Common Problems Addressed in Stream Restoration

Introduction

Streams are dynamic systems that adjust to tectonic, climatic and environmental changes imposed upon them (Dollar, 2000). Environmental changes can be either human-induced or natural. A stream system adjusts in order to maintain a steady state, or dynamic equilibrium between the driving mechanisms of flow and sediment transport and the resisting forces of bed and bank stability and resistance to flow (Soar et al., 2001). For example, a river might respond to an increase in flow due to a change in land use by adjusting its channel morphology and position on the floodplain until a new steady state is reached. However, there are times when the environmental change is so great that the stream system adjusts and/or reaches a new steady state that is considered an irreversible degradation of geomorphic, hydraulic, or ecological processes of the stream system, and restoration measures may be necessary.

Stream restoration has become a multi-billion dollar industry and a diversity of techniques have been developed and practiced. Various perceptions exist as to what is meant by the term "restoration." Wohl et al. (2005) emphasize that these perceptions reflect the wide range of stakeholder interests, scientific knowledge, scales of interest, and system constraints encountered in practice. Bernhardt et al. (2005) conducted a review of more than 38,000 projects identified as restoration projects in the United States. They concluded that the majority of projects had one or more of the following objectives: (1) enhance water quality, (2) manage riparian zones, (3) improve instream habitat, (4) create fish passage, and (5) stabilize stream banks. In recent years, river managers and scientists have proposed the term "restoration" be used only for projects with the objective of assisting in the establishment of improved hydrologic, geomorphic, and ecological processes in a degraded watershed system and replacing lost, damaged, or compromised elements of the natural system (Wohl et al., 2005; Kauffman, 1997; Palmer, 2005; and Roni et al., 2002). Recently, Palmer et al. (2005) proposed standards for measuring and guiding restoration success, with emphasis on a watershed-scale, ecological approach. These standards were endorsed by an international group of river scientists (Jansson et al., 2005) and practitioners (Gillilan et al., 2005).

Common Restoration Problems and Solutions

Below are common problems that river managers face in degraded stream systems, and a list of common restoration solutions that can be implemented to alleviate these problems. Regardless of the scale of the restoration objectives, the decision to proceed with restoration work on a stream requires a balance between the necessity and achievability of the restoration objectives based on a scientific evaluation, and economic and social constraints. Furthermore, the decision must be based on an understanding of the processes that affect river morphology, hydrology, and ecology and the cause of the disturbance to these processes. According to Evan S.J. Dollar (2000), "It is clear that tectonic, climatic and environmental changes have impacted fluvial [river] systems throughout geological time. It is necessary that this [be brought] to the attention of river managers, as it is possible to misinterpret natural instability in fluvial systems as being an impact, or to misdiagnose cyclical changes as channel instability, or to exaggerate human impact."

I. Bank Instability

Riparian plant roots penetrate and bind together channel bank soils, providing stability and resistance to stream bank erosion from the constant frictional forces of downstream-moving water. Poor landuse practices, channel entrenchment, and/or hydrologic changes may cause severe disturbance of the vegetation and/or lowering of the groundwater table below the riparian root zone (Skinner et al., 2000). Stream bank instability is characterized by sparse riparian vegetation and excessively eroding cut banks, which may slough into the active stream channel (Skinner et al., 2000). Stream bank erosion impairs instream habitat through generation of sediment, reduction in habitat complexity, and reduction in cover provided by stream banks and vegetation (Skinner, 1983). Examples of bank stabilization techniques used to stop excessive erosion of stream banks include:

Sloughing of unstable channel bank. Source: Skinner et al., 2000.

1) Riparian vegetation management to enhance riparian vegetation re-growth and associated root stabilization of bank soils;
2) Biotechnical slope protection using living vegetation and/or other natural or synthetic stabilizing components;
3) Armoring the stream channel with stone, cement, or other revetments; and
4) Use of structures that extend into the stream channel to redirect the flow and reduce the erosive stream power on the banks.

II. Sedimentation

Bank instability and erosion frequently results in excessive sediment inputs into stream channels. Sediment increases the turbidity of a stream and may adversely affect aquatic life and fisheries through sediment deposition in pools, spawning gravels, and stream-bottom habitat for aquatic invertebrates, and by restriction of light penetration necessary for photosynthesis by aquatic plants (Skinner, 1983). Excessive sediment inputs may also alter the stream channel morphology and change the composition of aquatic habitats and associated fish and macroinvertebrate communities. Potential sources of sediment include erosion of poorly vegetated and/or disturbed areas. The source can be local — such as stream banks or beds, and irrigation canals. Other sources may be runoff from poorly vegetated upslope areas affected by natural disturbance such as landslide or fire, or by human disturbance such as poorly located or constructed roads, and poorly managed timber harvest, mining,

Potential sediment from poor road construction and maintenance. Source: Skinner et al., 2000.

construction or agricultural practices. In stream systems with excessive erosion and sedimentation, reduction of sediment can only be effectively accomplished by addressing the source of sediment. This is typically accomplished by allowing for the reestablishment of vegetation on the eroding surfaces, either through changing landuse practices, seeding or planting. Severely eroding surfaces may also require slope regrading, decommissioning (removal) of poorly constructed roads, and/or implementation of management practices that minimize erosion from road surfaces (Roni et al., 2002).

III. Over-widened Channels

Unhealthy riparian areas with unstable stream banks can accelerate lateral erosion of riverbanks. This increases stream width and decreases stream velocity, which causes sediment deposition. Over-widened channels are characterized by a high width-to-depth ratio (calculated from river cross-sectional data), a lack of pool/riffle habitat, and a flat channel bottom (FISRWG, 2001). Extreme sediment deposition may result in a change in channel morphology from a single channel to a braided channel (Skinner, 2000). Restoration of over-widened channels may require using excavated substrate material and importing gravel and cobble or blocks of riparian vegetation to narrow the stream channel. Log jams and log complexes may also be used in decreasing the stream's width-to-depth ratio.

Braided channels are characterized by channel aggradation and a high width-to-depth ratio. Braiding may be natural, or induced from an upstream source of sediment. Source: Skinner et al., 2000.

IV. Channel Incision

The loss of energy-reducing riparian vegetation and root structures may cause redirection of stream frictional forces to the stream channel bed itself. The result is vertical erosion of a channel bed leading to channel incision or channel entrenchment. The severity of entrenchment is defined by the degree to which channel flow is confined during flood conditions and the overall erodability of riparian soils relative to the stream bed (Wilcox et al., 2001). The confinement leads to an increase in stream velocity and rapid deepening of the gully. As the banks become increasingly steepened, they become very unstable and stream bank sloughing and sedimentation begins due to the erosive force of the stream at the toe of the slope. The nearly vertical banks provide poor fish habitat. Channel widening may then commence, due to collapse of over-steepened banks. In addition, meadow aquifers may drain as the water table lowers, resulting in a conversion of vegetation from wet-meadow

An example of a channel that has incised. Source: Skinner et al., 2000.

species to more drought-tolerant species, and the summer stream flows may shift from perennial to intermittent conditions (Wilcox et al., 2001). Modified stream flow in the summer months may result in conditions uninhabitable for fish. Examples of restoration actions for channel entrenchment are raising the elevation of the channel by: gully fill, check dams, beaver reintroduction, or complete valley re-grading.

V. Headcutting

Headcutting involves the initiation of channel incision at a nick point as the stream channel bed elevation adjusts to a natural or human-induced disturbance. The nick point can be as subtle as an over-steepened riffle zone or as obvious as a "waterfall" or cascade. As the streambed erodes and lowers at the nick point, the active headcut will migrate upstream (Wilcox et al., 2001). Headcutting may eventually cause channel incision. Controlling a headcut is one of the most difficult challenges in stream restoration. Common headcut treatments are installing check dams, or sloping the bank face and laying in fabric and rock to control continued upstream migration of the nick point. Other methods for headcut control are to elevate the channel by: gully fill or complete valley re-grading.

An active headcut caused by channel elevation adjustment. Source: Skinner et al., 2000.

VI. Channel Avulsion

Channel avulsion is a sudden shift in channel location. Avulsions are formed during large storm events when high discharge erodes a new channel in the floodplain. Avulsions are more common in braided or aggrading stream channels (Washington Department of Fish and Wildlife, 2003). Rapid channel migration affects trout habitat through erosion and sedimentation and through reactionary attempts to stabilize stream banks to prevent further channel migration and excessive property loss.

VII. Channel Alteration

Channel alteration from bulldozing, dredging, and construction causes severe disturbance to the channel and to riparian vegetation. An example of channel alteration is channel straightening (channelization) to maximize land use. This disturbance can result in loss of floodplain connection and significant reduction in channel complexity important for fish habitat. Restoration of an altered channel may require reconstructing the channel. Channel design must take into account meander geometry, channel alignment, sinuosity, channel length and slope, channel cross section

A channelized stream through a developed area. Source: Skinner et al., 2000.

at design discharge, riffle/pool spacing, and channel stability (Washington Department of Fish and Wildlife, 2003). Reconstruction goals frequently center on reconnecting the stream and floodplain and recreating more natural channel geometries with the goal of restoring populations and habitat of individual species, or possibly restoring the entire ecosystem. In either case, using a guiding image is important in channel design (Palmer, 2005).

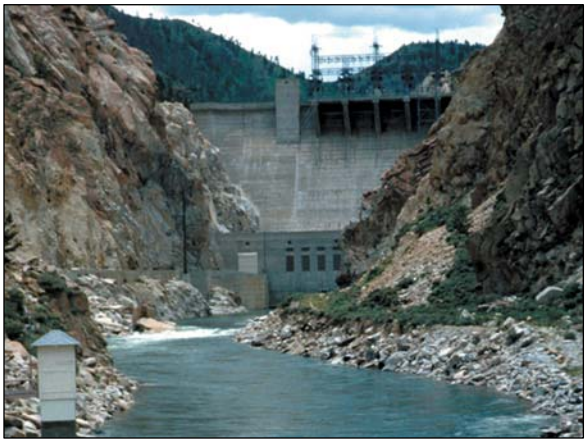
VIII. Berms, Levees and Dikes

Periodic flooding of rivers and streams and the subsequent inundation of the floodplain is a natural process. This process is important in sustaining the riparian community, and moderating surface and groundwater flow regimes by storing water in soils, stream banks and subsurface aquifers (Wilcox et al., 2001). This storage has the potential to extend late-season flow and benefit fish population survival. Construction of berms, levees or dikes has been a common practice for flood control. This practice leads to confinement of the channel, increased stream velocities during high-flow events, a cessation of the natural flooding process, and perhaps increased flooding downstream (FISRWG, 2001). Without flooding, riparian communities convert from water-loving species to more drought-tolerant species, and stream bank and aquifer storage of water necessary to sustain late-season flow may be lost (Wilcox et al., 2001). Mitigation for loss of the natural flooding process can be challenging if the purpose of the flood control structure is to protect development. For agricultural lands, conservation easements or increased setback of fields may allow restoration of the flooding process. In this case, complete removal of the levee or berm may not be desirable; a notch or a breach of the structure may suffice. In other cases, removal of the floodplain constriction may be needed to achieve desired reconnection of the stream and floodplain.

Photograph of the Sacramento River levee taken by Ayres Association for the U.S. Army Corps of Engineers on October 24, 2005. Source: CA Department of Water Resources, http://www.levees.water.ca.gov/report_photos.cfm.

VII. Flow Alteration

There are cases when the stream's natural flow regime and sediment transport capacity have been altered. Examples are dams and irrigation diversions, which can significantly decrease downstream flow. In highly-altered flow and sediment transport regimes (such as down stream of a dam) the current flow regime, sediment loads, and social and economic constraints on the system must be factored into the restoration approach. Another factor that must be considered is the amount of time the stream has been functioning under the altered flow regime and whether it has reached a steady



Dam on the Platte River constructed in the 1930s. Source: Skinner et al., 2000.

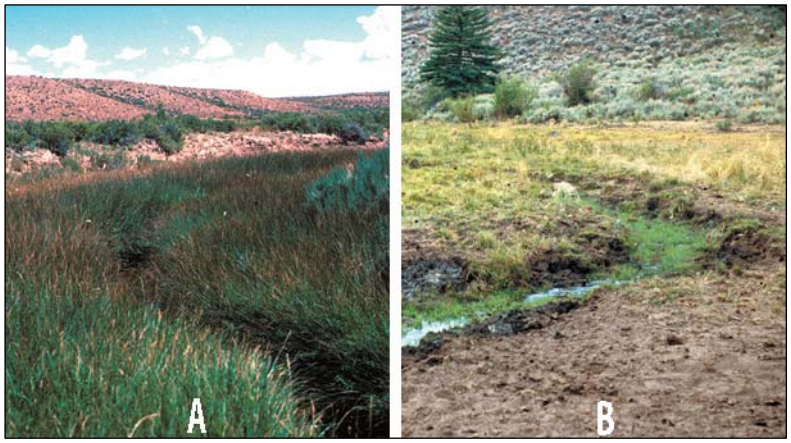
state (Wilcock et al., 1996). In recent years, the focus of river management for de-watered streams has shifted from determining a minimum flow requirement to recognizing the importance of floods in maintaining the dynamic nature of the stream's riparian and aquatic ecosystem (Kondolf and Wilcock, 1996). For example, water releases from dams may be designed for periodic flow events which cause transport of finer sediment from spawning gravels and flooding with inundation of the riparian zone.

VIII. Loss of Fish Habitat

In some cases, restoration efforts are directed primarily at restoring fish habitat in a particular stream. Common examples of habitat enhancement are the placement of materials, such as large pieces of wood or boulders into the stream channel, or manipulation of the channel itself to improve habitat for fish and/or other aquatic organisms. It is critical to understand habitat requirements at all seasons and for all life stages of the species of concern. In addition, habitat enhancement may be short-lived if the underlying processes causing habitat degradation are not addressed (Roni et al., 2002). Roni et al. (2002) state that habitat restoration should focus on restoring processes that form, connect, and sustain habitats. They emphasize that, by focusing on the restoration of natural processes, there is a higher probability of meeting restoration objectives and goals. It also enables the natural array of habitat types to form in all parts of a stream network. Moreover, this approach attempts to provide suitable habitats for all native aquatic species because it restores the conditions to which they are adapted.

IX. Reduction in Riparian Vegetation or Loss of Riparian Area

Riparian vegetation is critical to the over-all stream ecosystem. Plant roots provide stability to stream banks. The vegetation filters sediment and other contaminants from runoff (Skinner et al., 2000). Overhanging vegetation provides cover for fish and shade for stream temperature control. Logs from the riparian area can also be a source of instream fish habitat. There are cases where the riparian vegetation is reduced due to natural disturbance, such as fire or flood. Examples of disturbance due to human activity are:



A. Basin stream with lush grass riparian area: Source: Skinner et al., 2000.
B. Overgrazed and trampled riparian zone. Source: Skinner et al., 2000.

- Poorly located or constructed roads that negatively impact riparian zones through excess sedimentation and encroachment on the riparian zone;
- Overgrazing in riparian areas that leads to a loss of bank stabilizing plants, formation of an over-widened channel and increased sedimentation (Skinner et al., 2000). Reduction in vegetation can also lead to decreased cover for fish, and reduced shade to cool the stream;
- Timber harvest in riparian areas is typically no longer practiced, but effects of past logging practices in riparian areas are still apparent. A loss of stream bank stability and instream

large woody debris is common in logged riparian areas, which result in an over-widened channel and loss of fish habitat; or

- Encroachment on the riparian area by farming, development or other landuse practices.

Restoration measures to address a reduction in riparian vegetation may simply require a passive restoration approach, such as a change in land use within the riparian area. For example, one might exclude livestock grazing or implement a grazing management plan in the riparian area. Active restoration might include reseeding or replanting vegetation. Roni et al. (2002) emphasize the necessity for follow-up maintenance and protection measures in riparian vegetation replanting. Some trees and shrubs are vulnerable to out-competition by other species, and trees and shrubs planted in mesh tubing or another material are less vulnerable to browsing by deer and elk. Larger trees are vulnerable to beaver use. In cases where land development has encroached upon the riparian zone, restoration of riparian vegetation may be challenging, and in some cases, it may not be possible.

X. Fish Passage Barriers

Fish passage is critical to maintaining connectivity of habitat and/or populations. Fish passage barriers are man-made structures or natural obstacles, which are completely or partially impassable to fish. The barrier may be a velocity barrier and/or a vertical barrier based on adult or juvenile swimming and leaping capabilities (Roni et al., 2002). Barriers can inhibit fish from reaching their traditional spawning areas or colonizing areas up stream. They can also be a reason for fish mortality due to exhaustion from attempting to jump the barrier or from poaching below the structure. Barriers can also degrade fish habitat by altering or limiting the downstream movement of sediment, woody debris, and organic materials (Roni et al., 2002).

Beaver dams can be a partial or complete barrier to upstream fish passage. Source: Skinner et al., 2000.

Examples of man-made fish passage barriers are:

- Dams constructed for water storage or hydroelectric purposes that span the entire width of the stream or river;
- Road culverts, which may become a vertical barrier due to scour from a drop at the end of the culvert, or a velocity barrier during high flows if they are not constructed to accommodate bankfull flows; and
- Natural barriers like waterfalls, land or rock slides, log jams, narrow bedrock restrictions, and beaver dams.

Restoration of fish passage may include removal of the obstruction, replacing the culvert, or construction of a fishway, which provides a way through or around the obstruction. Examples of culvert replacements include bridges, open-bottom culverts or embedded (for example, countersunk) pipe-arch culverts (Roni et al., 2002). These structures allow continuity of the natural channel, which is important for the passage of adult and juvenile fish. Fishways generally consist of a flume with baffles or a series of stepped pools that slow

the water to a velocity easily negotiated by fish. Roni et al. (2002) emphasize that habitat quality above the fish passage obstruction is a primary factor when prioritizing fish passage restoration projects. Other factors to consider are risk of hybridization and spread of aquatic nuisance species and disease.

XI. Irrigation Canals and Diversions

It is a common practice to divert water from streams and rivers into canals for irrigation for crop production, flood control, hydroelectric production, and drinking water. In addition to decreasing instream flow, water diversions can block migration of fish as they travel up canals and become entrained in the canals, pipes, pumps, and even irrigation fields. Fish screens at the point of diversion are effective restoration practices to inhibit fish from swimming up the diversion and becoming entrained.

XII. Predation or Out-Competition of Native Fish

Many native fish species populations are dwindling due to predation or out-competition by non-native fish. In such situations, the installation of a fish passage barrier is an important tool in conservation of native fishes. They are constructed in stream to isolate native fishes from predaceous and competitive non-native fish, and to prevent hybridization with non-native fish. Fish passage barriers are vertical barriers constructed to inhibit upstream passage of fish based on fish swimming and leaping capabilities.

Fish passage barrier to keep brook trout from migrating up stream into restored westslope cutthroat trout habitat. Source: Ron Spoon, MT FWP.

XIII. Impacts from Mining

Impacts from mining on stream and riparian areas can be severe. Mining operations can severely disturb the landscape and/or stream-channel water quality. For example, early 20th Century gold mining was done in alluvial gravels using hydraulic systems, which often left the valley covered with conical tailings piles. These piles were sometimes placed to obstruct the floodplain and the course of the stream channel. Other impacts from mining are acidification of streams from acid mine drainage or metal contamination of the steam, which can result in conditions uninhabitable for fish. Reclamation of mine sites and impacted areas down stream can be challenging and might involve several steps to restore the natural physical, biological, and chemical conditions of the stream channel.

Mine tailings along a stream channel. Source: USFS Chugach National Forest.

References Cited

Bernhardt, E.S. et al. April 2005. Synthesizing U.S. river restoration efforts. Science 308: 636-637.

Dollar, E.S.J. 2000. Fluvial geomorphology. Progress in Physical Geography 24(3): 385-406.

Federal Interagency Stream Restoration Working Group (FISRWG). August 2001. Stream corridor restoration – principles, processes and practices, adopted as Part 653 of the National Engineering Handbook, USDA-Natural Resources Conservation Service. Available from: http://www.nrcs.usda.gov/technical/stream_restoration/.

Gillilan, S., K. Boyd, T. Hoitsma, and M. Kauffman. 2005. Standards for geomorphic river restoration projects: a practitioner's response to Palmer et al.. Journal of Applied Ecology 42(2): 223-227.

Jansson, R. et al. 2005. Stating mechanisms and refining criteria for ecologically successful river restoration: a comment on Palmer et al. Journal of Applied Ecology 42(2): 218-222.

Kauffman, J.B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22(5): 12–24.

Palmer, M.A. et al. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42(2): 208–217.

Skinner, M., and M. Stone. 1983. Identification of instream hazards to trout habitat quality in Wyoming. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-83-13. 69 p.

Skinner, Q.D. et al.. 2000. Wyoming watersheds and riparian zones. University of Wyoming Cooperative Extension Service.

Soar, P.J., and C.R. Thorne. September 2001. Channel restoration design for meandering rivers. U.S. Army Corp of Engineers. Report ERDC/CHL.

Washington Department of Fish and Wildlife. April 2003. Riparian habitat protection and restoration. Available from: http://www.wdfw.wa.gov/hab/ahg/ispgdoc.htm.

Wilcock, P.R., G.M. Kondolf, W.V.G. Matthews, and A.F. Barta. 1996. Specification of sediment maintenance flows for a large gravel-bed river. Water Resources Research 32: 2911–21.

Wilcox, J. et al., Feather River Resource Management Group. December 2001. Evaluation of geomorphic restoration techniques applied to fluvial systems. Available from: http://www.feather-river-crm.org/publications/preports/georest/cover.html.