Colorado NPS Stream Restoration and Stabilization Guidance

I. Introduction
Properly functioning stream and riparian areas are critical in maintaining water quality, water quantity, riparian habitat, fish populations and diversity, downstream beneficial uses, social and economic viability of Colorado. Although great strides have been made in improving water quality through various environmental programs and outreach, Colorado's streams and rivers are still being impacted from current and past land use. Project sponsors are encouraged to review the Colorado NPS Manual for guidance on conducting restoration/stabilization activities. Since the term "restoration" often implies restoring aquatic and ecosystem processes to a pre-European state, rehabilitation will also be used to describe improvements to stream and aquatic habitat. Streams are not listed on the 303(d) list as impaired due to stream instability or excessive erosion, however, projects to restore streams can be a preventative measure to prevent future 303(d) listings.

II. Environmental setting
Land management activities or land disturbance, either alone or in combination, affect the timing, magnitude and duration of streamflow, as well as sediment delivery processes from contributing watersheds. These changes in streamflow and sediment routing from those activities (alone or in combination) alter stream stability and cause erosion of some streams, and aggradations of sediment in others. Changes in stream stability can trigger changes in aquatic habitat including quality of streambed substrate, embeddedness, temperature and ultimately, aquatic macroinvertebrate communities. Stream chemistry is typically affected by urbanization, mining, atmospheric deposition, and agricultural runoff. Wetlands and riparian areas are critical in ameliorating impacts from upland nonpoint source pollution, and may decrease the need for costly stormwater controls and flood protection structures. Other benefits of streams, wetlands and riparian areas include habitat for nesting, feeding, cover and breeding of birds, fish, reptiles, amphibians, and mammals. Stream restoration activities are necessary to improve water quality, stream function, and overall aquatic habitat improvement.

III. Definition
For the purposes of the NPS program, stream restoration/stabilization can be defined as the measurable improvement of stream and riparian ecosystem processes. Following restoration and stabilization activities, streams must be able to convey the sediment and flow produced by the upstream watershed without excessive aggradations or degradation of bed and banks to attain the designated uses. Activities that improve fish habitat or stream temperature, sediment and stream stability may not be an issue.

IV. Colorado's approach to the improvement of stream and riparian systems
Colorado's Nonpoint Source program is designed to address impacts to streams and riparian systems from a multitude of activities, such as mining, urban growth, stormwater, return flows, hydrologic modification, agriculture and silviculture. The NPS program advocates adaptive management in improving aquatic and riparian habitat to prevent impairment, as well as preserving the beneficial uses of water.

A. Watershed approach

The stream restoration activities must be put into the context of the upstream contributing watershed. A risk assessment should be conducted downstream of the restoration activity. The watershed (sometimes referred to as a catchment or drainage) is defined as the area of land that drains water, sediment, and dissolved materials to a common point along a stream. The common point will be the area along a stream being restored. Knowing the past, current and potential development in a watershed will greatly improve chances for success in restoring streams and avoid "band-aid" approaches to stream restoration/stabilization. It's also imperative to implement a watershed approach for calculating flow and sediment discharge, impervious areas, diversions, identification of soils and geologic types, localized climate, etc. Watersheds can be delineated on aerial photos, USGS 7 ½ minute quadrangle maps, or other topographic maps.

V. Identification of impacted areas and stream rehabilitation priorities

Stream restoration is part of an overall watershed plan to improve habitat and water quality. A watershed plan will assist watershed groups and other local entities in prioritizing restoration needs, with the most critical needs addressed first. To ensure success at the least cost, careful planning and consultation with professionals with the appropriate expertise is necessary. The steps below provide assistance in attaining the objectives of the restoration.

1) *Identify the problems* (nature of impairment) and cause(s) and (disturbances) in the watershed and cease (or modify) those activities causing the stream degradation, if possible. Often times, eliminating or modifying the degrading activity will allow the stream to recover over time on its own. If rehabilitation actions are deemed necessary, begin gathering information about the watershed. In some watersheds, there will be extensive information about vegetation, water quality, stream morphology, geology, precipitation, streamflow, land use, etc. to draw from. In cases where little information is available, stakeholders will have to spend additional time reviewing maps, aerial photography, and collecting data.
2) Develop restoration goals and objectives. They should be realistic and cost effective and be based on reference condition.
3) Consider alternative treatments appropriate to the watershed/landscape.
4) *Assess the stream* of interest with an interdisciplinary group with knowledge of water, riparian corridor, wildlife, botany and fish resources. The watershed group and other stakeholders should walk the entire stream reach (both above and below the problem area) to assess the problem areas. It is also critical to assess and identify healthy stream and riparian areas for potential reference reaches. Using the *Proper Functioning Condition* survey technique or other acceptable technique would be useful in this step (refer to *Planning and Implementation Tools* section).
5) *Quantify* the magnitude of the problem and prioritize these problems; for example, the number of feet of eroding banks, the amount and composition of riparian plants, presence or absence of aquatic life, and the quality of in-stream habitat features such as pools.
6) Develop a restoration/*rehabilitation plan*. The plan should contain a range of alternatives and develop cost estimates for each alternative. An option common to all alternatives is to cease the degrading activities, if possible, that may have caused the problem initially. Alternatives may involve just planting native vegetation in a riparian area, or in some cases, the most extreme measure of installing in-stream structures to achieve the appropriate objectives. Alternatives should also evaluate management practices in the

contributing watershed that need to be addressed to enable a stream restoration project to be successful.

7) *Riparian Area improvements*. Consider actions that improve the amount, distribution and composition of native plant species. In some cases, willow plugs may suffice to control erosion. In other situations, bioengineering techniques may be necessary. Stream bank rehabilitation may involve the “pull-back” of stream banks to attain a favorable angle of repose for planting or installing bioengineered mats (refer to Gray and Sotir, 1996).

8) *In-stream structures and bank protection*. These measures are inherently expensive and require an in-depth analysis of the physical and hydrologic processes occurring along the stream reach of interest, as well as reference reaches (consult information below and references). The need for in-stream structures must be considered in the watershed context. Often times correcting instability in one location with a fixed structure will result in creating an area of instability either upstream or downstream of the project location. This just moves the problem and is not the correct solution.
If in-stream structures are deemed necessary, they must be properly designed and installed to be self maintaining over a wide range of flows. Reputable contractors that have expertise in fluvial geomorphology and stream channel restoration are necessary for implementing successful plans. References are listed to help project sponsors and others better understand fluvial and watershed processes and the breadth of data collection needed. Any earth moving in or along a stream will require permits.

9) *Identify monitoring* and long-term maintenance needs. Annually evaluate whether you are meeting your restoration objectives (CRA, 2001). This often overlooked step is critical in determining the effectiveness of the project. Practice adaptive management for those objectives not being met. The attached references can help determine the appropriate monitoring objectives and techniques. The amount and type of monitoring conducted will vary depending on the scope of restoration/rehabilitation activities. Physical (morphology and vegetation) and biological (macroinvertebrate sampling) will be necessary to determine reference or expected conditions, as well as the relative success of the project.

10) Identify potential partnership opportunities for the sharing of information and resources (cash and in kind support).

11) Identify necessary federal, state and/or local permits. For example, a Section 404 permit from the US Army Corps of Engineers may be required for activities within waters of the United States.

VI. Reference sites and the concept of expected condition

The stream morphology data collected at the reference site are applied to the impacted site to achieve desired restoration goals and stream conditions. The reference stream reaches that define the “*Expected Condition*”[1] need not be located in pristine areas, because these streams may not available, nor have similar stream morphology, geology, climate, range of streamflow, soils, precipitation, or land use history. The Aquatic Life Workgroup and WQCD developed the concept of *Expected Condition* when comparing a potential impaired stream reach to another stream of interest. *Expected Condition* is defined as: the condition of a water body resulting from the best biological, physical and chemical conditions attainable (considering past, present and future beneficial uses) given reasonable and appropriate land, soil and water quality management practices and avoiding material injury to water rights. “Where feasible, the expected condition for a water body, or group of water bodies, will be determined based on the best conditions that can be attained by an aggregate of similar water bodies within a regionally partitioned framework (i.e. ecoregions, elevation, and stream size)." *Expected Condition* is determined on a site specific basis and is based upon several acceptable reference sites (if available), to properly design stream restoration projects for the impacted stream of interest. The reference reaches chosen may be minimally impacted (non-urban areas), but must represent the stable form of the impacted channel within a similar valley type, stream type and physiographic characteristics.

In urban settings, most streams have been highly altered over time by check dams, diversions, canals, "hardening" of streams with rip-rap and concrete, and straightening of stream channels. Locating a stream to represent an *expected condition* for an urban stream may prove to be problematic. In urban settings, professional engineers or water resources professionals may have to focus on locating streams (expected condition) with similar streamflow, particle size distribution, bankfull width and depth, and gradient characteristics. Input from the Urban/Construction Committee will also be useful in determining proper streams for the *expected condition*.

A. Reference Site Selection

Reference site locations include sites directly upstream from the nonpoint source problem, and sites in comparable watersheds. The selection of sites may be made from areas that have the least anthropogenic influences, and represent the best attainable conditions that can be achieved by similar stream types within the watershed, or adjacent watersheds. Moreover, reference sites must be representative of the stream and habitat types of interest. Examples are offered below:

* Physical characteristics typical of the region (e.g., ecoregion (Hughes et al 1986) climate, topography, geology, and soils).
* Similar stream morphology typical of the region (e.g., Rosgen (1996) channel type, pools, riffles, runs, backwaters, and glides). For urban settings, the best attainable expected condition may be significantly altered from pre-development times.
* Representative diversity of substrate materials (fines, gravel, cobbles, boulders, woody debris) appropriate to the region.
* Similar streamflow characteristics - in some cases, the flow patterns display large seasonal differences in response to rainfall and snowmelt; in other cases, diversions, irrigation return flows, and stream alterations (in urban settings) will have to be analyzed.
* Banks representative of undisturbed streams in the region (generally covered by riparian vegetation with little evidence of bank erosion, or undercut banks stabilized by root wads.) Banks should provide cover for aquatic biota.
* Natural color and odor - in some area, clear, cold water is typical of the water body types in the region; in others, such as the Colorado River, the water may be more turbid.
* Natural riparian vegetation representative of the region.

Ideal <u>considerations</u> for good reference sites are:

- No upstream impoundments or significant diversions.
- No known point source discharges or contaminants in place.
- No known spills, pollution incidents, or hazardous waste sites.
- Low human population density, agricultural activities, and low road densities.
- Minimal nonpoint source problems.

Impaired sites displaying channel instability occur in a variety of ecosystems, from effluent dominated streams and streams receiving stormwater runoff in urban areas to high elevation streams in forested areas. The processes that determine the dimension, pattern and profile can be very different for varying geology, soils, precipitation, as well as, urban, agricultural and forested watersheds. The project proponents must also understand the streams stage of degradation or aggradation.

VII. Stream channel hydraulics and processes

To properly implement stream restoration projects, understanding channel adjustments requires an understanding of changes in streamflow and sediment delivery processes, as well as an understanding of watershed processes and land use. Streams are constantly adjusting to the water and sediment produced by the upstream watershed. It is important to understand the range of flows produced by the upstream watershed, as well as the role of bankfull discharge in moving sediment and shaping stream channels.

The bankfull stage corresponds to the discharge at which channel maintenance is most effective; moreover, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the morphologic characteristics of channels (Dunne and Leopold, 1978). The bankfull stage is the most effective or is the dominant channel forming flow over time, and has a recurrence interval of approximately 1.5 years. Bankfull flows occur every other year and may occur several times within a water year. Rosgen suggests the importance of bankfull morphologic features and identifying stream types in applying the correct restoration technique.

Regional curves and hydraulic geometry relations are useful (as a "1st cut") to gain some understanding of how bankfull channel dimensions change in the downstream direction for a particular watershed, and the potential design criteria for a stream restoration project. The curves relate independent variables, such as discharge or drainage area, to dependent variables such as width, depth, slope, and velocity.

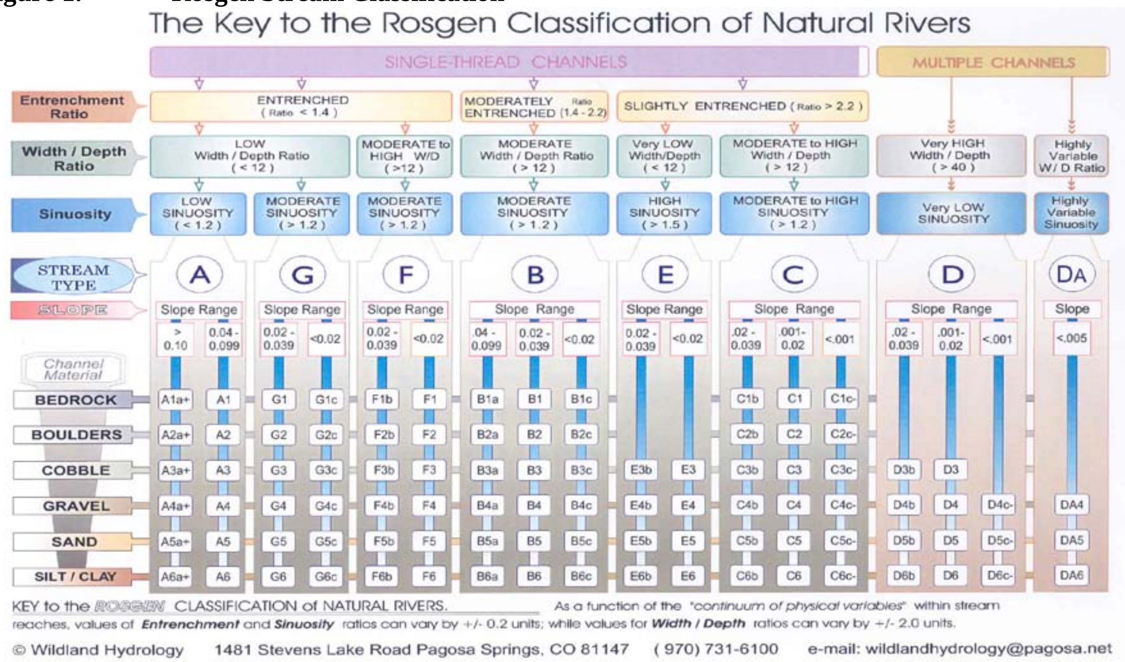
Regional curves for a particular area in Colorado can be developed by visiting current and past USGS gauging stations and gathering bankfull dimensions, as well as analyzing discharge data collected by the USGS. Regional curves should only be used as indicators to help identify the channel geometry at a restoration site, because of the large degree of natural variability in sites. For additional information on developing regional curves, review the procedure described by Rosgen, 1996. It can't be understated that field collection of channel morphology data for several cross sections at both the reference and design reaches is absolutely necessary.

A. Stream Classification

Stream classification can be useful in better understanding complex relationships between flow, sediment and stream morphology. Although following a stream classification is not necessary to design a restoration project, it does provide a step-wise process for collecting geomorphic field data that is important prior to implementing a stream restoration project. The Rosgen stream classification is arguably the most widely recognized and used classification nationwide. Refer to Applied River Morphology for more in-depth information on his classification.

The Rosgen methodology uses six morphological measurements for classifying a stream reach – entrenchment (level of incision), width/depth ratio, sinuosity, single and multi-thread channels, slope and bed material particle size. These criteria are used to define eight major stream classes (Figure 1).

Figure 1. Rosgen Stream Classification



- Rosgen uses the bankfull discharge to represent the channel forming flow and proper field identification of the bankfull stage is critical in using his classification. Moreover, all the morphological relationships are based upon the bankfull discharge; width/depth ratio is determined at the bankfull stage of the stream.

VIII. Riparian Vegetation

Riparian areas are lands directly influenced by the presence of flowing water – creeks, streams, rivers, ponds, lakes, and other bodies of surface or sub surface water (Naiman, 1992). Riparian areas are typically only a small portion of the overall watershed acres, but the diversity of vegetation and ecological processes therein are important for aquatic and wildlife species. Riparian vegetation provides the following benefits to stream channels:

- Dissipate stream energy and power associated with high streamflows, thereby minimizing erosion and maintaining existing water quality.
- Filter sediment, capture bedload (material transported downstream by rolling or bouncing along the stream bottom), and aid in floodplain development.
- Improve flood-water retention and ground water recharge.
- Provide shade that maintains or reduces temperature regime and marked fluctuations.
- Reduces nutrient loads to streams.
- Stabilize stream banks with vegetation.
- Reduce erosion by uncontrolled runoff (i.e. return flows).
- Protect fish habitat.
- Maintains ground water and surface water interactions, which are important to aquatic macroinvertebrates.

Vegetation is a fundamental controlling factor in stream corridor function, and restoration designs should protect existing native vegetation and restore native vegetation structure whenever possible. This may be challenging in deeply incised streams and/or in urban stream corridors, but every opportunity should be explored to improve vegetative cover along streams. Examination of reference reaches is a good way to determine the plant community composition and distribution needed at the disturbed site. It appears that the current trend in establishing vegetation is to plant a variety of species for improved habitat conditions. Numerous species have been used in stream restoration, including willows, alder, serviceberry, oceanspray, vine maple, cottonwood, poplar, and others. However, historical accounts of the area, as well as information from the reference reach, may dictate that only one species is planted rather than a mosaic of species.

Some streams flow through areas that receive very little precipitation, and the geology is such that little to no riparian vegetation is likely to be present. Intermittent and ephemeral streams have little to no riparian vegetation due to short periods of flow. Restoration objectives for these streams will be very different than perennial streams. Intermittent (or seasonal) streams flow at certain times during a year when they receive water from springs or snowmelt. Intermittent streams may flow longer than 30 days (+/-) as groundwater continues to recharge the channel, whereas ephemeral streams are likely to flow for very short periods (depending on the physiographic region) in direct response to convective thunderstorms, snowmelt runoff or overland flow. The amount and composition of vegetation in these streams depends on the period of flow, as well as the connectedness of the stream to the riparian area and water table. Ephemeral streams are generally above the water table. Given the importance of riparian vegetation, bioengineering must be considered in any stream bank restoration project. Even in urban settings where rip-rap has been used routinely for bank protection, willow (or other species) plugs can be installed between the rocks (Gray and Sotir, 1996).

IX. Best Management Practices/Planning

Best Management Practices (BMPs) can be defined as methods, measures or practices selected by an agency, watershed group, company or responsible party that meets Colorado's Nonpoint Source program. BMPs can describe a wide range of management procedures, scheduling of activities, operating procedures, treatment requirements and practices to control site runoff and sediment.

Nonstructural BMPs, such as preventative maintenance or preserving native vegetation, are components operational or managerial techniques. There are also structural BMPs such as diversion structures, silt fences and retention ponds to be considered. Such activities should be applied before, during and after activities to reduce or eliminate sedimentation. Since restoration/rehabilitation activities are considered construction activities, a review of the *Urban/Construction* BMPs found in this manual are suggested. Although the use of BMPs is voluntary, they are necessary to maintain or improve water quality over the long term. The following references and guides provide the specific information necessary for identifying the appropriate components to this best management practice. Many of these references are available on the Internet.

<u>Planning and Implementation Tools</u>

- Stream Corridor Restoration: Principles, Processes and Practices (The Federal Interagency Stream Restoration Working Group, 1998). See http://www.nrcs.usda.gov/technical/stream_restoration for the publication.
- National Management Measures to Protect and Restore Wetlands and Riparian Areas for the Abatement of Nonpoint Source Pollution (June 2001) EPA 841-B-01-001 (www.epa.gov/owowtr1/NPS/wetmeasures/wetmeasures.pdf)
- Applied River Morphology (Rosgen, 1996).
- Reconfigured Channel Monitoring and Assessment Program for additional information at http://co.water.usgs.gov/projects/rcmap/rcmap.html
- Colorado Riparian Association, 2001. Colorado Stream Corridor Guide. Information about the guide can be found at http://www.coloradoriparian.org
- An Introduction and User's Guide to Wetland Restoration, Creation and Enhancement. Interagency Workgroup on Wetland Restoration (www.epa.gov/owow/wetlands/restore/finalinfo.html)
- Principles for the Ecological Restoration of Aquatic Resources (USEPA, 2000) EPA 841-F-00-003 www.epa.gov/owow/wetlands/restore
- US Forest Service, Natural Resources Conservation Services and US Bureau of Land Management, 1998. A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas.
- USDA Forest Service Watershed Conservation Practices Handbook (FSH 2509.25) and other technical references www.fs.fed.us/im/directives/dughtml/fieldfsh2000.html
- Colorado Association of Stormwater and Floodplain Managers, Habitat Habitat Assessment Field Data Sheet, 2pp.

X. Who to Contact for Assistance in Planning and Implementation

The best source of assistance for planning and implementing any best management practice will be in the locality where the BMPs are used. Local offices of the various natural resource management agencies, whether local, state, or federal, can develop site-specific recommendations or designs that account for the local climate, soils, hydrology, etc., as well as any social or cultural considerations. In addition, topic-related professional organizations may also have the resources to provide assistance. There are also environmental resources consulting firms that provide stream restoration services.

XI. Examples of BMPs and other project design features

- Conduct activities during dry periods to minimize runoff and sediment delivery downstream. State and/or Federal permit(s) should have guidance on periods of operation.
- Comply with all requirements in permits. Projects may require a Phase II stormwater permit, and/or Corps of Engineer's 404 permits, respectively.
- Use silt fences and/or mulch to maintain sediment on site during construction activities.
- Complete the work in a reasonable time frame, or as designated in the permits.
- Minimize the amount of ground disturbance at the site.
- New access roads and drainage must be built to acceptable State and Federal engineering standards and reclaimed once work is completed.
- Comply with all applicable State and Federal Statutes.

- If fish are present at the site or downstream, conduct activities during periods when fish are not spawning, or when sediment delivery would not affect egg survival.
- Avoid activities near raptor nest sites or other critical habitat.
- Determine if drinking water sources downstream may be affected and notify the appropriate people.
- Re-vegetate or otherwise stabilize disturbed sites as soon as practicable following disturbance.

XII. Monitoring and Measurable Results

The Colorado Nonpoint Source program requires measurable results for all stream-restoration activities funded by EPA 319 grant money. Measurable results are numeric, and calculations for tons of sediment saved from the stream, or percent decreases in sediment load or sediment concentration must be determined. Restoration activities, such as fish structures, riparian plantings, or gravel placement in streams (for fish) typically are not sediment related and other measurable results would be valid. In these cases, pool habitat created, feet of bank restored, or acres of riparian habitat restored are reasonable measurable results. Measurable results enable the Water Quality Control Division (WQCD) to evaluate the success of the stream restoration activities by comparing pre- and post stream restoration conditions. Coordination between the WQCD and project proponents is important in collecting the appropriate data to obtain measurable results, as well as determining the measurable results of the project. Whenever practical, monitoring should be conducted through a cooperative arrangement among the various stakeholders, state and federal agencies. In some cases, state or federal agencies may have data that could supplement data to be collected per requirements in a *project implementation plan*.

The WQCD and stakeholders need to collaborate on selecting monitoring approaches, measurement and sampling methods, and overall monitoring design, including frequency and locations of sampling and measurements to evaluate success. Quality control and data quality will also be addressed in quality assurance plans. It is recommended that project sponsors consult with the Division prior to submitting a stream restoration/rehabilitation project to improve project objectives, design, and monitoring guidelines to ensure the approach is appropriate for the specific stream reach.

Measurable results can only be determined if baseline information or data are collected before the stream-restoration/rehabilitation activity. Depending on the scope of activities, maintenance and monitoring after the project will be necessary, and should be completed at appropriate time intervals. Monitoring results should guide decisions, such as the need to make potential adjustments to the project and determine measurable results. Project maintenance, monitoring schedule and approach should be adjusted (if necessary) to account for the variability in results over time. Selection of a particular monitoring approach will depend on the following factors:

- Monitoring Objectives – determining the objective is critical.
- Site and reach characteristics
- Scope of the project
- Cost
- Time available for the study
- Resources available

Examples of monitoring approaches to determine measurable results include**:**

- Collecting water-quality samples and analyzing for sediment concentration and particle size characteristics, such as percent silt- and clay-size material (Edwards and Glysson, 1999). Other constituents of concern may be collected and analyzed at this time, if necessary.
- Measuring macroinvertebrates, stream temperature or turbidity by acceptable scientific methods may be necessary in some situations depending on identified beneficial uses.

Geomorphology measurements (Elliott and Parker, 1999; Harrelson and others, 1994) and appropriate permits will be required if there is manipulation of the bed and banks of a stream. Some monitoring tools are suggested here:

- Surveying channel cross sections and longitudinal profile surveys of the streambed and channel banks to determine channel morphology through the monitoring reach
- Comparing aerial photographs to determine previous channel position, pattern, and depositional areas. After restoration to estimate improved stability of channel (channel pattern, width, sediment bar size, headcutting distance, area of vegetation) to determine sediment saved from erosion
- Measuring from bank pins to bank edge to calculate sediment saved from or lost to channel erosion
- Measuring changes in stream-bank height on bank pins or other reference point
- Measuring vertical distance from top of bank to stream bed
- Measuring stream-bank angles - these highlighted bullets can be determined from the cross section and longitudinal surveys.
- Measuring the volume or mass of sediment removed from or deposited in an area of the stream

Stream-bottom-substrate measurements (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2002):

- Measuring the extent that large particles are embedded or buried by fine sediment (MacDonald et al., 1991, p. 121)
- Measuring the percent of stream bed composed of fines <2mm (CDPHE, WQCD, not dated)
- Measuring the volume of pool occupied by fine sediment (Lisle and Hilton, 1992)
- Measuring the accumulation of fine particles in interstitial spaces of coarse-particle substrate (Carling and McCahon, 1987; Frostick et al., 1984)
- Measuring the subsurface particle-size distribution in cores (Petts, 1988; Lisle, 1989)
- Measuring the subsurface particle-size distribution through an in-situ sample of known volume (Lambert and Walling, 1998; MacDonald et al., 1991, p. 119; Platts et al., 1983, p. 17)
- Measuring the particle-size distribution in a specific area of stream bank, stream bed, or bar by measuring the intermediate axis of gravels, pebbles, cobbles, or boulders (Wolman, 1954; Bevenger and King, 1995)

Bioassessment measurements (Colorado Water Quality Forum, 1995; Plafkin et al., 1989;):

- Counting or measuring growth in vegetation planted to stabilize stream banks (percent cover, stem counting or in-depth community surveys)
- Counting the number (population) or biomass of each key aquatic species
- Counting the number of species at key locations (diversity measure)
- Calculating indices of community structure from benthic macroinvertebrate data
- Testing for the presence and quantity of trace elements or organic contaminants (Shelton and Capel, 1994)

Hydrologic measurements:

- Measuring streamflow at key locations (Carter and Davidian, 1968; Buchanan and Somers, 1969)

The measurements done to determine the success of the stream-restoration activity should be appropriate for the goal (or objective) of that stream-restoration activity. The matrix below is a guide to assist in determining the appropriate monitoring for various environmental goals.

Water Quality Component of Restoration

Water-quality goal	**Stream-restoration activity**	**Task**	**Baseline information**	**Post-activity information**	**Calculation of result**
Decrease sediment concentration in stream or downstream	Stabilize bank	• Plant vegetation • Add root wads • Flow-steering structures (J-Hooks, cross vanes)	• Bank geometry • Vegetated area • Channel surveys (XSect, longit)	• Bank geometry • Vegetated area • Channel surveys (XSect, longit)	Estimate mass of sediment saved out of the stream
Decrease sediment concentration in stream or downstream	Change stream morphology	Reconfigure channel	• Sediment concentration in stream • Stream depth, velocity Channel surveys	• Sediment concentration in stream • Stream depth, velocity Channel surveys	Difference in sediment concentration, depth, and velocity in stream
Decrease sediment concentration in stream or downstream	Filter runoff	Plant vegetation	Vegetated area Turbidity of stream	Vegetated area Turbidity of stream	Difference in vegetated area, turbidity
Decrease sediment concentration in stream or downstream	Slow the stream	Add drop structures and/or increase sinuosity	• Stream velocity • Sediment concentration • Channel surveys	• Stream velocity • Sediment concentration • Channel surveys	Difference in stream velocity, sediment concentration
Improve fish habitat	Decrease stream temperature	• Increase channel depth to width ratio • Add vegetation canopy • Add boulders or snags for cover	• Stream temperature • Bioassessment measurements	• Stream temperature • Bioassessment measurements	Difference in stream temperature, bioassessment measurements

Biological Component of Restoration

Water-quality goal	Stream-restoration activity	Task	Baseline information	Post-activity information	Calculation of result
Increase the abundance and diversity of aquatic macroinvertebrates	- Change stream morphology - Vegetate stream banks - Add root wads, boulders, trees to improve cover.	- Decrease width/depth ratio, increase sinuosity - Reduce fine sediment - Reduce fine sediment and increase pool habitat.	- Sediment concentration in stream, stream depth, velocity - Channel surveys Bank geometry, channel cross sections - Channel surveys, streamflow characteristics	- % of vegetated area and determination of mortality. - Channel surveys - Macroinvertebrate surveys and lab results - # of structures that moved or transported downstream	# of feet or acres treated Differences in fine sediment, vegetative cover, pool – riffle habitat, and #'s of structures in-place and functioning
Improve stream corridor vegetation composition and water availability through weed treatments	Mechanical, chemical and/or utilize biological agents to eradicate weeds. Plant native vegetation	Improve species composition and water quantity and quality by removing weeds. Tamarisk and Russian Olive are phreatophytes that use more water than native plants	Establish plots and conduct weed inventory along stream corridors	Re-visit plots to determine effectiveness of treatments	# of feet or acres treated. % reduction in weeds.