

## Appendix M

# A Pictorial Guide to Riparian Changes Following Flow Alteration

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## **A pictorial guide to riparian changes following flow alteration**

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There are many examples in the scientific literature of how stream and river ecosystems respond to flow modification (for a starting point, see Poff et al. 1997). A pilot study for the Roaring Fork basin presented “flow-ecology” relationships that describe the relationship of flow modification with cottonwood, warmwater fish, trout and invertebrates (Watershed Flow Evaluation Tool Pilot; CDM 2009). After receiving feedback on the pilot study from the basin roundtable, improved flow-ecology relationships were then developed for the upper Colorado River. This included further work on cottonwood and willow plant communities (Wilding and Sanderson 2010), warmwater fish (Wilding et al. 2011b), and invertebrates (Wilding et al. 2011a).

Predicting how ecosystems and species respond to flow alteration is key to environmental flow assessments. The predictions from scientific models, including flow-ecology relationships, are represented as numbers. If you cannot picture what these numbers translate to in reality then the models are not particularly informative for understanding the consequences of flow alteration. So we were asked to show how the numbers translate to real-life examples, presenting pictures of how plants and animals respond to flow change.

Our objective is to present examples that clearly and succinctly illustrate flow-induced changes for riparian vegetation (plants beside streams). For each example, the information presented includes the source, flow alteration and a picture showing the ecological change. We sought pictures – ideally photographs, but other images or charts were also used.

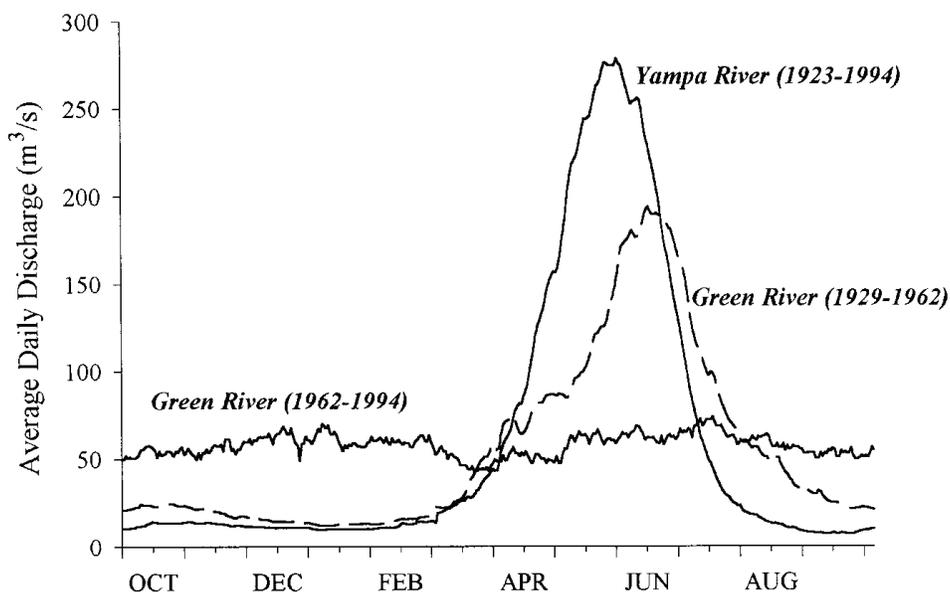
## Case Study 1: Riparian vegetation on the Green River below Flaming Gorge Dam (at Brown's Park, and in Desolation-Gray Canyon)

### Overview

Many studies have evaluated the effects of Flaming Gorge Dam on riparian vegetation and channel shape for the Green River, particularly at Brown's Park. Several studies compared the Green River to relatively unregulated Yampa River, using a site at Deerlodge Park (Cooper et al. 1999, Merritt and Cooper 2000, Cooper et al. 2003). Flaming Gorge Dam is located in northeastern Utah and was completed in 1962. Study sites were in northwest Colorado and northeast Utah. The Green River originates in Wyoming, reaching its confluence with the Colorado River in Canyonlands National Park. The unregulated Yampa River originates in the Park Range and White River Plateau of northwestern Colorado and flows west to its confluence with the Green River near Dinosaur National Monument in northwest Colorado.

### Changes in Flow

Flaming Gorge reservoir reduced peak-flows, increased the low-flows (Figure 1) and decreased the amount of sediment carried by Green River. As a consequence, the river channel is now less mobile, with little or no active point-bars on the river. These changes are important because cottonwood seedlings take root on active point-bars. We calculated a flow alteration of **-41%** for the Green River (wet year 90 day max at USGS 09234500), placing it in the "High Risk Class" for adult cottonwood and "Very High Risk Class" for cottonwood recruitment (using the flow-ecology methods from the WFET; Wilding and Sanderson 2010).

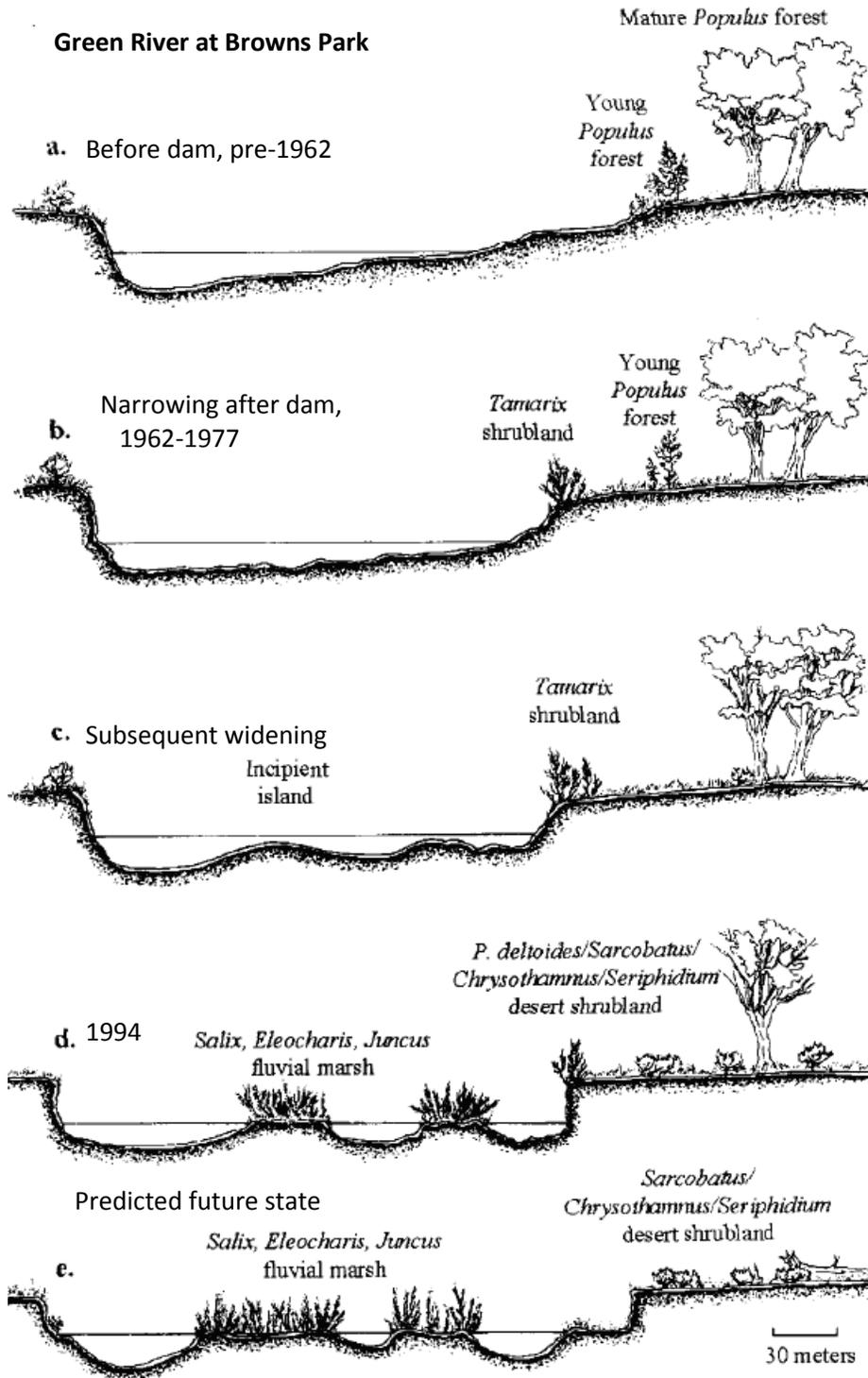


**Figure 1** Typical flows over a water-year (average daily flow, October-September) comparing three sites. The dashed line represents flows for Green River before Flaming Gorge Dam was built – compare that to the post-dam flows for 1962-1994. This graph also shows flows for the unregulated Yampa River. Graph from Merritt and Cooper 2000.

## **Changes in riparian vegetation at Brown's Park**

This diagram (Figure 2) represents changes in riparian vegetation for the Green River at Brown's Park (sourced from Merritt and Cooper 2000). For 10 years or so after dam construction, the river channel narrowed by 13% allowing young cottonwood and willow to establish in what was an active river bed (Figure 2b). But over the next 20 years (1977-1994) the channel widened and islands formed that were vegetated by wetland herbs and shrubs (Figure 2c & d). Cooper et al. (1999) found that cottonwood seedlings sprouted at Brown's Park, but none survived. Compare that to the unregulated Yampa River (Deerlodge Park) where a small but significant portion survived. There were many other changes in vegetation over time, in addition to reduced cottonwood, with Merritt and Cooper (2000) anticipating that desert shrubland will eventually dominate the area that was riparian forest (e. in Figure 2).

Photos were available for the Green River to capture the current state of riparian vegetation (Figures 3 and 4). Pre-dam photos were not available, but we do have photos of riparian vegetation from less regulated sites which have healthy riparian forest (Figure 5).



**Figure 2** Changes in channel and vegetation in the Green River at Browns Park, showing typical cross-section before and after construction of Flaming Gorge Dam. From Merritt and Cooper (2000).



**Figure 3** Green River at Brown's Park after construction of Flaming Gorge Dam. There are no young cottonwood trees and no willows in the understory. Remaining adult cottonwood have "self-pruned" and now have many dead limbs. In the lower photo most cottonwood have died with no young trees to replace them. Dryland vegetation has moved in beneath the cottonwoods. Photos courtesy of David Cooper, Colorado State University.



**Figure 4** This photo shows what was an open back-channel of the Green River that was open before dam construction (also from Browns Park). It is now dominated by grasses, willows, and tall whitetop, a noxious weed. Photo courtesy of David Cooper, Colorado State University.



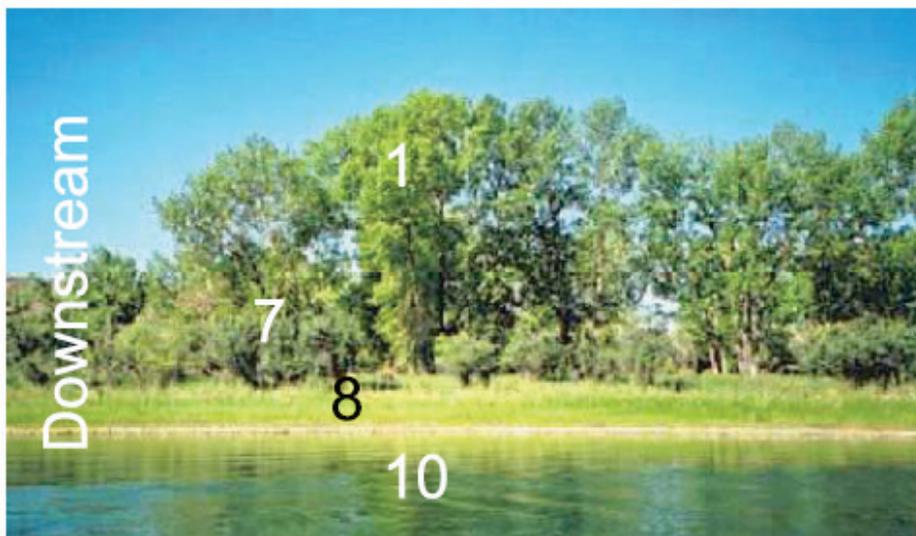
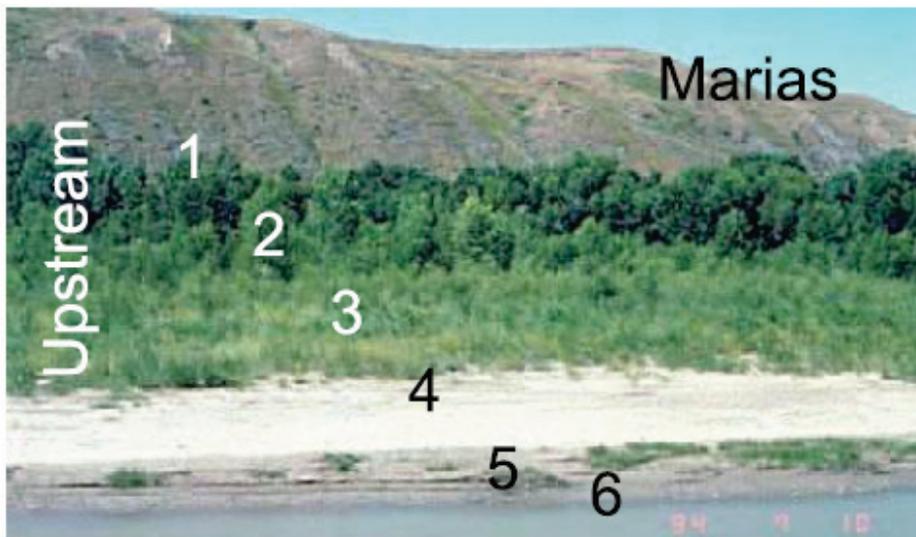
**Figure 5** White River in Utah. This is an example of riparian vegetation with near-natural flows. Note that both young and mature cottonwood are present with no dead limbs. Photo courtesy of Justin Jimenez, Bureau of Land Management.



## Case Study 2: Marias River (Montana)

Compare the top photo taken upstream of the Tiber Dam (constructed 1956), to the lower photo taken downstream of the dam. Both sites support mature cottonwood trees (labeled 1 in the photo). Juvenile cottonwood and willow are visible only at the upstream site (2 & 3), whereas downstream the zone adjacent to the cottonwoods supports species also found in uplands (7). Notice that grasses have encroached on the channel at the downstream site (8), with clear sandbars only present at upstream sites (4). Bare sand along the upstream channel shows the moist capillary fringe (5) and even in late summer the water is some turbid (6), in comparison to the clear water downstream (10). These photos are sourced from Rood et al. (2007).

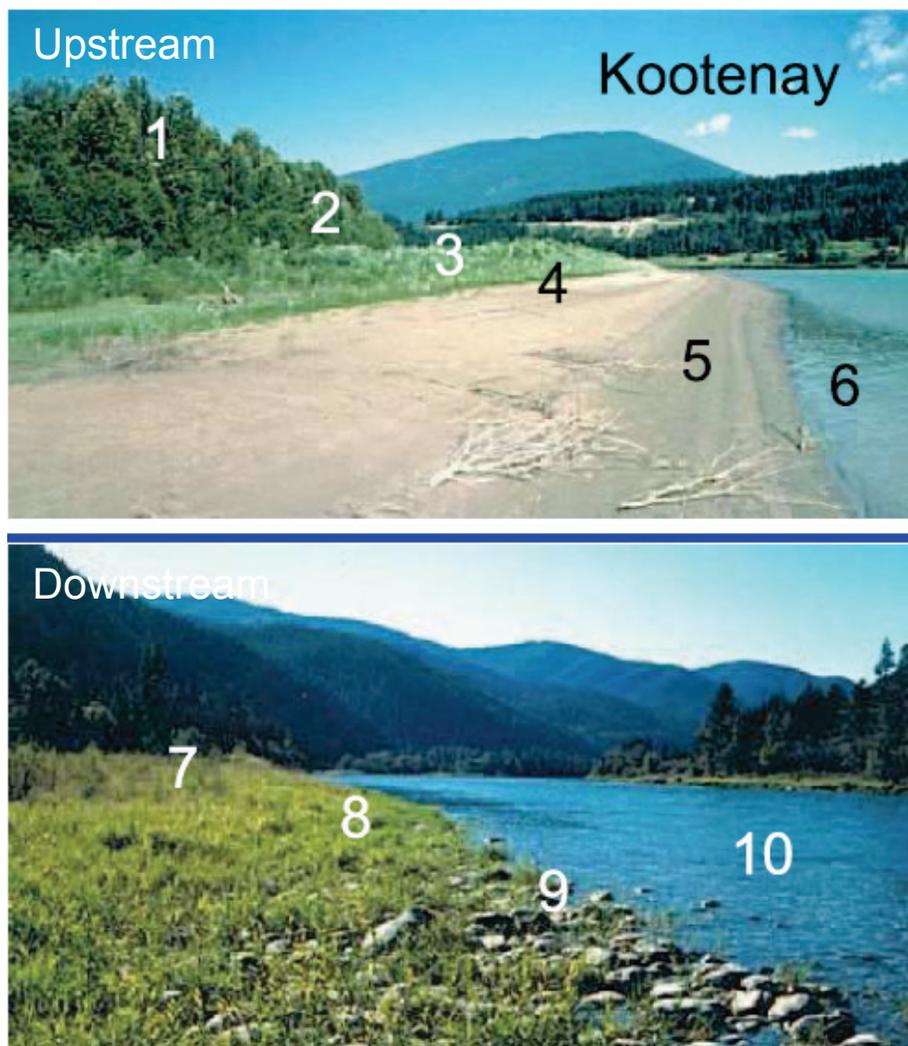
A **flow alteration of -26%** was calculated for the Marias River (wet year 90 day max at USGS 06099500 and 06101500), placing it in the “Moderate Risk Class” for adult cottonwood and “High Risk Class” for cottonwood recruitment (using the flow-ecology methods from the WFET; Wilding and Sanderson 2011).



### Case Study 3: Kootenay River (Montana)

Compare the top photo taken upstream of the Libby Dam (constructed 1971), to the lower photo taken downstream of the dam. Both sites support mature cottonwood trees (labeled 1 in the photo). Juvenile cottonwood and willow are visible only at the upstream site (2 & 3), whereas downstream the zone adjacent to the cottonwoods supports species also found in uplands (7). Notice that grasses have encroached on the channel at the downstream site (8), with clear sandbars only present at upstream sites (4) compared to cobbles along the water's edge downstream (9). Bare sand along the upstream channel shows the moist capillary fringe (5) and even in late summer the water is some turbid (6), in comparison to the clear water downstream (10). These photos are sourced from Rood et al. (2007).

A **flow alteration of -49%** was calculated for the Kootenay River (wet year 90 day max at USGS 12303000 and 12301933), placing it in the “High Risk Class” for adult cottonwood and “Very High Risk Class” for cottonwood recruitment (using the flow-ecology methods from the WFET; Wilding and Sanderson 2011).



#### **Case Study 4: Windy Gap, Colorado River**

This confined section of the Colorado River was photographed in 1922 by Harry Buckwalter (Figure 6). We reproduced this photo location in 2011 (Figure 7). The river appears to have narrowed considerably since the construction of Moffat tunnel (1936) and Lake Granby Dam (1954). Cottonwood, willow and grasses have encroached beyond the 1922 stream bank (Figures 7 and 8).

A **flow alteration of -62%** was calculated for the Colorado River at Windy gap (wet year 90 day max at StateMod node 09034250), placing it in the “Very High Risk Class” for riparian change (using the flow-ecology methods from the WFET; Wilding and Sanderson 2011).



**Figure 6** Photo by Harry H. Buckwalter, taken August 23 1922, looking west along the Colorado River from CO. Rd 57 at the narrowest point of Windy Gap. Image courtesy of History Colorado (Buckwalter Collection, CHS-B1724, scan #20031724).

[http://digital.denverlibrary.org/cdm4/item\\_viewer.php?CISOROOT=/p15330coll21&CISOPTR=5335&CISOBX=1&REC=6](http://digital.denverlibrary.org/cdm4/item_viewer.php?CISOROOT=/p15330coll21&CISOPTR=5335&CISOBX=1&REC=6)



**Figure 7** We estimated the location of the historic photo (Lat. 40.1085, Long. -106.0006, heading -80°) and took this photo August 2011. Cottonwood appear to have exploited the narrowing channel.



**Figure 8** This photo, taken in 2004 by Pieter en Marianne van de Sande, looks upstream from the bridge (CO. Rd 57) toward Windy Gap (rocky bluff). Shrubs and grasses appear responsible for most of the channel encroachment, though some of the smaller trees to the right (river true left) may occupy 1922 channel.

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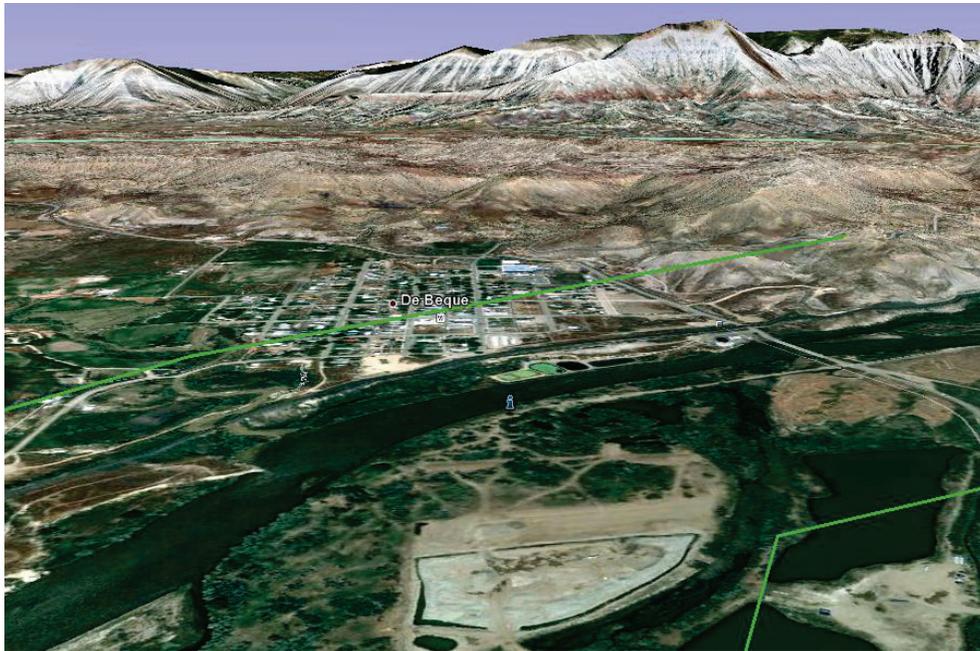
### **Case Study 5: De Beque, Colorado River**

This unconfined channel of the Colorado River has narrowed considerably between 1924 (Figure 9) and 2005 (Figure 10). Note that USGS09106000 records show the river was not experiencing flood flows at the time of photo (21 January 1924). It does not appear that cottonwood have extensively colonized the old river channel, nor have the island forests persisted. No doubt land use has played a role in the vegetation changes here.

A **flow alteration of -29%** was calculated for the Colorado River at De Beque (wet year 90 day max at StateMod node CONFL\_104), placing it in the “Moderate Risk Class” for adult cottonwood and “High Risk Class” for cottonwood recruitment (using the flow-ecology methods from the WFET; Wilding and Sanderson 2011).



**Figure 9** Aerial photo of De Beque and the Colorado River taken in 1924 (January 21). Image courtesy of History Colorado (Denver and Rio Grande collection, CHS.X4351, scan #2004351).



**Figure 10** The location of the historic photo was estimated using the streets of De Beque as reference points to produce this image in Google Earth (based on 9 June 2005 aerial photography), looking north across the Colorado River (Lat. 39.3234 Long. -108.2134, heading 7°). The channel has narrowed considerably since 1924. It does not appear that cottonwood have extensively colonized the old river channel, nor have the island forests persisted.

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