SETTING THE STAGE FOR CHANGE: GEOMORPHIC RESPONSE OF A SECONDARY CHANNEL ON THE RIO GRANDE

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INTRODUCTION

Anthropogenic and natural changes have influenced the morphology of the Rio Grande over the last century, especially in the reach below Cochiti Dam. The channel degradation that followed the closure of Cochiti Dam (1973) resulted in a floodplain that is rarely inundated and a river that is narrower and deeper, creating bank erosion and habitat diversity concerns as documented by Happ (1948), Dewey et al. (1979), Lagasse (1980), Salazar (1998), Scurlock (1998), Richard (2001), Makar et al. (2006), Massong et al. (2008), and Makar and AuBuchon (2012).

Makar and AuBuchon (2012), Richard (2001), and Shah et al. (2006) document the decrease in the frequency of the large magnitude floods, the sediment supply, and the mobility of the medial and point bars. The increased bar stability has simultaneously allowed an increase in vegetation establishment, which has increased the stability of the banks and the channel planform. Over the last few decades the channel has continued to narrow through incision and vegetation encroachment, both of which have served to further isolate the main channel from its floodplain. At the same time the exposure of a dominant gravel fraction in the bed material as shown by Salazar (1998) and Bauer (2009), and vegetation encroachment on the banks and bars has reduced the degrees of freedom for the river to adjust, increasing the channel stability and uniformity.

In the river reach below Cochiti Dam (~ first 5 miles downstream) recent analyses by AuBuchon and Bui (2014) have shown that the active channel width has fluctuated around 200 feet and the slope has flattened to about 0.0012 over the last 2–3 decades. The channel planform has also abandoned some of its variability with a decrease in the average number of channels from 2–3 prior to 1962 to about 1–2 since 1972. The sinuosity still fluctuates slightly, although not to the extent that it did prior to 1962, suggesting that there are local areas of instability amidst the observed stability.

PROJECT DESCRIPTION

In 2008, the U.S. Bureau of Reclamation constructed a project about four miles south of Cochiti Dam that combined erosion control and habitat restoration goals. The design at this location blocked off an existing side channel where there was a bank erosion concern and constructed a new secondary channel slightly downstream. This new side channel was constructed through a relatively stable island feature deposited in the 1950s; this date was based on tree-ring aging performed by Bio-West (2005). The composition of the island deposits are primarily gravels among a matrix of sand, as shown in the red circle on Figure 1.

The side channel was designed by Bio-West (2006; 2007) to mimic other naturally occurring side channels in the area. The design bottom width was about 10 to 25 feet, with a 5.5-foot to 7-foot design depth range from the island surface. While initial draft concepts explored the possibility of planting vegetation on the channel sides to provide stability, this was quickly abandoned in favor of allowing the river freedom to adjust. The high banks of the island surface were estimated by Bio-West (2005) to be about 8 to 10 feet above the river bed. This information, coupled with observations of bank erosion at similar locations, suggested that the river would be able to move the sediment at this site, creating an opportunity for the river to adjust the channel dimensions.

During construction the side channel outlet was moved downstream to avoid removing a mature stand of cottonwoods. This resulted in a channel length increase of about 100 feet. The relocation effort also took advantage of existing sparsely vegetated areas through which the new channel could be constructed, one of which is shown staked out with pink flagging in Figure 1. The actual constructed bottom width of the channel was about the width of two wheel tractor-scrapers (CAT 621G), or about 20 feet as shown in Figure 2. The actual excavated depth was estimated to be about 5 feet.

Figure 1 Proposed side channel location at RM 228.9 river maintenance priority site looking at upstream bend. Photo taken on November 29, 2007.

Figure 2 Constructing the side channel at RM 228.9 river maintenance priority site. Each path is the width of one tractor-scraper. Photo taken on January 30, 2008.

OBSERVATIONS

In the years since the construction of the new side channel, the river's morphological response has created a rich variety and complexity of stream features. High spring snow melt flows during the initial years of the project (see Figure 3 where flows are above 3500 cfs for an extended period of time in 2008 [55 days], 2009 [28 days], and 2010 [7 days]) provided the energy for change, creating width, depth, and sinuosity changes. The erosion of bed and bank material during the initial years (2008 to 2010) created a sediment source (sands and coarser materials) for the river. This is a significant change since the closure of Cochiti Dam in 1973, as Shah et al. (2006) and Richard (2001) found that Cochiti Dam, just 4.5 miles upstream, has had a high trapping efficiency, close to 98%. The initial years of high flow not only created a sediment source, but they also winnowed the finer material out of the channel bed (see Figure 4) and deposited bars that have a nominal size in the very coarse gravel range (see Figure 5, 2009 survey).

The high spring runoff years were followed by lower spring snow melt flows that allowed the establishment of plant species. Summer monsoon flows between 2011 and 2014 have also brought additional sediment into the reach. Of particular note are the higher turbidity measurements in 2013 shown in Figure 3. In 2013, an unusually high discharge from a tributary of the Rio Grande upstream of the project site blocked the river and created conditions that significantly increased the local turbidity throughout the reach. This event, as well as other smaller sediment spikes, shown in Figure 3, during the monsoon seasons of 2011, 2012, and 2014, likely contributed additional finer material, as was noted in a 2014 re-survey of the bed material present on the 2009 surveyed bar (see Figure 5). It should be noted that the gravel predominant in the 2009 measurement was still present in the 2014 measurement, just overlain by finer material. These observations indicate that both water and sediment have helped shape the river's morphological response on the constructed side channel.

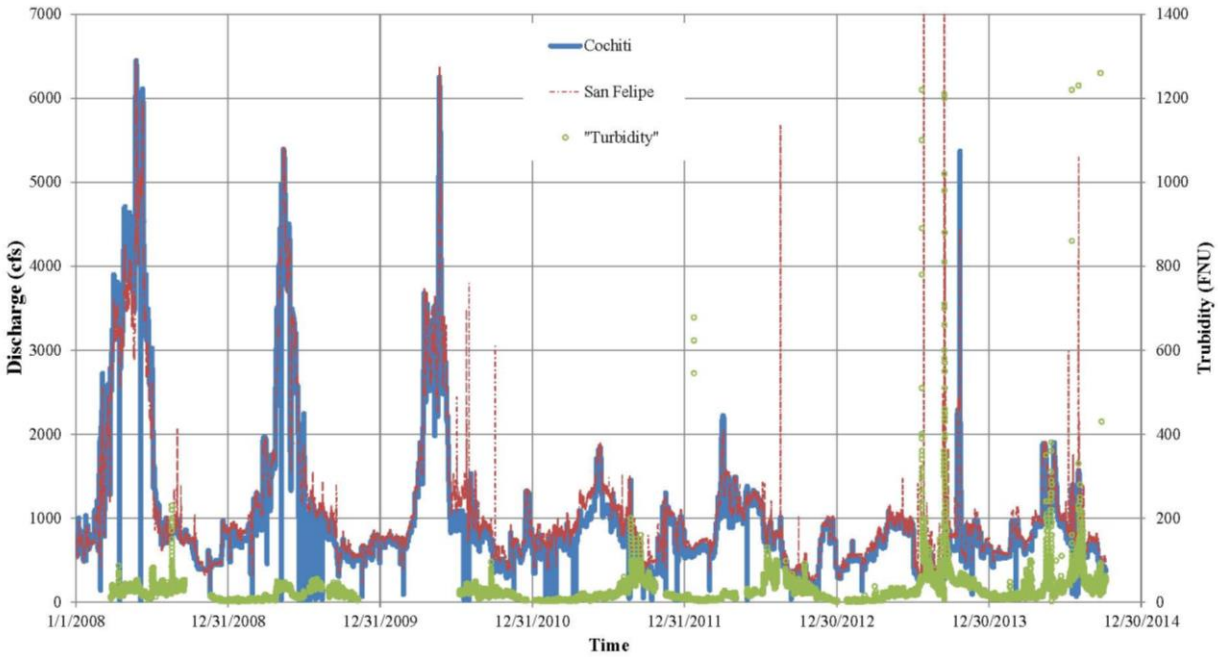


Figure 3 Discharge and turbidity (formazin nephelometric units–FNU) measurements at the USGS gage 08317400 Rio Grande Below Cochiti Dam, NM and discharge measurements at the USGS gage 08319000 Rio Grande at San Felipe, NM between January 2008 and October 2014.

Figure 4 Constructed side channel looking upstream. Note gravel bar on river right and gravel on the river left bank. Photo taken by L. Malone on August 4, 2009.

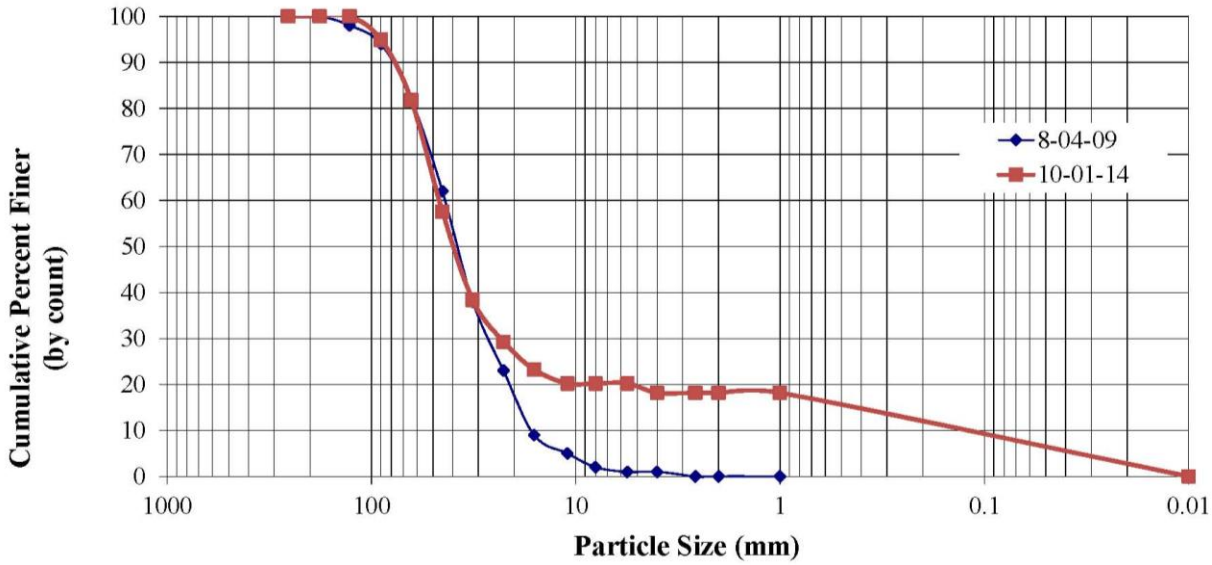


Figure 5 Grain size distribution plots (by count) of a bar forming on river left between CI-52.3B and CI-53.5B. Results are from measurements conducted using Wolman's (1954) methodology.

The specific morphological response of the constructed side channel is shown in planimetric view in Figure 6. A study of Figure 6 reveals not only a change in width and sinuosity, but also that the development of the meander bends is reflective of the locations where a major curvature was introduced during construction. Over the sequence of the provided aerial photography, this curvature has become more pronounced with downstream migration of the meander bends. Also of note in Figure 6 is the appearance of small channels on the backside of some of the meander bars which may indicate potential channel cutoffs and additional channel changes in the future.

Changes in the profile view over roughly the same time period are shown in Figure 7. The water surface elevation plot in Figure 7 reveals that the slope is adjusting with time (from ~0.0024 in 2009 to ~0.008 in 2012). The bed elevation plot in the same figure reveals a similar slope reduction (from ~0.0031 at the time of construction to ~0.0023 in 2009). The bed elevation plots also show the increase in depths along the thalweg with time. The August 2009 bed survey used an Acoustic Doppler Current Profiler (ADCP), so a higher resolution of the bed topography was possible. The January 2009 survey measured the depths at four cross section line across the constructed side channel; the profile plot only shows the deepest depth recorded at these four locations. Cross-sectional areal changes on the constructed side channel are shown in Figure 8. This figure provides a graphic illustration of the increase in cross section area (changes in width and depth) from construction to after the first two major spring runoff events in 2008 and 2009.

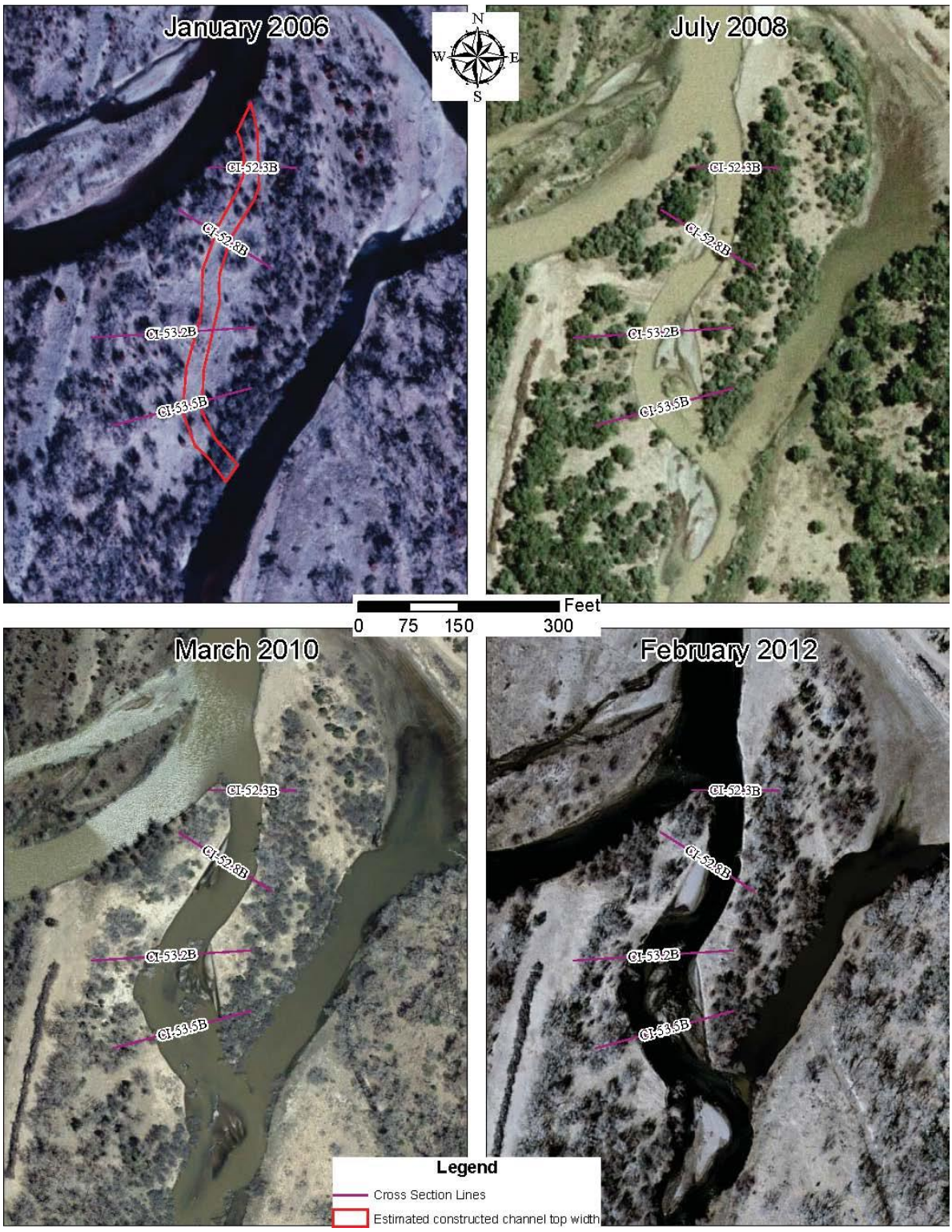
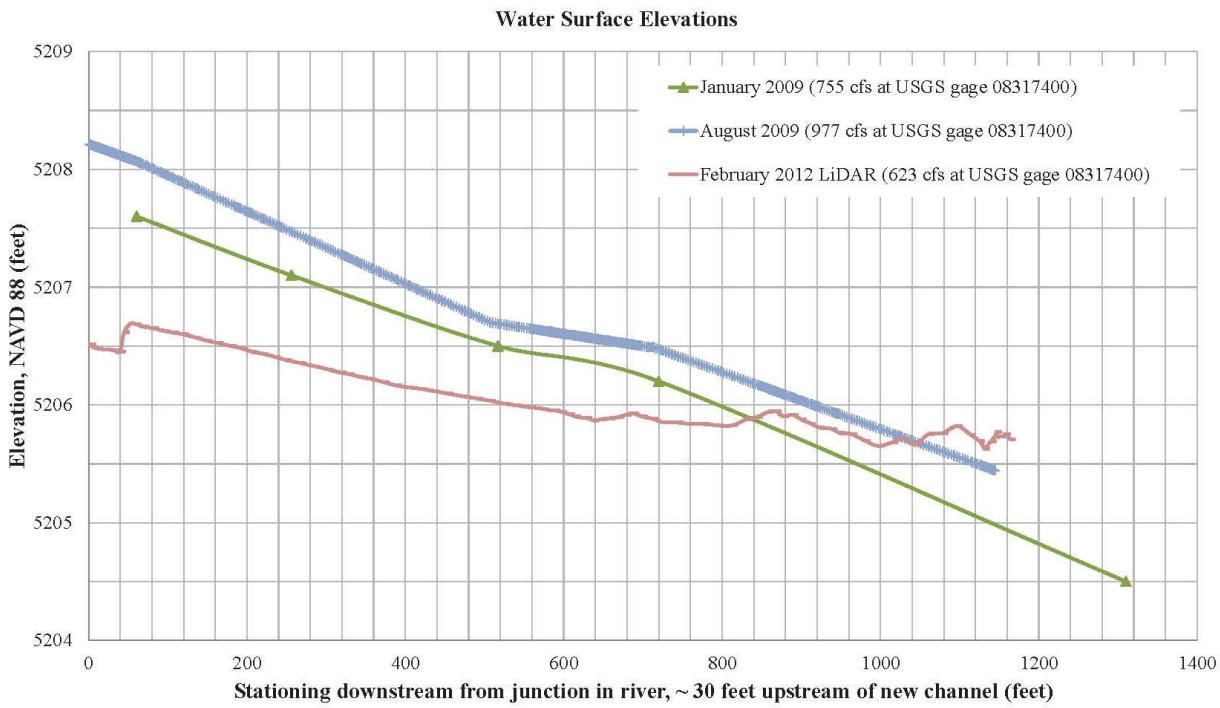


Figure 6 Planform changes observed on constructed side channel, from top left to bottom right: 2006 Reclamation aerial photography with estimated constructed channel top width, 2008 Reclamation post runoff aerial photography, 2010 Middle Rio Grande Council of Government (MRCOG) spring runoff aerial photography, 2012 Reclamation aerial photography.



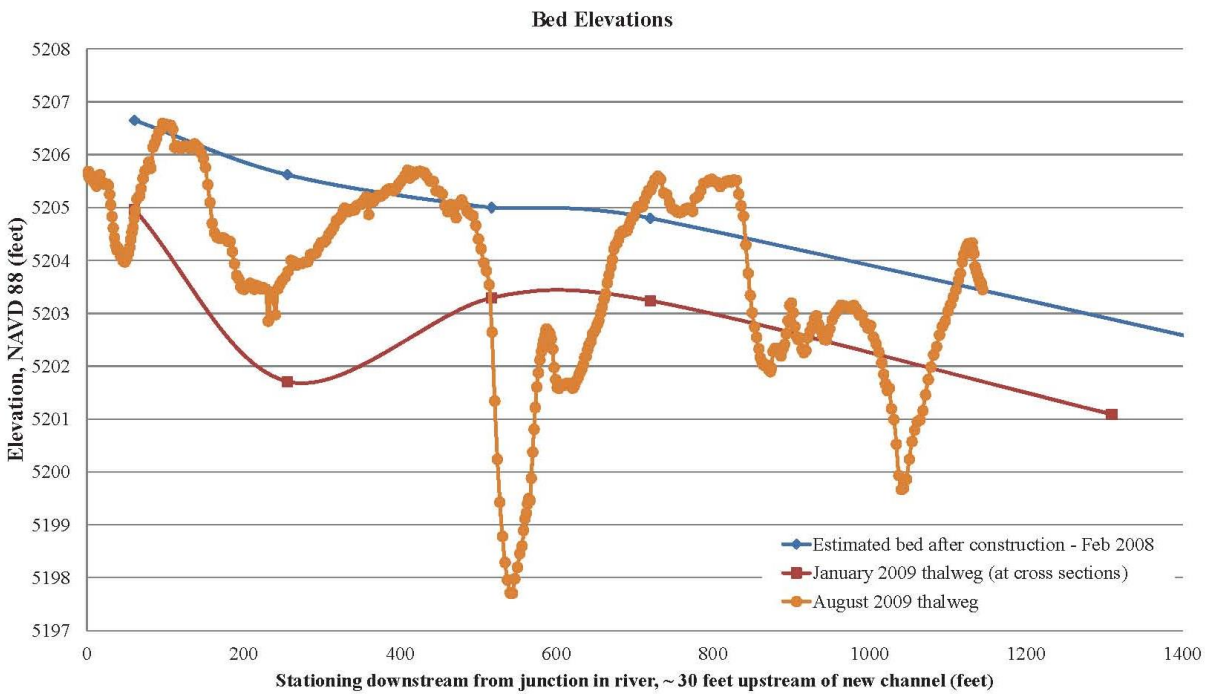


Figure 7 Slope changes on constructed side channel through time.

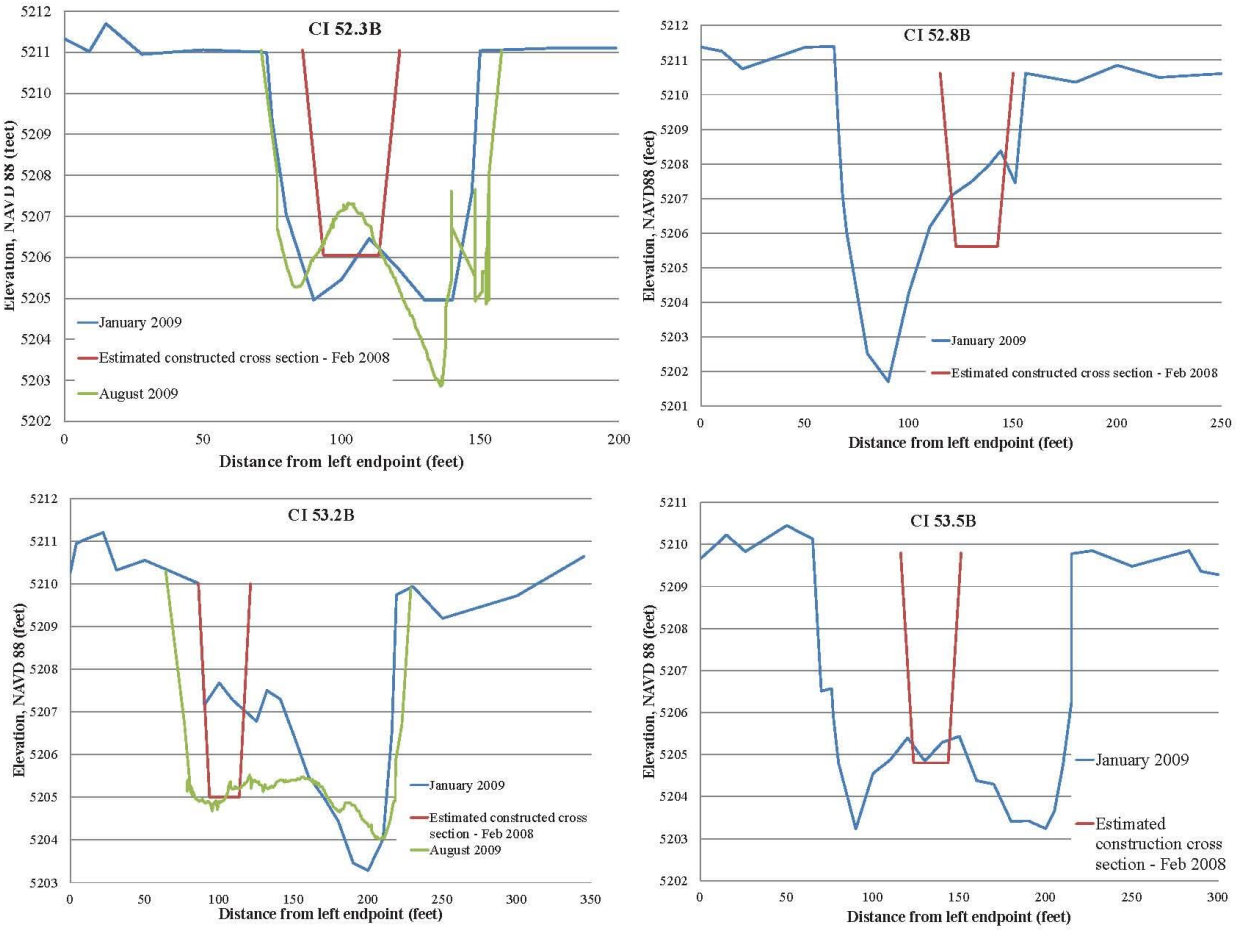


Figure 8 Cross-sectional changes on constructed side channel through time. Top two cross-section graphs are in the upper half of the constructed side channel. The bottom two cross-section graphs are in the lower half of the constructed side channel.

A summary of the planimetric changes that occurred on the constructed side channel is provided in Table 1. These changes were measured from the aerial photography shown in Figure 6. A similar planimetric analysis (Table 2) was performed using the same aerial photography sets on an upstream existing side channel. The constructed side channel showed a significantly more diverse morphological response than the existing side channel, with a larger range in the variability of number of bars, size of bars, and number of dead vegetation clusters in the channel. The side channel that was abandoned during construction was also assessed using this planimetric analysis (see Table 3), but for the time period prior to construction, this included three sets of aerial photography prior to the closure of Cochiti Dam. The width and sinuosity increases in the constructed side channel were seen to be similar to the abandoned side channel responses prior to construction of Cochiti Dam. Similarly, the quantity of bars observed in the constructed side channel was on par with the abandoned side channel up to about 1992; the volume of sediment available before Cochiti Dam though was far in excess (see maximum bar size) of what the constructed side channel could generate. The constructed side channel, though, had a significantly higher number of dead vegetation clusters than the abandoned channel, even before the closure of Cochiti Dam.

Table 1 Planimetric measurements of constructed side channel from aerial photography.

	February 2008	**July 2008**	**March 2010**	**February 2012**
Average width (feet)	64	83	110	107
Sinuosity	1.00	1.14	1.17	1.19
Number of bars	2	6	5	14
Minimum bar size (square feet)	1,883	1,147	161	67
Maximum bar size (square feet)	2,525	4,573	7,639	16,172
Number of dead vegetation clusters in channel: trees, wood piles, clumps of vegetation matted together, etc.	0	16	29	24

Table 2 Planimetric measurements of nearby side channel (unaffected by construction activities) from aerial photography.

	January 2006	**July 2008**	**March 2010**	**February 2012**
Average width (feet)	212	210	220	209
Sinuosity	1.17	1.16	1.20	1.22
Number of bars	6	6	5	9
Minimum bar size (square feet)	133	1,109	489	444
Maximum bar size (square feet)	8,201	5,407	2,513	10,281
Number of dead vegetation clusters in channel: trees, wood piles, clumps of vegetation matted together, etc.	1	1	1	1

Table 3 Planimetric measurements of abandoned side channel from aerial photography.

	1949	**1962**	**1972**	**1992**	**2001**	**2006**
Average width (feet)	407	264	137	126	123	119
Sinuosity	1.04	1.11	1.13	1.38	1.41	1.30
Number of bars	9	4	5	4	2	2
Minimum bar size (square feet)	1,052	8,745	537	460	27,249	1,329
Maximum bar size (square feet)	177,638	222,716	50,210	74,713	52,283	4,385
Number of dead vegetation clusters in channel: trees, wood piles, clumps of vegetation matted together, etc.	1	1	1	3	3	5

While there was likely some dead vegetation that made its way to the side channel from upstream, the larger wood piles were a result of trees that were left near the constructed side channel and which fell into the river as the side channel widened and deepened (Figure 9). In effect, the toppled trees created irregularities in the flow that increased the local channel sinuosity and width, in addition to providing traps for sediment, seeds, and other debris carried by the river (Figure 9). It is likely the presence of these trees that have helped create the rich

variety and complexity of morphological features that have developed over time, as can be seen in the time sequence of photographs in Figure 10 and Figure 11.

Figure 9 Left: Cottonwood tree that fell near CI-53.2B. Photo taken on April 16, 2008. Right: Same cottonwood tree that fell near CI-53.2B. Photo taken on October 1, 2014.

Figure 10 Temporal sequence of photographs looking downstream at the bend around CI 52.3B: 1–11/14/07, 2–1/30/08, 3–4/16/08, 4–5/27/08, 5–8/7/09, 6–6/16/10, 7–10/17/13, and 8–10/1/14.

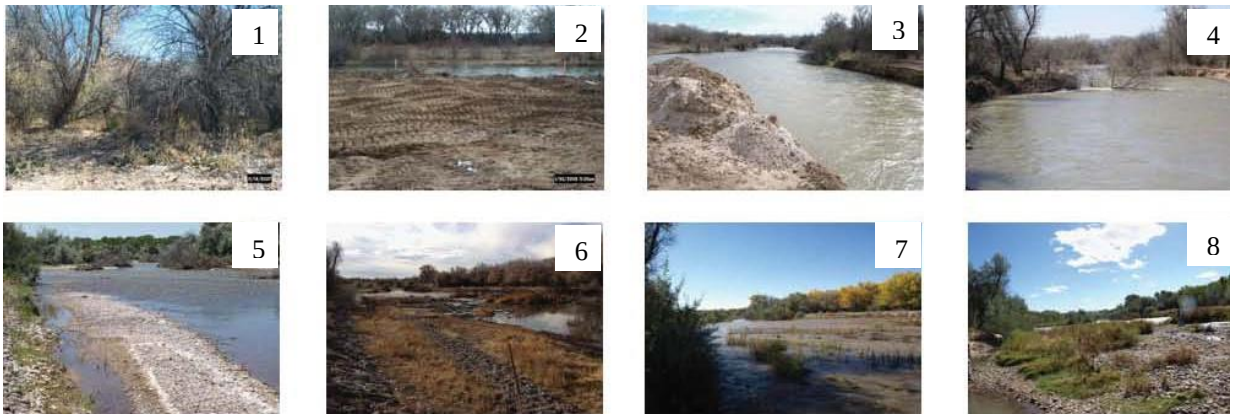


Figure 11 Temporal sequence of photographs looking downstream from around CI 53.5B: 1–11/14/07, 2–1/30/08, 3–3/6/08, 4–4/16/08, 5–6/16/10, 6–11/21/12, 7–10/17/13, and 8–10/1/14.

RECOMMENDATIONS

Experience with the fluvial geomorphic response of this secondary channel on the Rio Grande can provide a basis for recommendations for future stream restoration projects. These are shown below.

- Know your river's history. Understanding the historical morphological response and the changes in the system drivers, like water and sediment, is key in developing design concepts that work with the river processes to meet a variety of design goals.

- Know your river now. Spend time in the field, with repeat visits during different seasons to assess changes in the vegetation, bed and bank materials, and general river responses over time. Understand whether your system can benefit from an increase in the sediment supply and what size sediment would be beneficial. In addition, assess if there are potential sources and sinks for this sediment within your design area.

- Provide freedom for the river, where possible, to be a river. Let the river adjust the channel dimensions, especially in areas where the additional sediment supply is needed. Keep large trees near the constructed edges of the channel that may fall into the channel and cause complex flows that create rich and diverse morphological forms that cannot be replicated with construction equipment.

- Plan for an adaptive management process to best take advantage and document morphological changes that occur after construction.

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