Section 10.0
Channel and Floodplain Processes

Summary

Channel and floodplain processes are established by the continual interplay between runoff, sediment supply (erosion), and the slope of terrain across which the water flows. These forces also establish the parameters for the health of in-stream and streamside habitats. In several respects, the forces that maintain a healthy stream system are barely, or are no longer, functioning in the South Arkansas River. For instance, (1) the amount of water in the channel (runoff) has been affected by dams, water diversions, and development; (2) excessive erosion and deposition of fine sediments in the stream channel have increased due to changes in land use, both urban and rural; and (3) the channel has been straightened and otherwise constricted, adversely affecting in-stream and streamside habitat. As the river has reacted to these changes, humans have responded in many small ways at isolated locations as if the stream and the floodplain are separate, which they are not. Successful restoration requires clear understanding of the nature and extent of the disturbance as well as the nature of the channel and floodplain processes where restoration is planned.

This section discusses the physical processes that shape a river and its floodplain, how changes in those processes affect river and floodplain functions, and the resulting impacts on biological components of the ecosystem. The South Arkansas River and watershed are examined in light of those river and floodplain processes and how changes in those processes have affected and continue to affect the river.

Background

Channel and floodplain processes begin with climate and geology. Climate establishes the timing and intensity of precipitation. Geology establishes the parent material and topography upon which climate acts, and from which watershed substrate and soils are derived. Together, climate and geology determine rates of runoff, groundwater depth and rate of recharge, the character of the water that enters the stream, how quickly parent materials break down and weather to soil, and the character of that soil (e.g., erodibility, permeability). In turn, these factors influence a region's characteristic vegetation.

Stream channel and floodplain formation are created and sustained by the timing and intensity of runoff, the materials carried in runoff (sediment supply), and the slope of terrain across which runoff flows. The configuration and dimensions of an undisturbed stream system are considered to be in equilibrium with historical patterns of runoff, sediment supply, and slope. A river channel continually adjusts its width, depth, and shape to accommodate changes in the amount of water (“discharge”), the amount of sediments carried, and the slope of the terrain (Leopold 1994, Rosgen 1996; Figure 10-1).

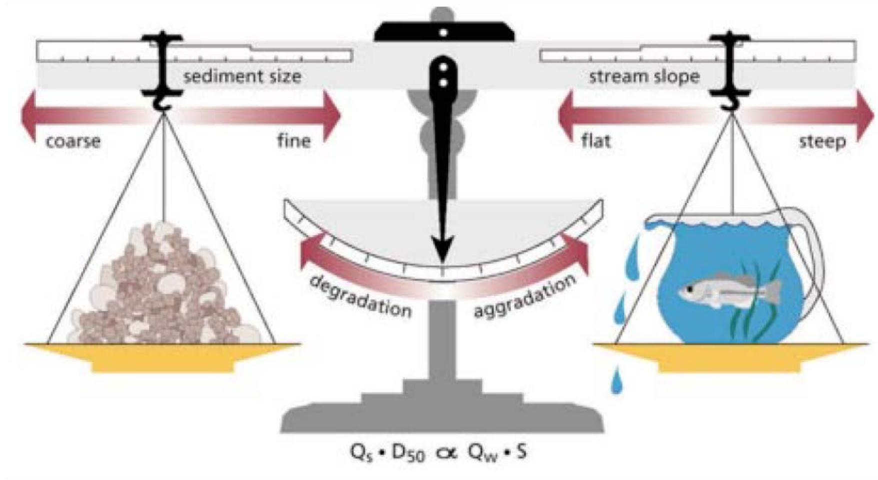

Figure 10-1. Depiction of interplay between stream flow, sediment supply, and slope (FISRWG 2001)

Changes in channel processes and dimensions that arise from changes in runoff, sediment supply, and slope may appear at the location of the change or they may be transmitted downstream a short or a long distance (Figure 10-2). For instance,

- If a large amount of water is diverted from a stream, the sediment carried to that point will be deposited in the immediate vicinity of the diversion structure.
- Hardening of a stream bank in one area may prevent erosion at that location, but the force of the water will likely erode other areas farther downstream, unless the original force is dissipated.

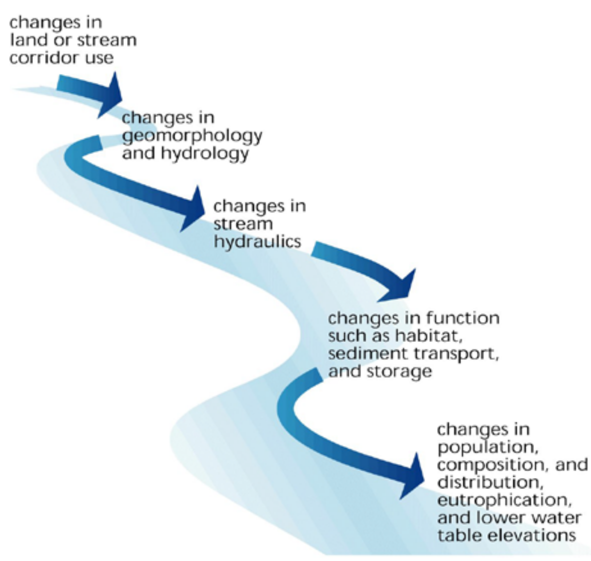

Figure 10-2. Disturbance is often transmitted downstream FISRWG (2001)

Floodplains

Floodplains are flat or nearly flat areas adjacent to a stream or river that experience periodic inundation. They range from large and distinct to small and inconspicuous.

Flooding, and the resulting erosion and deposition, heavily influence floodplain features, such as its shape, soils, vegetation, and the presence of wetlands. Flooding and the features it creates and maintains give rise to floodplain functions and values—the goods and services that society derives from floodplains, including:

- storing and conveying flood flows;
- reducing water velocities, the force of flood flows, and flood peaks;
- improving water quality by removing suspended sediments, nutrients, and other impurities;
- promoting infiltration and groundwater recharge, and sustaining stream base flows;
- enhancing agricultural lands and land productivity;
- providing open space and areas for active and passive recreation;
- providing resting, breeding, and feeding areas for wildlife;
- maintaining ecosystem integrity; and
- promoting biodiversity and protecting species of special concern (ASFPM 2008, ASWM 2011).

Floodplains are often considered as separate and distinct from the rivers within, but the processes that form the river-floodplain complex are inseparable from the functions and values provided by each. Floodplain encroachment and the loss of overbank flooding alter the natural components and processes and, therefore, alter the overall health of the system. For most regulatory purposes, the floodplain is defined as those areas that are likely to experience flooding once every 100 years. However, this definition does not usually correspond to those areas in a watershed or along a river that perform floodplain functions (ASFPM 2008, ASWM 2011).

Human activity that impacts floodplains often occurs in small ways at isolated locations, such as placing concrete slabs along an eroding back or pushing materials into flood-prone areas to expand developable space. Each activity yields site-specific benefits, but the impacts of such activities usually have repercussions elsewhere (Figure 10-2). This often leads to sometimes costly “reactive engineering” that also occurs in small ways at isolated locations. In this way, solutions continue to address symptoms rather than causes. Over the long term there is an “almost imperceptible destabilization of a watershed…[a] death by a thousand tiny impacts” (ASFPM 2008).

Large Woody Debris and Channel Processes

Headwater streams in forested areas are usually heavily influenced by large woody debris (Keller and Swanson 1979).[1] In such streams, woody debris is an important structural element that dissipates energy and alters channel flows, alters streambank and channel stability, and stores sediments and organic matter. These features

[1] Large woody debris has been variously defined as any woody material greater than one inch in diameter, as logs, limbs, and root wads at least four inches in diameter, and as wood at least six feet long and with one end greater than 12 inches (USFS 1990). Debris piles in streams composed of small limbs can also act like larger debris.

increase habitat diversity, create pools and provide cover for fish, and increase habitat and food for aquatic invertebrates at the base of the aquatic food chain. However, woody debris can reduce trout habitat quality by decreasing channel stability, reducing water quality, and blocking migration (Lienkaemper and Swanson 1987, USFS 1990).

The extent of woody debris in stream channels tends to be highest in first-order streams where trees are nearest the stream and where streams are smallest and stream power is lowest, that is, a small stream cannot move a large tree that has fallen across it. Woody debris is initially delivered to streams as a consequence of old age, bank erosion, windthrow, avalanches, and debris torrents. Thereafter, woody debris may be redistributed downstream by stream flows, abrasion, decomposition, and debris torrents. These patterns are often influenced by both prior and ongoing watershed activities, such as logging, land clearing for agriculture, and removal of debris from stream channels (Keller and Swanson 1979, Harmon et al. 1986, Lienkaemper, and Swanson 1987).

Analysis of South Arkansas River Channel Characteristics

Selected segments of the South Arkansas River were evaluated according to Rosgen (1996). This classification system involves analysis that uses increasing levels of watershed detail from valley-wide and landscape-level characteristics to site-specific stream physical, hydrological, and biological features and conditions. More intensive analysis is applied to a stream “reach,” a length of channel that has a consistent shape, that is, its planform (view from above) and profile (view in cross-section). An analyzed reach is usually 10 to 20 times the average width of the channel. At a minimum, data are gathered along a length of stream that includes at least two meander bends.

Conditions within the reach are governed by a fairly uniform set of conditions such that the reach provides “a useful scale over which to relate stream morphology to channel processes, response potential, and habitat characteristics” (Montgomery and Buffington 1998). In the Rosgen system, the reach selected for analysis “should be free to adjust its boundaries in response to frequent flows and should not have excessive deposition, nor constrictions.” Figure 10-3 depicts the location of the specific segments selected for more detailed evaluation. These segments were selected based on access and representative stream type. In the South Arkansas River project corridor, however, it was not possible to find reaches that extend through two meander bends and still exhibit these characteristics. Table 10-1 summarizes the results. (“CCR” refers to Chaffee County Road.) See Appendix F for stream profile and substrate data. Tributaries to the South Arkansas River are dominated by B-type channels with sections of lower-gradient C-type channels.

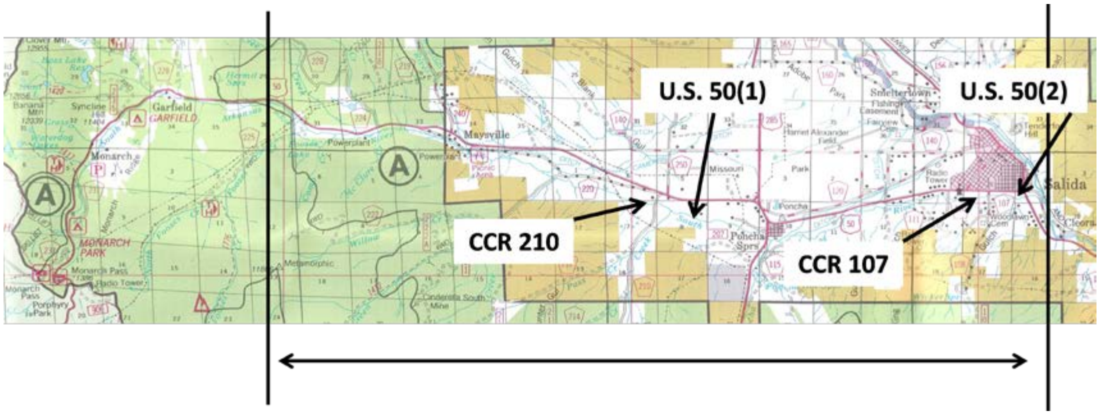

Figure 10-3. Channel evaluation sites in South Arkansas River project corridor

Table 10-1
Summary of Reach Analysis of the South Arkansas River

Site	Valley Slope (%)	Sinuosity	Entrenchment Ratio	Width-Depth Ratio	Pebble Count[2] (D_{50})	Stream Type
CCR 210	2.3	1.9	3.0	20	89 mm	C3
U.S. 50(1)[3]	1.4	1.1	2.1	16	90 mm	B3
CCR 107	1.4	1.2	1.4	11	103 mm	B3
U.S. 50(2)	1.8	1.2	2.3	19	98 mm	C3

The analysis of channel characteristics is used to determine what type of stream *should* be present given the landscape and channel information gathered. That information is compared to the type of stream that *is* present. This comparison also suggests factors responsible for current conditions and it guides subsequent restoration planning because stream types differ in how well various restoration techniques work (Rosgen 1996). For instance, most structural treatments work well in Rosgen B3 streams, but the suitability of those same treatments in Rosgen C3 streams ranges from excellent to poor (Figure 10-4) (Rosgen 1996). In C3 streams, some treatments are limited in terms of location and there may be need for additional bank protection to insure that the structure remains stable. Table 10-2 compares the sensitivity to change of two different stream types within the South Arkansas River project corridor.

[2] Silt and clay (< 0.62 mm); sand (0.62–2.0 mm); gravel (2–64 mm); cobble (64–256 mm); and boulders (256–4,096 mm). Pebble count procedure in Bevenger and King (1995).
[3] Source: Fitzgerald (2013)

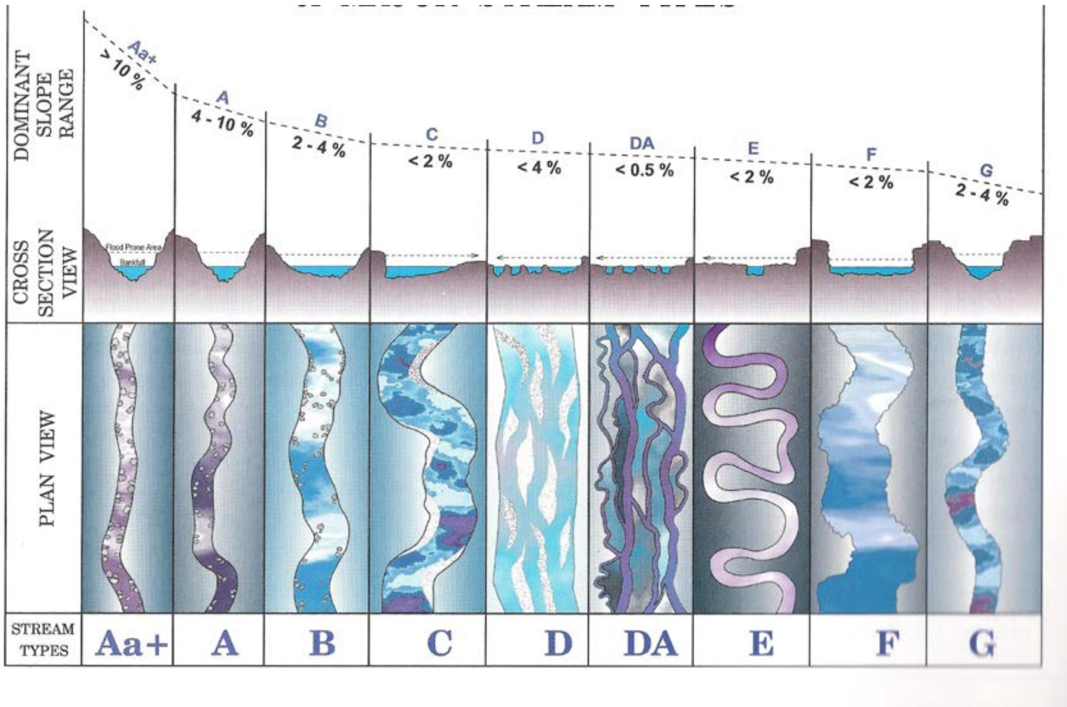

Figure 10-4. Channel types in the Rosgen classification system (Rosgen 1996)

Table 10-2
Comparison of Stream Type Characteristics—Disturbance and Recovery

Site	Rosgen Stream Type	Vegetation Control of Channel Stability	Streambank Erosion Potential	Sediment Supply	Sensitivity to Disturbance	Recovery Potential
CCR 210	C3	Very high	Moderate	Moderate	Moderate	Good
CCR 107	B3	Moderate	Low	Low	Low	Excellent

Channel and Floodplain Processes—
Impacts and Issues in the South Arkansas River and Watershed

The South Arkansas River within the project corridor exhibits several changes in stream flow, sediment supply, and slope that influence the river’s structure and function. These are summarized in Table 10-3; examples are depicted in Figures 10-4 through 10-8.

Table 10-3
Summary of Changes in Stream Flow, Sediment Supply, and Slope Observed in the South Arkansas River Project Corridor

Stream Flow Increase	Stream Flow Decrease
Development runoff	Water diversions Dams
Sediment Supply Increase	**Sediment Supply Decrease**
Tributary flows, debris flows Surface disturbance, urban runoff Excessive bank erosion	Bank hardening Dams and grade control structures
Slope Increase	**Slope Decrease**
Channel straightening	Grade control and water diversion structures

In Figure 10-5, a water diversion on the far bank reduces flow volumes, causes deposition locally, and leaves the channel too shallow for fish passage. In Figure 10-6, channel substrate is reconfigured to divert flows into an irrigation ditch. The periodic maintenance and seasonal reconstruction required represent ongoing channel disturbance as well as a source of turbidity and sediment. Other methods are available that do not require period reworking of the substrate. For example, in Figure 10-7, a large log diverts flows into an irrigation ditch to the upper left. The log is anchored into the banks on either side and serves to divert flows while also dissipating stream energy and providing fish habitat and passage. It will remain for many years and not require periodic maintenance or reconstruction of more common diversion practices.

Figure 10-5. South Arkansas River, 2012

In Figure 10-8, encroachment leads to straightening of the channel, loss of the floodplain access, and loss of the floodplain altogether in some situations. These changes usually involve loss of streambank vegetation that helps dissipate increasing stream energy and control or prevent streambank erosion. The usual response to the threat of erosion is hardening the stream bank, such as by installing wire gabions as in Figure 10-8 or the placement of other materials (Figure 10-9). Again, installing hardened banks to address erosion tends to transfer erosive forces—and the problem—

Figure 10-6. South Arkansas River, 2013

Figure 10-7. South Arkansas River, 2013.

Figure 10-8. South Arkansas River, 2012

Figure 10-9. South Arkansas River, 2012

downstream. However, alternatives exist. For instance, by positioning a log in the stream at a slight upstream angle, the force of the water can be directed away from the bank (Figures 10-10a, b). If built in conjunction with small vertical drops and larger stream substrate, the force of the water can be dissipated and fish habitat and passage can be maintained. Riparian vegetation can be installed to further stabilize the river bank and also provide additional habitat. Other configurations using natural materials exist to address a variety of conditions (Rosgen 1996).

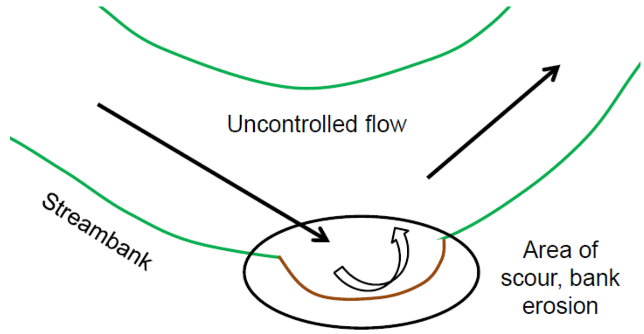

Figure 10-10a. Flows causing bank erosion

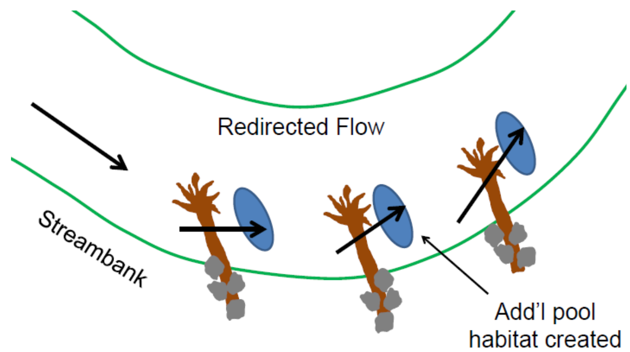

Figure 10-10b. Log vanes redirect flows

Restoration in Urban Streams

Brown (2000) evaluated 24 different types of urban stream restoration practices and found that "most practices, *when sized, located, and installed correctly*, worked reasonably well and are appropriate for use in urban streams" (emphasis added). Keys to success included "good understanding of stream processes and an accurate assessment of current and future stream channel conditions." Failure of a particular practice was caused by poor project design, using structures where channel conditions were inappropriate, and poor construction. For example, Brown (2000) noted that the impact of the weirs on storm flow conveyance often was not adequately considered prior to installation. The reduction in the channel cross-section by the weir led to bank scouring and weir failure. In other situations, practices were designed for current channel dimensions when the stream was still actively adjusting to altered urban flows.

The average age of the practices reviewed by Brown (2000) was four years (range 1–9 years). The author noted that "less than 60% of the practices fully achieved even limited objectives for habitat enhancement." He also noted that two practices were judged unsuitable in urban environments – rock weirs and log drops, "primarily because more reliable practices exist." Last, he noted "projects that attempted to reestablish or recreate natural channel geometry" failed most often, not from the practices themselves, but "from inaccurate predictions regarding design parameters…for the redesigned channels" (e.g., width, depth, meander radius). "Most of these projects attempted to create a natural (e.g., pre-disturbance) type channel morphology in an unnatural, disturbed watershed. While natural channel restoration has been successful in many rural and agricultural watersheds,…this design approach needs to be reconsidered in urbanized watersheds" (Brown 2000).

Floodplains

Space constraints, plus high costs and the need to protect existing property and structures, make the re-creation of a fully-functioning floodplain unlikely in many situations. However, even in confined areas, a stair-step design can be used to re-create a series of floodplain "shelves" that provide some floodplain benefits and still accommodate higher flows (BOR 2006). In Figure 10-11, the red line represents the existing steep-sided stream channel that is wide and shallow with no floodplain and little vegetation. The black dotted line represents the reconfigured bed and bank where two new floodplain "steps" are created on both sides. Such in-stream changes increase water depths and concentrate low flows to improve fish habitat. The new floodplain steps provide room for riparian vegetation where none existed before and also allow for overbank flooding at medium flows (1st step) and higher flows (2nd step). Programs are available to reconfigure river channels in this manner and to address degraded riparian areas, but if the land is not in agricultural production, the money and assistance available is limited.

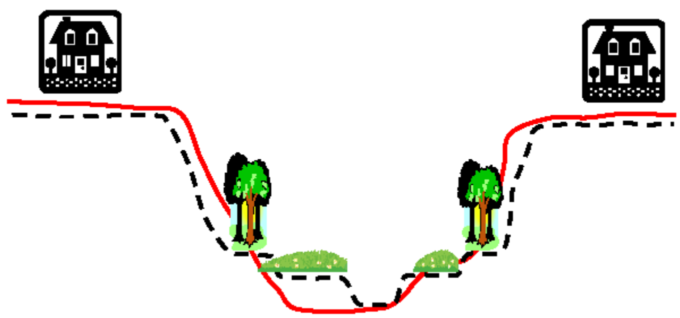

Figure 10-11. Diagram of stepped floodplain redesign
(Dotted line reflects reconfigured floodplain)

Conclusion

Historical flows in the South Arkansas River watershed shaped the overall channel and floodplain evident today. However, diversions and drought have diminished those flows significantly and, therefore, diminished or eliminated the role of the water in forming and re-forming the channel and floodplain. Last, development and other land use changes have confined the channel and floodplain and substantially altered or eliminated their function in several areas.

Some aspects of past and current impacts can be changed, while others cannot, whether for political, social, or economic reasons. For instances, a return to historical flows in the South Arkansas River—much less its natural flow regime—is not likely. However, redesigning in-stream habitats to better reflect and utilize lower flows is possible, and some of the ecosystem changes resulting from beaver activity could be accommodated. Therefore, to improve the health of the river, a smaller river-within-a-river concept is needed in several areas. However, this new template must still be capable of accommodating higher flows during spring runoff and summer thunderstorms.

A variety of structural ("hard") and bioengineering ("soft") approaches are available to accomplish these goals, but the technique(s) selected must understand:

- the nature of the disturbance causing the problem;
- that "most stream rehabilitation efforts that address only the in-stream symptoms of [overall watershed development] are unlikely to succeed" (Booth and Jackson 1997); and
- that the same results should not be expected from the same practice in different stream segments (Rinne 2004).

Other aspects of channel and floodplain processes are discussed in the following sections.

- Section 6.0, Hydrology and Flow Regime
- Section 7.0, Vegetation
- Section 8.0, Wildlife, Fish, and Aquatic Invertebrates
- Section 9.0, Water Quality

Restoration goals and recommendations for the South Arkansas River and watershed are discussed in more detail in Section 11.0, Establishing Watershed and Riparian Restoration Goals.

Rivers are ungovernable things, especially in hilly countries.
Canals are quiet and very manageable.

Ben Franklin, letter from London, 1772

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