FINAL TECHNICAL GUIDANCE◦ JUNE 2021

Technical Guidance for Observational Monitoring for Channel Maintenance Flows along the Colorado River

PREPARED FOR

Upper Colorado River Wild & Scenic Stakeholder Group

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Cover photos: Colorado River downstream from Pumphouse in 1938 (left) and 2019 (right).

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1 INTRODUCTION

1.1 Background

The Upper Colorado River Wild & Scenic (W&S) Stakeholder Group (SG) and Channel Maintenance Flow (CMF) Work Group is working to develop an observational monitoring plan to better understand the effects that peak flows have on channel maintenance functions in Bureau of Land Management (BLM) Segments 4 through 6 of the Colorado River, extending from the Gore Canyon to Dotsero (Figure 1-1). Segments 4 through 6 comprise the approximately 50-mile "study reach" that is the focus of this Technical Guidance for Observational Monitoring for CMF along the Colorado River (Technical Guidance), which will support the SG in developing the CMF Observational Monitoring Plan.

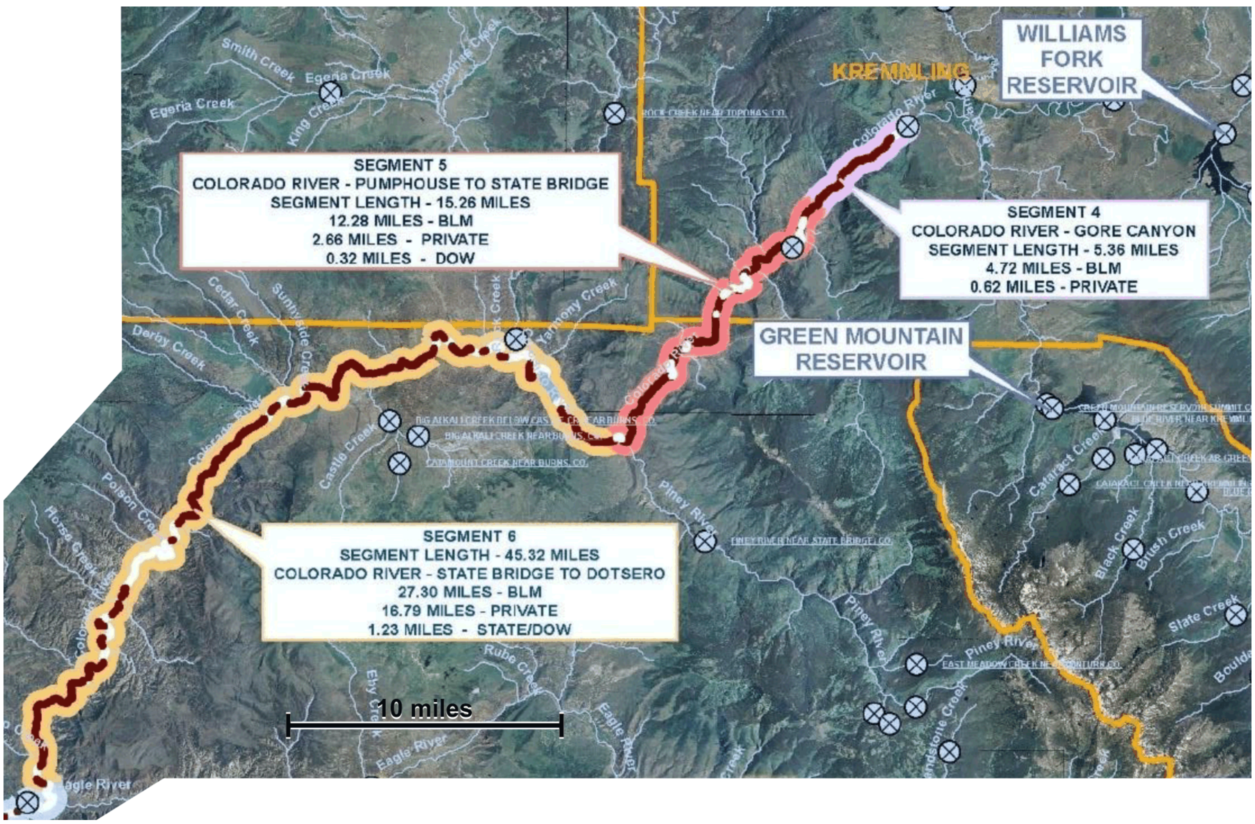

Figure 1-1. Site location map (from the 2020 *Amended and Restated Upper Colorado River Wild and Scenic Stakeholder Group Management Plan*).

The Amended and Restated Upper Colorado River Wild and Scenic Stakeholder Group Management Plan (the SG Plan) was adopted by the SG and approved by the BLM and U.S. Forest Service (USFS) in June 2020 to protect the outstandingly remarkable values (ORVs) identified for the Colorado River from its confluence with the Blue River to near Glenwood Springs, Colorado. The SG Plan is being implemented as a Wild and Scenic management alternative by the SG, which includes a broad range of interests, including east slope and west slope water users, landowners, local governments, state interests, float-boating interests, and conservation/environment/fishing interests. The SG's intention is to balance permanent protection of the ORVs described in the SG's Plan, certainty for the stakeholders, water project yield, and flexibility for water users.

Addressing CMF in the context of the SG Plan represents one of the most complicated issues that the SG has tackled over its 13-year history since inception in 2008. Differences remain within the CMF Work Group and Interest Groups regarding expectations, monitoring techniques/frequencies, and long-term funding of the CMF Monitoring Plan.

To assist with the complexity of addressing CMF in the context of the SG Plan, the SG retained the Stillwater Sciences Team (Stillwater Team) to help develop an observational CMF monitoring plan to better understand the effects that peak flows have on channel maintenance processes. Working with the SG, the Stillwater Team has developed this Technical Guidance to help inform the SG in developing the CMF Observational Monitoring Plan for the study reach. The intent is to include the final CMF Observational Monitoring Plan in Appendix C (Long-Term Monitoring Plan) of the SG Plan, when completed, with implementation starting as soon as practical.

1.2 Project Purpose

The SG recognizes CMF as being important to maintaining healthy aquatic and riparian ecosystems that, in turn, support a healthy recreational fishery and fishing experience. The SG has agreed that the purpose of the CMF Observational Monitoring Plan is not to identify a target flow or range of flows for CMF, but rather to monitor the effects that a given year's peak flows have on accomplishing general channel maintenance functions of: (1) mobilizing and transporting bedload substrate, and (2) the channel maintenance processes of:

1. Maintaining amount and diversity of aquatic habitat,
2. Maintaining active channel geometry,
3. Creating and maintaining non-vegetated sand and gravel features, and
4. Preventing growth of new rooted vegetation and/or scouring rooted plants from active channel.

Anticipated available budgets constrain the monitoring approaches that can be undertaken. The following budget targets have been defined by the SG[1]:

- Low annual cost = $5,000 to $10,000;
- Medium annual cost = $20,000 to $30,000; and
- High annual cost = $50,000 to $100,000.

The SG has determined that the backbone of the CMF Observational Monitoring Plan will be annual SG-led monitoring efforts, periodically supported and guided by trained/experienced expert(s) to assist with collecting and interpreting observational data. In most years, the Observational Monitoring Plan is expected to include methods in the low annual cost category due to budget constraints. In addition, this Technical Guidance identifies additional moderate- and high-cost monitoring methods that the SG may choose to consider for future application.

[1] There is not complete agreement within the SG or CMF workgroup on the following spending categorizations.

This Guidance presents and evaluates potential monitoring methods, from which the SG may select to best balance stakeholders' needs and available budget. This Guidance also provides relative cost and high-level information on the pros and cons for each of the potential methods. Additionally, this Guidance recommends priorities for selecting monitoring sites and identifies triggers that the SG may choose to apply to help determine when more costly monitoring methods may be warranted.

1.3 System Understanding

An understanding of this reach of the Colorado River, including both current and historical conditions, is critical to identifying monitoring methods that are appropriate and that will yield effective and meaningful results. The methods that best balance monitoring challenges, diverse stakeholders' needs, and available budget are also best informed by system understanding. Desktop analysis was completed to categorize the approximately 50-mile study reach into subreaches with similar geomorphic characteristics. Although current and historical hydrological conditions are also an important part of system understanding, the SG has developed hydrological understanding in separate efforts and so hydrological context is not included in this Guidance.

Review of readily available 1994 to 2019 Google Earth imagery suggests this reach of the Colorado River is not experiencing significant changes either to its channel planform or to large-scale geomorphic features (e.g., gravel bars or other depositional features observable in aerial imagery). While this 25-year time period is not long in duration, it does include six of the eight largest recorded peak flows since the Windy Gap dam came on-line in 1985.

Over the last ten years, CPW's fish biosurveys, macroinvertebrate surveys and angler surveys consistently indicate that this reach of the river supports healthy aquatic communities. In addition, recognizing the level of geomorphic processes necessary to support a healthy community of benthic organisms is likely an important component of system understanding. For example, potential relevance of major perennial tributary flow inputs (e.g., Blue River, Piney River) should not be overlooked.

Given the value of supporting the community of benthic organisms, understanding sediment transport in the reach is important to system understanding. Bedload, defined as the sediment particles in a river that reside and are transported along the stream bed (and the habitat for those benthic organisms), consists of boulders to sand-sized particles throughout the study reach. Moving downstream, bedload trends finer and with increasing sand content.

A deeper understanding of effective bedload mobilization requires more complicated (and more expensive) monitoring methods, such as tracer rock studies. Such understanding might include (1) what flows are necessary to move a given sediment size; (2) what flows can accomplish the four channel maintenance functions identified in the Project Purpose section (aquatic habitat, active channel geometry, depositional features, and vegetation scouring); (3) when are fine sediments flushed from a gravel bed; or (4) what are the effect of episodic (in time) and patchiness (in space) sediment transport mechanics? However, simpler (and less expensive) methods are expected to provide a general, albeit less sensitive, understanding of bedload mobilization in space and over time.

1.4 Previous Bedload Transport Studies

The following previous studies have provided relevant information on bedload transport in the study reach and have helped inform this Technical Guidance. They are available to serve as additional resources for subsequent preparation of the CMF Observational Monitoring Plan:

- Flushing Flow Analysis (Beeby and Bledsoe 2015)
- Incipient Bed Movement and Flood Frequency Analysis (USGS 2019)
- Instream Flow Report (Miller Ecological Consultants 2012)

2 MONITORING APPROACH & METHODS

The combined conditions of (1) minimal long-term geomorphic change, (2) productive fishery and high macroinvertebrate health, and (3) budgetary limitations on monitoring lead to the recommendation that CMF Observational Monitoring focus primarily on the element of the Project Purpose that seeks to identify any changes over time in the four channel maintenance functions:

1. Maintaining amount and diversity of aquatic habitat;
2. Maintaining active channel geometry;
3. The creation and maintenance of non-vegetated sand and gravel features; and
4. Preventing growth of new rooted vegetation and/or scouring rooted plants from the active channel.

Low-cost monitoring methods identified as suitable and feasible for this dam-altered, largely non-wadeable system provide coarse, but generally quite robust, evidence of significant geomorphic trends. Changes in these measured parameters typically accumulate over multiple years, allowing recognition of significant, decadal-scale changes. However, smaller year-to-year changes may be impossible to distinguish using these less sensitive methods.

This limitation, largely a function of budgetary constraints, informs Stillwater's recommended focus on identifying changes in the four channel-maintenance processes listed above. In contrast, we anticipate that the lack of visible, large-scale geomorphic change throughout the study reach means that direct monitoring of the channel maintenance function of mobilizing and transporting bedload substrate is unlikely to yield useful results using low-cost techniques. Meaningful monitoring of substrate transport can provide a more sensitive and immediate indications of geomorphic change (or its absence), but the associated effort and cost can be substantial.

The basic strategy recommended here is for the SG to monitor conditions for major changes over multiple years that can be readily observed via simple, low-cost methods; but to recognize that a lack of observed change from year-to-year does not guarantee the absence of a decline in system health. A combination of such methods, however (including on-going biological monitoring for other resource guides, and angler/boater intercept surveys that are being done to support ORV indicators) may provide sufficient evidence for when short-term variability in measured parameters warrants more in-depth investigation of potentially changing conditions.

The Stillwater Team investigated potential monitoring methods for SG consideration for inclusion in its CMF Observational Monitoring Plan. The intent here is to identify a suite of monitoring options that will provide meaningful results in a defensive, dependable, and repeatable manner, with documentation of associated level of uncertainty, and that meet the SG's need for a range of low-, medium-, and high-cost options. Methods known to be simple, quick, and easy, while still remaining defensible, dependable, and repeatable, constitute the options in the low-cost category. Their inclusion emphasizes SG guidance that the backbone of the CMF Observational Monitoring Plan should be SG-led monitoring efforts that focus on low-cost and repeatable options, periodically supported by trained/experienced expert(s) made available to assist with collecting and interpreting observational data.

Table 2-1 summarizes potential methods and provides information on pros and cons, as well as relative costs.

Table 2-1. Potential channel maintenance flow monitoring methods. See Appendix A for general references for monitoring methods, and specific methodologies or reference documents for selected items (indicated by *). "Low" relative cost assumes minimal equipment and little expert guidance or training needed.

Monitoring Method	What Is learned?	Pros/cons	Relative Cost
General Observer Notes* *Description:* General notes/observations conducted at identified locations	How areas of interest (e.g., specific bar, riffle, etc.) visually change over time in response to varying flows	Provides overall context for data collected via other methods Recommended for inclusion as part of any monitoring plan Only documents the most substantial of changes	Low
Repeated Photo Points* *Description:* Photo documentation repeated at strategic photo points	How areas of interest (e.g., specific bar, riffle, etc.) visually change over time in response to varying flows	Quick and easy data collection Framework for organizing data collected via other methods Recommended for inclusion as part of any monitoring plan	Low
Pebble Counts* *Description:* Repeatable sediment measurement to determine grain-size distributions by blinded "first-touch" technique	What size bedload material is mobilized, which can be tied to channel maintenance flows	Relatively quick, lower cost method for determining changes in gravel bar composition over time, coarse bedload movement	Low
Painted Rocks *Description:* Painting a patch of gravel to observe movement of individual particles and whether painted rocks were inundated by a given peak flow (e.g., different bar or floodplain elevations)	What peak flow magnitude and duration moves bedload material	Provides only limited information on gravel movement, and potentially subject to disturbance between placement (on dry bar) and any subsequent high flows Tracer rocks are of only modestly greater expense and more robust, reliable	Low
Measurement of Percent Coarse/ Fines/ Algae *Description:* "First-touch" measurement (see Pebble Counts, above) or grids to determine grain-size distributions and/or macrophyte coverage to provide indicators of potential movement.	Whether bedload material has moved, which can be directly tied to channel maintenance flows	Relatively quick, lower-cost method for determining coarse bedload movement, but feasible only in wadeable streams High uncertainty without expert guidance on location, technique; moderate uncertainty is unavoidable Can detect coarse magnitude of "change" but criteria for good/bad conditions need to be locally developed	Low, but can be time-consuming

Monitoring Method	What Is learned?	Pros/cons	Relative Cost
Measurement of Percent Embeddedness* *Description:* Fraction of coarse grains that are surrounded by fine sediment	Degree of substrate mobility	Difficult, imprecise measurement with generally poor repeatability Useful mainly for coarse-scale evaluation Can be time-consuming, depending on level of precision High uncertainty without expert guidance on location, technique	Low, but can be time-consuming
Cross-sectional Channel Survey *Description:* Topographic cross-sectional profile across the river, bank-to-bank Representative cross-sections can be identified at a range of spacings to scale with channel variability and available budget	How flows change channel geometry, which can be indicative of channel maintenance processes having occurred	Most useful in combination with other simple methods (e.g., Photo Points) to establish context for specific cross-sections Good, well-established approach for tracking channel change through time, particularly changes in bank position Very time-consuming for non-wadeable channels	Moderate
Scour Chains* *Description:* burial of chains during low water, with re-excavation following high water to evaluate how deep scour has occurred	Magnitude of gravel scour following high flows	Excellent indicator of gravel mobility, but difficult to install and requires multiple sites to achieve meaningful coverage	Moderate
Tracer Rocks using Visual Identification *Description:* Painting specific sized rocks and placing them along transects before peak flow and finding them again after peak flow	What peak flow magnitude and duration moves what size bedload material, which can be directly tied to channel maintenance flows	Finding the rocks after peak flow is more difficult visually versus using RFID, so fewer rocks may be relocated Visual identification is less expensive and quicker (with reduced relocation) than using RFID and still a strong line of evidence for determining coarse bedload movement	Moderate

Monitoring Method	What Is learned?	Pros/cons	Relative Cost
Tracer Rocks using Radio Frequency Identification (RFID) *Description:* Installing PIT Tags into specifically sized rocks of interest that reflect current bedload size distribution and then surveying their initial placement locations and re-surveying after high flow events	What peak flow magnitude and duration moves what size bedload material, which can be directly tied to channel maintenance flows	Can be expensive due to equipment and the amount of time needed to resample Continuous monitoring for movements of the same rock from year to year is only possible with RFID equipment This line of evidence is one of the strongest for determining coarse bedload movement	Moderate to high
Bathymetry *Description:* Topographic survey of the channel bottom	Changes in the nature of the stream channel, including coarse bed mobilization, bar development, pool scouring, etc.	Specialized equipment can make this method more expensive Strong line of evidence for tracking channel change, including aquatic habitat maintenance and bar creation	High
Aquatic Habitat Characteristics* *Description:* Detailed characterization of habitat features (pools, riffles, glides, runs, etc.)	Potential suitability of physical habitat for aquatic organisms; assumed to be able to track changes in habitat over time	Multiple studies show that observer bias and gradational features render most comparisons of limited value, except for tallying gross habitat categories on wadeable streams	High
Riparian Vegetation Surveys*	Change in coverage and community composition over time	Well-established methodologies can detect relatively rapid change. Suitable for non-wadeable channels Requires training and expertise, is time-consuming	High
Aerial Imagery/ Photogrammetry *Description:* Imagery that is publicly available or collected via drone flight or commercial vendor (e.g., Planet, www.planet.com)	Capture changes in channel planform, vegetation, and bar development in response to peak flows, which can be directly tied to channel maintenance flows	Often efficient (versus field mapping) to cover large areas Option to select representative areas for repeat flights to save time and money Strong long-term line of evidence for tracking channel changes through time	Low, if suitable imagery locations and dates available High to Very High, if not

Monitoring Method	What Is learned?	Pros/cons	Relative Cost
LiDAR (red or green)	Capture changes in channel planform and bar development in response to peak flows, which can be directly tied to channel maintenance flows	Invaluable for detailed comparison of topographic changes, for either bar growth/decay or planform Multiple years' repeat surveys required to be useful Green LiDAR captures bathymetric data; red LiDAR is terrestrial only, such that below water data is not captured Ground truthing and/or ground monuments is frequently required for accurate results	Low, if suitable imagery locations and dates available High to Very High, if not

The Observational Monitoring Plan will be comprised of methods in the low annual cost category. However, the SG could consider implementing medium- and high-cost methods. This Guidance provides information needed to determine cost-effective expenditures of available funding, along with options to prioritize monitoring sites and considerations for potential medium- and/or high-cost monitoring methods. It is recognized that differences remain within the SG regarding whether certain methods are "observational" in nature within the intent of the SG Plan.

Recommendations for prioritizing monitoring sites include placing more emphasis on easily accessible sites within less confined reaches, where any channel changes are more likely to be expressed, and at sites that overlap or are in close vicinity to existing or past monitoring sites (e.g., from macroinvertebrate sampling, channel cross-sections, instream flow habitat studies, CPW biosurvey reaches, or Pteronarcys research sites). Additionally, sites favoring sediment deposition, either with depositional features (e.g., mid-channel and point bars or riffle habitat) or downstream transitions in longitudinal gradient (steeper-to-flatter) or channel expansion (confined-to-unconfined), are the most likely to exhibit measurable change during channel maintenance flows and are therefore recommended for prioritization of monitoring using observational methods. Lastly, sites chosen for monitoring should include sites that incorporate the botanical species/communities in Segment 6 that are ranked by the Colorado Natural Heritage Program as globally vulnerable.

The CMF Work Group expressed interest in recommended triggers to help determine when to consider monitoring methods in the medium- or high-cost categories, as funding allows. The Stillwater Team suggests focusing on biological, rather than physical, parameters to guide potential future decisions by the SG to adjust its CMF Observational Monitoring Plan, given the challenges in observing geomorphic change in the reach and the presently healthy state of the fishery and macroinvertebrate populations. Systematic declines in the macroinvertebrate communities being monitored are likely to provide an earlier (as well as a more direct) indication of loss in biological health through the system. In other words, ongoing monitoring for biological conditions will likely be as or more sensitive in identifying potential decline than low-cost monitoring of physical conditions. Ideally, these two approaches can be implemented in concert with one another to provide a more complete picture of the river's health than either in isolation.

Table 2-2 summarizes considerations for observing the four channel maintenance processes recommended for observational monitoring.

Table 2-2. Considerations for observing channel maintenance processes.

Channel Maintenance Process	Expression	Monitoring Methods
1. Maintaining amount and diversity of aquatic habitat	• Coarse bedload mobilization and transport in the riffles, coarse bedload deposition in the tails of bars. • Sand transport in the riffles and deposition in the bars.	Primary: • General observer notes[1] • Repeated photo points • Grain-size changes on bars (pebble counts) • Guide surveys[2] Other potential monitoring methods: • Painted or tracer rocks • Percent embeddedness
2. Maintaining active channel geometry	• Coarse bedload mobilization and transport in the riffles and coarse bedload deposition in the bars.	Primary: • General observer notes[1] • Repeated photo points • Repeat aerial photos, as available • Guide surveys[2] Other potential monitoring methods: • Repeat cross-section surveys and/or bathymetry • Percent coarse, fines, algae counts in riffles • Percent embeddedness
3. Creating and maintaining non-vegetated sand and gravel features	• Non-vegetated bar development and change through time.	Primary: • General observer notes[1] • Repeated photo points • Repeat aerial photos, as available • Guide surveys[2] Other potential monitoring methods: • Grain-size changes on bars (pebble counts) • Drone aerial imagery or LiDAR (DEM differencing) • Riparian vegetation surveys
4. Preventing growth of new rooted vegetation and/or scouring rooted plants from active channel	• Coarse bedload mobilization and transport in the riffles and coarse bedload deposition in the bars. • Presence/absence of vegetation, and age distribution	Primary: • General observer notes[1] • Repeated photo points • Guide surveys[2] Other potential monitoring methods: • Grain-size changes on bars (pebble counts) • Scour chains • Riparian vegetation surveys

[1] Potential geomorphic changes that may be noted include planform, bar size/extent, riparian vegetation, channel dimensions, and sediment gradation
[2] Guide surveys entail repeatable annual survey forms completed by fishing and recreational boating guides

3 SUBREACHES & MONITORING LOCATIONS

Categorization of the study reach into subreaches based on similar geomorphic characteristics helps ensure that the selected monitoring locations are representative of the approximately 50-mile study reach. The Stillwater Team performed desktop analysis of available geologic, channel morphology, and aquatic habitat mapping to identify suitable geomorphic subreaches.

Lithologic variability of the bedrock underlying the Colorado River and its tributaries (Figure 3-1 and Figure 3-2) directly affects erodibility, which in turn shapes the overall valley setting (e.g., valley width, down-valley slope, tributary drainage pattern, etc.) These valley characteristics, in turn, influence flow, sediment transport, and the morphodynamics of different channel sections. Local geomorphic variability further complicates geomorphic expression of the bedrock signal.

From remote observations and brief literature review, the bedrock lithologies along the mainstem Colorado River in this study area comprises four broad categories:

From remote observations and brief literature review, the bedrock lithologies along the mainstem Colorado River in this study area comprises four broad categories (mapped units along the Colorado River listed in parentheses):

1. <u>Precambrian crystalline basement rocks</u> (old, hard granitic rocks: exposed in Gore Canyon; map unit Xg).
2. <u>Upper </u>Paleozoic, Mesozoic, and Tertiary sedimentary rocks (the most variable category, with both competent sandstones and typically less competent shales but all grouped in these units: at Pumphouse, Radium - above Piney Riv., State Bridge - above Red Dirt Cr.; map units labeled Kc, Kd, Jmce, Mcr, PPm, PPwm, Tpcs).
3. Tertiary volcanic rocks (basalt generally weathers slowly in semi-arid environments: above Piney Riv. - State Bridge; map unit Tbr).
4. <u>Paleozoic evaporite & fine-grained sedimentary rocks</u> (older sedimentary rocks, predominantly fine-grained and containing weak, salt-bearing sediments: around Red Dirt - Eagle confluence; map unit Pee).

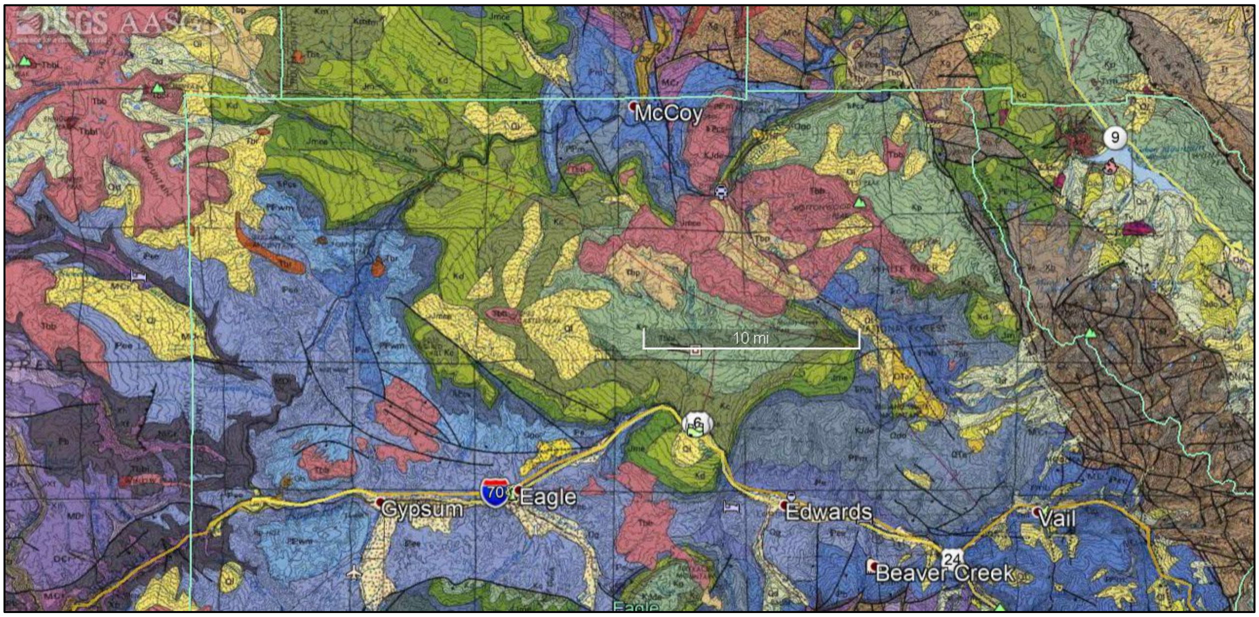

Figure 3-1. Generalized geologic map of the study area and surrounding region (from Tweto, Ogden, Moench, R.H., and Reed, J.C., 1978, Geologic map of the Leadville 1 degree x 2 degrees quadrangle, northwestern Colorado. U.S Geological Survey, Miscellaneous Investigations Series Map I-999, 1:250,000).

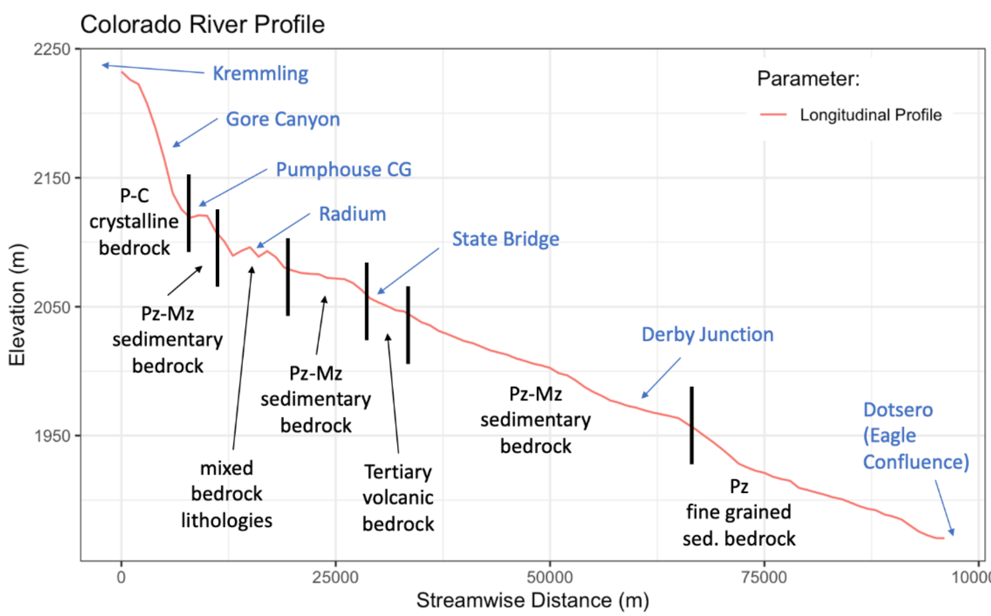

Figure 3-2. Bedrock lithologies along the mainstem Colorado River through the project area.

Subreach identification was additionally based on the Colorado River's tributary confluences located within the study reach. These tributaries are the source of flow and sediment *not* delivered from upstream reaches of the Colorado and may cause longitudinal variability in the morphology of the mainstem river.

This approach of dividing the Colorado River from confluence to confluence is effective because each reach below a tributary confluence will transport more flow and sediment than the subreach located upstream. This contributing area classification scheme results in nine unique subreaches as shown in Figure 3-3.

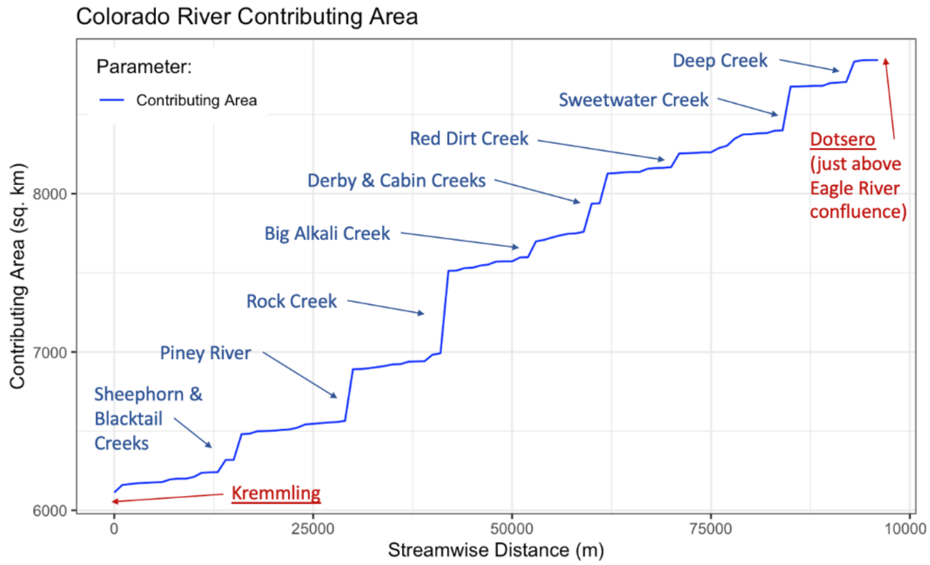

Figure 3-3. Contributing areas along the Colorado River through the project area.

Using the above-described methodology, a final list of 12 subreaches were identified based on changes in contributing area from perennial tributaries and other large-scale geomorphic changes:

5. Pumphouse to Blacktail Creek
6. Blacktail Creek to Sheephorn Creek
7. Sheephorn Creek to Red Gorge
8. Red Gorge to Rancho Del Rio
9. Rancho Del Rio to Piney River
10. Piney River to Rock Creek
11. Rock Creek to Big Alkali Creek
12. Big Alkali Creek to Derby Creek
13. Derby Creek to Red Dirt Creek
14. Red Dirt Creek to Sweetwater Creek
15. Sweetwater Creek to Deep Creek
16. Deep Creek to Dotsero

Distributed within these 12 subreaches, approximately 80 monitoring sites were identified, based on areas showing at least some degree of channel change between 2011 Google Earth aerial imagery and most current aerial imagery from 2019. Monitoring locations from previous studies are included in the recommended sites, including five flushing flow riffle cross-sections from Beeby and Bledsoe (2015) and other macroinvertebrate and sediment sampling locations.

Recommended monitoring sites within the 12 subreaches were selected to best represent the approximately 50-mile study reach, providing enough data points to reduce uncertainty in qualitative monitoring methods. Recommended sites focus on less confined sections of the study reach (e.g., areas where the canyon opens and islands have formed) as guided by both geomorphic considerations and the SG.

Particular focus was placed on mid-channel and point bar features, associated riffle habitat at bar features, split flow riffles around islands for shallower water depths, and select perennial and ephemeral tributary deltas. These areas are expected to be the most likely to see change during channel maintenance flows, if they occur. For example, the peak discharge of 2011 was 9,540 cfs, and new bar development is visible in the subsequent 2011 Google Earth aerial imagery. These relatively newly formed bar features are ideal for monitoring through time to capture any additional change that may now be occurring.

Figure 3-4 presents a Monitoring Locations Map. Additionally, a kmz file containing the recommended monitoring locations and a kmz file containing locations of the reach breaks for the 12 subreaches are provided as part of this Technical Guidance.

The kmz we provided with the 80 recommended monitoring sites is entitled "Final Sites.kmz" and includes labels that identify any sites that overlap with sites for other monitoring efforts, as follows:

- Bledsoe and Beeby riffle sampling (cross sections) site:
    - "riffle sampling site Above Dotsero"

- Macroinvertebrate sampling sites:
    - "macroinvertebrate sampling site Pumphouse"
    - "macroinvertebrate sampling site State Bridge"

- Combo sites – both Bledsoe and Beeby AND macro sampling sites:
    - "riffle/macroinvertebrate sampling site Below Red Dirt"
    - "riffle/macroinvertebrate sampling site Above Catamount"
    - "riffle/macroinvertebrate sampling site Radium"
    - "riffle/macroinvertebrate sampling site Pumphouse"

The second kmz file containing locations of the reach breaks for the 12 subreaches is entitled "Reach Breaks.kmz".

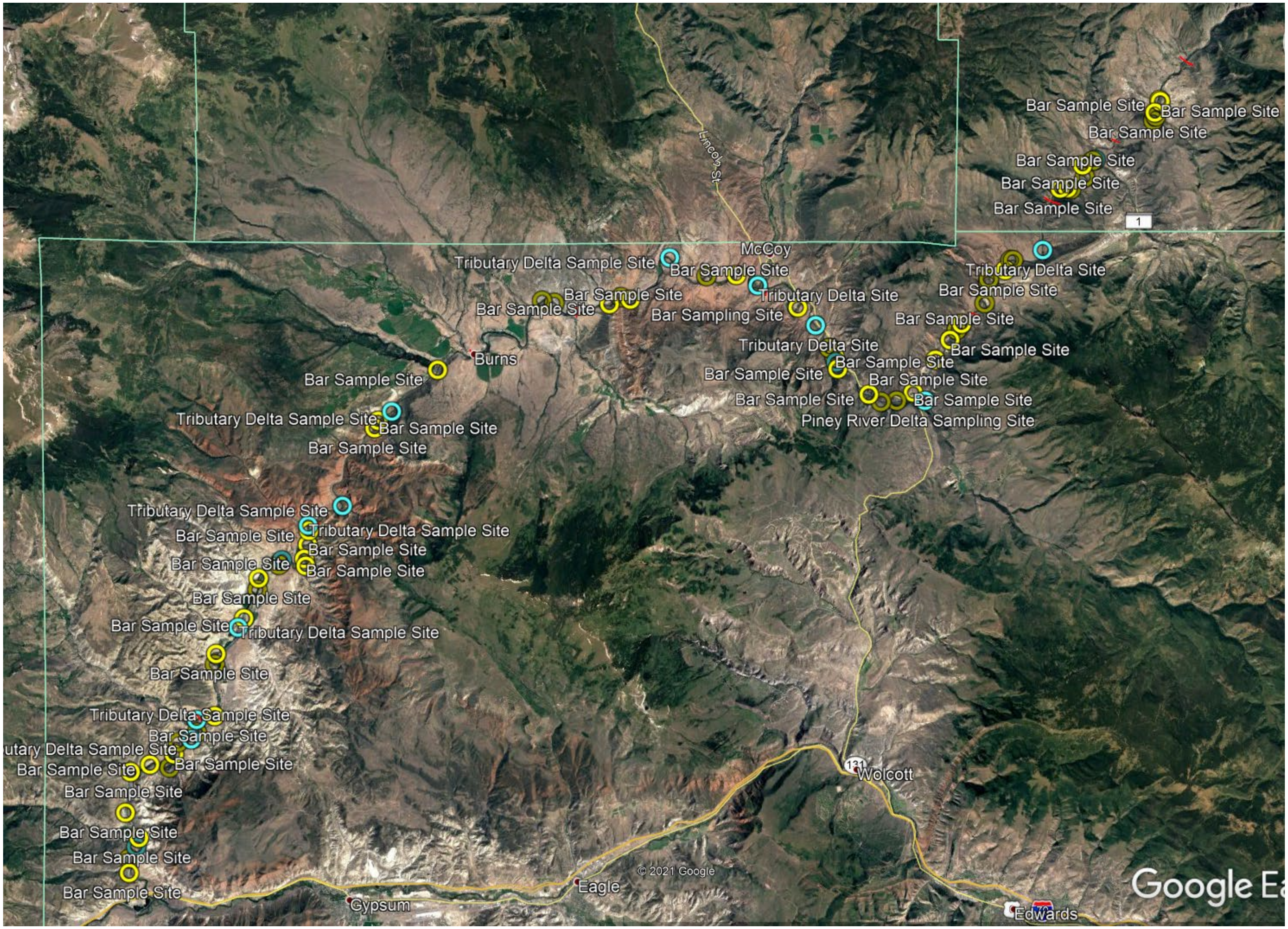

Figure 3-4. Monitoring locations map. Yellow circles mark bar sites, turquoise circles mark tributary delta sites.

4 MONITORING RECOMMENDATIONS

The following general monitoring recommendations are offered to help inform the SG's development of its CMF Monitoring Plan:

- Monitoring should occur during low flows (to increase the limited opportunities for wadeability), with the caveat that the SG's monitoring plan should be flexible enough to allow for monitoring opportunities at other times of the year and different flow levels.
- Monitoring data from the first few years should be used to inform optimal adjustment of future monitoring efforts (e.g., duration required for monitoring efforts, more/less accessible sites, etc.).
- Due to wadeability and access challenges, floating the reach may be the most cost-effective approach, but there may be other suitable approaches, depending on the site.
- Any sites selected for collecting channel-bed data will require fully crossing the channel, which should be vetted during the first sampling year due to potential wadeability issues.
- Rebar, coupled with GPS-tagged locations, should be used to mark monitoring sites or riffle transects for repeat occupation from year to year. If placement of rebar is infeasible or unsafe, GPS coordinates alone with a known level of imprecision can be used to mark sites, recognizing that any potential imprecision in location can skewing monitoring results (e.g., falsely indicating changed conditions from one year to the next).
- Observational monitoring should include indicators of water surface elevations, so as to discern whether encroaching vegetation is being scoured out or simply drowned out. The distinction is that drowning of vegetation is not a channel maintenance process, although it is sometimes mistaken for one.
- Because qualitative observations (e.g., general observer notes) rely extensively on experience and judgement and are more difficult to set up for repeatability, as compared to quantitative measurements (e.g., percent fines and pebble counts), support for monitoring preparation and implementation through training and/or field visits by trained/experienced expert(s) is recommended for qualitative observations.
- The use of citizen scientists should emphasize sampling activities (such as for water quality) where the final analyses are conducted by a laboratory and with the training and support of the appropriate experts. They can also be used to take repeat photos; but to avoid missing key features worth capturing and analyzing, some level of professional/expert input should be provided.

5 REFERENCES

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Miller, W.J. and K.M. Swaim, 2011. Final Instream Flow Report for the Colorado River from Kremmling, Colorado downstream to Dotsero, Colorado. Prepared for the Colorado River Water Conservation District and Colorado Water Conservation Board.

Rees, D.E. and E.S. Grape, 2020. Benthic Macroinvertebrate Biomonitoring Study, Upper Colorado River 2019. Prepared for the Upper Colorado River Wild and Scenic Stakeholder Group.

Appendices

Appendix A

Selected Monitoring Protocols

STANDARD REFERENCES FOR MONITORING METHODS

These protocols are drawn from three standard references (note that most protocols have been developed for wadeable streams; modifications and/or omissions are needed for non-wadeable channels):

1. Harrelson, Cheryl C; Rawlins, C. L.; Potyondy, John P. 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 pp.

   https://www.fs.usda.gov/treesearch/pubs/20753

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SPECIFIC PROTOCOLS

General Observer Notes (from Harrelson et al. 1994, pp. 10–12)
Draw the site map in the field notebook from direct observation. It should show the main features of the site and their relationship as accurately as possible. As field work continues, modify the map with features such as floodplain and terrace elevations. Draw additional maps in the field notebook to record features of the channel and supplement survey notes during field work if needed… Show the following items in field notes and on the site map. Some are self-evident, while others will be explained in the sections covering survey and measurement techniques that follow. This list can be a good reminder for mapping in the field:

- Stream name
- Date
- Surveyor names
- Location of benchmarks
- Direction of stream flow
- North arrow
- Note on map scale (e.g., not to scale or 1" = 50 ft.)
- General site elevation (e.g., 6200 ft.)
- Landmarks near stream
- Photo points
- Legend with scale
- Key to special symbols
- Valley cross-section sketch
- Terraces (height, vegetation)
- Features (trees, rocks, debris)
- Latitude/longitude
- Pool/riffle sequences
- Gravel and sand bars
- Abandoned channels
- Floodplain boundaries
- Cross-section (endpoint, bearing, and distance to benchmark)
- Longitudinal stations for slope measurements
- Pebble count location
- Other data sites (bank, bedload, bars, riparian vegetation)
- UTM: universal transverse mercator (optional)

The field book map is a minimum.

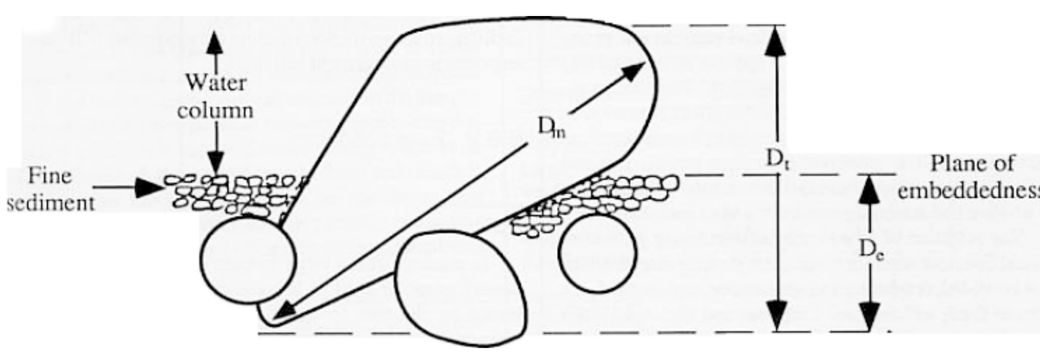
Repeated photo points (see https://www.fs.fed.us/pnw/pubs/pnw_gtr526.pdf)

Pebble counts (from Harrelson et al. 1994, pp. 49–50; more extensive discussion in Bunte and Abt 2001)

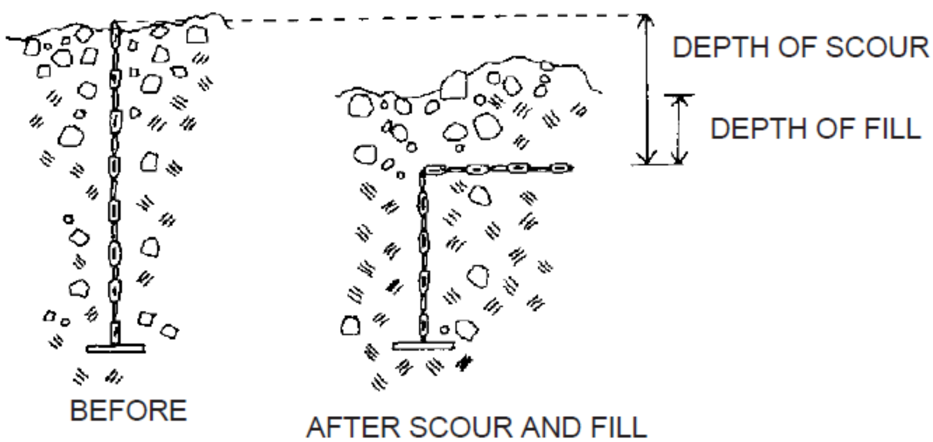
1. Select a reach on or near the cross-section and indicate it on your site map. For stream characterization, sample pools and riffles in the same proportions as they occur in the study reach. For other purposes, it may be appropriate to sample pools and riffles separately. Measure a minimum of 100 particles to obtain a valid count. Use a tally sheet to record the count.
2. Start the transect at a randomly selected point (perhaps by tossing a pebble) at one of the bankfull elevations (not necessarily the present water level). Averting your gaze, pick up the first particle touched by the tip of your index finger at the toe of your wader.
3. Measure the intermediate axis (neither the longest nor shortest of the three mutually perpendicular sides of each particle picked up). Measure embedded particles or those too large to be moved in place. For these, measure the smaller of the two exposed axes. Call out the measurement. The note taker tallies it by size class and repeats it back for confirmation.
4. Take one step across the channel in the direction of the opposite bank and repeat the process, continuing to pick up particles until you have the requisite number (100 or more) of measurements. The note taker keeps count. Traverse across the stream perpendicular to the flow. Continue your traverse of the cross-section until you reach an indicator of bankfull stage on the opposite bank so that all areas between the bankfull elevations are representatively sampled. You may have to duck under bank-top vegetation or reach down through brush to get an accurate count. Move upstream or downstream randomly or at a predetermined distance and make additional transects to sample a total of at least 100 particles.

<u>Measurement of Percent Embeddedness (from MacDonald et al. 1991, p. 123</u>)
The basic procedure for measuring embeddedness is to select a particle, remove it from the streambed while retaining its spatial orientation, and then measure both its total height and embedded height perpendicular to the streambed surface [see sketch below]. Percent embeddedness is calculated for each particle until at least 100 particles are measured. Individual embeddedness values are averaged to yield a mean embeddedness value.

The technique as modified…uses 60-cm hoops as the basic sample units…The number of hoops needed to characterize a site depends on the variability among hoop samples and the desired level of precision. A general rule is that one reach requires approximately 20 hoops (approximately 500-700 particles and may require up to a1 full field day for a two-person field crew to complete.



Scour Chains (from Harrelson et al. 1994, p. 51)
Scour chains may be used to measure the aggradation or degradation of the stream bed. Place a standard length of chain or abrasion-resistant cord vertically into the bed material with the lower end anchored to a horizontal pin below the estimated extent of scouring. The loose end should drape over the bed surface [see sketch below]. Install scour chains at a surveyed cross-section, at intervals according to channel width and complexity (generally 5 to 10 chains per cross- section). Measure and record (along with a tape measurement of the length of chain left exposed, if any) the elevation of the lower end of each chain and the present elevation of the bed material. Excavate chains after peak flow events and repeat measurement of the chains along with a survey of the cross-section. A kink or bend in a buried chain indicates scouring and reburial.



Aquatic Habitat Characteristics (from MacDonald et al. 1991, p. 117)
Quantitative habitat data are obtained by identifying and measuring individual habitat units within a designated stream reach. The typical procedure is for a two-person crew to walk a stream channel, with one person measuring individual habitat units while the other person records the data. Hankin (1984) recommended that stratified sampling be utilized to increase efficiency and reduce error. This concept has led to the procedure of visually estimating the area of each habitat unit, and measuring a systematic sample of each typed o develop a correction factor for the visual estimates…an experienced two-person crew [can] inventory approximately 1-3 miles of stream channel per day…generally the data are used only to generate summary statistics, and changes in individual channel units, or in the sequence of units, are not evaluated.

Riparian Vegetation Surveys (see extensive discussion of methods and applications in https://www.fs.fed.us/biology/watershed/riparian/USFS_National_Riparian_Protocol.pdf)