R2CROSS FIELD MANUAL

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Colorado Water Conservation Board

Stream and Lake Protection Section

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COLORADO

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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.

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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.

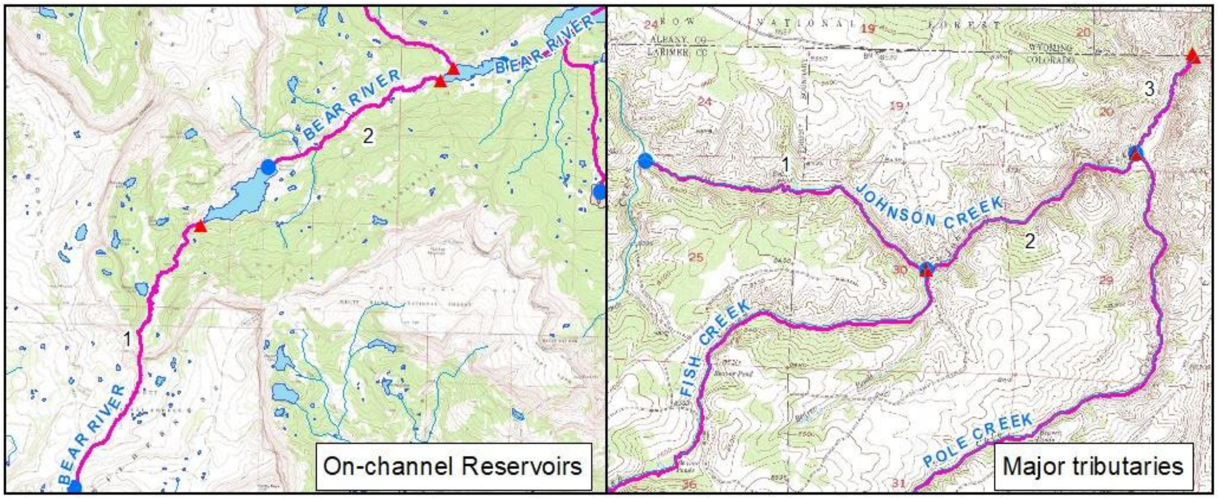


Figure 1. ISF examples that show reach delineation for on-channel reservoirs or lakes and major tributaries. Reaches are shown in pink, upstream termini are blue dots, downstream termini are red triangles.

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.

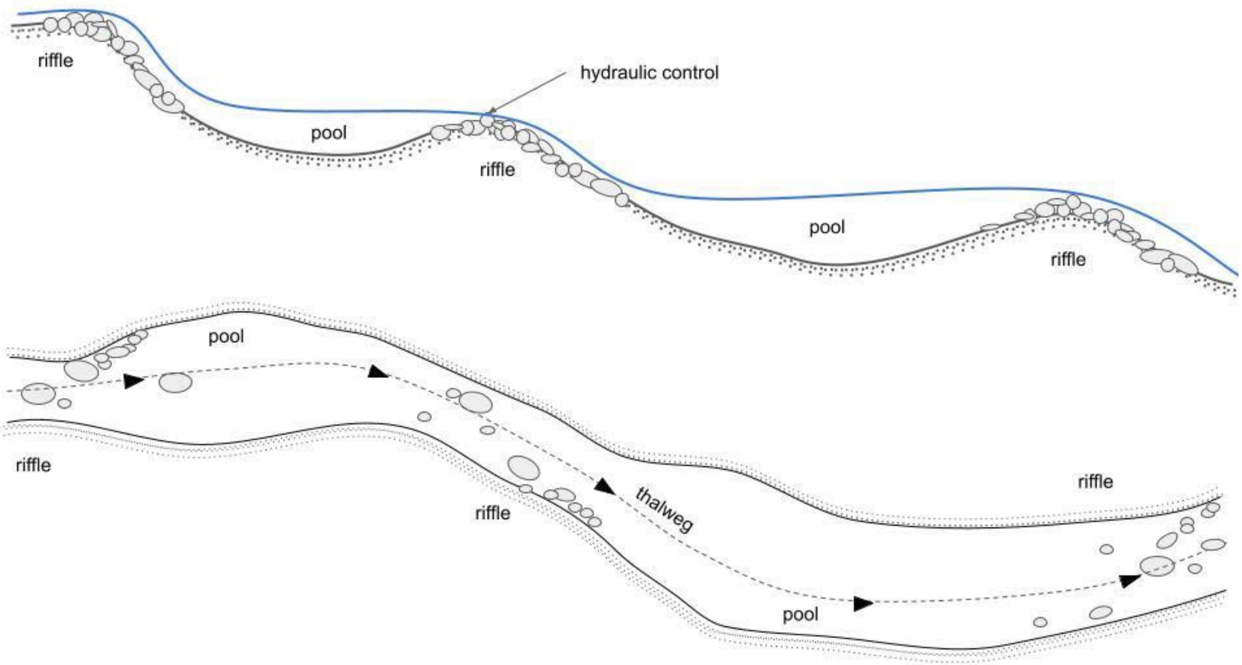


Figure 2. Longitudinal and plan view diagram of a riffle-pool sequence. Note the changes in water surface slope that occur in the pool to riffle transitions (hydraulic control points).

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). .

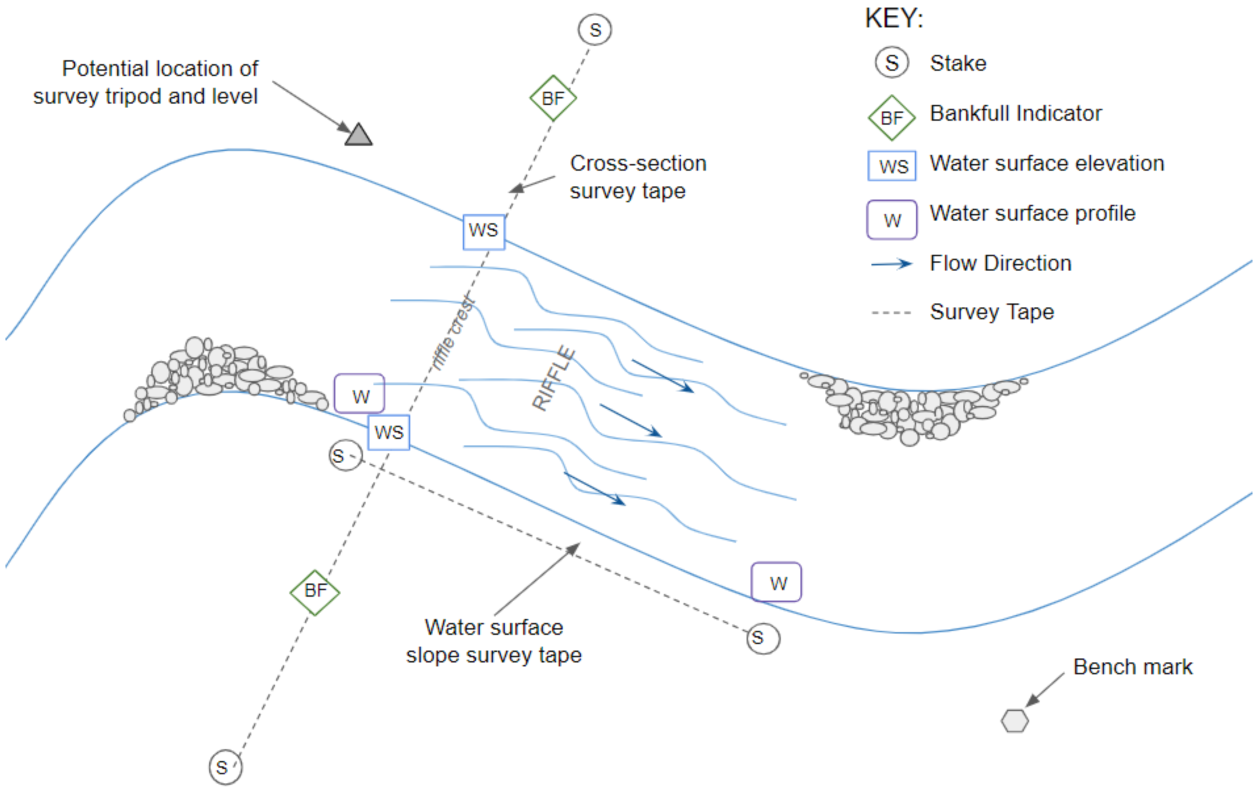


Figure 4. Schematic plan view of a R2Cross cross-section site.

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.

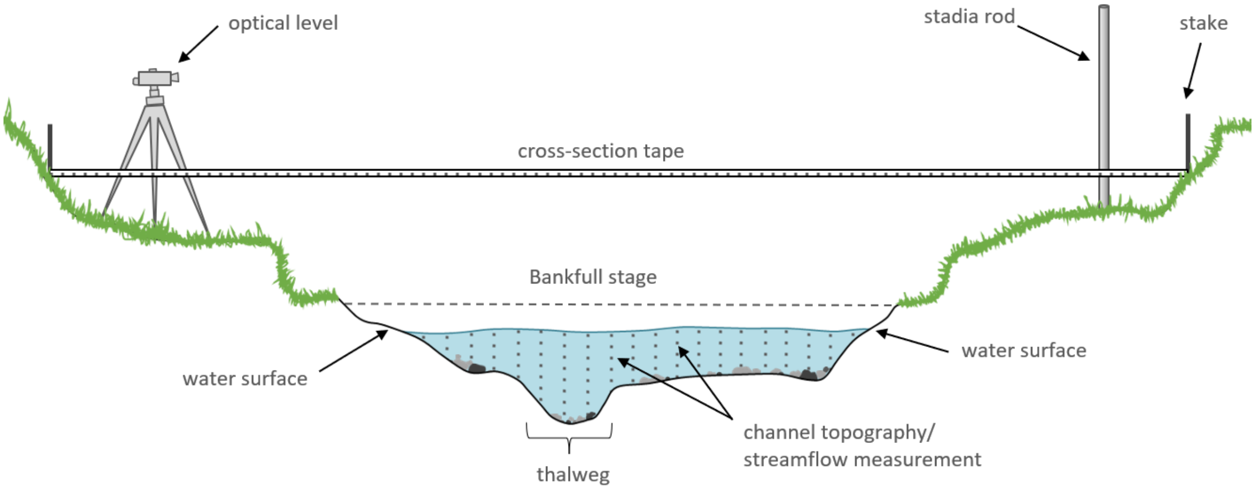


Figure 5. Schematic view of R2Cross cross-section and measurements.

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

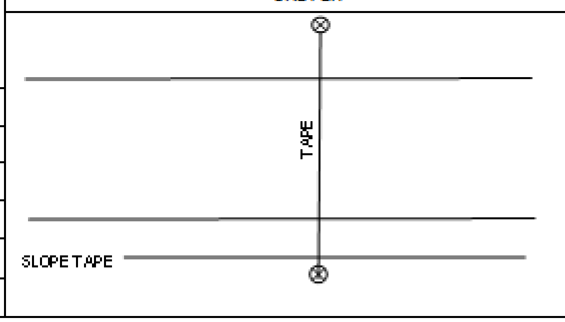
FLOW METER TYPE/METER #:			
FLOW MEASUREMENT TAKEN AT R2CROSS XSEC?	YES / NO	IF NO, MEASURED DISCHARGE:	cfs
IF NO, WHERE?			
CHANNEL BED MATERIAL SIZE RANGE:			
PEBBLE COUNT COLLECTED AT THIS LOCATION?	YES / NO	PHOTOS:	YES / NO

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



LEGEND:
Stake
Station
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.

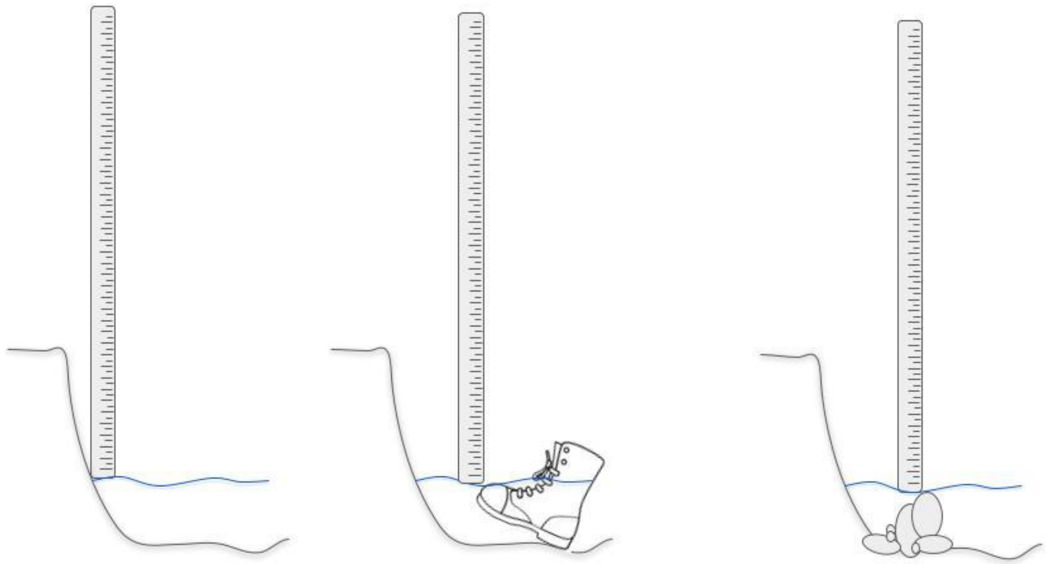


Figure 8. Three options for accurately measuring water surface elevations include using the bed at the water's edge (left), the "boot method" (middle), and using substrate elements (right) to support the rod at the water surface elevation.

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).

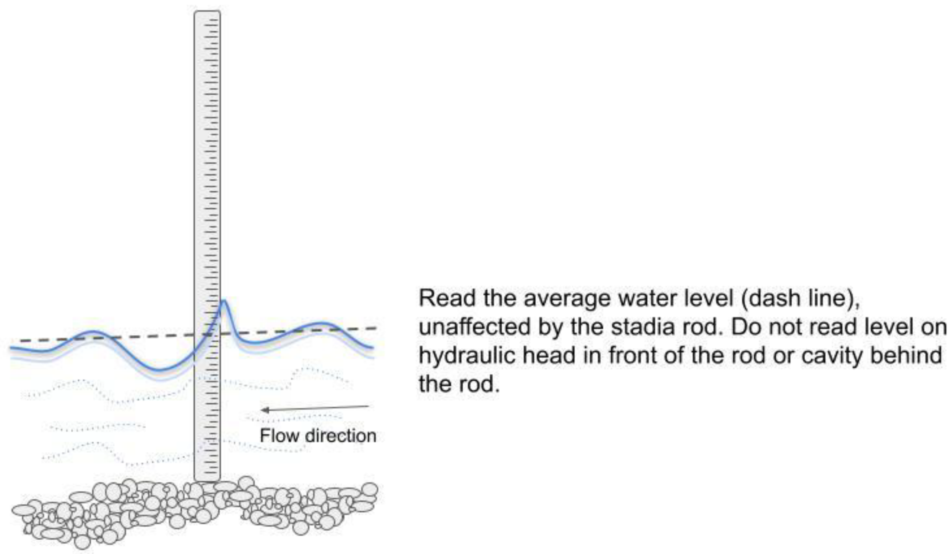


Figure 9. Reading the depth of water off the stadia rod.

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).

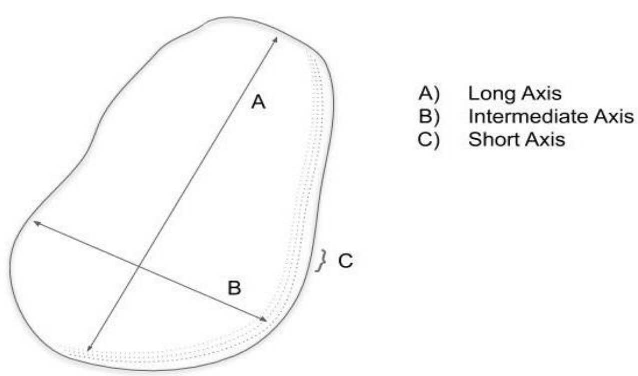


Figure 10. Illustration of the three axes of a substrate particle; in the pebble count procedures, the intermediate axis should be measured with a ruler or gravelometer.

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.

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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

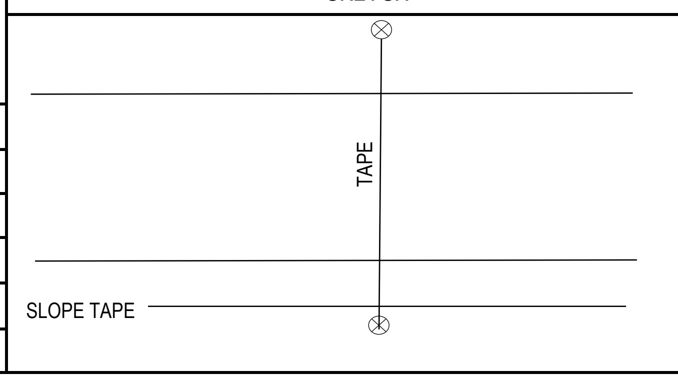
FLOW METER TYPE/METER #:			
FLOW MEASUREMENT TAKEN AT R2CROSS XSEC?	YES / NO	IF NO, MEASURED DISCHARGE:	cfs
IF NO, WHERE?			
CHANNEL BED MATERIAL SIZE RANGE:			
PEBBLE COUNT COLLECTED AT THIS LOCATION?	YES / NO	PHOTOS:	YES / NO

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

Page ____ of ____

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			NOTES
				WIDTH (ft)	AREA (ft^2)	Q (cfs)	

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			