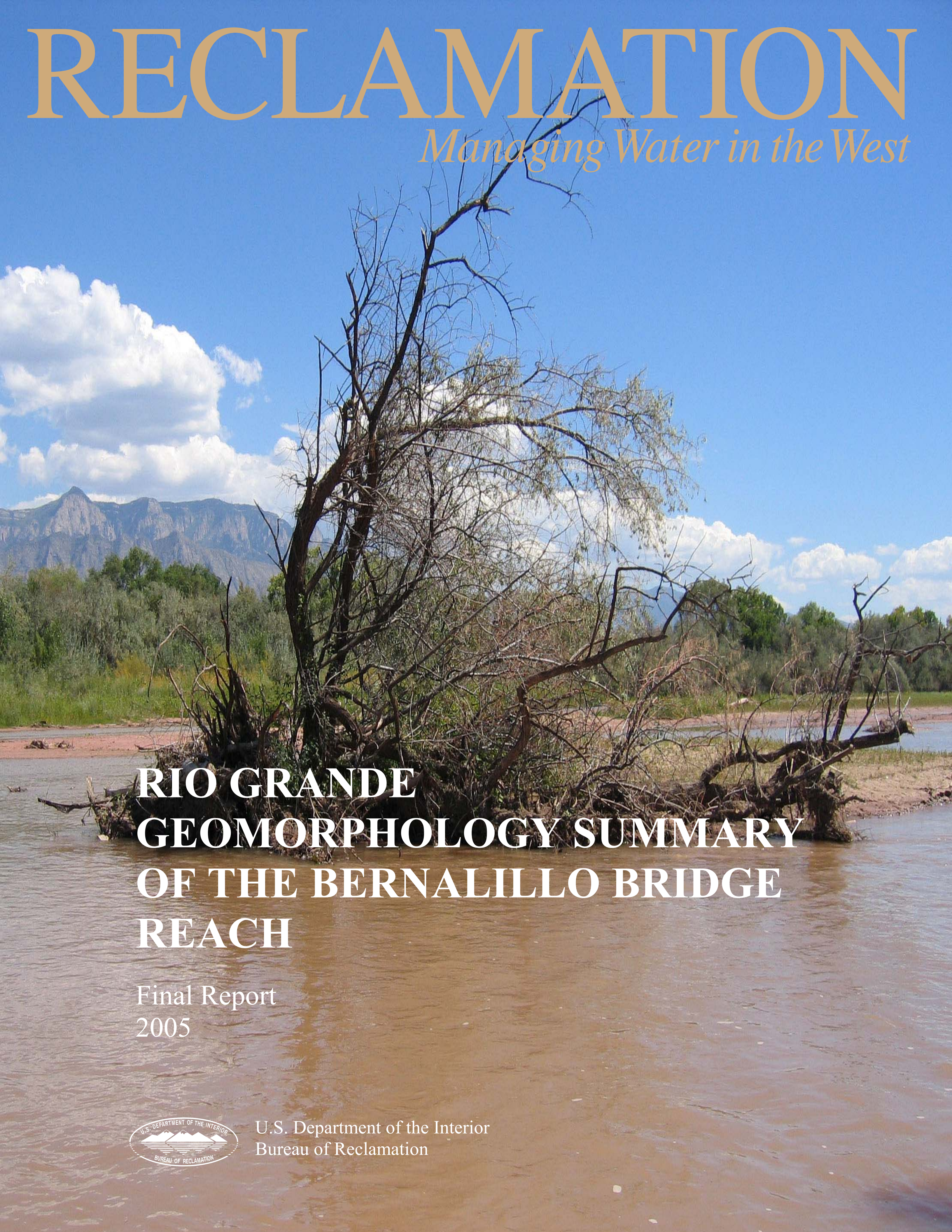

RECLAMATION

Managing Water in the West

RIO GRANDE GEOMORPHOLOGY SUMMARY OF THE BERNALILLO BRIDGE REACH

Final Report
2005

U.S. Department of the Interior
Bureau of Reclamation

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RIO GRANDE GEOMORPHOLOGY SUMMARY OF THE BERNALILLO BRIDGE REACH

Final Report
2005

Funding provided by
U.S. Bureau of Reclamation
Albuquerque Area Office
River Maintenance-Priority Site Program

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U.S. Bureau of Reclamation-Albuquerque Area Office

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1.0 INTRODUCTION-BACKGROUND SUMMARY

The Bernalillo Bridge reach of the Rio Grande extends downstream from the New Mexico Highway 550 bridge crossing in the city of Bernalillo to Arroyo de las Montoyas/Harvey Jones Outfall confluence: a reach of approximately 5.3 miles in river length (Figure 1). Results from three individual studies are synthesized in this report. The Bernalillo Bridge Reach, Highway 44 Bridge to Corrales Flood Channel Outfall, Hydraulic Modeling Analysis, 1962-2001 report (Appendix A) was completed in June 2003 by Claudia Leon and others in the Civil Engineering Department at Colorado State University as part of a cooperative agreement with the U.S. Bureau of Reclamation (Reclamation). The Preliminary Geomorphic Assessment of the Bernalillo-Albuquerque Reach, Middle Rio Grande near Albuquerque, New Mexico report (Appendix B) was prepared by Richard Ortiz in July 2003. Ortiz's study is part of a cooperative agreement between the Earth and Planetary Sciences Department at the University of New Mexico and Reclamation. The third report (Appendix C), Current Fluvial Conditions, Rio Grande-Bernalillo Bridge Reach, was prepared in draft form by myself in July 2003. The entirety of this study is funded by the Middle Rio Grande Project, allocated through the Albuquerque Area Office-Technical Services Division of Reclamation in Albuquerque, New Mexico.

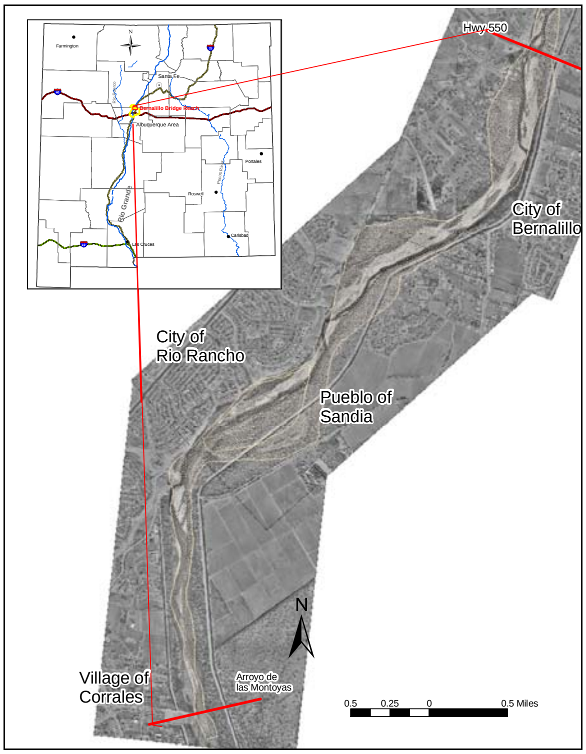

Figure 1: Location of the Bernalillo Bridge reach of the Rio Grande, NM overlain on a contour/topographic map (left), and the 2001 aerial photos of the reach (right) with an estimated location of the Rio Grande in 1918 (source: digitized USGS 1918 topographic quadrangles). Figure from Massong 2005.

Maintenance History

During the first major rehabilitation of the Rio Grande channel by the Middle Rio Grande Conservancy District (MRGCD), a floodway was constructed along the river 1930 - 1936 (Woodson and Martin 1962). The constructed floodway was noticeably narrower than the original channel (Figure 2). Although several bends and side channels were abandoned the general location of the river did not change significantly. An initial levee system was also constructed during this time period. By the 1950's, the Rio Grande was a wide shallow channel occupying the entire area between the levees. The river banks were at this time poorly developed (Leopold 1994). The average level of the channel bed, especially in the Albuquerque area, was above the elevation of the floodplain located outside of the levees (Woodson and Martin 1962). Continued flooding outside the levees prompted the U.S. Congress in 1948 and 1950 to authorize additional river modifications to control sedimentation and flooding along the Rio Grande. As part of this authorization, the Rio Grande was re-channelized, Kellner jettyjack fields were placed along the floodway to control channel location, an improved levee system was built, and several large dam were installed in the watershed to reduce the total sediment load.

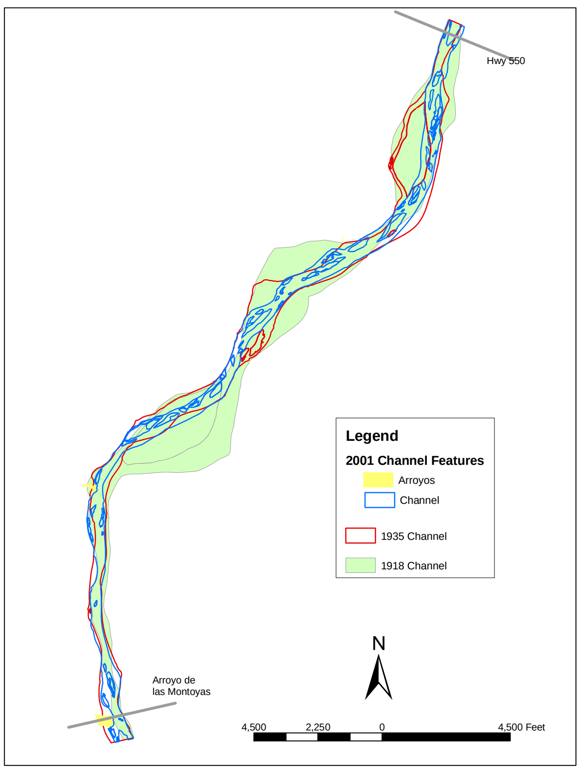

Figure 2: Historic and current channel locations in 1918, 1935 and 2001, Rio Grande - Bernalillo Bridge reach. Modified data: digitized Rio Grande channel and river features from aerial photography, produced by Reclamation, Technical Services Center-GIS and Remote Sensing Group, Denver, CO.

As part of the U.S. Congressional authority to control the Rio Grande, especially through the Albuquerque Reach, several flood and sediment control dams were built. Three dams were built on tributaries: Rio Chama (Abiquiu dam), Rio Galisteo and Jemez River (Woodson and Martin 1963). In addition to the tributary dams, a dam was built on the mainstem Rio Grande near the Pueblo of Cochiti (a.k.a., Cochiti dam), and began operations in November 1973 (Lagasse, 1980). Although the three tributary dams do influence the Rio Grande, the Cochiti dam/reservoir effects are clearly the most visible in the flood and sedimentation records for this section of the Rio Grande.

Precipitation, Flow and Sediment History

Precipitation data indicates that the yearly rainfall has generally been elevated in the 1980s and 1990s in the Albuquerque area. At present, the yearly average precipitation is 10.5 in/yr at the Corrales climate gage, 1984-1999, and 8.7 in/yr at the Albuquerque Airport climate gage, 1931-1999 (data summarized in Massong 2005, Figure 2 and Table 1). The largest rainfall year on record for the Albuquerque area occurred in 1942, with just over 16 inches of precipitation at the Albuquerque Airport gage.

In conjunction with the high rainfall in 1942, the last major flood event occurred in 1942 (data from Massong 2005, Figure 4). Although the 1942 event was large, over 20,000 cfs, the largest flow at the USGS Rio Grande gage at San Felipe was in 1937, peaking at just over 27,000 cfs. Partial peak data (Hydrosphere 2000) show that other than one peak in 1955, the 1942 event was the last large flow (>15,000 cfs) to pass the San Felipe gage. Prior to 1973, the 2-year recurring peak flow was estimated just over 10,000 cfs, however post-1973 data indicates a current peak flow of under 6,000 cfs (data in Massong 2005). In fact, no flows greater than 10,000 cfs have passed San Felipe since 1967 (Figure 3). Despite the lower peak flows, the average yearly volume of water doubled after 1978 from 700,000 acre-feet to approximately 1,400,000 acre-feet (data from Leon et al. 2003, Figure 4-1). The average yearly water volume decreased after 1987 to approximately 960,000 acre-feet.

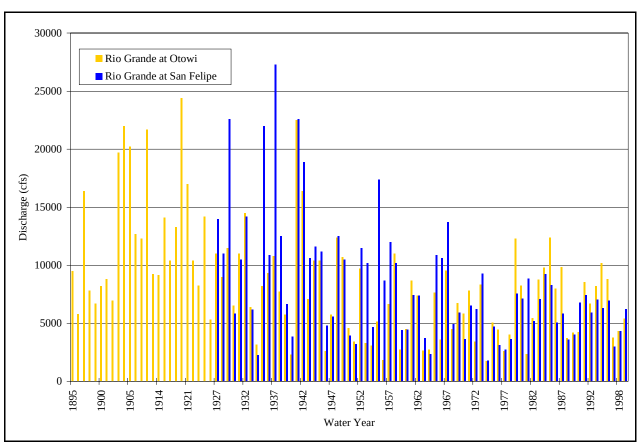

Figure 3: Peak discharge records measured upstream (Otowi gage) and downstream (San Felipe) of Cochiti dam; USGS Rio Grande gage data at Otowi Bridge (1895-1999)

and San Felipe (1927-1999), (USGS 2000). Figure reprinted from Massong 2005, Figure 4.

Along with the lower peak flow data, suspended sediment data indicates a decreasing sediment load from historic levels (Table 1). USGS Rio Grande suspended sediment gage records at San Felipe, San Acacia and San Marcial indicate that the whole Rio Grande transported higher levels of sediment prior to 1958 (Table 1, Reclamation 2003). Since 1958, the suspended sediment supply decreased, with a dramatic decrease after 1973. As Cochiti dam began operations in 1973, the decrease in suspended sediment since 1973 is likely due to the reservoir's sediment trap efficiency. The average suspended sediment load in the Albuquerque area is currently less than one million tons per year.

Table 1: Average yearly amount of suspended sediment measured at the USGS Rio Grande gages at Albuquerque and Bernalillo, NM (USGS 2000). Table reprinted from Massong 2005, Table 2.

Time Period	Average Suspended Sediment (million tons/yr)
1956-1958	10.8
1958-1972	3.0
1972-1973	7.6
1973-1985	1.2
1985-1993	0.3
(1989-1992)	(no data collected)
1993-1995	2.8
1995-1999	0.8

Combining both the discharge with the suspended sediment data shows the 1980s produced flows with relatively low concentrations of sediment. The concentration of suspended sediment definitely decreased after 1973 (data from Leon et al. 2003, Table 4-3), by nearly half to an average of 1,600 mg/l. Except for 1993-1995, the concentration of sediment currently ranges between 280-660 mg/l.

General Reach Descriptions

The current channel description, based on 2000-2001 field observations, indicates that the study area is in a state of transition: 1) the channel bed material is coarsening from a sand bed to gravel, 2) vegetated islands have formed from bars that were active in the late 1980s, and 3) the planform is changing towards a single, deep channel at low flows. Initially, the study area was divided into three sub-reaches (Figure 4). The divisions were determined based on estimated slope and channel form observations from the 1992 photographs and profile data. However, after assessing the area, sub-reach 2 is further divided into sub-reach 2a and 2b.

Sub-reach 1 which extends approximately 2 miles downstream from the NM Hwy 550 bridge and sub-reach 2a, another ¾ mile downstream, have already converted from the sand bed, braided morphology to a gravel bed, single-threaded morphology. At high flows, several high flow channels become wetted, creating an island-braided morphology. The low flow characteristics include a slightly meandering, deep thalweg. The size of bed material is gravel/cobble with only occasional, thin sand deposits in the main channel. More sand is present in the high flow channels than in the low flow channel. Sediment transport of the larger sized bed material begins at the channel forming flow indicating the gravel bed is relatively stable. High flow channels and abandoned bars/islands are numerous in this sub-reach. Sediment composing these bars and the islands consist of a mixture of sand and gravel.

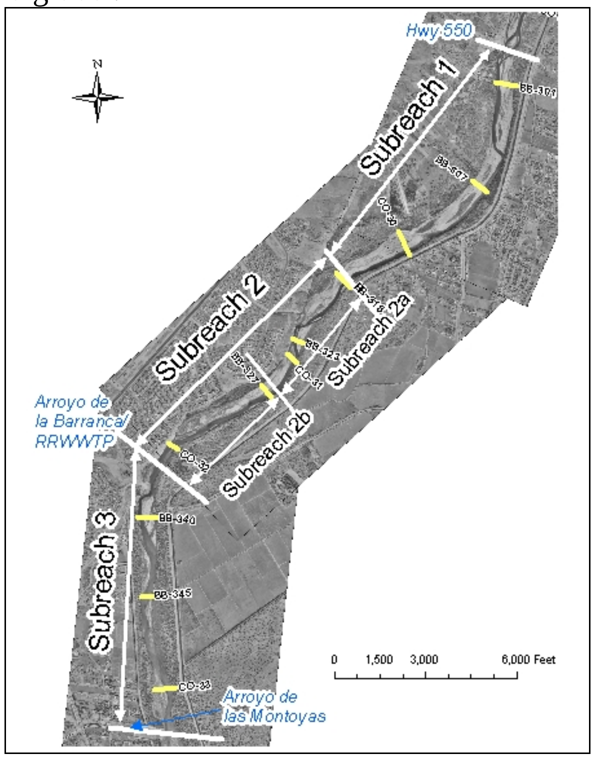

Figure 4: Reach map displaying location of the Reclamation range lines and the delineation of the sub-reaches for the Rio Grande, Bernalillo Bridge Reach. Underlying aerial photos taken in 2001.

Sub-reach 2b (about 1 mile in length) appears to be an upstream depositional zone for Arroyo de la Barranca, such that the bed material is fine gravel. The channel form is more of a braided form with a slightly wider channel at low flows than found in sub-reach 2a. The main feature that differs in this sub-reach from the upstream channel is a smaller bed material size, small gravel, and a generally thicker over-lying sand layer. The bed material is easily transported at nearly all flows. Bar and island formation is limited in this sub-reach.

Sub-reach 3 (1.5 miles in length) is in transition from the low-flow braided morphology to a slightly meandering thalweg/single-threaded channel pattern. The channel morphology can not be clearly described as braided, single-threaded or meandering. Although a relatively deeper thalweg is present in this section, the flow spreads out across the whole active channel. Small sections of the channel are gravel, while most is sand bedded. The gravel is generally transported at high flows, while the sand sections transport material at most flows. Islands are present; however, they are not as numerous as upstream.

2.0 SEDIMENTATION HISTORY AND CURRENT TRENDS

Although the first systematic data collection along the middle Rio Grande occurred in 1962, historic anecdotal data dating back into the 1800s often describes the middle Rio Grande as a sandy, aggrading river system (Scurlock 1998), however recent field data indicates a change from historic conditions. This section will briefly cover the historic sedimentation trends, present a combination of current sedimentation trend assessments, and describe potential future sedimentation trends.

Historic Sedimentation, Sediment Size and Incision

As discussed earlier, a significant amount of channel work has been accomplished on this section of the Rio Grande, most of which was designed to protect public infrastructure from flooding and/or provide water to irrigators in the area. Since the Rio Grande transports a large volume of sediment, much of the channel work has been designed to decrease flooding by controlling location and rate of aggradation. Although some levees were informally constructed prior to the 1930s mostly by local landowners (Scurlock 1998), the first semi-formal levee system was built in the 1930s along with floodway construction. The 1930s levee confined most of the flow and sedimentation, including the large flows and sedimentation of the late 1930s-1940s. Riverine data collected since the 1960s clearly shows that the Bernalillo Bridge reach of the Rio Grande was still aggrading from 1962-1972 (Figure 5). According to USGS suspended sediment data collection in Albuquerque, approximately three million tons of suspended sediment was transported through this reach each year in the 1960s (Table 1). Although three million tons per year of suspended sediment is a relatively low amount of sediment on the Rio Grande (Massong 2000, Massong et al. 2002, Reclamation 2003) it was enough in this reach to continue the aggradational trends during that time. As a consequence of the continued aggradation, the channel became elevated over the historic floodplain. By the early 1970s, the channel within the levee system was approximately 4 feet (1.5 m) higher than the historic floodplain outside the levees (data from Ortiz 2003).

Cochiti dam appears to have been one of the most effective sediment control features placed on the Rio Grande, such that the suspended sediment volume dropped immediately at all USGS gaging stations within a few years of operations (Table 1, Bauer 2000, Lagasse 1980, Leon et al. 2003, Massong 2000, Massong et al. 2002, Reclamation 2003); this decrease in sediment supply is coincident with the initiation of channel incision and a system wide degradational trend (Massong et al. 2002, Mussetter Engineering Inc. 2002).

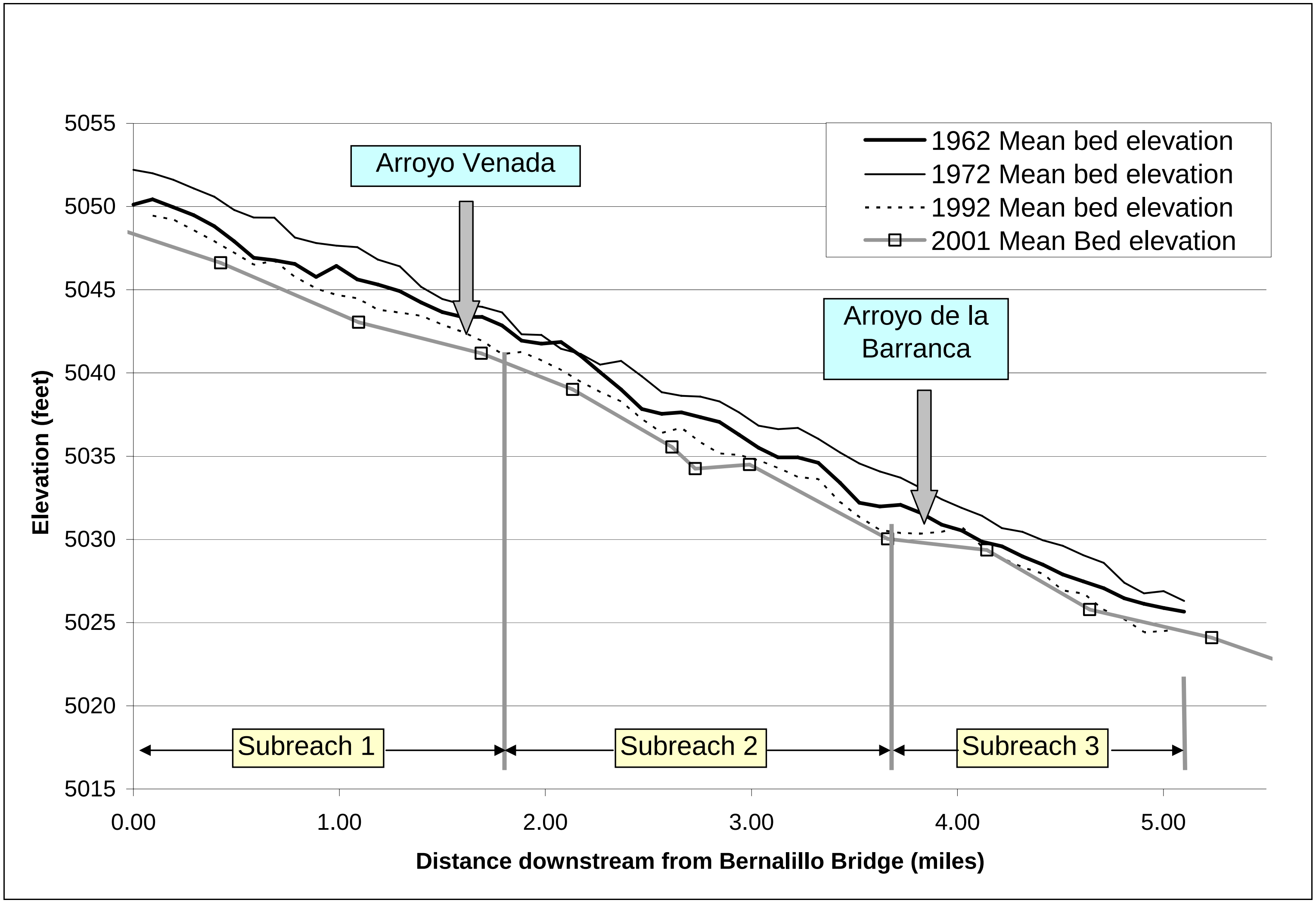

Figure 5: Mean Bed Elevation Profile of entire Bernalillo Bridge Reach for 1962, 1972, 1992 and 2001. Distance downstream is measured from agg/deg line number 298 near the Hwy 550 bridge crossing. Data for 1962, 1972 and 1992 is photo surveyed data from their respected aggradational/degradational survey projects. The 2001 data is field measured cross section data collected by Reclamation contractor. Figure reprinted from Leon et al. 2003, Figure 3-8.

Riverine data collected at the CO-lines (data presented in Leon, 2003, Figure 3-6) clearly shows that by the late 1970s this reach began degrading. In fact, the data from CO-31 shows nearly 5.5 feet of mean bed erosion between 1971 and 1998. A comparison of cross section data between 1972 and 1992 clearly indicates a bed-lowering trend (Figure 5). The floodplain surface that formed within the levee through the 1960s is now elevated from the river and appears to be abandoned (Ortiz 2003). Mid-channel bars that were actively re-worked until the late 1980s have become vegetated and appear to be either relatively high floodplain surfaces or abandoned surfaces. Other side-attached bars, especially near the Hwy 550 bridge, are becoming abandoned as the channel bed incision processes continue (Ortiz 2003).

Approximately 10-15 years after the channel began incising, the bed material in the Bernalillo Bridge reach coarsened. Historic data collected along the CO-lines (Figure 6) and from the USGS river gage, Rio Grande at Bernalillo from 1962-1969 (Leon et al, 2003) both confirm that the historic channel bed through this reach was sand. Although the first gravel was sampled in June 1975 and again in September 1980, the conversion to a gravel bed appears to have begun in earnest between the 1982 and 1992 sampling dates (Figure 6). Bank material samples collected by R. Ortiz (2003) also supports the temporal introduction of gravel to the reach in the 1980s. Ortiz found that the material composing the abandoned floodplain created prior to the 1970s was composed of fine to medium grained sand (data from Ortiz 2003, Figure 10), while the more recent deposits in the channel bars and islands (late 1980s) contained measurable amounts of gravel.

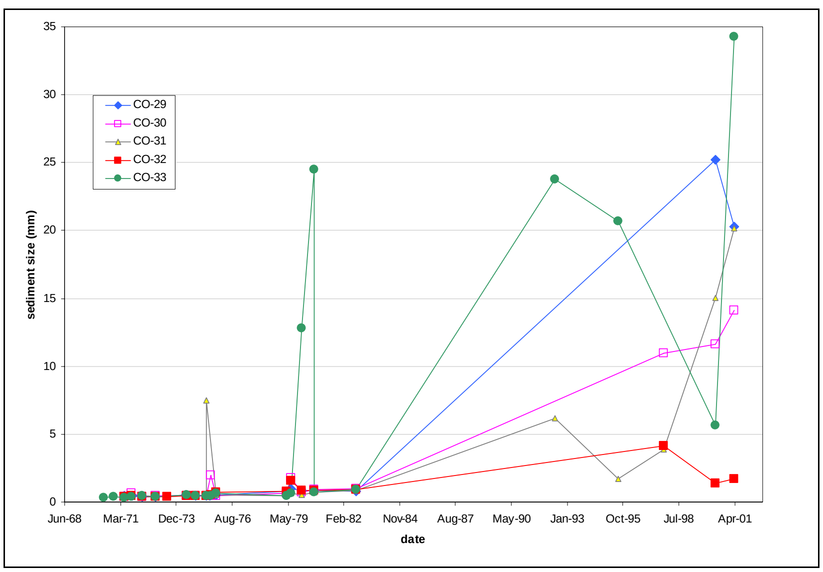

Figure 6: Historic bed material data (d84) in millimeters for the CO-lines, Rio Grande, Bernalillo Bridge area; data collected by Reclamation contractors.

At present, the channel is gravel-bedded downstream to approximately Arroyo de la Barranca, with an intermittent gravel/sand bed downstream to Arroyo de las Montoyas (Massong 2005, and Ortiz 2003). The gravel sized bed material present upstream of Arroyo de la Barranca appears to be only mobile during channel forming flows (data from Massong 2005, Tables 7&8), while the smaller material sampled downstream of Arroyo de la Barranca was mobile with much smaller flows.

Channel incision, the recent formation of abandoned surfaces (both bars and floodplain) coupled with the emergence of a gravel bed all indicate that this reach of the Rio Grande is in the process of adjusting to the lower supply of sediment. As the Cochiti dam is permanent, the supply of sand sized sediment is not expected to increase back to historic levels. The arroyos both in this reach and upstream of the reach supply a mixture of sand and gravel (USACE 1994). Since this local supply of sediment is expected to continue and be the main supply of sediment to the reach, the current bed material trends are expected to persist. Based on the sediment transport assessment (from Massong 2005, Sections 2.5 and 3.1), the bed material is expected to coarsen as the sand sized material is transported out of the reach. The incision trend is expected to slow or even stop in the section of the channel that has already become gravel (upstream of Arroyo del la Barranca), but continue in the sand-bed sections (from Massong 2005, Section 3.2).

Sediment Capacity Estimates

Leon et al. (2003) performed a series of sediment transport analyses using the total sediment load data collected by the USGS and found that estimated transport capabilities in 1992 were within the lower range of the total estimated sediment load, while the estimated capacities in 2001 were within the gravel load estimates. Using the Modified Einstein Procedure (MEP) and USGS Rio Grande gage data at Albuquerque, Leon et al. (2003) determined that current channel transported 3,000 – 60,000 tons of sediment per day at a 5,000 cfs flow (1978-1999). Specifically, sub-reach 1 transported 2,000-10,000 tons/day, sub-reach 2 transported 5,100-13,500 tons/day, and sub-reach 3 transported 600-14,300 tons/day. Up to 8% of the estimated sediment load is estimated to be gravel sized material: 240-4,800 tons/day with an 'average' of about 1,700 tons/day at 5,000 cfs flows. As this gage is several miles downstream, with several tributaries entering the Rio Grande between the gage and the study area, these sediment load values likely over estimate the amount of sediment that actually pass through the study area. Also, the wide range of sediment load estimates is due to the high variation present in the data (Leon et al. 2003, Appendix G); spring flows carry relatively little sediment while the summer flows are overloaded with sediment; a riverine process described as 'scour and fill' (Leopold 1994, and Lagasse 1980).

Transport capacity calculations were performed for both the 1992 channel geometry and the 2001 channel geometry. Calculations for the 2001 channel in sub-reaches 1 and 2 used models that were used for gravel-sized sediment, while all other calculations were based on transporting a dominantly sand-sized material. A full description of methods and results is located in Leon et al. 2003, section 5.0. Results for the 1992 channel data indicate that each of the sub-reaches could transport quantities within the lower estimates of the estimated sediment load. Transport capacity results for the 2001 channel found that although some models didn't predict sediment movement at flows of 5,000 cfs in sub-reaches 1 and 2 where there was gravel, a finding consistent with results from Massong 2005, the other models indicated a relatively low volume of gravel transport compared to the MEP results. Calculations for the 2001 channel in sub-reach 3 were based on sand transport and indicated that 600-7,000 tons/day of material could be transported; about half the amount that was estimated with the 1992 channel dimensions.

Comparisons between all the calculated transport capacities and the estimated load (MEP results) indicate that the supply of sediment is potentially much greater than the river's ability to transport it during high flows. As discussed earlier, this reach of river is incising, therefore the river is actually transporting not only the incoming supply of sediment, but also stored sediment within the active channel, hence the degradation. One conclusion, substantiated by field observations, is that sediment transport occurs in significantly quantities year-round rather than only during high flows; indicating that although the high flows transport a large volume of sediment, the smaller more persistent flows also move a large amount of sediment.

3.0 EVOLUTION OF CHANNEL SHAPE AND FLOW PATTERNS

This reach of the Rio Grande has occupied approximately the same location since the early 1900s (Figure 2), while maintaining a fairly constant sinuosity (data from Leon et al., 2003, Figure 3-4); however, in the last 30 years, the channel shape and the flow patterns have changed significantly. This section will discuss how the channel itself has changed in shape (i.e., width and depth) changes on capacity, flow speed, and how the channel pattern (i.e., meandering or braided) has evolved.

Channel Width and Island Formation

The most noticeable change in channel shape has been a decrease in channel width since the early 1900's (Figure 2 and Figure 7). The largest change in width occurred between 1918 and 1935, a change coincident with the construction of a floodway through the reach by the MRGCD. In the years that followed the 1930s, the general trend continued to be narrowing although at a relatively slow rate until the 1990s when the rate increased again (Figure 7). The width established in the 1930s with the building of the floodway is approximately the maximum width between the levees. By the 1940s, this reach had developed a small floodplain that appears to have remained relatively active until the 1960s. Some additional narrowing occurred after 1972 presumably in response to the operations of Cochiti dam and flood control, however the upper section of the reach (sub-reach 1) widened. In the last 9 years (1992-2001), the channel width is narrowing at an average rate of 11 feet per year for the reach, with a maximum rate of almost 16 feet per year in the area around Arroyo de la Barranca, sub-reach 2 (Table 2).

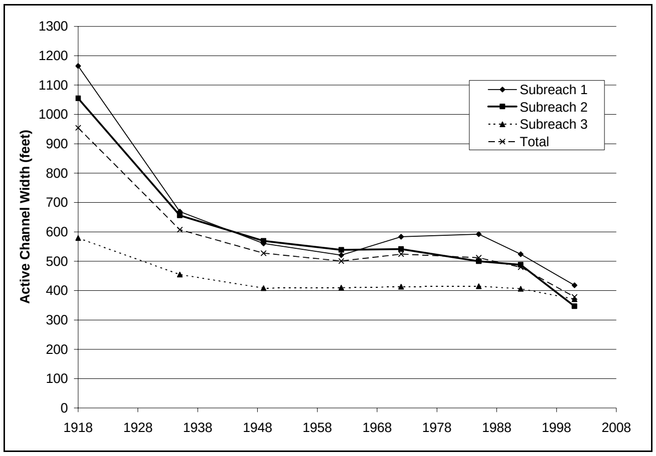

Figure 7: Reach average active channel width from digitized aerial photos. Re-print from Leon et al., 2003, Figure 3-13.

Table 2: Rates of active channel width decrease as determined from digitized channel location from 1992 and 2001 aerial photographs. Digitized channel data prepared by Reclamation, GIS and Remote Sensing Group, Denver, Colorado.

	Rate of Width Decrease (1992-2001)
Sub-reach 1	-11.8 (ft/yr)
Sub-reach 2	-15.7 (ft/yr)
Sub-reach 3	-3.9 (ft/yr)
Reach Average	-11.2 (ft/yr)

The narrowing prior to the 1980s/1990s occurred mostly through bank and point bar growth, however, the narrowing of the 1990s was been through the evolution of mid-channel bars stabilizing, vegetating and becoming at least partially abandoned from the main flow of the channel. This island-narrowing process has occurred fairly rapidly in the last 9 years, and initiated width reduction most dramatically in the upstream end of the reach (Figure 8).

Due to this latest island-initiated channel narrowing, predicting future channel widths is difficult; Leon et al. (2003) explored several traditional and non-traditional methods for predicting future channel widths, however, none of the methods yielded realistic results considering the new narrowing. The use of traditional hydraulically driven models/equations that predict channel width yielded results that were considered unrealistic (analysis in Leon et al. 2003, Section 5, Table 5-10 and Figure 5-4). The three non-traditional models, a simple width vs. discharge model, a hyperbolic model, and an exponential model, yielded better results for modeling the historic widths up to 1992. However, since the hyperbolic and exponential models are based on culminating on a stable width after a period of time, these two models do not produce good results after 1992 due to the accelerated channel narrowing. The simple width vs. discharge model (Figure 5-5 in Leon et al. 2003) predicts stable channel widths for a 5,000 cfs ranging from 550 ft to 410 feet (Table 3), results relatively similar to the 1992 widths.

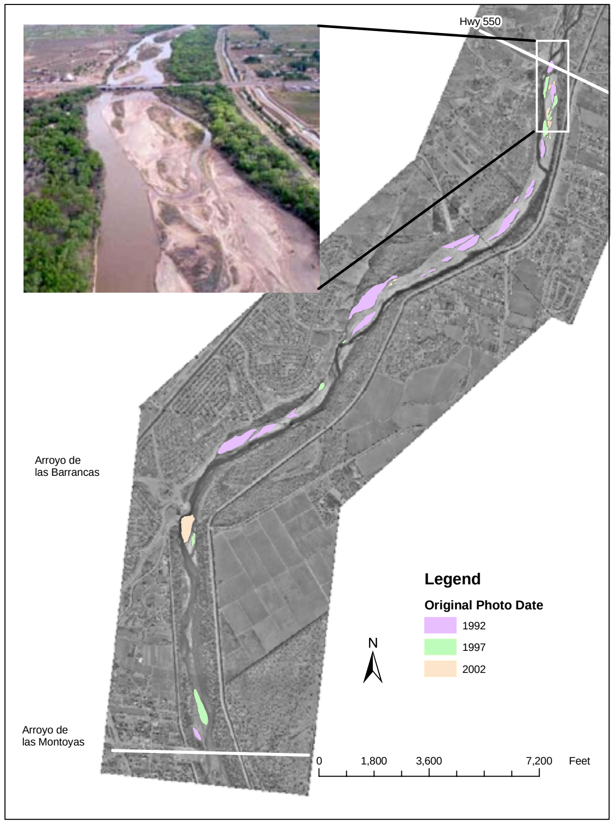

Figure 8: Island locations (R. Ortiz, 2002) and estimated formation dates in the Bernalillo Bridge reach of the Rio Grande. Background aerial photos taken in 2001. Inset photo taken in 2002. Re-print from Massong, 2003, Figure 11.

Table 3: Potential future channel widths for the Bernalillo Bridge reach, Rio Grande. Predicted width values based on empirically derived equations from Leon et al. 2003, Figure 5-5.

	1992	2001	Predicted Width Values
Average flow (cfs)	4140	4520	Estimated 5000 cfs flow
Reach 1 (width-ft)	520	418	550
Reach 2 (width-ft)	490	347	490
Reach 3 (width-ft)	410	371	410
Total (width-ft)	480	378	490

In summary, predicting width is particularly difficult in this reach due to the rapidly changing processes/transition at present. However, the three non-traditional models explored by Leon et al. appear to have the greatest potential. With the development of the increased channel narrowing, the simple width-discharge empirical model appears to yield the best results, however additional analysis after the major transition currently underway is complete would improve the results of the model.

Channel Capacity (depth, area, bank height, and overbank flooding)

Although the channel width decreased dramatically in the 1990s, a trend often associated with a decrease in channel flow capacity, the other channel dimensions changed such that the channel still conveys high flows without any overbank flooding. Historically, even moderately high flows caused overbank flooding, however this changed by 1992. Surveys since 1992 indicate that little overbank flooding occurs, such that a flow of 5,000 cfs is contained completely within the active channel.

As the channel's width decreased, especially in the upstream half of the study area, the channel depth increased. Estimated depth calculations dating back to the 1960s indicates a dramatic increase in channel depth for both the channel's maximum depth (Table 4) and the mean depth (data in Leon et al. 2003, Figure 3-12). However, the increasing channel depth has been most rapid in sub-reach 1. Although the depth did increase substantially in sub-reach 3, this increase was less pronounced than upstream increases. As a consequence to the increased channel depth, the wetted channel area also increased to an average of over 1,500 square feet, from approximately 1,200 square feet in 1992 at 5,000 cfs (data in Massong 2005, Section 2.3).

Table 4: HEC-RAS model maximum depth (ft) estimates for the Rio Grande, Bernalillo Bridge reach.

Year	Sub-Reach 1	Sub-Reach 2	Sub-Reach 3	Reach Average
1962	3.7	3.6	3.8	3.7
1972	3.9	2.8	2.8	3.2
1992	3.3	3.3	3.7	3.4
2001	8.1	7.3	5.8	7.1

Another in-channel feature that has changed dramatically to the benefit of containing higher flows is the increase in bank height. Although bank height was only indirectly assessed by Ortiz 2003 in terms of the abandoned floodplain surface of the 1960s, a review of cross section data distinctly shows an increased bank height (Figure 9).

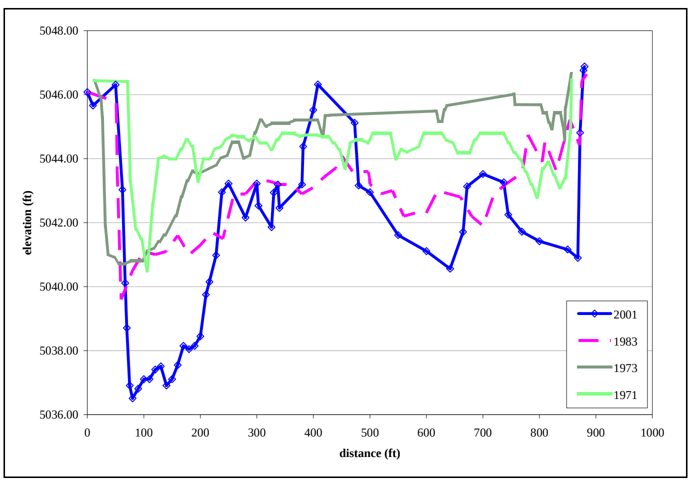

Figure 9: Cross section data from 1971, 1973, 1983 and 2001 at CO-30, Rio Grande, Bernalillo Bridge Reach showing an increase in bank height and an obviously deepening thalweg.

Flow Velocity and Channel Slope

As part of the eroding channel bed, the channel slope has decreased throughout the reach, and estimates of water velocity indicate a slower flow rate than found in the 1992 data. According to data provided in Figure 3-11 of Leon et al. 2003, the water surface slope as estimated by the HEC-RAS model has decreased since 1992. In fact, the channel slope for all three sub-reaches is approximately 0.0009 ft/ft. In 1992, the water surface slope varied from over 0.0011 in sub-reach 3 to about 0.0009 in sub-reach 1. Perhaps in conjunction to the lessening slope, the water velocity has also decreased. In the 2001 data, the estimated velocity is about 3 ft/sec for all sub-reaches (data in Leon et al. 2003, Figure 3-12) while it was higher than 4 ft/sec in the 1992 data. These data indicate that the channel profile has flattened and the water is moving slower through the reach at present.

Flow Patterns – Channel Morphology

Even though a portion of this reach is still semi-braided at low flows, the future channel pattern will likely be the full conversion to a single-threaded channel that may have sections of ‘island-braiding’ as described by Ortiz 2003. At present, sub-reach 1 and sub-reach 2a exhibit this pattern which emerged in the 1990s with a slight meandering pattern; this pattern appears stable. Sub-reach 2b and all of sub-reach 3 still has a mostly multiple-thalweg pattern. Within this downstream section, small reaches have already begun concentrating flow into one main channel which appears to be the pre-cursor to reach-scale morphology change. This conversion is expected to progress until the channel is a continuous single-threaded channel throughout the entire reach.

4.0 CONCLUSIONS

This reach of the Rio Grande has changed significantly in the last century especially upstream of Arroyo de la Barranca. The channel was physically changed during the floodway construction in the 1930s and then again with the floodway rehabilitation in the 1950s. The change in sediment supply and flow control when Cochiti dam began operations in 1973, although it began subtlety has perhaps had a more dramatic effect on the channel than is even realized today. Although the upstream section appears well into conversion, the full realization will occur after the gravel bed and single-thread channel pattern conversions are complete and the channel bed has stopped incising. This study and especially the future channel predictions should be re-visited at that time.

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