.93		
	65.6	1.96		

COMPUTED FROM MEASURED FIELD DATA

Wetted Perimeter (ft)	Water Depth (ft)	Area (ft^2)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0.95	0.3	0.28	0.16	1.29
1	0.4	0.4	0.03	0.23
1.01	0.55	0.55	0.68	5.56
1	0.6	0.6	0.9	7.39
1	0.6	0.6	0.82	6.7
1	0.5	0.5	0.72	5.96
1	0.6	0.6	0.39	3.2
1.02	0.8	0.8	1.14	9.4
1	0.8	0.8	1.38	11.3
1	0.7	0.7	1.16	9.49
1	0.8	0.8	1.26	10.32
1	0.8	0.8	0.99	8.15
1.1	0.35	0.35	0.54	4.4
1	0.4	0.4	0.49	4.01
1	0.5	0.5	0.64	5.22
1	0.45	0.45	0.59	4.84
1.02	0.25	0.25	0.18	1.46
1	0.2	0.2	0.03	0.28
1	0.3	0.3	0.1	0.81
1.04	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

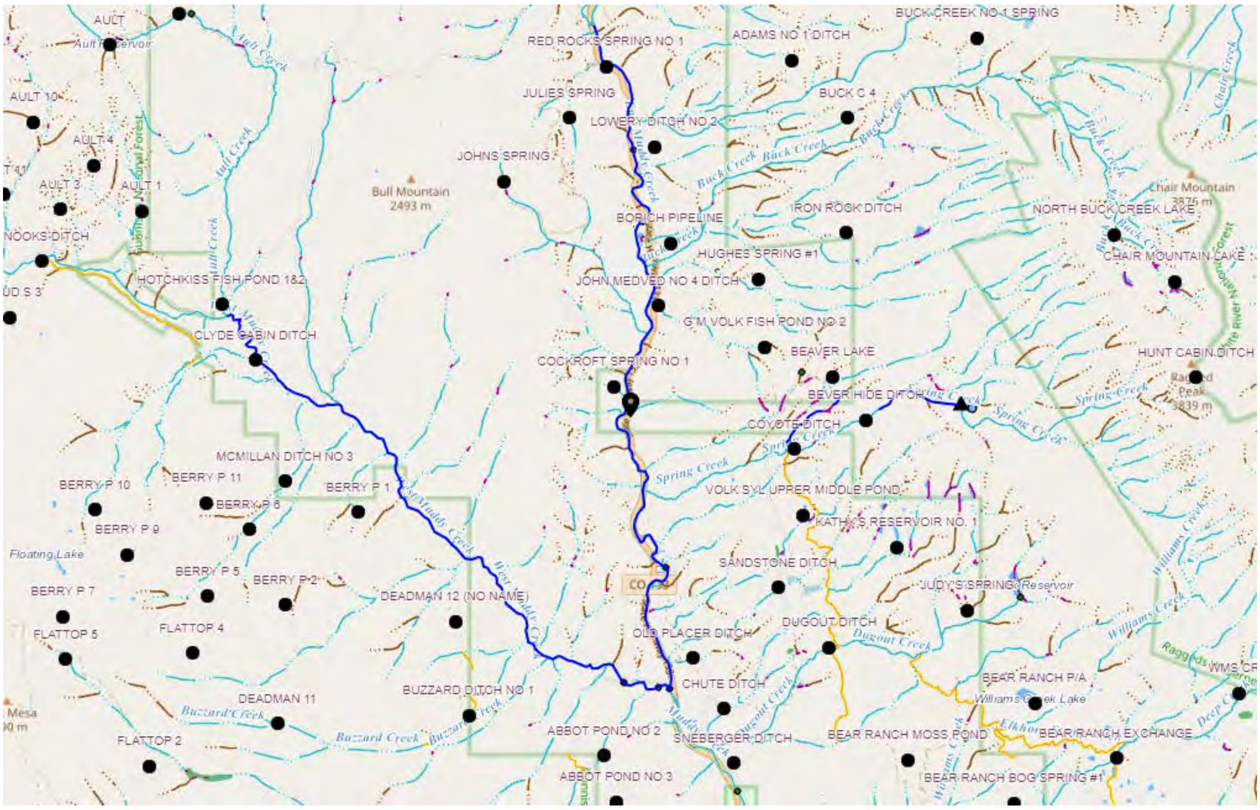
DISCLAIMER

"The Colorado Water Conservation Board makes no representations about the use of the software contained in the R2Cross platform for any purpose besides that for which it was designed. To the maximum extent permitted by applicable law, all information, modeling results, and software are provided “as is” without warranty or condition of any kind, including all implied warranties or conditions of merchantability, or fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event shall the Colorado Water Conservation Board or any state agency, official or employee be liable for any direct, indirect, punitive, incidental, special, consequential damages or any damages whatsoever including, without limitation, damages for loss of use, data, profits, or savings arising from the implementation, reliance on, or use of or inability to use the R2Cross platform.

R2Cross RESULTS

Stream Name: East Muddy Creek
Stream Locations: Approx 1.57 miles upstream from Paonia Reservoir
Fieldwork Date: 09/24/2019
Cross-section: 1
Observers: J. Sondergard
Coordinate System: UTM Zone 13
X (easting): 295348.2
Y (northing): 4322971.9
Date Processed: 05/29/2023
Slope: 0.009
Discharge: R2Cross data file: 11.58 (cfs)
Computation method: Ferguson VPE
R2Cross data filename: East Muddy Creek 9-24-19 #1.xlsx
R2Cross version: 2.0.2

LOCATION



ANALYSIS RESULTS

Habitat Criteria Results

Bankfull top width (ft) = 50.54

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft)	0.5	17.19
Percent Wetted Perimeter (%)	55.3	3.52
Mean Velocity (ft/s)	1.0	13.42

STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (sq ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Manning's n	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	2.74	50.54	1.71	2.76	86.19	51.49	100.0	1.67	0.04	4.68	403.78
	2.75	50.41	1.7	2.75	85.69	51.36	99.74	1.67	0.04	4.67	400.23
	2.8	49.73	1.67	2.7	83.19	50.67	98.41	1.64	0.04	4.6	382.51
	2.85	49.05	1.65	2.65	80.72	49.99	97.08	1.61	0.04	4.53	365.26
	2.9	48.38	1.62	2.6	78.28	49.3	95.75	1.59	0.04	4.45	348.48
	2.95	47.7	1.59	2.55	75.88	48.62	94.42	1.56	0.04	4.38	332.15
	3.0	47.03	1.56	2.5	73.51	47.93	93.08	1.53	0.04	4.3	316.28
	3.05	46.35	1.54	2.45	71.18	47.25	91.75	1.51	0.04	4.23	300.86
	3.1	45.67	1.51	2.4	68.87	46.56	90.42	1.48	0.04	4.15	285.88
	3.15	45.0	1.48	2.35	66.61	45.88	89.09	1.45	0.04	4.07	271.35
	3.2	44.33	1.45	2.3	64.37	45.2	87.78	1.42	0.04	4.0	257.2
	3.25	43.68	1.42	2.25	62.17	44.54	86.5	1.4	0.04	3.91	243.39
	3.3	43.03	1.39	2.2	60.01	43.88	85.22	1.37	0.05	3.83	230.01
	3.35	42.38	1.37	2.15	57.87	43.22	83.94	1.34	0.05	3.75	217.06
	3.4	41.73	1.34	2.1	55.77	42.56	82.66	1.31	0.05	3.67	204.53
	3.45	41.08	1.31	2.05	53.7	41.9	81.37	1.28	0.05	3.58	192.42
	3.5	40.43	1.28	2.0	51.66	41.24	80.09	1.25	0.05	3.5	180.72
	3.55	39.79	1.25	1.95	49.65	40.58	78.81	1.22	0.05	3.41	169.43
	3.6	39.14	1.22	1.9	47.68	39.92	77.53	1.19	0.05	3.33	158.55
	3.65	38.49	1.19	1.85	45.74	39.26	76.25	1.16	0.05	3.24	148.07
	3.7	37.84	1.16	1.8	43.83	38.6	74.97	1.14	0.05	3.15	137.99
	3.75	37.19	1.13	1.75	41.96	37.94	73.69	1.11	0.05	3.06	128.31
	3.8	36.54	1.1	1.7	40.11	37.28	72.41	1.08	0.05	2.97	119.02
	3.85	35.89	1.07	1.65	38.3	36.62	71.12	1.05	0.05	2.87	110.11
	3.9	35.24	1.04	1.6	36.53	35.96	69.84	1.02	0.05	2.78	101.59

	3.95	34.59	1.01	1.55	34.78	35.3	68.56	0.99	0.05	2.69	93.45
	4.0	34.14	0.97	1.5	33.06	34.85	67.67	0.95	0.05	2.57	85.09
	4.05	33.75	0.93	1.45	31.37	34.44	66.88	0.91	0.05	2.45	76.99
	4.1	33.35	0.89	1.4	29.69	34.03	66.08	0.87	0.06	2.33	69.28
	4.15	32.96	0.85	1.35	28.03	33.62	65.29	0.83	0.06	2.21	61.98
	4.2	32.56	0.81	1.3	26.39	33.21	64.5	0.79	0.06	2.09	55.08
	4.25	32.17	0.77	1.25	24.77	32.81	63.71	0.76	0.06	1.96	48.59
	4.3	31.77	0.73	1.2	23.18	32.4	62.91	0.72	0.06	1.83	42.52
	4.35	31.38	0.69	1.15	21.6	31.99	62.12	0.68	0.06	1.71	36.85
	4.4	30.98	0.65	1.1	20.04	31.58	61.33	0.63	0.07	1.58	31.6
	4.45	30.58	0.6	1.05	18.5	31.17	60.54	0.59	0.07	1.45	26.77
	4.5	30.19	0.56	1.0	16.98	30.77	59.75	0.55	0.07	1.32	22.35
	4.55	29.79	0.52	0.95	15.48	30.36	58.95	0.51	0.08	1.19	18.36
	4.6	29.4	0.48	0.9	14.0	29.95	58.16	0.47	0.08	1.06	14.77
Waterline	4.65	29.01	0.43	0.85	12.54	29.54	57.37	0.42	0.09	0.93	11.61
	4.7	28.73	0.39	0.8	11.1	29.24	56.78	0.38	0.09	0.79	8.8
	4.75	28.45	0.34	0.75	9.67	28.94	56.2	0.33	0.1	0.66	6.42
	4.8	28.18	0.29	0.7	8.25	28.64	55.61	0.29	0.11	0.54	4.44
	4.85	27.9	0.25	0.65	6.85	28.34	55.03	0.24	0.13	0.42	2.86
	4.9	26.57	0.21	0.6	5.49	26.96	52.35	0.2	0.15	0.33	1.79
	4.95	25.9	0.16	0.55	4.18	26.26	50.99	0.16	0.18	0.23	0.95
	5.0	22.24	0.13	0.5	2.97	22.53	43.76	0.13	0.21	0.17	0.51
	5.05	17.73	0.11	0.45	1.97	17.96	34.89	0.11	0.25	0.13	0.26
	5.1	13.48	0.09	0.4	1.19	13.65	26.51	0.09	0.3	0.09	0.11
	5.15	5.84	0.11	0.35	0.66	5.95	11.56	0.11	0.24	0.13	0.09
	5.2	3.36	0.13	0.3	0.43	3.45	6.69	0.12	0.22	0.16	0.07
	5.25	2.22	0.13	0.25	0.29	2.28	4.43	0.13	0.22	0.16	0.05
	5.3	1.82	0.1	0.2	0.19	1.87	3.64	0.1	0.26	0.12	0.02
	5.35	1.43	0.08	0.15	0.11	1.47	2.85	0.07	0.34	0.07	0.01
	5.4	0.95	0.05	0.1	0.05	0.98	1.9	0.05	0.48	0.04	0.0
	5.45	0.48	0.03	0.05	0.01	0.49	0.95	0.02	0.85	0.01	0.0
	5.49	0.14	0.01	0.01	0.0	0.15	0.28	0.01	2.33	0.0	0.0

This Manning's roughness coefficient was calculated based on velocity estimates from the Ferguson VPE method

MODEL SUMMARY

Measured Flow (Qm) =	11.58	(cfs)
Calculated Flow (Qc) =	11.59	(cfs)
(Qm-Qc)/Qm * 100 =	-0.10%	
Measured Waterline (WLm) =	4.64	(ft)
Calculated Waterline (WLc) =	4.65	(ft)
(WLm-WLc)/WLm * 100 =	-0.10%	
Max Measured Depth (Dm) =	0.85	(ft)
Max Calculated Depth (Dc) =	0.85	(ft)
(Dm-Dc)/Dm * 100 =	-0.02%	
Mean Velocity =	0.92	(ft/s)
Manning's n =	0.086	
0.4 * Qm =	4.63	(cfs)
2.5 * Qm =	28.96	(cfs)

FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
	2.9	1.79		
Bankfull	5.3	2.74		
	17.25	3.96		
Waterline	20.45	4.64	0	0
	21.4	4.85	0.2	0
	22	5.1	0.45	0.63
	23	5.15	0.5	1.23
	24	5.1	0.45	0.6
	25	5	0.35	1.05
	26	5.15	0.5	1.34
	27	5.05	0.4	1.68
	28	5.15	0.5	1.4
	29	5.15	0.5	0.67
	30	5.05	0.4	1.52
	31	5.15	0.5	2.11
	32	5.05	0.4	1.78
	33	4.95	0.3	2.26
	34	5.05	0.4	1.55
	35	4.95	0.3	1.09
	36	5.05	0.4	0.48
	37	4.9	0.25	0.86
	38	4.85	0.2	0.69
	39	5.15	0.5	0.01
	40	5.15	0.5	0.31
	41	5.25	0.6	0.1
	42	5.05	0.4	0.24
	43	4.95	0.3	1.07
	44	5.05	0.4	1.4
	45	5.2	0.55	0.6
	46	5.15	0.5	0.55

	47	5.35	0.7	0.76
	48	5.5	0.85	0.9
	49	5.15	0.5	0.22
Waterline	49.5	4.65	0	0
	54.2	3.18		
Bankfull	56.25	2.63		
	56.85	2.12		

COMPUTED FROM MEASURED FIELD DATA

Wetted Perimeter (ft)	Water Depth (ft)	Area (ft^2)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0.97	0.2	0.15	0	0
0.65	0.45	0.36	0.23	1.96
1	0.5	0.5	0.61	5.31
1	0.45	0.45	0.27	2.33
1	0.35	0.35	0.37	3.17
1.01	0.5	0.5	0.67	5.78
1	0.4	0.4	0.67	5.8
1	0.5	0.5	0.7	6.04
1	0.5	0.5	0.34	2.89
1	0.4	0.4	0.61	5.25
1	0.5	0.5	1.05	9.11
1	0.4	0.4	0.71	6.15
1	0.3	0.3	0.68	5.85
1	0.4	0.4	0.62	5.35
1	0.3	0.3	0.33	2.82
1	0.4	0.4	0.19	1.66
1.01	0.25	0.25	0.21	1.86
1	0.2	0.2	0.14	1.19
1.04	0.5	0.5	0.01	0.04
1	0.5	0.5	0.15	1.34
1	0.6	0.6	0.06	0.52
1.02	0.4	0.4	0.1	0.83
1	0.3	0.3	0.32	2.77
1	0.4	0.4	0.56	4.83
1.01	0.55	0.55	0.33	2.85
1	0.5	0.5	0.28	2.37

1.02	0.7	0.7	0.53	4.59
1.01	0.85	0.85	0.77	6.61
1.06	0.5	0.38	0.08	0.71
0.71	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

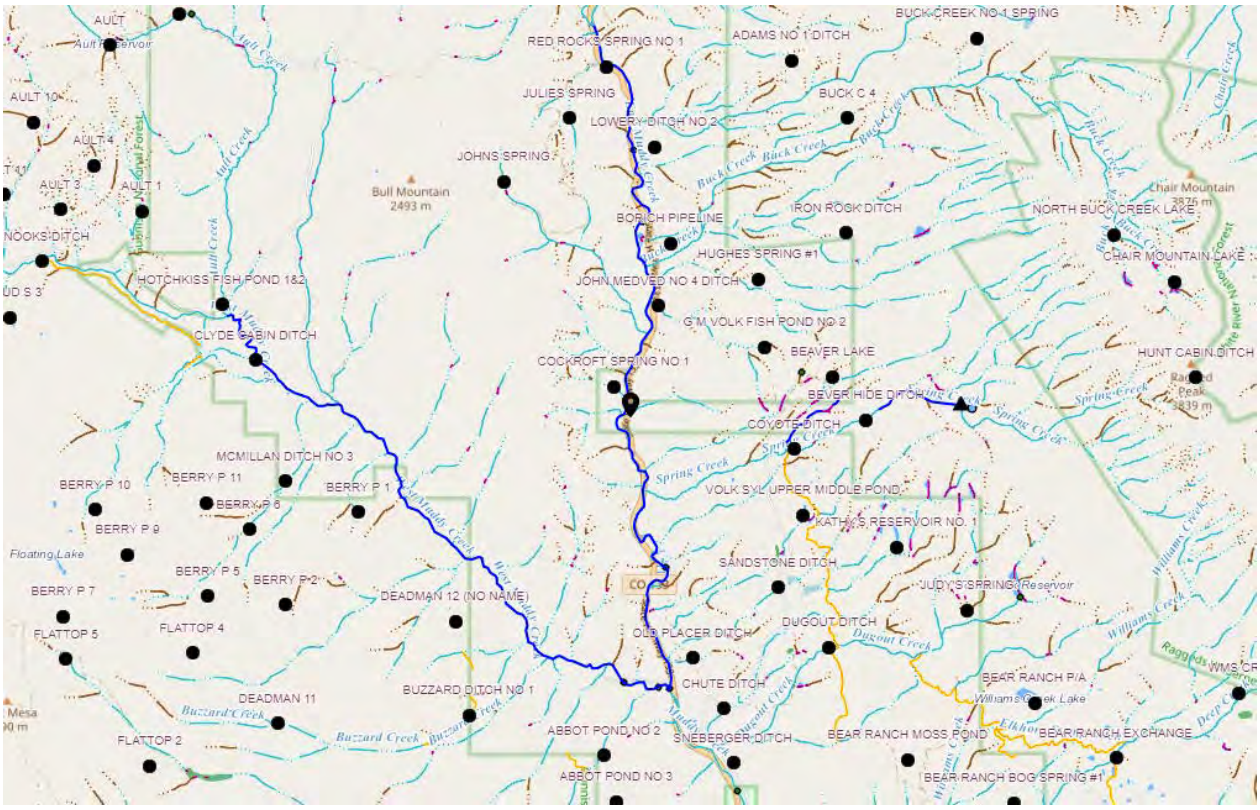
DISCLAIMER

"The Colorado Water Conservation Board makes no representations about the use of the software contained in the R2Cross platform for any purpose besides that for which it was designed. To the maximum extent permitted by applicable law, all information, modeling results, and software are provided “as is” without warranty or condition of any kind, including all implied warranties or conditions of merchantability, or fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event shall the Colorado Water Conservation Board or any state agency, official or employee be liable for any direct, indirect, punitive, incidental, special, consequential damages or any damages whatsoever including, without limitation, damages for loss of use, data, profits, or savings arising from the implementation, reliance on, or use of or inability to use the R2Cross platform.

R2Cross RESULTS

Stream Name: East Muddy Creek
Stream Locations: Approx. 1.0 mile upstream from confluence with Spring Creek
Fieldwork Date: 06/01/2018
Cross-section: 2
Observers: R. Smith, J Sondergard
Coordinate System: UTM Zone 13
X (easting): 295345
Y (northing): 4323005
Date Processed: 05/29/2023
Slope: 0.0048
Discharge: R2Cross data file: 43.24 (cfs)
Computation method: Ferguson VPE
R2Cross data filename: East Muddy Creek 6-1-18 #2 New.xlsx
R2Cross version: 2.0.2

LOCATION



ANALYSIS RESULTS

Habitat Criteria Results

Bankfull top width (ft) = 42.37

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft)	0.4	6.8
Percent Wetted Perimeter (%)	51.2	1.53
Mean Velocity (ft/s)	1.0	15.59

STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (sq ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Manning's n	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	3.43	42.37	1.41	2.17	59.78	43.44	100.0	1.38	0.05	2.78	166.19
	3.45	42.1	1.4	2.15	58.93	43.16	99.36	1.37	0.05	2.76	162.5
	3.5	41.42	1.37	2.1	56.85	42.47	97.78	1.34	0.05	2.7	153.53
	3.55	40.74	1.35	2.05	54.79	41.78	96.19	1.31	0.05	2.64	144.85
	3.6	40.06	1.32	2.0	52.77	41.09	94.61	1.28	0.05	2.59	136.47
	3.65	39.38	1.29	1.95	50.79	40.41	93.02	1.26	0.05	2.53	128.38
	3.7	38.69	1.26	1.9	48.84	39.72	91.43	1.23	0.05	2.47	120.58
	3.75	38.01	1.23	1.85	46.92	39.03	89.85	1.2	0.05	2.41	113.06
	3.8	37.33	1.21	1.8	45.03	38.34	88.26	1.17	0.05	2.35	105.83
	3.85	36.65	1.18	1.75	43.18	37.65	86.67	1.15	0.05	2.29	98.88
	3.9	35.79	1.16	1.7	41.37	36.78	84.68	1.12	0.05	2.24	92.72
	3.95	34.89	1.14	1.65	39.61	35.87	82.57	1.1	0.05	2.2	86.96
	4.0	34.0	1.11	1.6	37.88	34.97	80.52	1.08	0.05	2.15	81.42
	4.05	33.15	1.09	1.55	36.2	34.11	78.52	1.06	0.05	2.1	76.06
	4.1	32.29	1.07	1.5	34.57	33.24	76.53	1.04	0.05	2.05	70.97
	4.15	31.43	1.05	1.45	32.98	32.38	74.54	1.02	0.05	2.01	66.12
	4.2	30.77	1.02	1.4	31.42	31.7	72.98	0.99	0.05	1.94	61.07
	4.25	30.1	0.99	1.35	29.9	31.03	71.43	0.96	0.05	1.88	56.27
	4.3	29.43	0.97	1.3	28.41	30.35	69.87	0.94	0.05	1.82	51.7
	4.35	28.77	0.94	1.25	26.96	29.67	68.31	0.91	0.05	1.76	47.35
Waterline	4.4	28.1	0.91	1.2	25.53	29.0	66.75	0.88	0.06	1.69	43.24
	4.45	27.7	0.87	1.15	24.14	28.58	65.8	0.84	0.06	1.61	38.89
	4.5	27.3	0.83	1.1	22.76	28.17	64.85	0.81	0.06	1.53	34.77
	4.55	27.05	0.79	1.05	21.41	27.9	64.23	0.77	0.06	1.43	30.69
	4.6	26.8	0.75	1.0	20.06	27.63	63.61	0.73	0.06	1.34	26.86

4.65	26.62	0.7	0.95	18.72	27.42	63.13	0.68	0.06	1.24	23.21
4.7	26.43	0.66	0.9	17.4	27.21	62.65	0.64	0.07	1.14	19.83
4.75	26.25	0.61	0.85	16.08	27.0	62.17	0.6	0.07	1.04	16.73
4.8	26.07	0.57	0.8	14.77	26.79	61.68	0.55	0.07	0.94	13.89
4.85	25.73	0.52	0.75	13.48	26.4	60.78	0.51	0.08	0.85	11.44
4.9	25.39	0.48	0.7	12.2	26.01	59.87	0.47	0.08	0.76	9.24
4.95	25.05	0.44	0.65	10.94	25.61	58.97	0.43	0.09	0.67	7.29
5.0	24.71	0.39	0.6	9.69	25.22	58.06	0.38	0.09	0.58	5.59
5.05	23.98	0.35	0.55	8.48	24.44	56.26	0.35	0.1	0.5	4.23
5.1	23.24	0.31	0.5	7.3	23.65	54.45	0.31	0.11	0.42	3.09
5.15	22.5	0.27	0.45	6.15	22.87	52.65	0.27	0.12	0.35	2.14
5.2	21.76	0.23	0.4	5.05	22.08	50.84	0.23	0.14	0.27	1.39
5.25	20.86	0.19	0.35	3.98	21.14	48.67	0.19	0.16	0.21	0.83
5.3	18.95	0.16	0.3	2.96	19.2	44.2	0.15	0.19	0.15	0.46
5.35	16.71	0.12	0.25	2.07	16.9	38.92	0.12	0.23	0.11	0.23
5.4	12.47	0.1	0.2	1.29	12.61	29.03	0.1	0.27	0.08	0.11
5.45	9.57	0.08	0.15	0.74	9.66	22.24	0.08	0.34	0.05	0.04
5.5	5.67	0.06	0.1	0.33	5.71	13.16	0.06	0.43	0.04	0.01
5.55	3.33	0.03	0.05	0.11	3.36	7.73	0.03	0.69	0.02	0.0
5.58	1.7	0.01	0.01	0.02	1.71	3.93	0.01	1.6	0.0	0.0

This Manning's roughness coefficient was calculated based on velocity estimates from the Ferguson VPE method

MODEL SUMMARY

Measured Flow (Qm) =	43.24	(cfs)
Calculated Flow (Qc) =	43.24	(cfs)
(Qm-Qc)/Qm * 100 =	0.01%	
Measured Waterline (WLm) =	4.28	(ft)
Calculated Waterline (WLc) =	4.4	(ft)
(WLm-WLc)/WLm * 100 =	-2.92%	
Max Measured Depth (Dm) =	1.2	(ft)
Max Calculated Depth (Dc) =	1.2	(ft)
(Dm-Dc)/Dm * 100 =	0.00%	
Mean Velocity =	1.69	(ft/s)
Manning's n =	0.056	
0.4 * Qm =	17.3	(cfs)
2.5 * Qm =	108.1	(cfs)

FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
	0	2.94		
Bankfull	4	3.43		
	8	3.86		
Waterline	12	4.15		
	14.5	4.4	0	0
	15	4.5	0.1	0.13
	16	5	0.6	0.81
	17	5.1	0.7	1.56
	18	5.2	0.8	1.7
	19	5.3	0.9	1.99
	20	5.3	0.9	1.09
	21	5.4	1	1.88
	22	5.4	1	2.01
	23	5.3	0.9	1.58
	24	5.4	1	2.03
	25	5.5	1.1	2.86
	26	5.4	1	2.14
	27	5.5	1.1	2.06
	28	5.5	1.1	1.9
	29	5.4	1	1.52
	30	5.5	1.1	2.38
	31	5.6	1.2	1.51
	32	5.5	1.1	1.99
	33	5.6	1.2	2.19
	34	5.6	1.2	1.6
	35	5.3	0.9	2.29
	36	5.6	1.2	1.54
	37	5.5	1.1	1.41
	38	4.8	0.4	0.98
	39	5.4	1	1.06

	40	5.4	1	0.69
	41	5.2	0.8	0.31
	42	4.6	0.2	0
Waterline	42.6	4.4	0	0
	44	3.98		
Bankfull	46.5	3.4		

COMPUTED FROM MEASURED FIELD DATA

Wetted Perimeter (ft)	Water Depth (ft)	Area (ft^2)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0.51	0.1	0.07	0.01	0.02
1.12	0.6	0.6	0.49	1.12
1	0.7	0.7	1.09	2.52
1	0.8	0.8	1.36	3.15
1	0.9	0.9	1.79	4.14
1	0.9	0.9	0.98	2.27
1	1	1	1.88	4.35
1	1	1	2.01	4.65
1	0.9	0.9	1.42	3.29
1	1	1	2.03	4.7
1	1.1	1.1	3.15	7.28
1	1	1	2.14	4.95
1	1.1	1.1	2.27	5.24
1	1.1	1.1	2.09	4.83
1	1	1	1.52	3.52
1	1.1	1.1	2.62	6.05
1	1.2	1.2	1.81	4.19
1	1.1	1.1	2.19	5.06
1	1.2	1.2	2.63	6.08
1	1.2	1.2	1.92	4.44
1.04	0.9	0.9	2.06	4.77
1.04	1.2	1.2	1.85	4.27
1	1.1	1.1	1.55	3.59
1.22	0.4	0.4	0.39	0.91
1.17	1	1	1.06	2.45

1	1	1	0.69	1.6
1.02	0.8	0.8	0.25	0.57
1.17	0.2	0.16	0	0
0.63	0	0	0	0
0	0	0	0	0
0	0	0	0	0

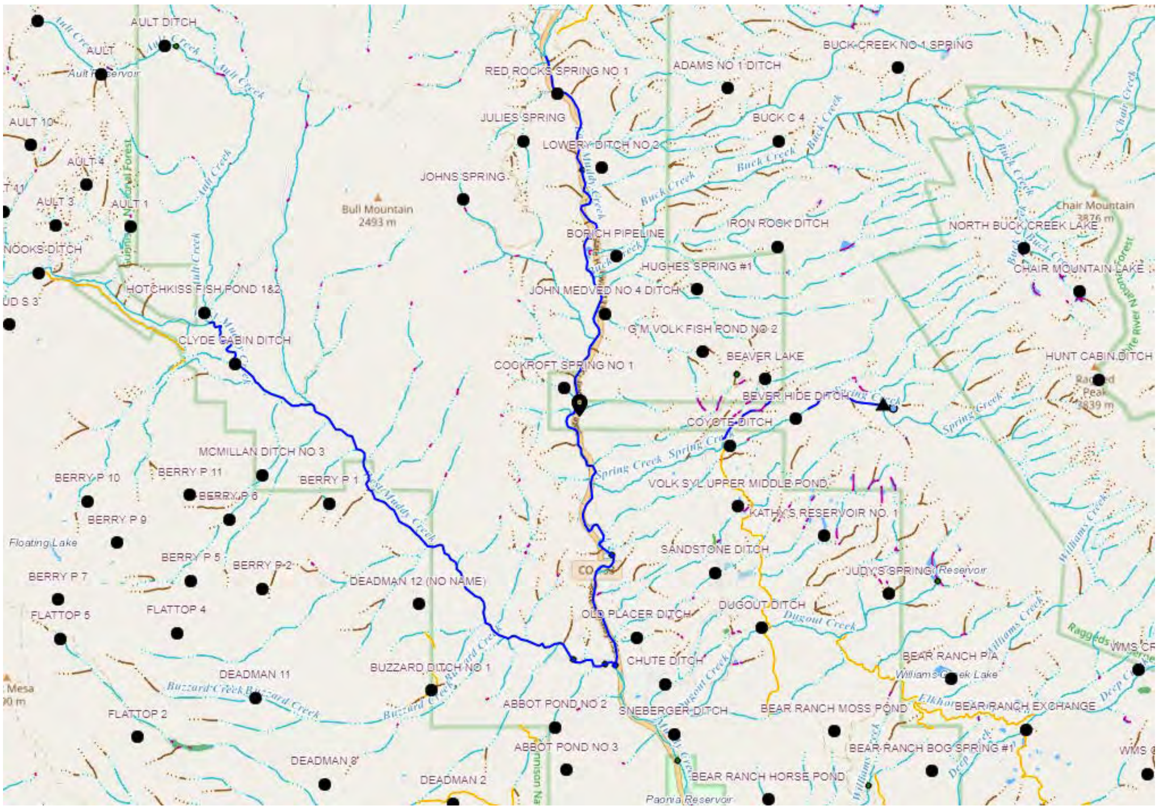
DISCLAIMER

"The Colorado Water Conservation Board makes no representations about the use of the software contained in the R2Cross platform for any purpose besides that for which it was designed. To the maximum extent permitted by applicable law, all information, modeling results, and software are provided “as is” without warranty or condition of any kind, including all implied warranties or conditions of merchantability, or fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event shall the Colorado Water Conservation Board or any state agency, official or employee be liable for any direct, indirect, punitive, incidental, special, consequential damages or any damages whatsoever including, without limitation, damages for loss of use, data, profits, or savings arising from the implementation, reliance on, or use of or inability to use the R2Cross platform.

R2Cross RESULTS

Stream Name: East Muddy Creek
Stream Locations: Approx 1.0 mile upstream from confluence with Spring Creek
Fieldwork Date: 06/01/2018
Cross-section: 1
Observers: R. Smith, J. Sondergard
Coordinate System: UTM Zone 13
X (easting): 295335
Y (northing): 4322956
Date Processed: 05/29/2023
Slope: 0.0056
Discharge: R2Cross data file: 45.34 (cfs)
Computation method: Ferguson VPE
R2Cross data filename: East Muddy Creek 6-1-18 #1 New.xlsx
R2Cross version: 2.0.2

LOCATION



ANALYSIS RESULTS

Habitat Criteria Results

Bankfull top width (ft) = 49.9

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft)	0.5	15.16
Percent Wetted Perimeter (%)	55.0	32.41
Mean Velocity (ft/s)	1.0	10.7

STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (sq ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Manning's n	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	3.55	49.9	1.58	2.5	78.65	50.41	100.0	1.56	0.04	4.02	315.88
	3.6	49.32	1.55	2.45	76.28	49.82	98.82	1.53	0.04	3.95	301.34
	3.65	48.7	1.52	2.4	73.83	49.2	97.59	1.5	0.04	3.88	286.52
	3.7	48.09	1.48	2.35	71.41	48.58	96.36	1.47	0.04	3.81	272.08
	3.75	47.48	1.45	2.3	69.02	47.96	95.13	1.44	0.04	3.74	258.03
	3.8	46.86	1.42	2.25	66.66	47.33	93.9	1.41	0.04	3.67	244.37
	3.85	46.25	1.39	2.2	64.33	46.71	92.66	1.38	0.04	3.59	231.1
	3.9	45.64	1.36	2.15	62.03	46.09	91.43	1.35	0.04	3.52	218.21
	3.95	44.91	1.33	2.1	59.77	45.36	89.98	1.32	0.04	3.45	206.2
	4.0	44.18	1.3	2.05	57.54	44.62	88.51	1.29	0.04	3.38	194.59
	4.05	43.44	1.27	2.0	55.35	43.88	87.04	1.26	0.04	3.31	183.36
	4.1	42.71	1.25	1.95	53.2	43.14	85.57	1.23	0.04	3.24	172.5
	4.15	41.98	1.22	1.9	51.08	42.4	84.1	1.2	0.04	3.17	162.01
	4.2	41.18	1.19	1.85	49.0	41.59	82.5	1.18	0.04	3.1	152.13
	4.25	40.33	1.16	1.8	46.96	40.73	80.8	1.15	0.04	3.04	142.8
	4.3	39.48	1.14	1.75	44.97	39.88	79.1	1.13	0.04	2.98	133.83
	4.35	38.62	1.11	1.7	43.01	39.02	77.4	1.1	0.04	2.91	125.21
	4.4	37.89	1.08	1.65	41.1	38.27	75.92	1.07	0.04	2.84	116.61
	4.45	37.18	1.05	1.6	39.23	37.56	74.51	1.04	0.04	2.76	108.23
	4.5	36.48	1.02	1.55	37.38	36.85	73.1	1.01	0.04	2.68	100.19
	4.55	35.77	0.99	1.5	35.58	36.14	71.69	0.98	0.04	2.6	92.5
	4.6	35.07	0.96	1.45	33.81	35.43	70.28	0.95	0.04	2.52	85.13
	4.65	34.37	0.93	1.4	32.07	34.72	68.87	0.92	0.04	2.44	78.09
	4.7	33.44	0.91	1.35	30.38	33.78	67.02	0.9	0.04	2.37	71.9
	4.75	32.5	0.88	1.3	28.73	32.84	65.15	0.87	0.04	2.3	66.06

	4.8	31.57	0.86	1.25	27.13	31.9	63.28	0.85	0.04	2.23	60.53
	4.85	30.63	0.83	1.2	25.57	30.95	61.4	0.83	0.05	2.16	55.31
	4.9	29.69	0.81	1.15	24.06	30.01	59.53	0.8	0.05	2.09	50.39
Waterline	4.95	28.81	0.78	1.1	22.6	29.13	57.78	0.78	0.05	2.02	45.66
	5.0	28.3	0.75	1.05	21.17	28.6	56.73	0.74	0.05	1.92	40.61
	5.05	27.8	0.71	1.0	19.77	28.09	55.72	0.7	0.05	1.81	35.82
	5.1	27.3	0.67	0.95	18.39	27.58	54.71	0.67	0.05	1.7	31.33
	5.15	26.85	0.63	0.9	17.04	27.12	53.8	0.63	0.05	1.59	27.08
	5.2	26.44	0.59	0.85	15.71	26.69	52.95	0.59	0.05	1.47	23.1
	5.25	26.02	0.55	0.8	14.4	26.26	52.1	0.55	0.06	1.35	19.44
	5.3	25.6	0.51	0.75	13.1	25.84	51.25	0.51	0.06	1.23	16.09
	5.35	25.19	0.47	0.7	11.84	25.41	50.4	0.47	0.06	1.1	13.06
	5.4	24.53	0.43	0.65	10.59	24.74	49.08	0.43	0.06	0.99	10.5
	5.45	23.86	0.39	0.6	9.38	24.06	47.74	0.39	0.07	0.88	8.23
	5.5	23.51	0.35	0.55	8.2	23.7	47.02	0.35	0.07	0.75	6.14
	5.55	23.18	0.3	0.5	7.03	23.35	46.33	0.3	0.08	0.62	4.36
	5.6	22.85	0.26	0.45	5.88	23.01	45.64	0.26	0.09	0.49	2.91
	5.65	22.51	0.21	0.4	4.75	22.66	44.95	0.21	0.1	0.37	1.77
	5.7	22.18	0.16	0.35	3.63	22.31	44.26	0.16	0.13	0.26	0.94
	5.75	21.05	0.12	0.3	2.55	21.17	42.0	0.12	0.16	0.17	0.43
	5.8	15.66	0.11	0.25	1.67	15.75	31.25	0.11	0.18	0.14	0.23
	5.85	12.16	0.08	0.2	0.98	12.23	24.25	0.08	0.23	0.09	0.09
	5.9	7.89	0.06	0.15	0.5	7.94	15.75	0.06	0.27	0.06	0.03
	5.95	4.64	0.04	0.1	0.19	4.66	9.25	0.04	0.4	0.03	0.01
	6.0	1.78	0.04	0.05	0.07	1.79	3.55	0.04	0.39	0.03	0.0
	6.04	1.23	0.01	0.01	0.02	1.23	2.43	0.01	0.98	0.01	0.0

This Manning's roughness coefficient was calculated based on velocity estimates from the Ferguson VPE method

MODEL SUMMARY

Measured Flow (Qm) =	45.34	(cfs)
Calculated Flow (Qc) =	45.53	(cfs)
(Qm-Qc)/Qm * 100 =	-0.44%	
Measured Waterline (WLm) =	4.92	(ft)
Calculated Waterline (WLc) =	4.95	(ft)
(WLm-WLc)/WLm * 100 =	-0.46%	
Max Measured Depth (Dm) =	1.1	(ft)
Max Calculated Depth (Dc) =	1.1	(ft)
(Dm-Dc)/Dm * 100 =	-0.20%	
Mean Velocity =	2.01	(ft/s)
Manning's n =	0.047	
0.4 * Qm =	18.13	(cfs)
2.5 * Qm =	113.34	(cfs)

FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
Bankfull	0	3.5		
	4	4.17		
	8	4.65		
Waterline	11.9	4.95	0	0
	13	5.15	0.2	0.33
	14	5.35	0.4	1.19
	15	5.45	0.5	2.19
	16	5.75	0.8	1.68
	17	5.85	0.9	2.3
	18	5.75	0.8	1.92
	19	5.75	0.8	2.43
	20	5.85	0.9	1.89
	21	5.75	0.8	2.48
	22	5.95	1	2.53
	23	5.85	0.9	2.86
	24	5.85	0.9	2.64
	25	5.75	0.8	2.58
	26	5.85	0.9	2.56
	27	5.95	1	2.34
	28	5.95	1	2.42
	29	5.85	0.9	1.65
	30	5.95	1	1.71
	31	5.85	0.9	1.57
	32	6.05	1.1	1.63
	33	6.05	1.1	1.46
	34	5.95	1	1.81
	35	5.95	1	2
	36	5.75	0.8	1.73
	37	5.75	0.8	1.64
	38	5.7	0.75	1.65

	39	5.4	0.45	1.46
	40	5.1	0.2	0.54
Waterline	40.9	4.9	0	0
	44	4.36		
	48	3.9		
Bankfull	50.2	3.55		

COMPUTED FROM MEASURED FIELD DATA

Wetted Perimeter (ft)	Water Depth (ft)	Area (ft^2)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
1.12	0.2	0.21	0.07	0.15
1.02	0.4	0.4	0.48	1.05
1	0.5	0.5	1.09	2.42
1.04	0.8	0.8	1.34	2.96
1	0.9	0.9	2.07	4.57
1	0.8	0.8	1.54	3.39
1	0.8	0.8	1.94	4.29
1	0.9	0.9	1.7	3.75
1	0.8	0.8	1.98	4.38
1.02	1	1	2.53	5.58
1	0.9	0.9	2.57	5.68
1	0.9	0.9	2.38	5.24
1	0.8	0.8	2.06	4.55
1	0.9	0.9	2.3	5.08
1	1	1	2.34	5.16
1	1	1	2.42	5.34
1	0.9	0.9	1.49	3.27
1	1	1	1.71	3.77
1	0.9	0.9	1.41	3.12
1.02	1.1	1.1	1.79	3.96
1	1.1	1.1	1.61	3.54
1	1	1	1.81	3.99
1	1	1	2	4.41
1.02	0.8	0.8	1.38	3.05
1	0.8	0.8	1.31	2.89
1	0.75	0.75	1.24	2.73

1.04	0.45	0.45	0.66	1.45
1.04	0.2	0.19	0.1	0.23
0.92	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

DISCLAIMER

"The Colorado Water Conservation Board makes no representations about the use of the software contained in the R2Cross platform for any purpose besides that for which it was designed. To the maximum extent permitted by applicable law, all information, modeling results, and software are provided “as is” without warranty or condition of any kind, including all implied warranties or conditions of merchantability, or fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event shall the Colorado Water Conservation Board or any state agency, official or employee be liable for any direct, indirect, punitive, incidental, special, consequential damages or any damages whatsoever including, without limitation, damages for loss of use, data, profits, or savings arising from the implementation, reliance on, or use of or inability to use the R2Cross platform.

General Site Field Visit Data Report *(Filters: Name begins with East Muddy Creek; Division = 4;)*

Type		Div	Name	CWCB Case Number	Segment ID	Visit Date	Location Description	Watershed Name
Stream		4	East Muddy Creek		21/4/A-005	4/7/2021	From McClure Pass to Paonia Reservior	North Fork Gunnison
	Remarks	Date: 07/04/21 00:00	Remark: Site Investigation: potential locations for CWCB temp gage, USGS and DWR gages on Muddy Creek, tributaries above and below confluence with West Muddy, photos.					
	GPS Log	No GPS Log records for this visit.						
	Photo Log	No Photo Log records for this visit.						
		4	East Muddy Creek		21/4/A-005	4/8/2021	At DWR gage and confluence with West Muddy Creek. Collaborated with DWR, Josh Casper, about the segments and potential temporary gage locations.	North Fork Gunnison
	Remarks	Date: 08/04/21 00:00	Remark: Determined no good gage location on East Muddy Creek with public access between Spring Creek trib and confluence with West Muddy Creek.					
	GPS Log	No GPS Log records for this visit.						
	Photo Log	No Photo Log records for this visit.						

Discharge Measurment Field Visit Data Report *(Filters: Name begins with East Muddy Creek; Division = 4;)*

Div	Name	CWCB Case Number	Segment ID	Meas. Date	UTM	Location	Flow Amount (cfs)	Meas #	Rating	Station ID
4	East Muddy Creek		21/4/A-005	11/06/2023	UTMx: 295498 UTMy: 4322126	measurment taken near the bridge	16.94			

Discharge Measurement Summary

Site name	EMUDDY Bridge at rv park
Site number	Bridge at rv park
Operator(s)	Lfs
File name	Bridge at rv park_20231106-140228.ft
Comment	

Start time	11/6/2023 12:40 PM
End time	11/6/2023 1:00 PM
Start location latitude	-
Start location longitude	-
Calculations engine	FlowTracker2

Sensor type	Top Setting
Handheld serial number	FT2H2322005
Probe serial number	FT2P2317010
Probe firmware	1.30
Handheld software	1.7

# Stations	Avg interval (s)	Total discharge (ft^3/s)
20	40	16.9441

Total width (ft)	Total area (ft^2)	Wetted Perimeter (ft)
42.700	38.4120	50.940

Mean SNR (dB)	Mean depth (ft)	Mean velocity (ft/s)
38	0.900	0.4411

Mean temp (°F)	Max depth (ft)	Max velocity (ft/s)
41.525	2.000	0.6266

Discharge Uncertainty

Category	ISO	IVE
Accuracy	1.0%	1.0%
Depth	0.2%	3.1%
Velocity	0.5%	2.4%
Width	0.1%	0.1%
Method	1.6%	
# Stations	2.8%	
Overall	**3.4%**	**4.0%**

Discharge equation	Mid Section
Discharge uncertainty	IVE
Discharge reference	Rated

Data Collection Settings

Salinity	0.000 PSS-78
Temperature	-
Sound speed	-
Mounting correction	0.000 %

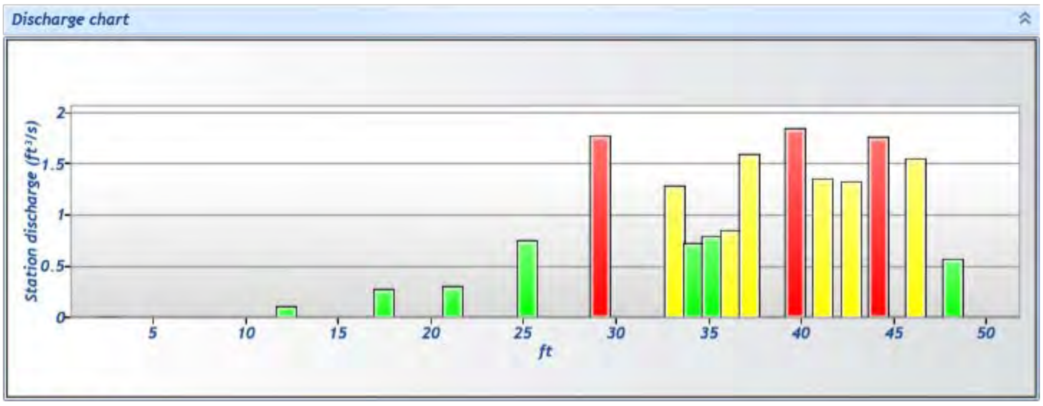
Summary overview

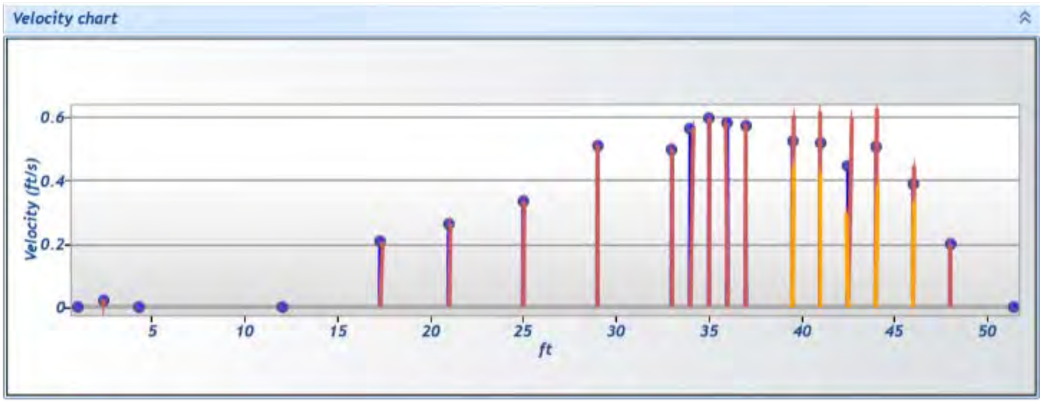
No changes were made to this file
Quality control warnings

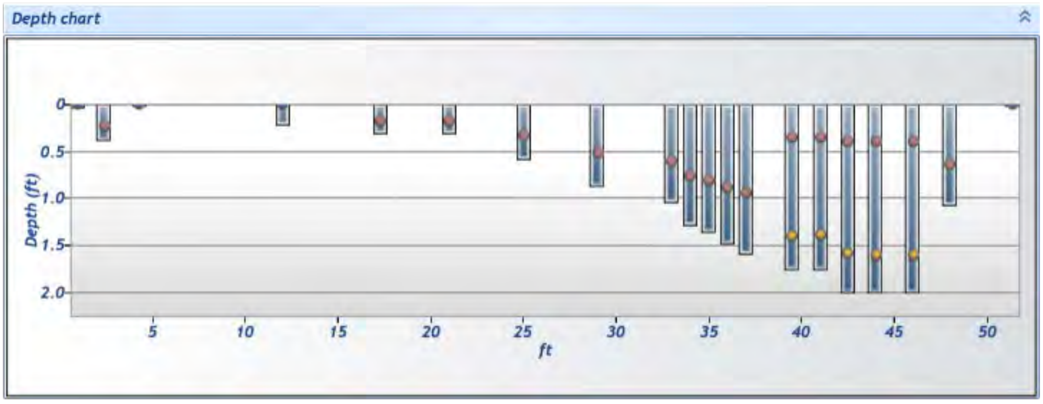
Discharge Measurement Summary

Site name	EMUDDY Bridge at rv park
Site number	Bridge at rv park
Operator(s)	Lfs
File name	Bridge at rv park_20231106-140228.ft
Comment	

Station Warning Settings		
Station discharge OK	Station discharge < 5.00%	
Station discharge caution	5.00% >= Station discharge < 10.00%	
Station discharge warning	Station discharge >= 10.00%	







11/6/2023 3:31:44 PM

Discharge Measurement Summary

Site name	EMUDDY Bridge at rv park
Site number	Bridge at rv park
Operator(s)	Lfs
File name	Bridge at rv park_20231106-140228.ft
Comment	

Measurement results

St#	Time	Location (ft)	Method	Depth (ft)	%Depth	Measured Depth (ft)	Samples	Velocity (ft/s)	Correction	Mean Velocity (ft/s)	Area (ft²)	Flow (ft³/s)	%Q	
0	1:40 PM	1.000	None	0.030	0.0000	0.000	0	0.0000	1.0000	0.0240	0.0210	0.0005	0.00	✓
1	1:41 PM	2.400	0.6	0.370	0.6000	0.222	16	0.0240	1.0000	0.0240	0.6105	0.0146	0.09	✓
2	1:41 PM	4.300	None	0.010	0.0000	0.000	0	0.0000	1.0000	0.0240	0.0095	0.0002	0.00	✓
3	1:42 PM	12.000	None	0.200	0.0000	0.000	0	0.0000	1.0000	0.2086	0.5300	0.1106	0.65	✓
4	1:43 PM	17.300	0.6	0.300	0.6000	0.180	25	0.2086	1.0000	0.2086	1.3500	0.2817	1.66	✓
5	1:44 PM	21.000	0.6	0.300	0.6000	0.180	17	0.2637	1.0000	0.2637	1.1550	0.3046	1.80	✓
6	1:45 PM	25.000	0.6	0.570	0.6000	0.342	21	0.3332	1.0000	0.3332	2.2800	0.7597	4.48	✓
7	1:46 PM	29.000	0.6	0.870	0.6000	0.522	28	0.5107	1.0000	0.5107	3.4800	1.7773	10.49	✓
8	1:47 PM	33.000	0.6	1.030	0.6000	0.618	18	0.4980	1.0000	0.4980	2.5750	1.2825	7.57	✓
9	1:47 PM	34.000	0.6	1.280	0.6000	0.768	18	0.5646	1.0000	0.5646	1.2800	0.7227	4.26	✓
10	1:48 PM	35.000	0.6	1.350	0.6000	0.810	20	0.5946	1.0000	0.5946	1.3500	0.8028	4.74	✓
11	1:49 PM	36.000	0.6	1.470	0.6000	0.882	15	0.5816	1.0000	0.5816	1.4700	0.8550	5.05	✓
12	1:50 PM	37.000	0.6	1.580	0.6000	0.948	29	0.5760	1.0000	0.5760	2.7650	1.5926	9.40	✓
13	1:50 PM	39.500	0.2/0.8	1.760	0.2000	0.352	13	0.6046	1.0000	0.5239	3.5200	1.8442	10.88	✓
13	1:50 PM	39.500	0.2/0.8	1.760	0.8000	1.408	17	0.4432	1.0000	0.5239	3.5200	1.8442	10.88	✓
14	1:52 PM	41.000	0.2/0.8	1.750	0.2000	0.350	36	0.6171	1.0000	0.5179	2.6250	1.3595	8.02	✓
14	1:52 PM	41.000	0.2/0.8	1.750	0.8000	1.400	14	0.4187	1.0000	0.5179	2.6250	1.3595	8.02	✓
15	1:53 PM	42.500	0.2/0.8	1.990	0.2000	0.398	14	0.6001	1.0000	0.4478	2.9850	1.3366	7.89	✓
15	1:53 PM	42.500	0.2/0.8	1.990	0.8000	1.592	29	0.2954	1.0000	0.4478	2.9850	1.3366	7.89	✓
16	1:55 PM	44.000	0.2/0.8	2.000	0.2000	0.400	18	0.6266	1.0000	0.5051	3.5000	1.7680	10.43	✓
16	1:55 PM	44.000	0.2/0.8	2.000	0.8000	1.600	25	0.3837	1.0000	0.5051	3.5000	1.7680	10.43	✓
17	1:57 PM	46.000	0.2/0.8	2.000	0.2000	0.400	12	0.4465	1.0000	0.3888	4.0000	1.5550	9.18	✓
17	1:57 PM	46.000	0.2/0.8	2.000	0.8000	1.600	21	0.3311	1.0000	0.3888	4.0000	1.5550	9.18	✓
18	1:59 PM	48.000	0.6	1.070	0.6000	0.642	13	0.1983	1.0000	0.1983	2.8890	0.5728	3.38	✓
19	2:00 PM	51.400	None	0.010	0.0000	0.000	0	0.0000	1.0000	0.1983	0.0170	0.0034	0.02	✓

Discharge Measurement Summary

Site name	EMUDDY Bridge at rv park
Site number	Bridge at rv park
Operator(s)	Lfs
File name	Bridge at rv park_20231106-140228.ft
Comment	

Quality Control Settings	
Maximum depth change	50.00%
Maximum spacing change	100.00%
SNR threshold	10 dB
Standard error threshold	0.0328 ft/s
Spike threshold	10.00%
Maximum velocity angle	20.0 deg
Maximum tilt angle	5.0 deg

Quality control warnings

St#	Time	Location (ft)	Method	Depth (ft)	%Depth	Measured Depth (ft)	Warnings
1	1:41 PM	2.400	0.6	0.370	0.6000	0.222	SNR Threshold Variation
4	1:43 PM	17.300	0.6	0.300	0.6000	0.180	Velocity Angle > QC
7	1:46 PM	29.000	0.6	0.870	0.6000	0.522	High Stn % Discharge
10	1:48 PM	35.000	0.6	1.350	0.6000	0.810	Stn Spacing > QC
13	1:50 PM	39.500	0.2/0.8	1.760	0.2000	0.352	High % Spikes,High Stn % Discharge
13	1:50 PM	39.500	0.2/0.8	1.760	0.8000	1.408	High % Spikes,High Stn % Discharge
16	1:55 PM	44.000	0.2/0.8	2.000	0.2000	0.400	High Stn % Discharge
16	1:55 PM	44.000	0.2/0.8	2.000	0.8000	1.600	High Stn % Discharge
19	2:00 PM	51.400	None	0.010	0.0000	0.000	Water Depth > QC

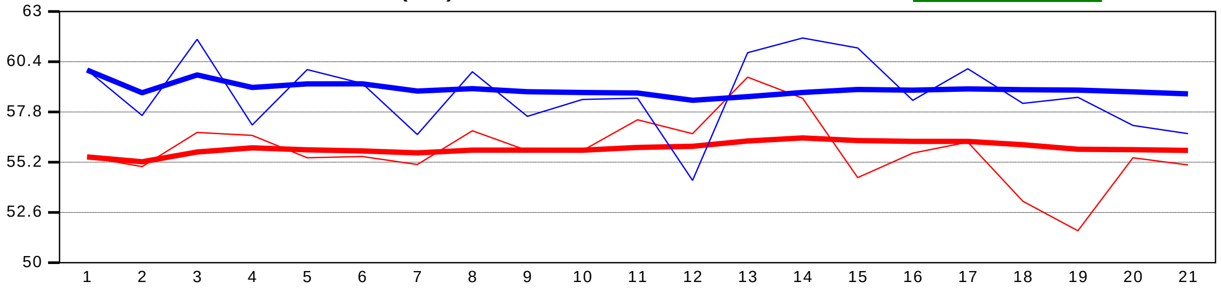
Discharge Measurement Summary

Site name	EMUDDY Bridge at rv park
Site number	Bridge at rv park
Operator(s)	Lfs
File name	Bridge at rv park_20231106-140228.ft
Comment	

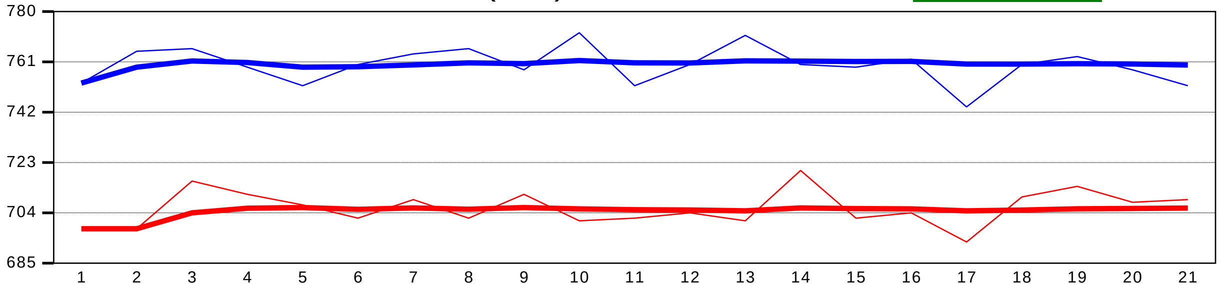
Beam 1	(red)
Beam 2	(blue)

Automated beam check Start time 11/6/2023 1:40:25 PM

Automated beam check SNR(dB) PASS



Automated beam check Noise level(cnts) PASS



Automated beam check Quality control warnings
No quality control warnings

11/6/2023 3:31:44 PM

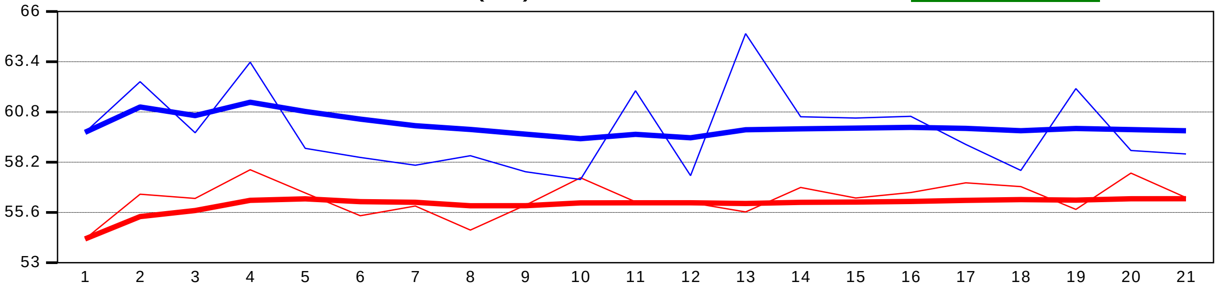
Discharge Measurement Summary

Site name	EMUDDY Bridge at rv park
Site number	Bridge at rv park
Operator(s)	Lfs
File name	Bridge at rv park_20231106-140228.ft
Comment	

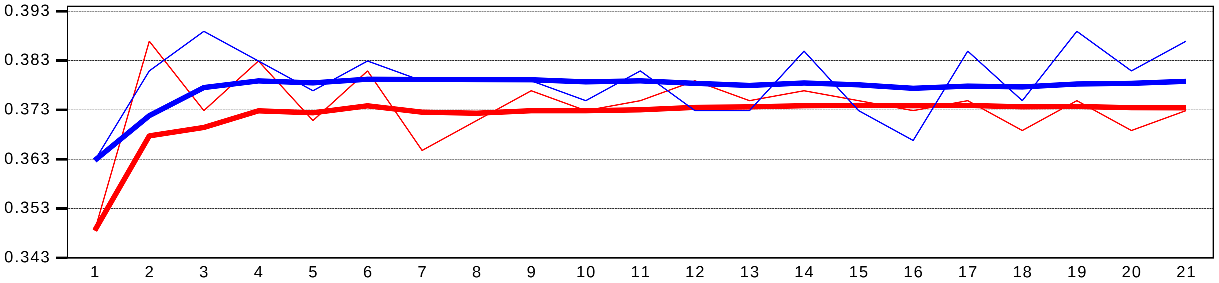
Beam 1	
Beam 2	

Automated beam check Start time 11/6/2023 1:40:25 PM

Automated beam check Peak level(dB) PASS



Automated beam check Peak position(ft) PASS



Automated beam check Quality control warnings
No quality control warnings

11/6/2023 3:31:44 PM

















Uncompahgre Field Office

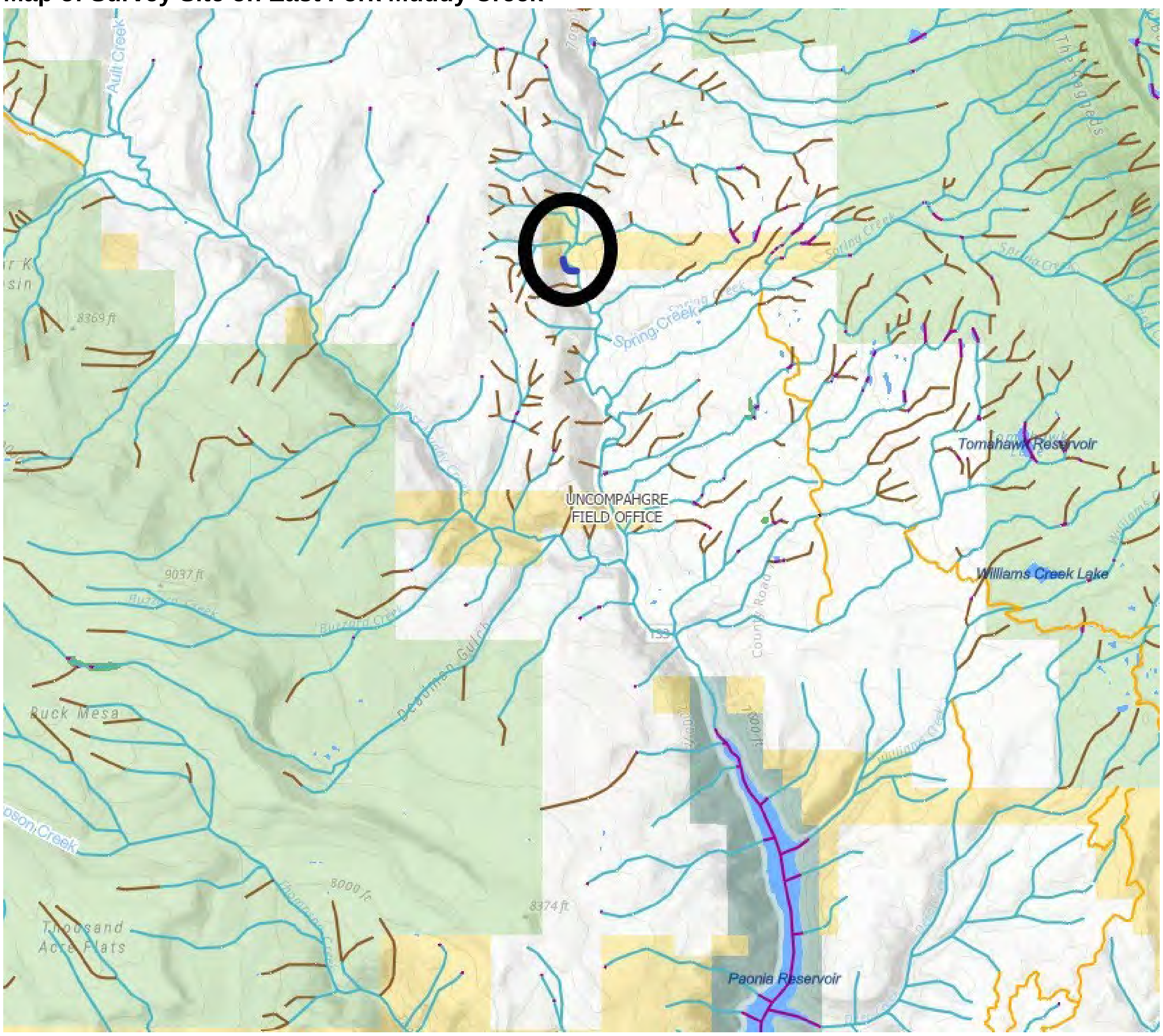
Stream Survey July 2025

East Fork Muddy Creek – Water Code: 41765

Introduction:

A site on East Fork Muddy Creek (see map below), located north of Paonia Reservoir on public lands managed by the Bureau of Land Management's (BLM) Uncompahgre Field Office, was sampled on July 24, 2025. The stream joins with West Muddy Creek to form Muddy Creek just above Paonia Reservoir. The purpose of the sampling was to assess the fishery and determine species composition and obtain population data on select resident fish species.

Map of Survey Site on East Fork Muddy Creek



Methods:
Two electro-fishing backpack units working side by side along with two back-up netters were used to complete a two-pass depletion population estimate in an approximate 500-foot stream reach. Personnel present for the survey included Zachary Hooley-Underwood and crew, Colorado Parks and Wildlife, and Tom Fresques, BLM.

Results:
A total of six species and five hybrid fish were collected during the survey. Native fish species and numbers of individuals collected included: 36 Speckled Dace, 33 Flannelmouth Suckers, 25 Sculpin, and 7 Bluehead Suckers. Nonnative fish and sportfish and numbers of individuals collected included: 4 Brook Trout, 1 Rainbow Trout, 4 White Suckers, 1 White Sucker x Bluehead Sucker hybrid, 3 White Sucker x Flannelmouth Sucker hybrids, and 1 White Sucker x Bluehead Sucker x Flannelmouth Sucker hybrid.

Flannelmouth Sucker

Bluehead Sucker

A population estimate was obtained on Flannelmouth Sucker at the site and is noted here:

East Muddy Creek Flannelmouth Sucker Density

7/24/2025	
Flannelmouth Sucker at sample site (500 feet length)	**48 fish + or - 35 fish (95% CI)**
Flannelmouth Sucker per stream mile	**503 fish + or - 370 fish (95% CI)**

Based on the sampling data, East Muddy Creek contains a primarily native fishery including two BLM Sensitive Species (Bluehead Sucker and Flannelmouth Sucker). Nonnative White Sucker (N=4) and White Sucker Hybrids (n=5) were relatively rare. Sculpin and Speckled Dace were common. Brook Trout and Rainbow Trout densities were low.

Discussion:
Flannelmouth Sucker were common in the sample reach, although age class diversity was a bit lacking as no smaller/younger fish were seen or collected. Lengths ranged from 262mm (10.3") to 441mm (17.4") total length. Bluehead Sucker were less abundant, and sizes ranged from 125mm (4.9") to 257mm (10.1") total length. Given the small amount of habitat sampled, it is likely that additional age classes of both species are present in the system.

Trout densities were low, and this is likely attributed to the site being on the lower end of the elevational and thermal tolerance range for these cold-water species. Sculpin and Speckled Dace were both common. Given the presence of Paonia Reservoir, the Flannelmouth Sucker and Bluehead Sucker populations are resident and complete all life history requirements within the Muddy Creek drainage above the reservoir, which is relatively uncommon, particularly for the Flannelmouth Sucker.

Habitat:
Riparian
Streamside vegetation in the sample reach is comprised primarily of narrowleaf cottonwood, alder, spruce, coyote willow, and some rush, sedge, and riparian grasses. Vegetation is relatively dense and provides good bank stability and some cover. Of note, use by off highway vehicles was noted within the riparian area within the sample reach as evidenced by tire tracks in the willows (see photo). This appears to be coming from the adjacent private land parcel to the west.

Representative Pool

Representative Riffle

Off Highway Vehicle Use in the Riparian Area

Stream

Stream habitats are comprised of a good mix of riffles, short runs/glides, and deep (3'+) pools. As expected, riffle habitats contained the majority of Sculpin and Speckled Dace, while the larger sucker species and trout were found primarily in the deeper pool and undercut bank habitats. Channel substrate consisted of a mix of gravels and small cobbles with some larger rock/boulders and fine sediments in the pools. The stream appears to carry substantial bedload material as noted by the large point bars and steep riffles. Although bed material is abundant, the stream appears to largely be in balance with the landform, hydrology, and sediment load and no substantial impairments were noted.

Recommendations:

- Continue to periodically monitor the resident fish populations and stream and riparian habitats – consider sampling fish at other times of year to document spawning and to document additional age classes
- Monitor off highway vehicle use within the stream/riparian corridor and consider signing or other deterrents

R2CROSS FIELD MANUAL

July 2024

COLORADO
Department of Natural Resources

Colorado Water Conservation Board
Stream and Lake Protection Section
1313 Sherman Street, Room 721
Denver, Colorado 80203
(303) 866-3441
http://cwcb.state.co.us/Pages/CWCBHome.aspx

Contributors

Jay Skinner, retired Colorado Parks and Wildlife, Denver, CO

Brandy Logan, Colorado Water Conservation Board, Denver, CO

Kathryn Birch, Colorado Parks and Wildlife, Denver, CO

Kara Scheel, Colorado Water Conservation Board, Denver, CO

Robert Viehl, Colorado Water Conservation Board, Denver, CO

Laura Corona, Colorado Water Conservation Board, Denver, CO

Marielle Sidel, Colorado Water Conservation Board, Denver, CO

Acknowledgements

The Colorado Water Conservation Board would like to thank everyone involved in the development of the R2Cross Field Manual. We wish to acknowledge Jay Skinner for his work preparing this document and providing his insight and knowledge about field methods and development of ISF recommendations that come from a career spent working with the ISF program. We also wish to thank Roy Smith of the Bureau of Land Management and Katie Birch of Colorado Parks and Wildlife for their review and suggestions that greatly improved the final document.

Abstract

In 1973, the Colorado State Legislature vested the Colorado Water Conservation Board (CWCB) with the authority to appropriate instream flow (ISF) and Natural Lake Level (NLL) water rights in the State of Colorado. Today, the Board holds over 1,700 instream flow water rights covering approximately 9,700 miles of Colorado streams. R2Cross is one method used by the CWCB to model hydraulic parameters and determine minimum instream flow rates for streams and rivers. This manual describes field procedures to collect the necessary data to run the R2Cross model. This document also includes a discussion on how to develop an instream flow recommendation based on the R2Cross methods. The R2Cross Model User's Manual & Technical Guide describes to how to process the field data using the R2Cross Online Program which performs the calculations and evaluates which flows meet the hydraulic criteria.

Acronyms and Abbreviations

Term	Definition
BLM	Bureau of Land Management
cfs	Cubic feet per second
CWCB	Colorado Water Conservation Board
CPW	Colorado Parks and Wildlife
ft	Feet/foot
ft/s	Feet per second
GPS	Global Positioning System
ISF	Instream Flow
NLL	Natural Lake Level
USFS	United States Forest Service
USGS	United States Geological Survey

Disclaimer

This manual provides guidance on how to collect field data necessary for the R2Cross methodology. User assumes all responsibility and liability for application and use of such guidelines and specifically acknowledges the CWCB is not responsible for any such use by user of this manual. For best results, CWCB recommends that an experienced instream flow practitioner conduct ANY field work and data analysis.

Contents

List of Figures

List of Tables

Introduction

Colorado's Instream Flow Program originated in 1973 with the passage of Senate Bill 97 (SB 97). Under SB 97, the Colorado Water Conservation Board (CWCB) was vested with the authority to appropriate instream flow (ISF) and natural lake level (NLL) water rights in the State of Colorado (§37-92-102(3), C.R.S. (2002). The CWCB holds these water rights are on behalf of the people of the State of Colorado to "preserve the natural environment to a reasonable degree." Today, the CWCB holds over 1,700 ISF water rights covering approximately 9,700 miles of Colorado streams and 506 NLL water rights distributed around the state.

The Instream Flow statute requires the CWCB to make three findings: (1) "determine that the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made; (2) determine that there is a natural environment that can be preserved to a reasonable degree with the CWCB's water right, if granted; and (3) determine that such environment can exist without material injury to water rights" (§37-92-102(3c), C.R.S. (2002)). The CWCB makes these determinations based on the supporting technical data and a final instream flow executive summary prepared by the CWCB staff. The Colorado Instream Flow Program Rules (CWCB 1993) describe the procedure used by the Board to appropriate new ISFs.

The statute directs the CWCB to request instream flow recommendations from other state and federal agencies such as Colorado Parks and Wildlife, United States Department of Agriculture, and United States Department of Interior. However, any entity can make ISF recommendations to the CWCB if they develop the necessary technical data to support the recommendation and participate in the appropriation process. For more information please see the ISF Appropriations website.

Determining the amount of water necessary to preserve the natural environment to a reasonable degree is a key component of ISF recommendations. R2Cross is one method used by the Colorado Water Conservation Board to determine minimum instream flow rates for streams and rivers. The R2Cross method has been used in most, but not all ISF appropriations to date.

This manual provides guidance on how to collect field data necessary for the R2Cross method. Field methods presented in this manual may be modified or adjusted, depending on site specific conditions, using best professional judgement. CWCB recommends that an experienced instream flow practitioner conduct all field work and data analysis. CWCB recommends contacting staff with any questions regarding the methodology. A companion document, R2Cross Model User’s Manual & Technical Guide, explains how to process the field data using the R2Cross online tool. This document also describes the underlying equations in the model in more detail.

Use of the R2Cross Method

Before initiating field investigations to determine ISF needs, it is important to carefully consider the natural environment to be protected and the level of protection necessary. The natural environment can include a fish population, aquatic community, riparian community, or other organisms dependent on streamflow. The value and rarity of the natural environment can vary, from common species such a brook trout, to species found nowhere else. The critical habitat necessary to protect the natural environment may differ depending on the life cycle requirements for the species of interest. The flow needed to protect specific species and habitat may also differ and R2Cross will not be suitable for all applications.

Other methods for ISF quantification should be considered when the natural environment or channel of a given stream is complex or requires special considerations. Streams with high value species or assemblage of species may require additional flow considerations. Multi-thread channels or large river systems may be better modeled with different techniques. When the critical habitat for the fish species of interest is not a riffle or riffles do not occur in the stream type, then other approaches should be assessed. R2Cross may also not be suitable if protection is needed for overbank flows for a critical life stage of plant or animal species. Please contact CWCB and CPW to discuss when it is more appropriate to use other methods to determine ISF flow rates.

In general, the approach in Colorado has been to focus on the most critical low flow habitat type or the most critical life stage of the aquatic organism or water dependent natural resource value. In most cases, the critical low flow habitat for fish is a riffle. Riffles are most easily visualized as locations that would dry up first if streamflow ceased. R2Cross is best suited to streams where riffles are the critical habitat type, the stream is single thread, channel width is generally 100 feet or less, and a base level of protection is appropriate.

R2Cross Overview

R2Cross has come to be the Colorado ISF Program's standard approach for several reasons. R2Cross was recommended as an economical approach to quantifying ISF needs in Colorado (Nehring, 1979). R2Cross was originally developed by the United States Forest Service (Silvey, 1976). The field effort associated with R2Cross is relatively easy to apply, repeatable, and involves real on-the-ground, site-specific measurements. It is superior to desktop methods because it is based on data collected on the stream of interest. Other methods are more data intensive, time consuming, and expensive but these factors do not necessarily mean better information for decision makers. The CWCB and CPW believe that the underlying technical basis for R2Cross remains scientifically sound and this approach is still widely used by the ISF program today.

R2Cross is a standard-setting technique that is based on the retention of hydraulic characteristics in a flowing water environment. The R2Cross method is based on a hydraulic model developed from field data collected during one or more site visits. Field data collection includes surveying stream channel geometry, water surface elevations, water surface slope, bankfull indicators and measuring streamflow. The R2Cross method collects field data in a riffle stream habitat type.

Riffles are biologically significant because they are (1) important for fish passage from pool to pool (Thompson, 1972), (2) they contain the highest diversity and biomass of invertebrates (Heino et al., 2004), the food source for most fish, and (3) they contain the right mixture of substrate size, water velocity, turbulence, depth and dissolved oxygen to make them the preferred habitat for spawning fish, especially salmonids (Espergren, 1996). Riffles, therefore, are a habitat type that is both critical during low flow periods (for passage and connectivity), critical for completion of a fish's life cycle (reproductive success), and for feeding and growth. Riffles are also the stream habitat type most sensitive to changes in hydraulic parameters with variations in discharge (Nehring, 1979). A small reduction in streamflow may result in a large reduction in water depth and the amount of wetted perimeter available for aquatic habitat. A key assumption in use of the R2Cross method is that maintaining adequate streamflow in riffles will also maintain adequate habitat conditions for most life stages of fish and aquatic invertebrates in other important stream habitat types such as pools and runs (Nehring, 1979).

The data collected in a riffle is uploaded to an online tool that generates a staging table for the measured cross-section. Please refer to the R2Cross Model User's Manual & Technical Guide for an explanation of the procedures used to input the data and run the R2Cross model. The staging table includes calculated channel characteristics and hydraulic variables in increments from the stage of zero flow up to bankfull stage.

The R2Cross method is based on maintaining three hydraulic criteria related to depth, velocity, and wetted perimeter (Table 1). The average depth and percent wetted perimeter directly vary as a function of the bankfull top width (Nehring, 1979). CPW has determined that maintaining these parameters are good indices of flow-related stream habitat quality (Nehring, 1979).

Table 1. Hydraulic criteria used in the R2Cross method. Percent wetted perimeter is measured relative to the bankfull wetted perimeter. Modified from Nehring (1979).

Bankfull Width[1] (feet)	Average Depth (feet)	Percent Wetted Perimeter[2] (percent)	Average Velocity (feet/second)
≤20	0.2	50	1.0
>20 to ≤40	0.2-0.4	50	1.0
>40 to ≤60	0.4-0.6	50-60	1.0
>60 to ≤100	0.6-1.0	>70	1.0

The R2Cross program determines the lowest streamflow that meets the appropriate hydraulic criteria outlined in Table 1. The average depth criteria for streams wider than 20 feet is determined by multiplying the bankfull top width by 0.01. For example, a stream that has a bankfull top width of 44 feet would have an average depth criteria of 0.44 feet.

Streamflow corresponding with these hydraulic criteria are used to recommend seasonal flow rates. CPW recommends meeting all three of the hydraulic criteria during the spring, summer, and fall, and meeting two of the three hydraulic criteria during the winter, when streams are typically at base flows. For additional information about interpreting R2Cross results, please

[1] When the bankfull top width is greater than 100 feet, please contact staff at CWCB and CPW for more information.
[2] User should select an inflection point on the wetted perimeter-discharge curve that corresponds with a flow that fully wets the bottom of the channel. The inflection point usually occurs at a value greater than 70%.

refer to the section on Determine ISF Flow rates and the R2Cross Model User's Manual & Technical Guide.

Pre-Field Work Planning

Defining the Instream Flow Reach

ISF water rights are defined between two points on a stream. These points are referred to as the upper and lower termini and the length of stream in between is referred to as a reach. It is helpful to consider the potential ISF reach prior to going to the field. Factors that can influence the reach boundaries include:

- existing upstream and downstream ISF water rights or existing ISF water rights on tributaries within the reach of interest,
- factors that influence channel geometry or hydrology such as tributary inflows, significant diversions, dry up points, reservoirs, significant spring inflows, or trans-basin inputs,
- physical considerations such as land use like livestock grazing or mining, channelization due to roads, railroads, utility corridors, etc. or water quality changes,
- biological factors or natural environment changes such as a cold water to cool water/warm water fishery transition, angling regulation changes, or other management considerations.

Significant changes to hydrology are particularly important as they may indicate changes in channel geometry or the amount of water that is available for an appropriation. When considering an ISF reach length, it is generally better to err on the side of dividing a stream into smaller reaches and collecting R2Cross field data at more locations. This can refine the flow recommendation and help to avoid the need for additional trips to the field. After data is collected and analyzed with the R2Cross model, reaches with similar R2Cross results can subsequently be combined into one reach following the initial R2Cross analysis.

In general, R2Cross data should be collected in the lower half to the lower third of the intended reach unless access issues (private land, difficult terrain, etc.) prevent it. ISF reaches typically do not go "through" large on-channel lakes or reservoirs unless there are negligible changes to hydrology. If there is an on-channel reservoir, consider having one ISF reach end at the inundation zone and a second reach start at the outlet (Figure 1). If the impoundment is a natural lake, a Natural Lake Level water right should be considered. The pre-planning exercises associated with reach delineation allow the investigator to be efficient and to anticipate a variety of field logistical issues in advance of the initial field visit.

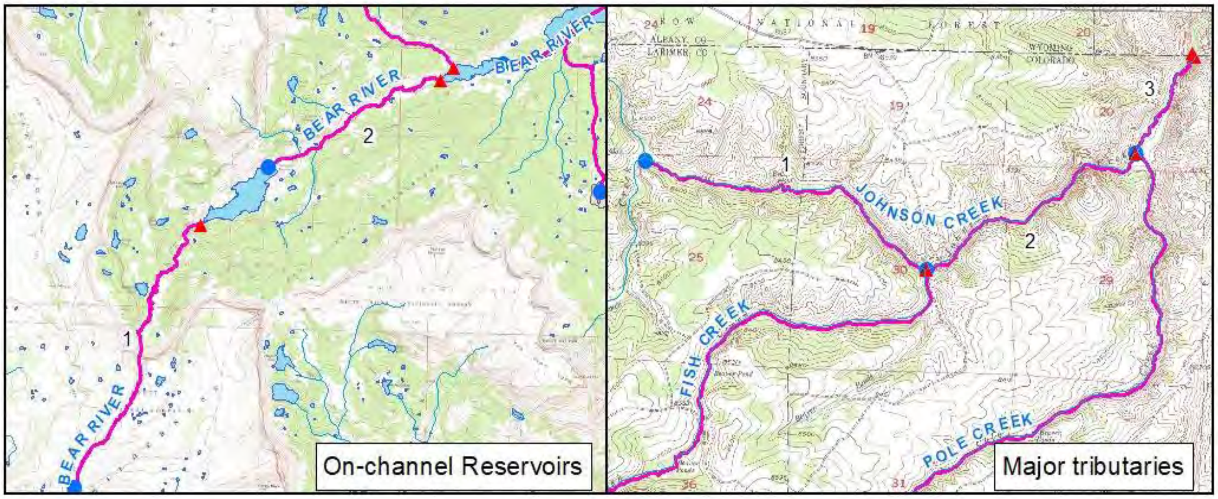


Figure 1. ISF examples that show reach delineation for on-channel reservoirs or lakes and major tributaries. Reaches are shown in pink, upstream termini are blue dots, downstream termini are red triangles.

Timing of Field Work

Planning activities prior to field work should consider the timing of anticipated flows before initiating ISF field investigations. R2Cross data must be collected at flows between low flow and bankfull, but ideally should be collected near the anticipated flow rates for the ISF recommendation. Making measurements at high flows can make it difficult to identify riffles, pose safety issues, and may produce model results that are outside of the suggested accuracy range. The R2Cross model also does not make calculations above the bankfull indicators and will not run if data is collected at flows above that elevation. Measurements taken at very low flows can make it challenging to accurately measure discharge particularly in small streams with coarse substrate. The timing of the ideal range of measurable streamflow is highly dependent upon basin elevation, local precipitation patterns, and winter snowpack.

R2Cross can be used to determine seasonal ISF flow needs in ephemeral or intermittent streams. It may be important to secure ISF protection in these streams which can provide refuge habitat for some species of fish as well as intermittent habitat connectivity to larger stream and river systems. Intermittent and ephemeral streams are also important in supporting other species of plants, insects, and terrestrial wildlife. In these cases, it is necessary to schedule field investigations during times when water is typically flowing.

Natural Environment Investigation

One of the three statutory determinations the CWCB makes is that "a natural environment exists." This is identified by the presence of water dependent natural resource values such as fish, macroinvertebrates, or riparian vegetation. Descriptions of the stream channel and the natural environment as well as fish or macroinvertebrate sampling efforts help to more fully describe the natural environment.

In most cases, ISF appropriations are based on the existence of a fishery or fish population. CPW prefers the use of recent fishery information when available to document the natural environment, rather than conducting new electrofishing efforts which can add unnecessary stress on the fishery. CPW has an extensive statewide database of fish data; in most cases, no additional aquatic sampling is necessary if there is documentation of the fishery in the CPW database. Another source of frequently used natural environment data is CPW fish stocking records. While extensive aquatic investigations with population estimates or biomass calculations are not required, this type of data should be included if available. Length-frequency data is especially useful as it can provide information about natural reproduction and overall population structure. Both fish sampling and stocking data can be accessed free of charge by writing a request to the CPW Aquatic Research Section: https://cpw.state.co.us/Documents/Research/Aquatic/Aquatic-Data-Request-Form.pdf

If the CPW database does not have fisheries data for the reach, contact local CPW or federal agencies staff to gain a better understanding of what fish may be present in the system. These entities maybe be able to assist in conducting biosurveys. Recommending entities can also complete their own assessments of macroinvertebrates and riparian vegetation or rely on studies or reports by other entities. In addition, the Colorado Natural Heritage Program also conducts detailed surveys of vegetation, ecology, and animals at locations throughout the state. This information is available online at: https://cnhp.colostate.edu/ourdata/

Equipment Checklist

The following list of equipment is recommended to collect all data necessary for the R2Cross method, including cross-section and channel measurements, streamflow measurement, site documentation and description (Table 2). Supplies for conducting fish biosurveys are also listed if needed. A printable equipment list is provided in the Appendix.

Table 2. Field equipment checklist.

	Data forms for cross-section measurement, pebble count, and discharge measurement on either Rite-in-the-Rain paper or bond paper (a cotton/paper blended paper).
	Writing surface and utensils
	Digital camera and GPS unit
	Maps or mapping applications. Maps could include USGS topographic maps, DeLorme Gazetteer, Road Atlas, BLM Planimetric Map, USFS maps (for land survey legal descriptions), or digital applications.
	Optical level or laser level, tripod, and stadia rod. Stadia rod should be at least 15 feet long.
	Water velocity meter Flowtracker, Marsh-McBirney, ADCP, or similar with top-setting wading rod. Mechanical velocity meters with moving parts (Price AA, or Pygmy) can be used but need proper maintenance.
	Two reel-style surveying tapes of adequate length for the bankfull top width of the stream being measured and for water surface slope measurements. Tapes divided into feet and 0.10 feet increments are preferred (tapes in feet and inches can be used but values will have to converted prior to R2Cross processing).
	Anchoring pins to hold the cross-section tape with at least one scissor clamp or similar strong clamp.
	Chaining pins or similar.
	Surveyor's flags or rolls of colorful flagging tape[2] or a can of surveyor's marking paint (optional).
	Gravelometer or millimeter scale (optional).
	Safety equipment as needed such as personal floatation devices, first aid kit, communication equipment, etc.)
	Waders or hip boots dried sufficiently or disinfected
	Extra batteries for velocity meter, radios, GPS unit, camera, and laser level (if used).
	Basic set of tools including a hammer, Phillips and standard screwdrivers, short sections of rebar, etc.
	Vegetation tools including clippers, machete, hedge trimmer, or small hand saw to clear vegetation to improve line of sight for surveying.
	If natural environment data is needed, equipment to collect this information may include electrofishing gear, insulated gloves, nets, buckets, measuring board, scale, water quality sampling equipment (if needed - bottles, filters, meters, thermometer, etc.), and/or macroinvertebrate kick net (or similar). Scientific data collection permit if needed.

[2] Flagging can be useful to mark bankfull or other indicators in photos. Flagging is also helpful to string across the cross-section tape to stabilize the tape and prevent "bounce" on larger rivers in the wind.

Field Work

Field work consists of several steps that are critical to obtain usable data. The first step is to select an appropriate riffle and measurement location. Once a cross-section is established, survey the topography, channel features, and the water-surface slope using an engineering level or other survey equipment. Next, make a discharge measurement using a flow meter and top-setting wading rod. Discharge should be measured in a nearby suitable location or in the cross-section riffle if an accurate measurement is possible. These steps are detailed in the following sections.

Site Selection

As stated above, R2Cross is intended for use in riffle habitats (Figure 2). Riffles are generally the steeper habitat that exists between pools in some stream types or between glide or run habitats in other stream types. Riffles, as the name suggests, are areas in the stream environment where water flow is shallow and somewhat turbulent. The most significant visual feature of a riffle is that they occur at a break in slope where the water surface becomes steeper, velocities increase, and water depths decrease. This break in slope can occur at the tail end of a pool or at the end of a run or glide. Riffles are more easily identified during lower flow conditions. At higher flows, the hydraulics of the riffle may get “washed out” and the riffle feature may not be identifiable.

The riffle’s length is highly dependent upon the size of the stream channel and can be a very subtle feature. In larger streams, the riffle can be long (10 or 20 feet or longer) and very easy to see at almost any flow; in small streams, the riffle can be a very short section – sometimes only 2 or 3 feet long. In some stream types, the riffle can be very hard to spot due to the confinement or entrenchment of these stream types. In these cases, look for short sections of stream where there is turbulent flow that is indicative of a rise in the bed profile and perhaps some coarser bed material. In general, in smaller streams with higher gradients, the riffles tend to be short, subtle features.

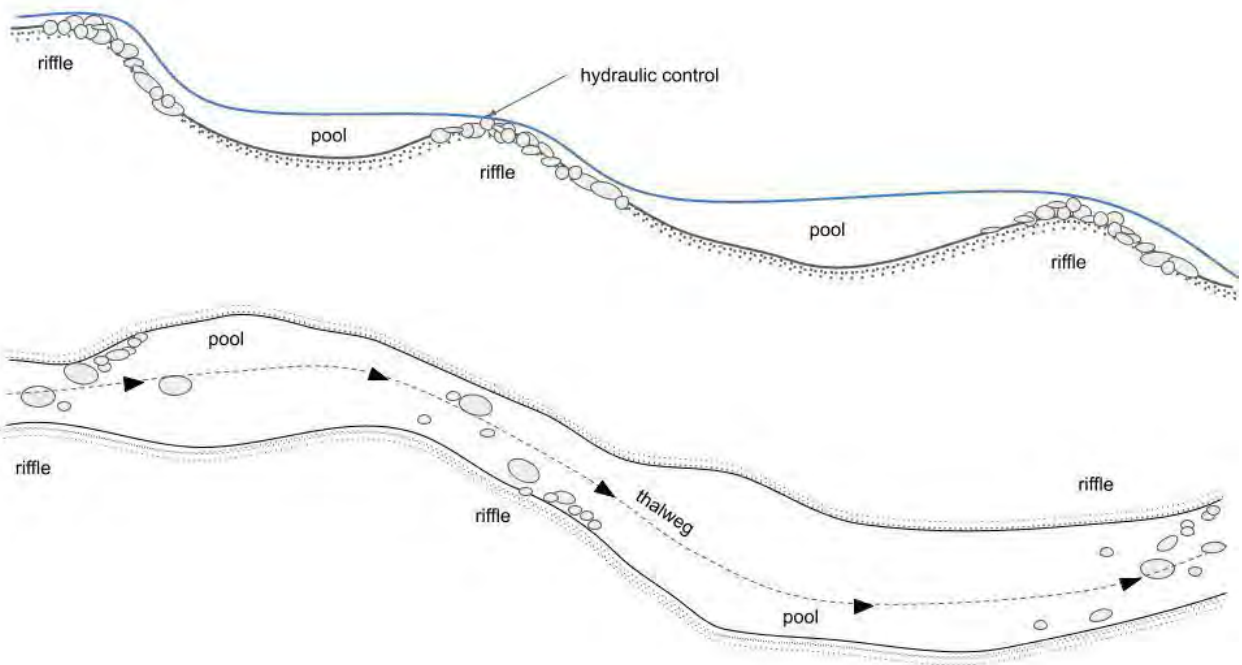


Figure 2. Longitudinal and plan view diagram of a riffle-pool sequence. Note the changes in water surface slope that occur in the pool to riffle transitions (hydraulic control points).

Figure 3. Photo of typical riffle R2Cross cross-section.

Before selecting a riffle to measure, conduct a reconnaissance investigation of a representative reach. An ideal reach should be at least 20-30 channel widths in length, to assess the typical range and variability of riffle habitat and to look for suitable riffles for the cross-section measurements. The riffle needs to be somewhat straight (perpendicular to the banks) and uniform in depth. Sites with undercut or eroding banks should be avoided. Also, avoid sites with mid-channel bars or islands and braided channels or locations that may become braided at lower flows. In streams where there is evidence of beaver activity, reconnaissance needs to include lateral investigation of the riparian zone. Beaver dam complexes often force the stream to cut numerous side channels and spread the flow out laterally into those side channels. Longitudinal reconnaissance will reveal the natural variability in riffles that exists in most streams – some riffles are wide and shallow while others can be relatively deeper and narrower. A thorough ISF investigation will capture the natural variability that exists in riffles by collecting data at two or more riffles in the identified reach. Even if there appears to be little natural variability in stream channel geometry, collecting more than one R2Cross data set in more than one riffle is recommended.

The precise location for the cross-section within the selected riffle should be near the hydraulic control, or the critical limiting transect within the riffle[3]. Avoid very turbulent hydraulics, hydraulic jumps, areas of zero or negative velocities, and undercut banks. Ideally, cross-sections selected will have relatively uniform depths and velocities where the flow is distributed somewhat uniformly across the channel. Make sure that at least one of the banks has a good bankfull indicator. It is always preferable if both banks have good indicators of the bankfull discharge but sometimes this is not possible while attempting to meet all the other conditions of a good R2Cross cross-section.

Bankfull Indicators

Bankfull indictors are signs or marks that show the stage or elevation of bankfull discharge (Harrelson, et al., 1994, Rosgen 1996; Leopold, et al., 1995) Bankfull discharge controls the shape and size of the active channel and is usually the discharge associated with the point of incipient flooding. As stated above, all R2Cross field work should be conducted at a flow less than bankfull, therefore physical indicators of the elevation of bankfull flow will need to be identified in the field. Bankfull indicators are important because the hydraulic criteria used with the R2Cross-method for ISF recommendation are dependent on an accurate measurement of the bankfull elevation[4]. Field observations of bankfull are therefore a critical piece of information that must be collected and documented in the field.

Bankfull indicators can be very subtle features on the streamside landscape. In general, bankfull indicators are a mixture of physical features and vegetative changes that occur on the stream bank (Table 3). Ideally, more than one type of physical feature or vegetation change will be

---

[3] Often referred to as the riffle crest, or the apex of the riffle. Placing the cross-section at the riffle crest will result in the best estimate of flow needs. The riffle crest is generally the shallowest cross-section in the riffle, and therefore the most important for maintaining connectivity. Cross-sections placed in locations other than the riffle crest may result in flow recommendations that are lower than what is needed for fish passage at the riffle crest.

[4] The term “grassline” has been used as a synonymous term for bankfull in previous R2Cross documentation and elsewhere.

apparent to provide multiple lines of evidence to support selection of the bankfull elevation. When there is uncertainty associated with the determination of bankfull elevations at the selected R2Cross site, the field crew should measure bankfull widths in other nearby riffles to confirm and guide determinations made at the measured R2Cross site or select a new location with clearer indicators.

Table 3. Summary of bankfull indicators.

Category	Description
Slope Break	Breaks in slope between the channel edge and the floodplain or a break in channel bank slope.
Point Bars	Sediment may be deposited on the inside of meander bends to form point bars. The top of a point bar (the highest elevation of the bar typically located near the channel margin) may show the minimum elevation of bankfull.
Vegetation	A transition from herbaceous plants (grasses, sedges, or rushes) to woody plants (willows, alders, cottonwoods, or even sage). The base of alders can provide good indicators if the channel has not migrated into the alders or the alders have not slumped into the channel. Willows are not always reliable indicators because they are more tolerant of long term root submersion.
Soil	The change from river sediments such as gravel and sand to more developed soils with organic matter.
Water lines	In bedrock channels, bankfull indicators can be water mineral stains on rocks or the lower extent of lichens.

Setting up the Field Site

The following section is a step-by-step procedure for setting up the field site in preparation for measurements and filling out site information on the field form. The optimal size of the field crew under most circumstances is three people, but the procedure can be accomplished with two. This procedure assumes that the reach has been identified, that the stream reconnaissance procedure has been done, that the appropriate cross-section locations have been identified, and the equipment has been transported to the streamside. An example of an appropriateR2Cross cross-section site is shown below (Figure 4). .

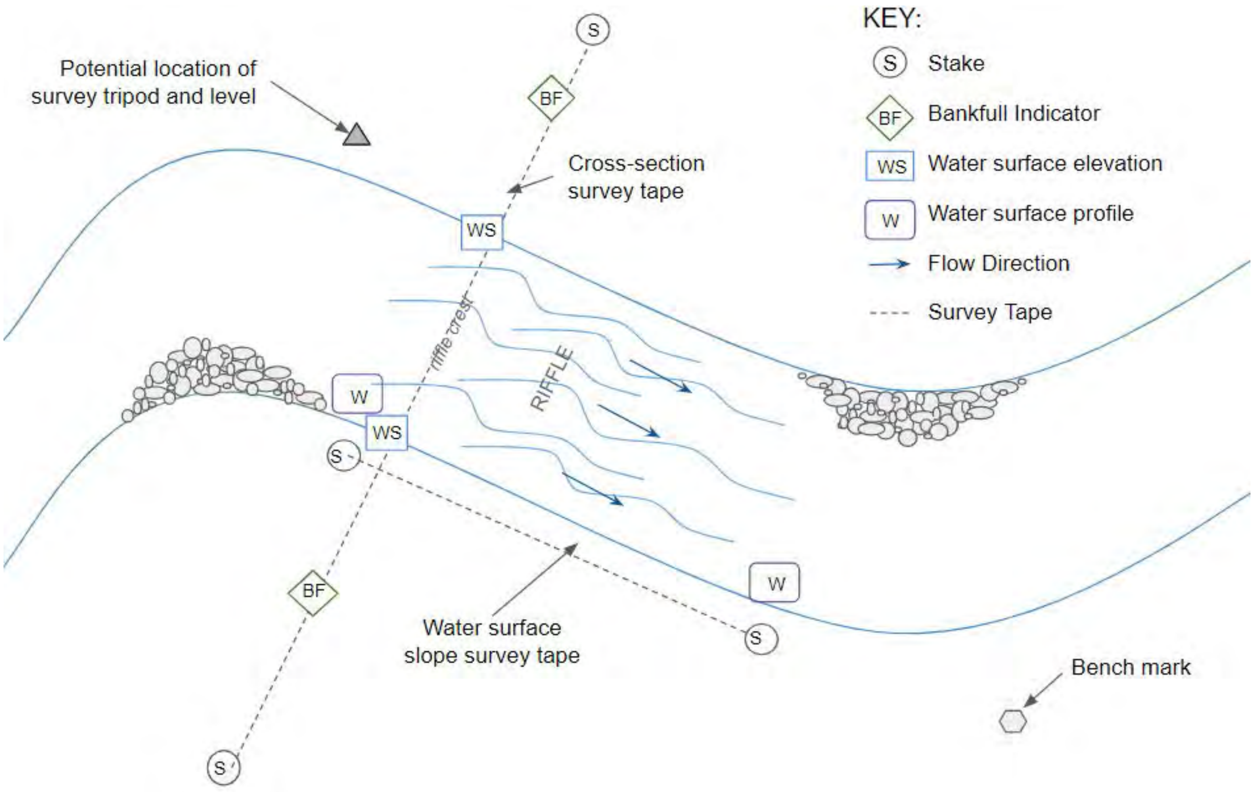


Figure 4. Schematic plan view of a R2Cross cross-section site.

Cross-Section Tape

1. Place the cross-section tape across the stream channel near the top of the riffle at the location of the hydraulic control (the shallowest depths on average or transect most prone to dry up, Figure 5). Take care to look for cross-sections with adequate bankfull indicators. Set the tape so that it is perpendicular to the flow direction at the time of the measurement as well as the presumed flow direction at bankfull discharge. Cross-section should be placed at a location nearest to uniform flow. Avoid locations that have large drops, steps, and hydraulic jumps.
2. Drive anchoring pins (stakes) into the ground on each bank above the elevation of the bankfull indicators. The R2Cross hydraulic model does not calculate any hydraulic information above the bankfull elevation, but it is important to measure some topography above the bankfull indicators.
3. Attach one survey tape to the stakes, making sure that the tape is tight, straight, and fairly level.
4. Remove minor obstructions from the cross-section, such as rocks and sticks, to create more uniform flow conditions. Once the stream cross-section measurements are initiated, all objects or obstructions (even if they are movable) must remain in place. Moving objects or obstructions after measurements are initiated will change the hydraulics of the cross-section.

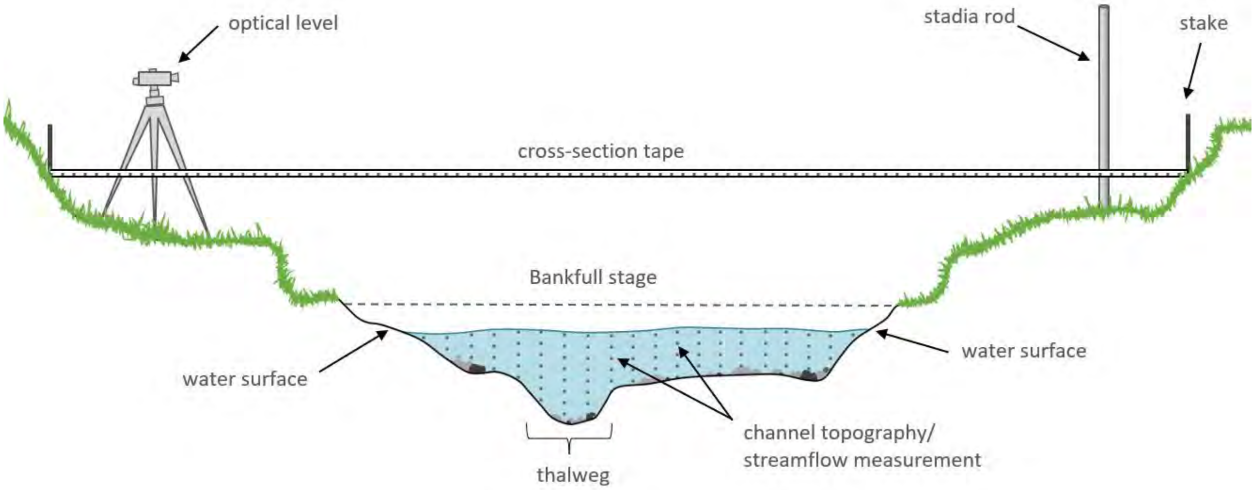


Figure 5. Schematic view of R2Cross cross-section and measurements.

Water Surface Slope (Longitudinal) Tape

5. Secure a second survey tape that extends from the most upstream point of the riffle to the most downstream point of the riffle along one of the banks. This tape is used to measure the local slope of the water surface in the riffle habitat. R2Cross uses the local slope of the water surface along the riffle, not the overall slope of the reach (Figure 4).

Tripod and Level

6. Select a location for the tripod that does not have obstructions between the level and the entire cross-section (bank-to-bank) as well as the points at the top and bottom of the riffle for the measurement of water surface slope. The line of sight should be free from excessive vegetation or other obstructions and should be close enough to allow for communication between the operator of the level and the operator of the stadia rod. Hand-held radios can be used in larger sites or sites with excessive background noise. In some cases, the best location for the level and tripod is in the middle of the stream – this is acceptable provided that the tripod can be made secure in its location and does not affect discharge measurements.
7. Securely set up the tripod and level the instrument using standard techniques for the instrument being used.

Filling out the Field Form

The CWCB and CPW use a standardized field form to record all field data (Figure 6 and Figure 7). Use of this form helps to ensure that the necessary data are collected in a uniform way for ISF recommendations. The front page (Page 1) of the form provides space for documenting the stream and data collection effort, which are discussed below. The back page (Page 2) of the form is for the stream cross-section measurements. A printable R2Cross field form is provided in the Appendix.

Observational documentation of the R2Cross site is important in the analysis phases of the R2Cross process. These notes and photographs often are useful when troubleshooting modeling results.

1. Stream Information
    a. **Stream Name**: can be identified from a USGS map, atlas, local signage, etc. If the name of the stream is not named, it is acceptable, for example, to call it Unnamed Tributary [identifiable creek].
    b. **Cross-Section #**: determine a numbering convention for multiple cross-sections being taken on the same stream on the same date. Each location should have its own number assigned (for example – Cross-Section #1 and Cross-Section #2).

2. Location Information
    a. **Cross-Section Location Description:** This section can be used to provide narrative description of the location of the cross-section and a description of the location relative to features on the ground. For example – upstream of Hwy 9 bridge, near Forest Service boundary, downstream of trailhead parking lot.
    b. **Division**: Water division as defined by the Colorado Division of Water Resources
    c. **Watershed:** major watershed the stream drains to. For example – Upper Colorado, Eagle River, Yampa River, Lower South Platte.
    d. **Coordinate System:** A GPS point should be taken at each cross-section location. This is essential for later data analysis performed by CWCB staff. GPS location can be taken in UTM or Lat/Long Coordinates. It is optional to include the Public Land Survey System (PLSS) coordinates.

3. Supplemental Data:
    a. **Flow Meter Type & Meter Number:** should be recorded so that flow data can be found later if needed. Acceptable Flow Meters are listed above in the Equipment Checklist.
    b. **Flow Measurement Taken at R2Cross Xsec:** record if flow was measured at the cross-section. If no, note the measured discharge and provide a description of the location of the measurement.
    c. **Channel Bed Material Size Range:** record substrate size. Can be qualitative (i.e., pebble, gravel, cobble etc.) or quantitative (i.e., less than ½” in size).
    d. **Pebble Counts:** are not mandatory but they are encouraged. This data can be used to accurately describe substrate and channel roughness.
    e. **Photos:** notes about photos can be documented.

4. Channel Profile Data
    a. **Sketch:** a schematic drawing that includes the location of instrumentation with respect to the cross-section tape, the location of slope measurements, and the number, order, and locations of the photographs of the site.
    b. **Water Surface Measures:** This section of the form also includes space to record the water surface (WS) elevation measurements at left and right bank and the upstream and downstream water surface elevation measurements used to calculate slope.

5. Natural Environment Notes

    The R2Cross field form includes a section on the Natural Environment to document field observations about the presence of fish, aquatic macroinvertebrates, riparian species or other biota. In addition, information about the stream such as valley type, channel type, bed material, stream condition (for example degraded or pristine) can be noted. Descriptions of habitat such as pools, connectivity, cover, temperature, etc. can be documented.

a. **Aquatic Species Observed:** This section of the field form contains space for observations made about aquatic species (fish and/or aquatic macroinvertebrates). Please note that fish surveys or macro-invertebrate surveys could also be completed during the R2Cross site visit. However, this is not required to be collected at the same time and some information may already be available. Please see the section on the Natural Environment for more information.
b. **Riparian Vegetation Observed:** This section of the field form contains space for observations made about riparian vegetation, as well as upland habitat type.
c. **Other (Valley Type, Geology, Water Diversions, etc):** This section of the field form contains space for observations about other aspects of the natural environment such as water quality samples, water temperature, water diversions, etc. General observations regarding the site and flow conditions such as recent or current weather conditions, water clarity, and precipitation prior to or during the measurement, gage or flume readings, etc., may also be helpful to include.

6. R2Cross Cross-Section Data
   a. Page 2 of the field form is used to record the cross-section measurements including the **start and end times**, **staff gage** readings, **benchmark** measurements, **features**, **distance from initial point** (or horizontal station), **rod height** (stadia level elevations), **water depth**, **velocity (which is optional)**, and other **notes**. These measurements are discussed in depth in the following sections below.

COLORADO
Department of Natural Resources

R2CROSS FIELD FORM

STREAM INFORMATION

STREAM NAME:	DATE:
OBSERVERS:	CROSS SECTION #:

LOCATION INFORMATION

CROSS-SECTION LOCATION DESCRIPTION:			
DIVISION:	COUNTY:	WATERSHED:	
COORDINATE SYSTEM (circle one):	UTM Zone 13	UTM Zone 12	Lat/Long
X (EASTING):		Y (NORTHING):	
TOWNSHIP: N/S	RANGE:	E/W SECTION:	1/4 SECTION:

SUPPLEMENTAL DATA

FLOW METER TYPE/METER #:			
FLOW MEASUREMENT TAKEN AT R2CROSS XSEC?	YES / NO	IF NO, MEASURED DISCHARGE:	cfs
IF NO, WHERE?			
CHANNEL BED MATERIAL SIZE RANGE:			
PEBBLE COUNT COLLECTED AT THIS LOCATION?	YES / NO	PHOTOS:	YES / NO

CHANNEL PROFILE DATA

STATION	DIST. FROM TAPE (ft)	ROD HEIGHT[1] (ft)
WS @ Tape LB (LB)	0	
WS @ Tape RB (RB)	0	
WS UPstream (1)		
WS Downstream (2)		
Slope:		

[1] Measurement should be taken to the hundredth decimal place

SKETCH

TAPE

SLOPE TAPE

LEGEND:
Stake ⊗
Station (A)
Photo ◇▶
Direction of flow: ← →

NATURAL ENVIRONMENT NOTES

AQUATIC SPECIES OBSERVED (FISH/MACROINVERTEBRATES/ETC):

RIPARIAN VEGETATION OBSERVED:

OTHER (VALLEY TYPE, GEOLOGY, WATER DIVERIONS,ETC):

Figure 6. Front of the R2Cross field form.

R2CROSS CROSS-SECTION DATA Page ____ of ____

STREAM NAME:

CROSS SECTION #: DATE:

TIME START: TIME END:

STAFF GAGE START (ft): STAFF GAGE END (ft):

BENCHMARK DESCRIPTION:

BENCHMARK START (ft): BENCHMARK END(ft):

FEATURE: Stake (S) Bankfull (BF) Waterline (WL) Rock (R)	DISTANCE FROM INITIAL POINT (ft)	ROD HEIGHT (ft)	WATER DEPTH (ft)	VELOCITY (ft/sec)	NOTES:

Figure 7.Back of the R2Cross field form.

Making Field Measurements

The following section is a step-by-step procedure for cross-section measurements for the R2Cross method. This manual does not provide an overview of general surveying techniques, please review other resources such as Harrelson, et al. (1994) if needed.

Initial QA/QC Checks

1. **Benchmark:** A temporary benchmark should be located or established for the cross-section survey. This benchmark can be a piece of rebar (or similar) driven into the ground or a marked point on a rock or log near the site. The first and last readings from the level should be the elevation of the benchmark; record these elevations on the field form. Both readings should match, confirming that the level did not move during the survey.
2. **Temporary Gage:** A temporary staff gage (a chaining pin or similar) should be placed in the water near the streambank; the water surface elevation on the staff gage and time will be noted on the field form prior to the start of the measurement and when the measurement in complete. This is done to ensure that there was not a drastic increase or decrease in the streamflow while the measurements were taken.
3. **Water Surface Elevations**: To ensure that the cross-section tape is perpendicular to flow, a set of water surface elevation measurements are taken at the water's edge on left and right bank (labeled as WS in Figure 4). These measurements are taken at the left and right extent of the wetted channel at the water surface (Figure 8 for methods for accurately measuring water surface elevation). The water surface elevations on each bank should be made at least to the 0.01 feet level of accuracy and should be nearly identical (within 0.05 feet of one another). If these readings are off by more than 0.05 feet, then either the cross-section has not been placed perpendicular to flow or there is a difference in topography that is forcing water on one bank to be higher. Try adjusting one end of the cross-section tape either upstream or downstream so that these water surface elevations match. If this does not work, the entire tape might have to be moved slightly upstream or downstream. A completely different cross-section may need to be located which does not have stream hydraulics or bank topography issues. Once these readings have been finalized, they can be recorded in the Channel Profile Data section on the first page of the field form.

Survey Water Surface Elevations to Calculate Slope

1. The next two measurements are water surface elevation measurements (labeled WS in Figure 4) taken at the upstream most point and downstream most point of the riffle. Place the stadia rod at the water surface using one of the three methods, bed at water's edge method, the boot method, or substrate support method (Figure 8). Record the rod reading and distance upstream or downstream from the cross-section tape on the field form in the Channel Profile Data section. These measurements are used to calculate the water surface slope along the length of the riffle (slope = rise/run). After recording the information, verify that the elevations reflect water moving in a downhill direction. The locations of these readings as well as the location of the tripod and instrument should be noted on the sketch drawing of the site (Figure 4). These measurements should be made at least to the 0.01 feet level of accuracy.

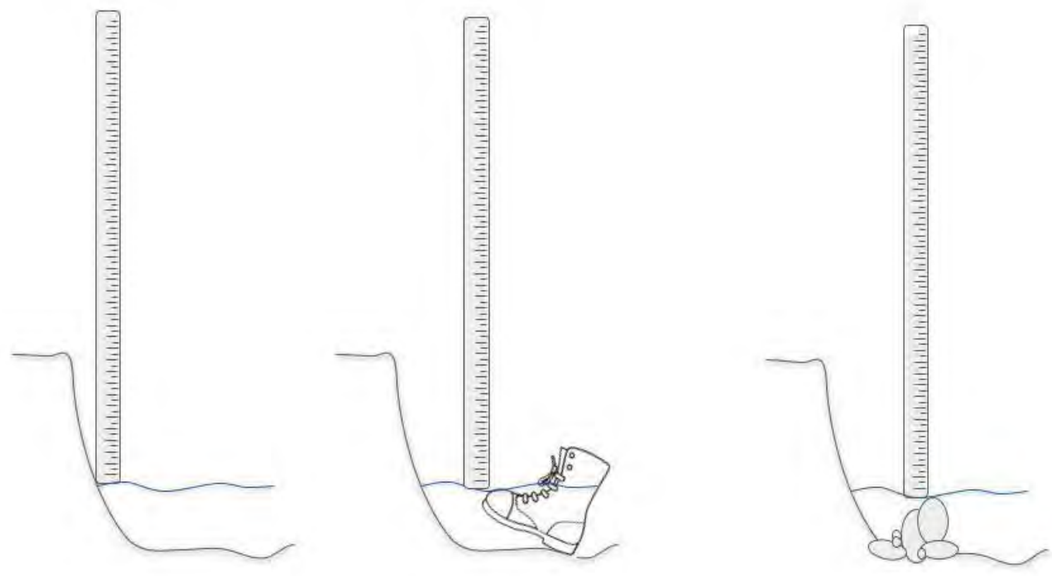


Figure 8. Three options for accurately measuring water surface elevations include using the bed at the water's edge (left), the "boot method" (middle), and using substrate elements (right) to support the rod at the water surface elevation.

Surveying the Channel

1. Note the starting time of the measurement and the staff gage reading on page 2 of the field form.

Overbank Channel Measurements

2. Starting at the 0.00 end of the cross-section tape, record the distance from initial point (station) and stadia rod height (rod level) in sufficient detail (to at least the 0.05 ft level of vertical accuracy) to describe the two-dimensional shape of the cross-section outside of the wetted channel. Distance and elevation coordinates on the bank should be recorded at every break in elevation on the bank, not at regular intervals. This is to accurately describe the topography of the banks to the R2Cross model. On each bank, distance and elevation coordinates need to be recorded at the stake, at the bankfull elevation, and at the water surface at a minimum. These stations need to be specifically noted in the Features column on the field form. Use the Notes field to describe bankfull indicators or any other prominent features of interest.
3. Great care should be taken when measuring the bankfull indicators. The two indicators should be relatively close in elevation but may not be an exact match. R2Cross does not require the two elevations to be an exact match. The R2Cross model selects the lower elevation indicator and projects that elevation across the stream to the opposite bank. The R2Cross model then calculates the top width from this calculated projection. Be sure to record Bankfull in the Feature column of the field form. If only one indicator is reliable, make note of this in the Notes column of the field form, and then measure a point on the other bank that is close in elevation to the reliable indicator and note that point as estimated bankfull ("BF – est"). The R2Cross model requires the user to enter two bankfull points in the features column to run.

Wetted Channel Measurements

4. The water surface elevation measurements collected here should match the ones collected during the initial check that flow is perpendicular to the cross-section tape.
5. When surveying the wetted portion of the channel, try to make at least 20 individual measurements. This is particularly important if the cross-section is being used to measure discharge as well[5]. The increment between measurements can vary in order to best record the shape of the cross-section. Note that it may not be possible to have 20 individual measurements in very small channels[6]. At every station in the wetted portion of the stream, record the horizontal distance off the cross-section tape (Distance from Initial Point), the stadia rod level (Rod Height), and the water depth (Water Depth) in the appropriate columns on the field form. Any large rocks or obstructions can be noted in the features column.
6. The water depth should be read from the side of the stadia rod because water tends to create a small hydraulic head on the upstream side and a cavity the downstream side (Figure 9).

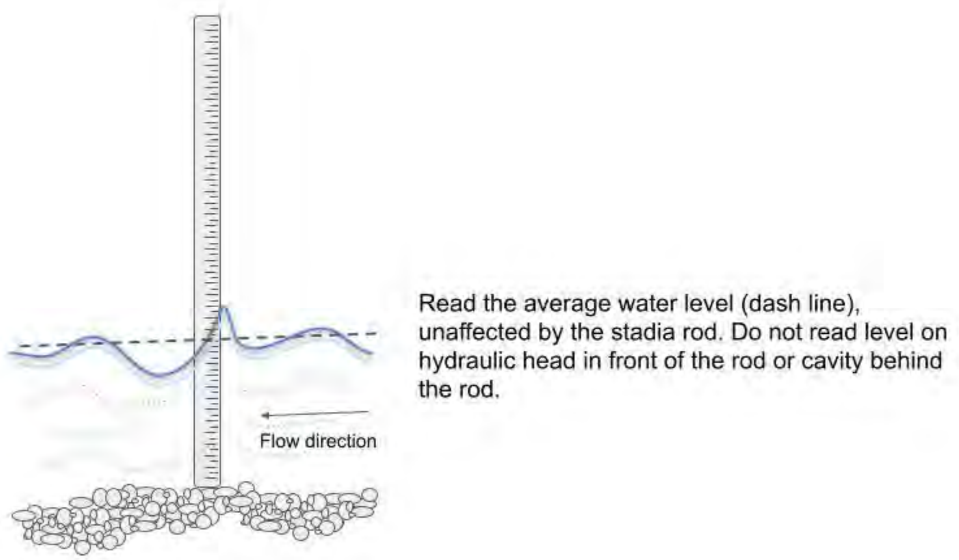


Figure 9. Reading the depth of water off the stadia rod.

Discharge Measurement Options

The R2Cross method requires a measured discharge that corresponds to the flow when the cross-section data was measured. It is preferable to measure discharge at a nearby location that has the same streamflow as the measured riffle cross-section. In most cases, locations other than riffles will result in more accurate discharge measurements. The optimal location for an accurate discharge measurement is within a run feature, where there is straight laminar

[5] 20 data points is a rule-of-thumb that reflects guidance that no more than 5% of the total flow should be measured in a single discharge measurement station.

[6] The minimum distance between stations is 0.3 ft (due to the size of the base of the typical stadia rod, the base of the typical top-setting wading rod, and the size of the typical water velocity meter).

flow and an even streambed. However, if the R2Cross cross-section is suitable for a discharge measurement, then a discharge measurement can be made at that location. Both options are presented in more detail below.

One discharge measurement can be used for multiple R2Cross cross-sections measured in the same reach provided there are no tributaries or diversions between the locations. Discharge data from a nearby stream gage can also be used if the streamflow is representative of the measured R2Cross cross-sections. For detailed instructions and best practices for making discharge measurements, refer to USGS publications (Turnipseed and Sauer 2010) and documentation for the current meter used.

Option 1: Measuring discharge at another location

If discharge is measured at a location different from the R2Cross cross-section, make a note of the location relative to the R2Cross cross-section on the field form. An optional printable form to record information from the discharge measurement is provided in the appendix. The velocity column on page 2 of the R2Cross field form should not be used for this option. The Discharge Calculator within the R2Cross program allows the user to import the data collected in the field and it performs the necessary calculations.

Option 2: Measuring discharge at the R2Cross cross-section

If the R2Cross location is suitable for an accurate discharge measurement, then water velocity can be measured along the R2Cross tape line.

At every station measured in the wetted channel (steps 4-6 above), use a current meter to measure velocity. The person operating the current meter and the note taker should check that the depth measured and recorded in steps 4-6 roughly match the depth that is read off the top-setting wading rod. This practice addresses a potential source of computational error in the calculation of the stream's cross-sectional area that arises when the depths are not similar. Record the average velocity for each location following the directions of the velocity meter being used and the USGS's published standards for discharge measurements.

Depending on the current meter, the 2-point method should be utilized when depths are greater than the published threshold for the current meter. Additional stations can be added to the cross-section measurements during the discharge measurement to address changes in water depths or velocity that may affect the accuracy of the discharge measurement. Adding stations is recommended when flow conditions are affected by large rocks or other upstream obstructions, or if more than 5% of the flow is in one station. If stations are added for any reason, the station and stadia rod elevation will need to be added to the field form before the cross-section tape is removed.

Final Survey Checks

1. Once all the water velocity measurements are completed, the elevation of the temporary benchmark should be measured again to serve as a quality control to ensure the tripod and level have not moved during the measurement.
2. The staff gage should also be re-read to check for flow change during the measurement. Record this information and the time in the spaces for Time End and Staff Gage End. The note taker should review all the recorded data for oversights, erroneous elevations, things to double-check, etc. This should be done before the cross-section tape is removed. The most common error is a mis-read elevation and frequently the error is

exactly 0.50 or 1.00 foot. Another common error is to forget to measure both bankfull indicators.

Photos

1. A picture of the field form can be taken to serve as a reminder that the next 4 photos in the camera are associated with the site described on the field form.
2. Before the cross-section tape is removed, take photos of the site (with the tape in place). It is recommended that at least 4 photos be taken – one from each bank looking straight across the cross-section, one upstream of the tape looking downstream, and a fourth downstream of the tape looking upstream. An overview vantage of the upland ecosystem can also be helpful. Record the location and order of these photos on the schematic drawing of the site. Where possible, place flagging or pin flags at the bankfull indicators so that these points are visible in the photographs.

Pebble Count/Particle Size Distribution Measurements

Pebble counts are optional but provide a quantitative description of the bed material that can be helpful when describing channel characteristics. The Wolman Pebble Count procedure is a widely used and accepted methodology for determining the particle size distribution in coarse bed material streams. One of the benefits of the pebble count procedure is that it can be completed relatively quickly and with very little investment in equipment. The preferred approach is to use a gravelometer, which is a metal template with square cutouts of known sizes. The gravelometer works conceptually the same way as sieve-based analyses. If a gravelometer is not available, the intermediate axis of every sampled particle can be measured by hand to the nearest millimeter using a ruler (Figure 10).

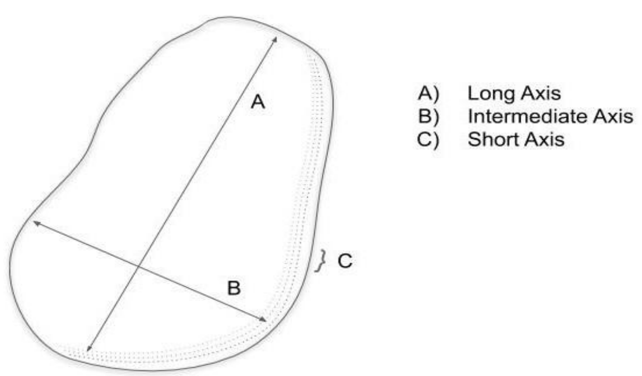


Figure 10. Illustration of the three axes of a substrate particle; in the pebble count procedures, the intermediate axis should be measured with a ruler or gravelometer.

There are several write-ups of the field procedure for a Wolman Pebble Count available in the published literature (USFS, 2016; Harrelson et al.,1994; Bevenger and King, 1995). The procedure as it relates to R2Cross follows the published procedures with only one slight alteration. Many field guides describe the use of a “zig-zag method” for a pebble count in a reference reach; for R2Cross the focus is not on a reference reach but the riffle in isolation. For a pebble count, we are interested in the particle size distribution for a reference riffle habitat type. The “zig-zag method” is still used but is restricted to the particles in the riffle.

All the pebble count procedures call for the measurement of at least 100 randomly selected particles within the bankfull channel. Particles are randomly selected by picking up and measuring the first particle touched at the toe of your boot while zig-zagging across the riffle in a random fashion; when particles are too large or are too embedded to pick up and measure, use the gravelometer or scale to estimate the intermediate axis of the particle touched. If the water is deep, swift, cold or turbid, the smaller particles can be collected in a bucket and measured on the stream's bank.

After the particles are measured and categorized, the particle data is used to construct a cumulative distribution table and curve where "% Finer Than" values can be obtained. The R2Cross Particle Size Calculator within the R2Cross program allows the user to import the grain size information collected in the field and it performs the necessary calculations.

Particle size distribution data is very site-specific. Therefore, it is good field practice to collect a pebble count data set for every riffle analyzed with the R2Cross tool. If the riffle is only a few square feet in size, it may be necessary to collect and measure particles from a few adjacent riffles in order to get the required 100 particle sample. This is a reasonable approach if the substrate is similar in adjacent riffles. It is good practice to document the thought processes behind these decisions on the field forms for future reference if needed.

Observations and notes can be made on the Pebble Count Field Form (Figure 11). A printable pebble count field form is provided in the Appendix. It is important to note that the R2Cross Particle Size Calculator has only one field for particles less than 2 millimeters in diameter (i.e. silts, clays, and sands). This is because fine grain sizes cannot be accurately measured in the field without sieves of varying sizes. The fields of silts, clays, and sands are included on the field form to serve as supplemental information but can be aggregated on the Pebble Count Data Template that is uploaded into the R2Cross Particle Size Calculator.

COLORADO
Department of Natural Resources

PEBBLE COUNT FIELD FORM

STREAM NAME: DATE:

OBSERVERS: CROSS SECTION #:

LOCATION DESCRIPTION:

PARTICLE	SIZE (mm)		PARTICLE COUNT	TOTAL
SILT/CLAY	<.062	S/C		
VERY FINE	.062 - .125	SAND		
FINE	.125 - .25			
MEDIUM	.25 - .5			
COARSE	.5 - 1.0			
VERY COURSE	1.0 - 2.0			
VERY FINE	2.0 - 4.0	GRAVEL		
FINE	4.0 - 5.7			
FINE	5.7 - 8.0			
MEDIUM	8.0 - 11.3			
MEDIUM	11.3 - 16.0			
COARSE	16.0 - 22.6			
COARSE	22.6 - 32.0			
VERY COARSE	32.0 - 45.0			
VERY COARSE	45.0 - 64.0			
SMALL	64.0 - 90.0	COBBLE		
SMALL	90.0 - 128			
LARGE	128 - 180			
LARGE	180 - 256			
SMALL	256 - 362	BOULDER		
SMALL	362 - 512			
MEDIUM	512 - 1024			
LARGE - VERY LARGE	1024 - 2048			
BEDROCK	>2048			

Figure 11. Pebble count field form.

Post Field Work Analysis

Collected R2Cross data is processed using the R2Cross program housed on the eRAMS platform by One Water Solutions Institute at the Colorado State University. The R2Cross program is used to upload data, run the calculations, and review and export the results. In addition to running R2Cross, the program also has tools to calculate discharge from field measurements, process pebble count data, and map the cross-section location and other data layers. Detailed information about the R2Cross program is provided in the R2Cross Program User's Guide & Technical Manual. The R2Cross tool is available at: https://r2cross.erams.com/

Determining ISF Flow rates

In the early years of the ISF Program, only single year-round flow rates were proposed. These single year-round flow amounts were based on meeting two of the three critical hydraulic criteria identified by Nehring (1979). In the mid 1980's, state biologists began developing seasonal flow recommendations which used all three of the identified critical criteria. Seasonal flow recommendations are an attempt to mimic the natural flow regime on a simplified and smaller scale. When water availability allows, CPW recommends meeting all three of the hydraulic criteria during the spring, summer, and fall, and meeting two of the three hydraulic criteria during the winter, typically during base flows. CPW believes seasonal flow recommendations better addresses the range of hydrologic and hydraulic conditions required for the habitat and its associated aquatic community. Research has shown that single year-round minimum flows, when maintained as a long-term condition, cannot be expected to sustain the same fish populations or aquatic life as a natural flow regime, where low flow conditions occur infrequently and for shorter periods (Stalnaker and Wick, 2000).

Once data has been processed in R2Cross using the eRAMS platform, recommenders can use the R2Cross model results as well as information about hydrology and biological information to develop seasonal flow recommendations. In general, model results for multiple cross-sections located in the same reach are averaged to determine the overall flows that meet the winter and summer rate. In other words, the flows that meet two of three criteria are averaged from multiple cross-sections, to determine the "winter" or base flow recommendation. Flows that meet three of three criteria are averaged together to determine the flows during the rest of the year.

Aquatic biologists may modify flow recommendations based on biological considerations such as stream conditions, species composition, and aquatic habitat quality using best professional judgment. Recommenders can adjust the proposed flow rates in terms of magnitude or timing if the streamflow necessary to meet the hydraulic criteria are not likely to be met based on an initial water availability review. However, recommending entities do not need to complete a detailed analysis of water availability. CWCB staff conducts detailed streamflow assessments in order to determine water availability. If less water is available than the biological need, CWCB and the recommending entity work together to refine flow rates.

Developing ISF Recommendations

Recommending entities are responsible for collecting all required data necessary to document the natural environment and determine the ISF flow rates before submitting a formal recommendation to the CWCB. In addition, staff request recommending agencies to submit a formal recommendation letter that summarizes information about the ISF reach. Guidance for writing a recommendation letter is available on the CWCB website: https://dnrweblink.state.co.us/cwcbsearch/ElectronicFile.aspx?docid=211049&dbid=0

Entities present their recommendations at the annual Instream Flow Workshop, typically held in January of each year. This begins the formal outreach process and staff investigation. For more information on the new appropriation process, visit the CWCB website.

References

Bovee, K.D. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: Theory and techniques. Instream Flow Information Paper No. 5. Washington, DC: U.S. Fish and Wildlife Service (FWS/OBS -78/33). 143pp.

Bevenger, G.S. and R.M. King. 1995. A pebble count procedure for assessing watershed cumulative effects. Res. Pap. RM-RP-319. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 17 p.

Bjornn T.C. and D.W. Reiser 1991. Habitat requirements of salmonids in streams. In Influence of forest and range management on salmonid fishes and their habitats, Pages 83-138. American Fisheries society Special Publications 19, Bethesda, MD.

Colorado Water Conservation Board. 1993. Statement of Basis and Purpose and Rules and Regulations Concerning the Colorado Instream Flow and Natural Lake Level Program. Department of Natural Resources. Denver, CO. 80203.

Espegren, G. D. 1996. Development of Instream Flow Recommendations in Colorado Using R2Cross. Colorado Water Conservation Board. Denver, CO. 80203.

Harrelson, C.C., Rawlins, C. L., and J.P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

Heino, J., P. Louhi, and T. Muotka 2004. Identifying the scales of variability in stream macroinvertebrate abundance, functional composition and assemblage structure. Freshwater Biology 49:1230-1239.

Leopold, L.B., W.E. Emmett, H.L. Silvey, and D.L. Rosgen. 1995. A Guide for Field Identification of Bankfull Stage in the Western United States (video). USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Stream Systems Technology Center. Fort Collins, Colorado

Nehring, R.B. 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the State of Colorado. Colorado Division of Wildlife. Fort Collins, CO.

Rosgen, D.L. 1996. Applied River Morphology: Pagosa Springs, Colo. Wildland Hydrology Books, 385 p.

Rossi, G.J. 2012. Developing Hydraulic Relationships at the Riffle Crest Thalweg in Gravel Bed Streams. Master's Thesis. Humboldt State University. Arcata, CA.

Silvey, L. 1976. R-2 Cross Program: A sag-tape method of channel cross section measurement for use with instream flow determinations. United States Department of Agriculture, Forest Service Region 2. 11177 W. 8th Avenue. Lakewood, CO 80225.

Stalnaker, C.B. and E.J. Wick. 2000. Planning for Flow Requirements to Sustain Stream Biota, in: Wohl, E.E. (Ed.), Inland Flood Hazards: Human, Riparian, and Aquatic Communities. Cambridge University Press, pp. 411–448. https://doi.org/10.1017/CBO9780511529412.017

Thompson, K. 1972. Determining stream flows for fish life. Pages 31-46 in Proc. Instream flow Requirement Workshop, Pacific Northwest River Basins comm., Portland, Or.

Turnipseed, D.P., and V.B. Sauer. 2010. Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (Also available at http://pubs.usgs.gov/tm/tm3-a8/.)

U.S. Forest Service. 2016. Stream Inventory Handbook: Level 1 and 2. Pacific Northwest Region. Version 2.16. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd538833.pdf

Appendix A: Field Equipment Checklist

FIELD EQUIPMENT CHECKLIST

	Data forms for cross-section measurement, pebble count, and discharge measurement on either Rite-in-the-Rain paper or bond paper (a cotton/paper blended paper).
	Writing surface and utensils
	Digital camera and GPS unit
	Maps or mapping applications. Maps could include USGS topographic maps, DeLorme Gazetteer, Road Atlas, BLM Planimetric Map, USFS maps (for land survey legal descriptions), or digital applications.
	Optical level or laser level, tripod, and stadia rod. Stadia rod should be at least 15 feet long.
	Water velocity meter Flowtracker, Marsh-McBirney, ADCP, or similar with top-setting wading rod. Mechanical velocity meters with moving parts (Price AA, or Pygmy) can be used but need proper maintenance.
	Two reel-style surveying tapes of adequate length for the bankfull top width of the stream being measured and for water surface slope measurements. Tapes divided into feet and 0.10 feet increments are preferred (tapes in feet and inches can be used but values will have to converted prior to R2Cross processing).
	Anchoring pins to hold the cross-section tape with at least one scissor clamp or similar strong clamp.
	Chaining pins or similar.
	Surveyor's flags or rolls of colorful flagging tape or a can of surveyor's marking paint (optional).
	Gravelometer or millimeter scale (optional).
	Safety equipment as needed such as personal floatation devices, first aid kit, communication equipment, etc.
	Waders or hip boots dried sufficiently or disinfected
	Extra batteries for velocity meter, radios, GPS unit, camera, and laser level (if used).
	Basic set of tools including a hammer, Phillips and standard screwdrivers, short sections of rebar, etc.
	Vegetation tools including clippers, machete, hedge trimmer, or small hand saw to clear vegetation to improve line of sight for surveying.
	If natural environment data is needed, equipment to collect this information may include electrofishing gear, insulated gloves, nets, buckets, measuring board, scale, water quality sampling equipment (if needed - bottles, filters, meters, thermometer, etc.), and/or macroinvertebrate kick net (or similar). Scientific data collection permit if needed.

Appendix B: R2Cross Field Form

COLORADO
Department of Natural Resources

R2CROSS FIELD FORM

STREAM INFORMATION

STREAM NAME:	DATE:
OBSERVERS:	CROSS SECTION #:

LOCATION INFORMATION

CROSS-SECTION LOCATION DESCRIPTION:			
DIVISION:	COUNTY:	WATERSHED:	
COORDINATE SYSTEM (circle one):	UTM Zone 13	UTM Zone 12	Lat/Long
X (EASTING):		Y (NORTHING):	
TOWNSHIP: N/S	RANGE:	E/W SECTION:	1/4 SECTION:

SUPPLEMENTAL DATA

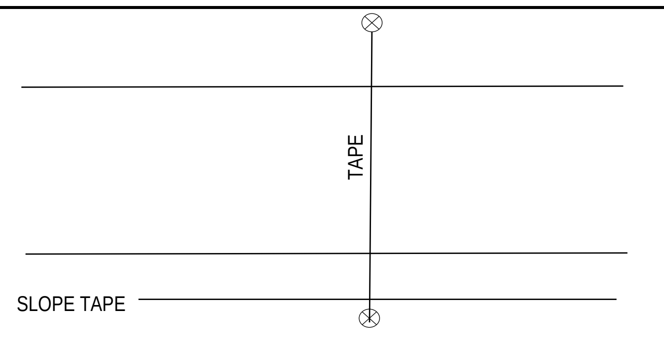
FLOW METER TYPE/METER #:			
FLOW MEASUREMENT TAKEN AT R2CROSS XSEC?	YES / NO	IF NO, MEASURED DISCHARGE:	cfs
IF NO, WHERE?			
CHANNEL BED MATERIAL SIZE RANGE:			
PEBBLE COUNT COLLECTED AT THIS LOCATION?	YES / NO	PHOTOS:	YES / NO

CHANNEL PROFILE DATA

STATION	DIST. FROM TAPE (ft)	ROD HEIGHT[1] (ft)
WS @ Tape LB (LB)	0	
WS @ Tape RB (RB)	0	
WS UPstream (1)		
WS Downstream (2)		
Slope:		

[1]Measurement should be taken to the hundredth decimal place

SKETCH



LEGEND:
Stake ⊗
Station (A)
Photo ◇1▶
Direction of flow:
←
→

NATURAL ENVIRONMENT NOTES

AQUATIC SPECIES OBSERVED (FISH/MACROINVERTEBRATES/ETC):

RIPARIAN VEGETATION OBSERVED:

OTHER (VALLEY TYPE, GEOLOGY, WATER DIVERIONS,ETC):

R2CROSS CROSS-SECTION DATA Page ____ of ____

STREAM NAME:

CROSS SECTION #: DATE:

TIME START: TIME END:

STAFF GAGE START (ft): STAFF GAGE END (ft):

BENCHMARK DESCRIPTION:

BENCHMARK START (ft): BENCHMARK END(ft):

FEATURE: Stake (S) Bankfull (BF) Waterline (WL) Rock (R)	DISTANCE FROM INITIAL POINT (ft)	ROD HEIGHT (ft)	WATER DEPTH (ft)	VELOCITY (ft/sec)	NOTES:

Appendix C: Discharge Measurement Field Form

DISCHARGE MEASUREMENT FIELD FORM

COLORADO Department of Natural Resources

STREAM INFORMATION

STREAM NAME: DATE:

OBSERVERS: NAME OF STREAMGAGE (IF APPLICABLE):

SITE VISIT DATA

CROSS-SECTION LOCATION DESCRIPTION:

DIVISION: COUNTY: WATERSHED:

COORDINATE SYSTEM (circle one): UTM Zone 13 UTM Zone 12 Lat/Long

X (EASTING): Y (NORTHING):

TOWNSHIP: N/S RANGE: E/W SECTION: 1/4 SECTION:

MEASUREMENT EQUIPMENT TYPE: METER NUMBER:

WEATHER CONDITIONS (current or recent weather events that may effect discharge measurement):

CROSS-SECTION DESCRIPTION (channel type - pool tail, riffle, run, glide - and substrate type/size):

FLOW CONDITIONS AT THE SITE (circle one): TURBULENT SLIGHTLY TURBULENT CALM

DISCHARGE MEASUREMENT COMMENTS

NATURAL ENVIRONMENT NOTES

AQUATIC SPECIES OBSERVED (FISH/MACROINVERTEBRATES/ETC):

RIPARIAN VEGETATION OBSERVED:

OTHER (VALLEY TYPE, GEOLOGY, WATER DIVERIONS,ETC):

DISCHARGE MEASUREMENT DATA

STREAM NAME:

CROSS SECTION NO.: DATE:

STAFF GAGE START (ft): STAFF GAGE START TIME:

DISCHARGE START TIME: DISCHARGE END TIME:

STAFF GAGE START (ft): STAFF GAGE END TIME:

Total A (ft^2):

Total Q (cfs):

FEATURE: Waterline (WL) Rock (R)	STATION (ft)	WATER DEPTH (ft)	VELOCITY (ft/sec)	CALCULATED VALUES WIDTH (ft)	AREA (ft^2)	Q (cfs)	NOTES

Appendix D: Pebble Count Field Form

COLORADO
Department of Natural Resources

PEBBLE COUNT FIELD FORM

STREAM NAME:	DATE:
OBSERVERS:	CROSS SECTION #:
LOCATION DESCRIPTION:	

PARTICLE	SIZE (mm)		PARTICLE COUNT	TOTAL
SILT/CLAY	<.062	s/c		
VERY FINE	.062 - .125	SAND		
FINE	.125 - .25			
MEDIUM	.25 - .5			
COARSE	.5 - 1.0			
VERY COURSE	1.0 - 2.0			
VERY FINE	2.0 - 4.0	GRAVEL		
FINE	4.0 - 5.7			
FINE	5.7 - 8.0			
MEDIUM	8.0 - 11.3			
MEDIUM	11.3 - 16.0			
COARSE	16.0 - 22.6			
COARSE	22.6 - 32.0			
VERY COARSE	32.0 - 45.0			
VERY COARSE	45.0 - 64.0			
SMALL	64.0 - 90.0	COBBLE		
SMALL	90.0 - 128			
LARGE	128 - 180			
LARGE	180 - 256			
SMALL	256 - 362	BOULDER		
SMALL	362 - 512			
MEDIUM	512 - 1024			
LARGE - VERY LARGE	1024 - 2048			
BEDROCK	>2048			