Conceptual Restoration Plan and Cumulative Effects Analysis, Rio Grande—Caballo Dam to American Dam, New Mexico and Texas

Prepared for:

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Prepared by:

U.S. Army Corps of Engineers
Albuquerque District

MEI
Mussetter Engineering Inc.
Fort Collins, Colorado

Riada Engineering, Inc.
Nutrioso, Arizona

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1. INTRODUCTION

The United States Section of the International Boundary and Water Commission (USIBWC) is evaluating long-term river management alternatives for the Rio Grande Canalization Project (RGCP), a river corridor that extends 105 miles from Percha Dam at River Mile (RM) 105.4 in Sierra County, New Mexico to American Dam at RM 0 in El Paso, Texas (USIBWC, 2004; **Figure 1.1**). The RGCP reach is contained within the Lower Bioregion (Caballo Dam, NM to Candelaria, TX) geomorphic subreach of the Rio Grande (Fullerton and Batts, 2003). The Albuquerque District of the U.S. Army Corps of Engineers (USACE) is conducting this evaluation for the USIBWC under authority of the Economy in Government Act (31 USC 1535), and the USIBWC will use the information to support the management evaluation for the RGCP.

1.1. Project Objectives

The primary objectives of this study are to identify and provide conceptual designs for river restoration sites where it would be feasible to produce enhanced cover and aquatic diversity and restore healthy riparian function to enhance natural riverine processes and improve terrestrial wildlife habitat, while protecting existing infrastructure. Habitat improvements to meet these objectives were previously identified in a baseline report that was prepared for USIBWC by Parsons at 20 locations within the RGCP (Table 2-9, USIBWC, 2003). The suggested habitat improvements at these locations included native vegetation plantings, bank shave-downs for riparian vegetation, re-activating former meanders and modifications of dredging practices at the mouths of the tributary arroyos (USIBWC, 2003). The specific purpose of this study is to assist the project sponsors and stakeholders in reassessing the restoration potential along the entire 105-mile project reach to identify feasible restoration sites and determine the most suitable restoration actions at these sites.

1.2. Scope of Work

The initial phase of this study consisted of an analysis of baseline conditions that involved compiling and evaluating the available data for the RGCP. Other tasks included modifying the FLO-2D hydraulic model of the reach that was previously prepared by Tetra Tech (2004) for the Upper Rio Grande Water Operations Study (URGWOPS), applying the modified model to assess overbank flow potential, sediment-transport and geomorphic processes, and developing a baseline description of geomorphic conditions within the reach that would affect restoration potential. Mussetter Engineering, Inc. (MEI) and Riada Engineering (Riada) completed the baseline conditions study in May 2007, and the baseline conditions report (MEI and Riada, 2007) was finalized in September 2007. Since that time, the USACE, Riada and MEI have identified and evaluated a suite of over 30 potential restoration sites. The tasks completed for this site evaluation include the following:

1. Coordination with the primary stakeholders which include the USIBWC, World Wildlife Federation (WWF), and Elephant Butte Irrigation District (EBID);
2. Application of the FLO-2D model to assess the amount of overbank inundation that could be achieved at the identified sites under existing conditions for a range of target restoration flows;

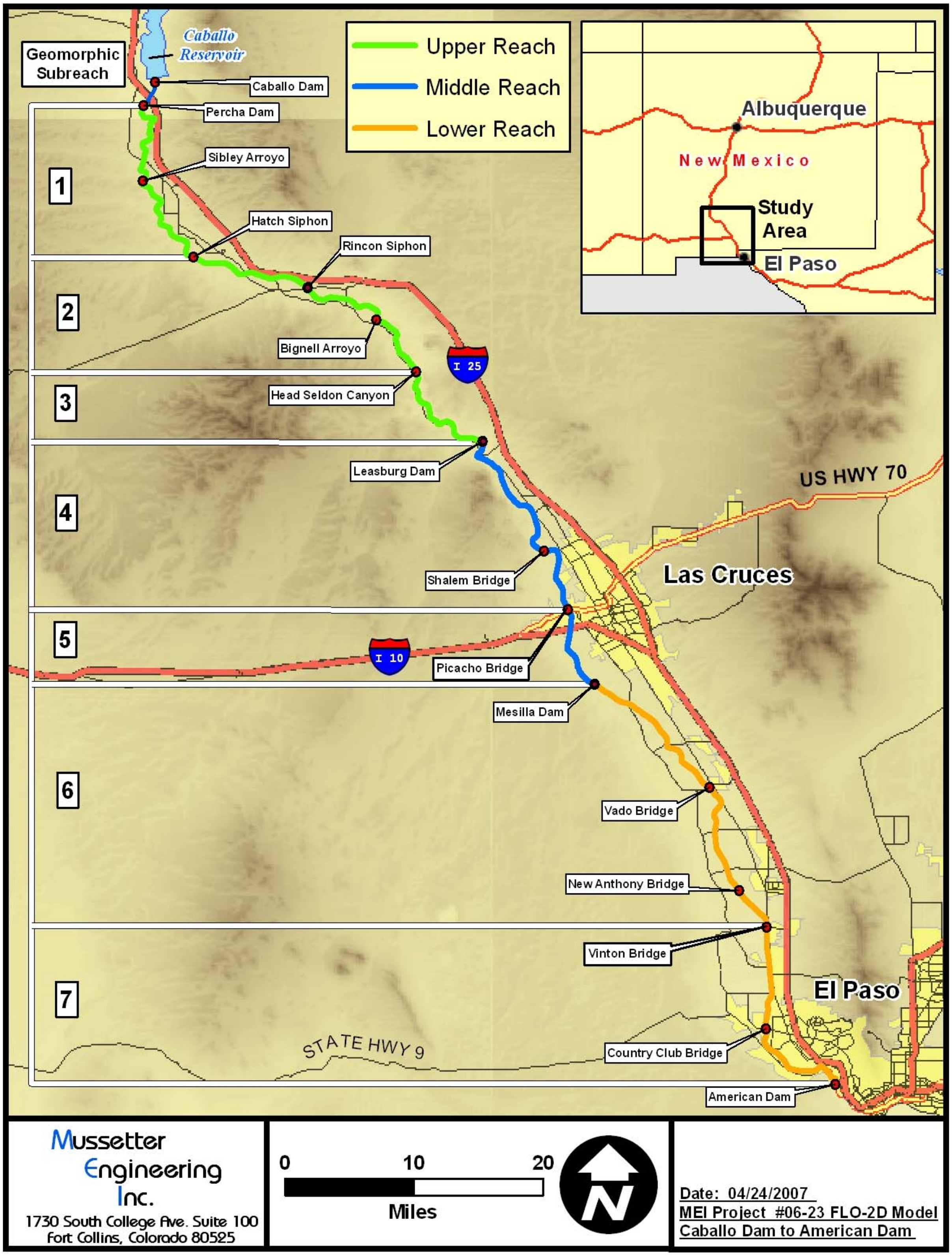

Figure 1.1. Map showing the location of the Rio Grande Canalization Project.

3. Assessment of possible site modifications to improve river-floodplain hydrologic connectivity;
4. Analysis of the anticipated long-term sustainability of the sites;
5. Assessment of the cumulative effects of the sites on flood hazard and water depletion.

This report provides a brief summary of the baseline conditions analysis, a brief description of the potential restoration sites and site selection criteria, discussion and results of the FLO-2D model, simulation of overbank flood inundation, and the cumulative impact analyses. Sites were selected primarily by USACE and Riada, with input from the primary stakeholders and MEI. USACE also identified the treatments that are believed to be most appropriate at each of the sites and evaluated the potential evapotranspiration (ET) losses associated these treatments.

2. SUMMARY OF BASELINE CONDITIONS

An analysis of the existing (baseline) conditions in the RGCP reach was conducted to provide a basis for assessing restoration potential along the reach and predicting the response of the reach to the proposed restoration actions (MEI/Riada, 2007). The analysis included an evaluation of the geologic and geomorphic setting, mean daily and peak flow hydrology, hydraulic conditions along the reach, and sediment transport and channel stability under baseline conditions. For this analysis, the RGCP was subdivided into three primary subreaches for purposes of assessing overall restoration potential. The reach was further subdivided into seven geomorphic subreaches that correspond closely to the USIBWC River Management Units (RMU) to identify the geomorphic and anthropogenic controls, and to facilitate evaluation of channel process and stability (Figure 1.1, **Table 2.1**). For purposes of the sediment-transport analysis, Subreaches 1 and 7 were further subdivided to account for the effects of existing hydraulic controls (**Table 2.2**). The following sections summarize the key findings from the baseline conditions analysis.

Table 2.1. Subreach boundaries for the RGCP (modified from USIBWC, 2003).

Subreach Number	Subreach Name	Upstream Boundary (RM and Station)	Downstream Boundary (RM and Station)	Subreach Length (mi)	Upstream Location	Downstream Location
1	Upper Rincon	105.4 5576+00	92 4768+00	13.4	Percha Diversion Dam	Hatch Siphon
2	Lower Rincon	92 4768+00	72 3730+00	20	Hatch Siphon	Head of Selden Canyon
3	Selden Canyon	72 3730+00	63 3280+00	9	Head of Selden Canyon	Leasburg Diversion Dam
4	Upper Mesilla	63 3280+00	46.5 2416+00	16.5	Leasburg Diversion Dam	Picacho Bridge
5	Las Cruces	46.5 2416+00	40 2076+00	6.5	Picacho Bridge	Mesilla Diversion Dam
6	Lower Mesilla	40 2076+00	16 832+00	24	Mesilla Diversion Dam	Vinton Bridge
7	El Paso	16 832+00	0 0+00	16	Vinton Bridge	American Diversion Dam

2.1. Baseline Geomorphology

The geologic and geomorphic investigation indicated that the quantity and size of the sediments delivered to the RGCP by arroyos downstream from Caballo Dam is closely related to the local geology. In general, the west-side tributaries deliver a greater percentage of coarser sediments to the river than the east-side tributaries. Deposition of these coarse-grained materials at tributary confluences can create channel constrictions and sediment plugs in the river. The loss of conveyance capacity due to this deposition can induce local backwater and higher water-surface elevations.

Table 2.2. Subreaches defined for the channel-stability analyses and method used to estimate flows within each subreach.

Subreach[1]	Feature at Upstream End	Upstream Station (ft)	Length (ft)	Length (mi)	Gages Used to Calculate Reach Mean Daily Flow Values
1.1	Caballo Dam	568,640	10,992	2.1	Rio Grande below Caballo
1.2	Percha Dam	557,648	38,613	7.3	Rio Grande below Caballo - Percha Private Lateral - Arrey Canal
1.3	Sibley Arroyo	519,035	42,035	8.0	Rio Grande below Caballo - Percha Private Lateral - Arrey Canal
2.1	Hatch Siphon	477,000	43,812	8.3	Reach 1.3 - Spillway #5 Hatch Main + Garfield Drain
2.2	Rincon Siphon	433,188	32,688	6.2	Rio Grande at Haynor Bridge (MOVE.1 extension with Reach 2.1 values)
2.3	Bignell Arroyo	400,500	27,200	5.2	Rio Grande at Haynor Bridge (MOVE.1 extension with Reach 2.1 values)
3	Head Selden Canyon	373,300	45,354	8.6	Rio Grande above Leasburg Dam (MOVE.1 extension with Haynor Gage values)
4	Leasburg Dam	327,946	86,294	16.3	Rio Grande below Leasburg Dam (RG above Leasburg - Leasburg Heading values)
5	Picacho Bridge	241,652	33,906	6.4	Rio Grande at Picacho Bridge (MOVE.1 extension with RG below Leasburg values)
6.1	Mesilla Dam	207,746	60,685	11.5	Rio Grande at Vado Bridge (MOVE.1 extension with Anthony Gage values)
6.2	Vado Bridge	147,061	63,802	12.1	Rio Grande at Anthony Bridge (MOVE.1 extension with El Paso values)
7.1	Vinton Bridge	83,259	41,695	7.9	Rio Grande at Anthony Bridge (MOVE.1 extension with El Paso values)
7.2	Country Club Bridge	41,564	41,564	7.9	Rio Grande at El Paso
	American Dam	---			

[1]The first number in the subreach designation corresponds to the modified RMU designation from USIBWC (2003), and the second number represents a subdivision of the corresponding RMU.

Comparison of the pre-canalization thalweg profile with the 1943, as-built, profile showed that the canalization project significantly increased the depth of the Rio Grande through most of the RGCP (**Figure 2.1**). The 2004 profiles indicate that most of the RGCP channel has degraded since 1943 due to the combined effects of the Canalization Project, reduction in upstream sediment supply by mainstem reservoirs, and the reduced tributary sediment supply due to numerous flood-control detention dams. The reach between Percha Dam and the Hatch Siphon in Subreaches 1.2 and 1.3 has incised by up to 6 feet. Immediately downstream from the Hatch Siphon at the head of Subreach 2.1 and downstream of the Rincon Siphon, there has been between 9 and 10 feet of incision. Less than 2 feet of degradation has occurred in the Salem Bridge-Hatch portion of Subreach 2, where vegetated mid-channel bars are present in the channel. The lower portion of Subreach 2.2 has aggraded by up to 2 feet, primarily in the reach upstream of Bignell Arroyo. No historical data were available for the Selden Canyon reach (Subreach 3), but field observations suggest that the canyon may in fact be somewhat aggradational. Downstream from Leasburg Diversion Dam in Subreach 4, there has been between 2 and 4 feet of degradation, and the reach through Las Cruces (Subreach 5) has experienced about 2 feet of degradation. Downstream of the Mesilla Diversion Dam in Subreaches 6.1 and 6.2, degradation ranges from about 6 feet near the dam to negligible at the Vinton Bridge. In Subreaches 7.1 and 7.2 near El Paso, up to 2 feet of channel aggradation has been observed.

Several samples of the bed material have been collected from the mainstem and the mouths of tributaries along the RGCP over the past 10 to 15 years. Prior to this investigation, bed-material samples were collected by Resource Technology Inc. (RTI, 1996) (three samples) and by Tetra Tech (2004) (six samples). In February 2007, MEI collected 14 bulk samples of sediment from the bed of the Rio Grande and the mouths of tributary arroyos, and conducted pebble counts (Wolman, 1954) of the coarse surface bed material at two locations in the Rio Grande and one location in the mouth of Tierra Blanca Arroyo specifically for this study. The bed material is coarsest in the reaches upstream from the Hatch Siphon, where the most degradation and bed armoring has occurred, and where there are a large number of tributaries that deliver sediment from the west side of the valley that drain through the Lower Santa Fe Group and Tertiary volcaniclastic sedimentary units (**Figure 2.2**). In the remainder of the RGCP reach, the bed material is primarily sand, with little variation in the bed-material size.

2.2. Baseline Hydrologic Analysis

To assess the hydrologic characteristics of the study reach, the available streamflow records were used to analyze the post-Caballo Dam period flow record (WY1938-WY2006) at several mainstem gages. Irrigation diversions and return flows were also investigated. The resulting flow-duration curves that were developed for the 25-year period between 1975 and 2006 were used in the baseline conditions sediment-transport analyses. These curves demonstrate that the flows for a given exceedence value typically decrease in the downstream direction as water is diverted from the river. For example, the 50-percent exceedence flow decreases from about 800 cfs below Caballo Dam (Subreach 1.1) to 425 cfs at El Paso, and the 10-percent exceedence flow decreases from about 2,100 cfs below Caballo Dam to about 1,160 cfs at El Paso (**Figure 2.3**).

A statistical peak flood-frequency analysis for rainfall-generated events was conducted for the El Paso (Courchesne) gage based on historic annual peak flow records. (Although originally part of

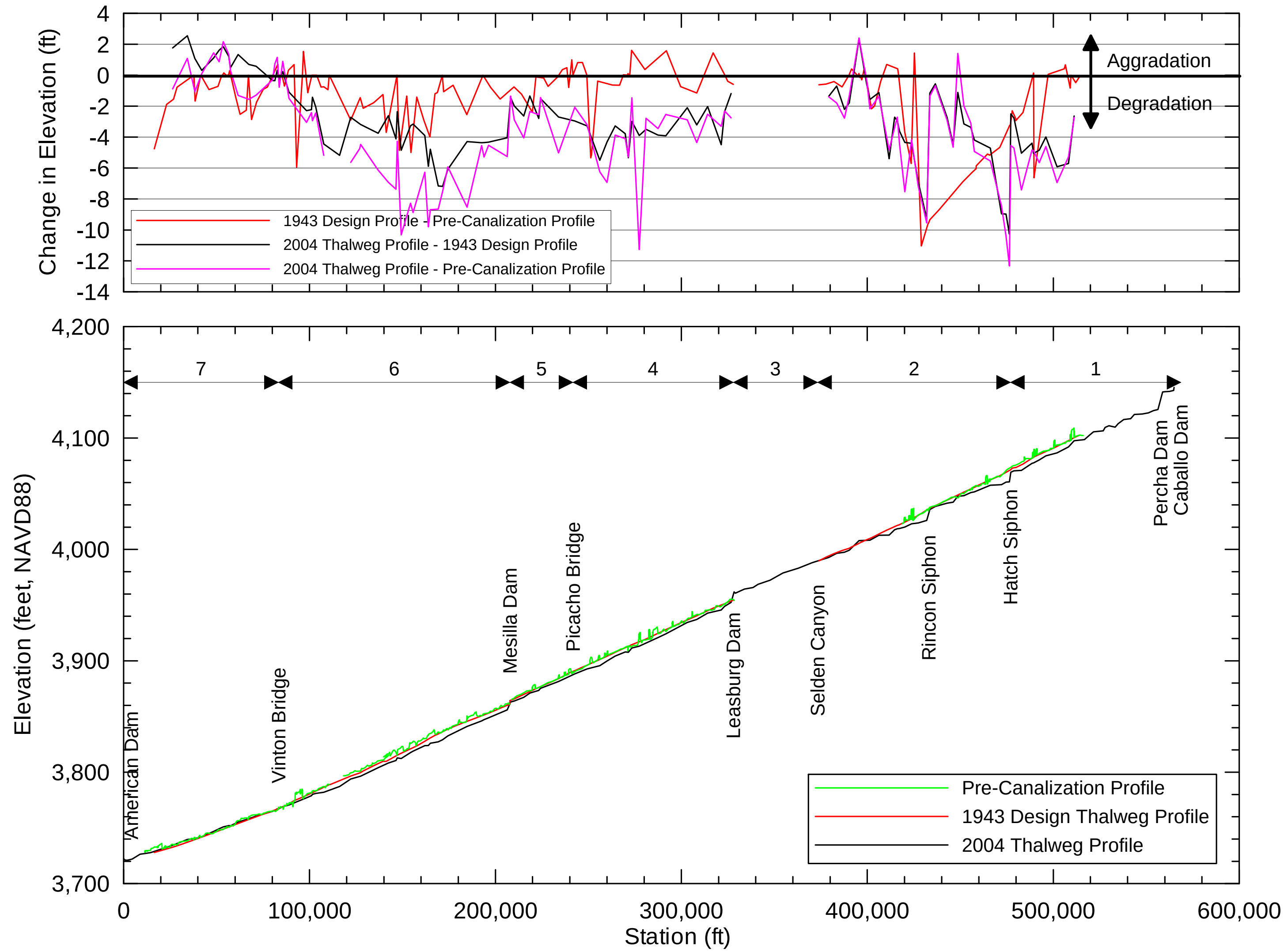

Figure 2.1. Pre-canalization, 1943 design and 2004 thalweg profiles of the RGCP. Also shown are the changes in elevation between the pre-canalization and 1943 profiles (green line) and between the 1943 profile and the 2004 profile (red line).

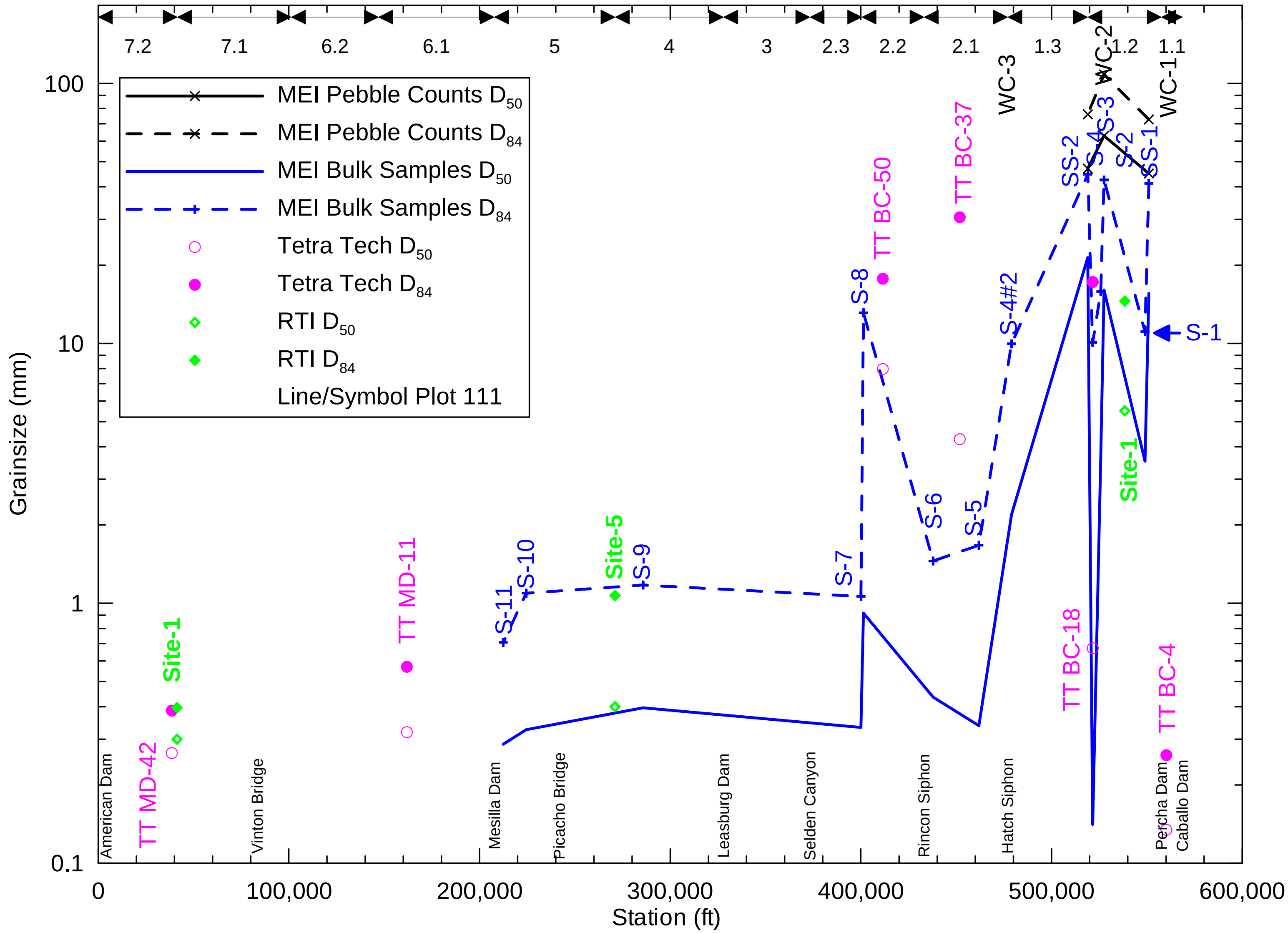

Figure 2.2. Longitudinal profile of D_{50} and D_{84} sediment sizes collected by MEI, Tetra Tech, and RTI.

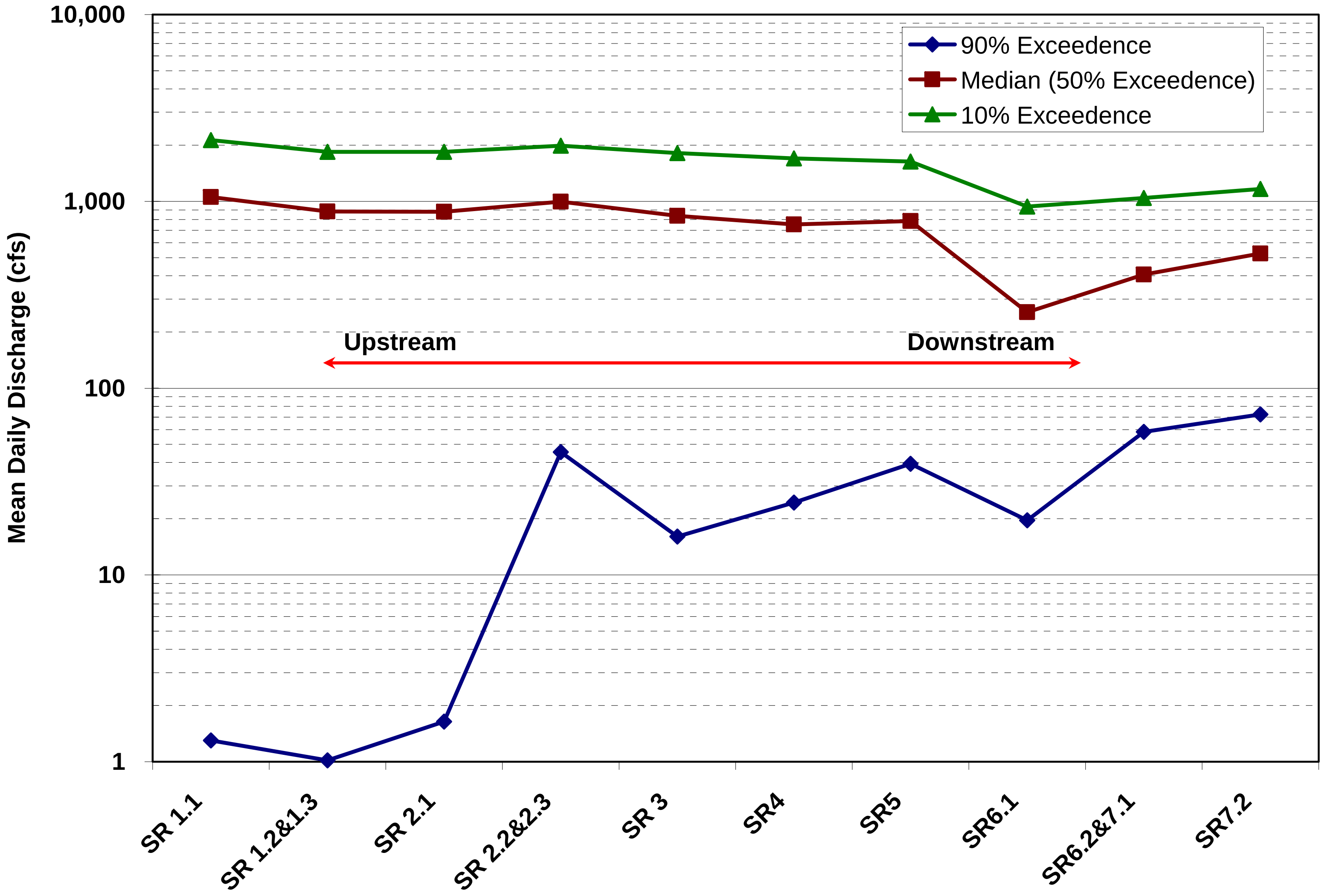

Figure 2.3. Variation in median (50-percent exceedence), 10-percent exceedence, and 90-percent exceedence flows along the study reach for the period from WY1975 through WY2006.

the workplan, this analysis could not be conducted for the Rio Grande below Leasburg or the Rio Grande below Caballo gages because peak flow data are not available at these locations.)

The analysis indicates that the 2- through 100- year peak discharges at El Paso range from 4,040 to 11,100 cfs (**Figure 2.4**). To provide information on the frequency of high flows at Leasburg and below Caballo Dam, a statistical frequency analysis was performed using the annual maximum mean daily flows. The analysis was also performed for the mean daily flows at El Paso for comparison purposes. At discharges greater than the 5-year recurrence interval, the maximum mean daily flow values at all three gages are very similar (Figure 2.4).

2.3. Baseline FLO-2D Hydraulic Analysis

An updated version of the FLO-2D model of the RGCP reach that was originally developed for the Upper Rio Grande Water Operations Study (URGWOPS) by Tetra Tech (2004) was used to estimate baseline hydraulic conditions in the project reach, including the amount of overbank inundation at potential restoration flows up to 5,000 cfs to assist in evaluating restoration potential along the reach. A brief description of the FLO-2D model is included in **Appendix A**, and more detailed information about the development and calibration of the model can be found in the Baseline Report (MEI and Riada, 2007). The model results indicate that, with no diversions along the reach, there is essentially a linear increase in the area of inundation with discharge for steady-state releases from Caballo Dam ranging from 2,350 to 4,500 cfs, with a higher rate of increase between 4,500 and 5,000 cfs (**Figure 2.5**). Considering average irrigation diversions, the amount of overbank flooding is negligible for Caballo Dam releases up to about 3,000 cfs, increasing linearly to about 1,200 acres at 5,000 cfs. Downstream from Mesilla Dam, the channel capacity is only about 1,800 cfs; thus, most of the overbank inundation in the range of modeled flows occurs in this portion of the reach.

The FLO-2D results for the lower range of discharges from 2,350 to 3,000 cfs showed limited overbank inundation north of El Paso (Subreach 7.1), minor overbank inundation in Subreaches 4 and 5 (Mesilla to Leasburg) and no overbank inundation north of Leasburg. For the mid-range of steady flows from 3,250 to 3,750 cfs, the amount of overbank inundation in the El Paso reach (Subreaches 7.1 and 7.2) increases, while limited overbank flow occurs in the upstream portions of the study reach. For discharges greater than 4,000 cfs, overbank inundation is predicted at various locations throughout the entire RGCP reach, with the most inundation occurring between Las Cruces and El Paso, moderate inundation between Leasburg and Las Cruces, and minimal overbank inundation between Percha Dam and Leasburg. Above 4,500 cfs, there is little difference in the amount of inundation between the diversion and no-diversion scenarios.

To evaluate the hydraulic characteristics in the main channel over a broad range of flows, the FLO-2D model was applied for a range of steady-state releases from Caballo Dam from 10 to 6,000 cfs, with the discharge increasing in 250-cfs increments up to 3,000 cfs and 500-cfs increments between 3,000 and 6,000 cfs. Each increment of flow was modeled for a period of 120 hours to allow the model to reach steady-state conditions during each discharge period. This range of discharges encompasses the range of flows observed in the available flow records. The depth-averaged hydraulic results for the main channel (e.g., flow velocity, depth, topwidth, and energy slope) for the stepped hydrograph were used to develop reach-averaged hydraulic information for each subreach that was subsequently used in the sediment-transport and channel stability analysis.

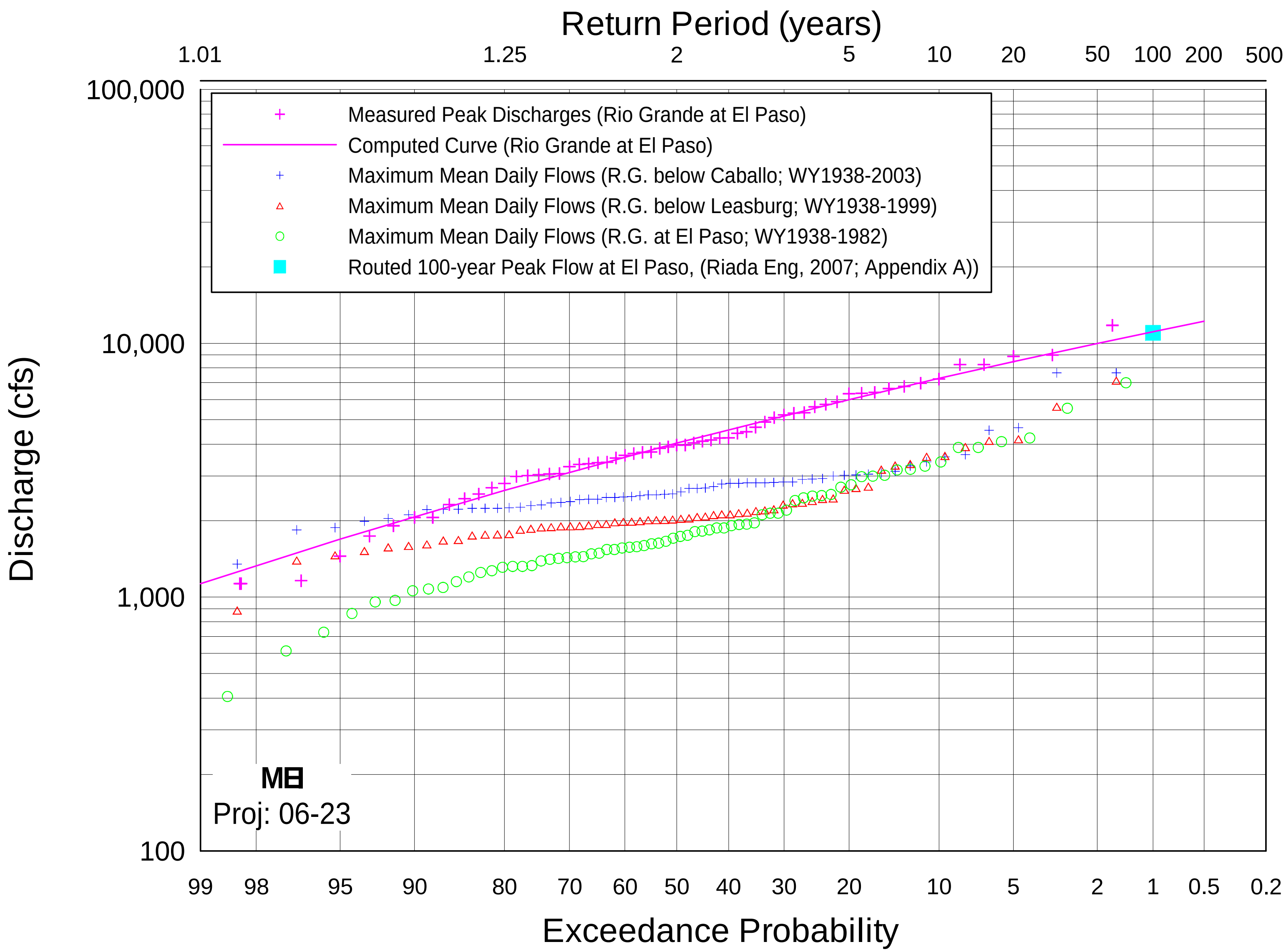

Figure 2.4. Computed flood-frequency curve for the Rio Grande at El Paso gage and maximum mean daily flows for the Rio Grande gages below Caballo, Leasburg, and at El Paso.

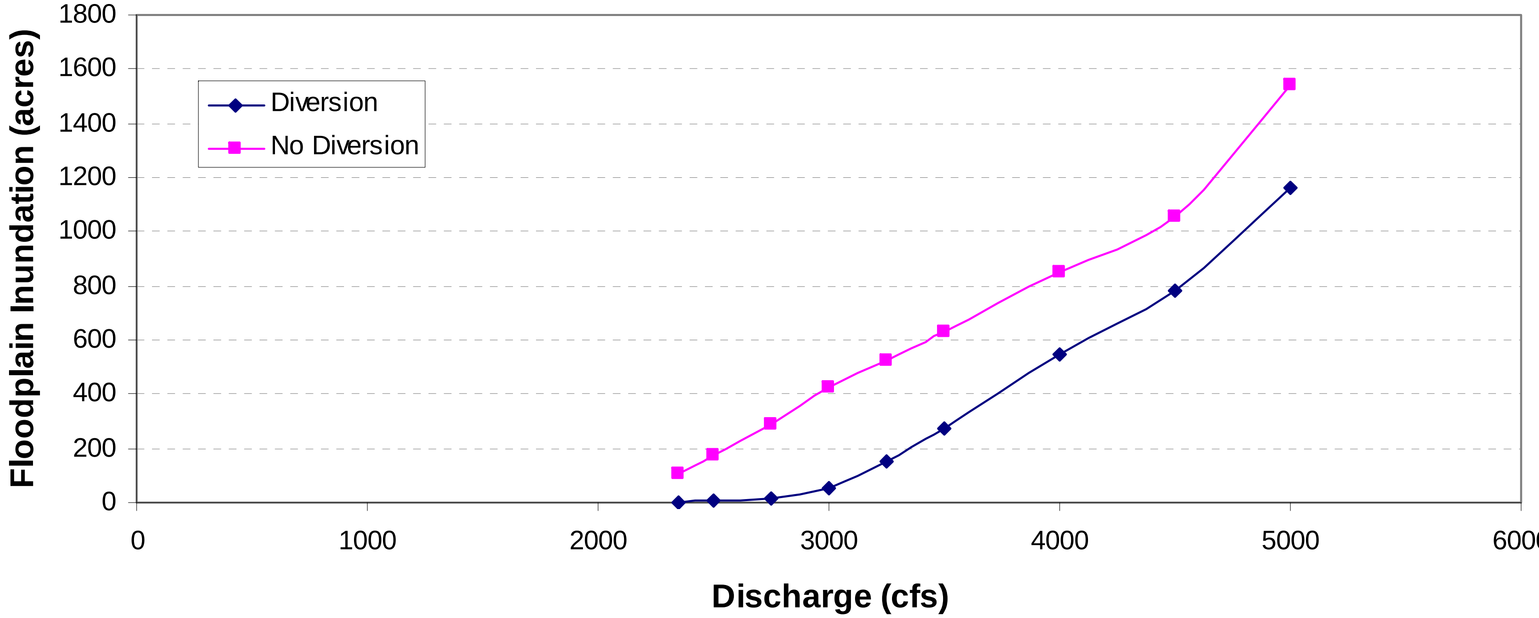

Figure 2.5. Predicted area of inundation for the range of potential restoration release with and without the diversion operating at their typical levels.

2.4. Baseline Sediment-continuity Analysis

The baseline sediment-continuity analysis was performed to evaluate the potential for aggradation or degradation with the present channel configuration and reservoir operations. In general, the analysis was conducted by estimating the annual bed-material transport capacity of each subreach and comparing the resulting transport capacity with the supply from the upstream river and tributaries within the reach.

The annual transport capacity was estimated by developing bed-material transport capacity rating curves for each subreach using Yang's (Sand) sediment-transport equation (Yang, 1973) and integrating each rating curve over the applicable mean daily flow-duration curves to obtain a transport volume. Tributary sediment loadings used in the sediment-continuity analysis were estimated based on results from Tetra Tech (2004) with the assumption, based on experience with other tributaries to the Rio Grande, that the bed-material load represents 35 percent of the total supply. For the relatively coarse-grained Geomorphic Subreach 1, an incipient motion analysis was also carried out using the subreach-averaged hydraulics and the representative bed-material gradation that consisted primarily of very coarse gravel. The analysis indicates that the bed is effectively armored over the range of flows that could reasonably occur in this portion of the reach. The bed-material load in Subreaches 1.2 and 1.3 were, therefore, assumed to be negligible and the sand-sized sediment delivered from the tributaries is assumed to be transported as a veneer (or wash load) over the existing bed material, without significant accumulation.

The long-term aggradation/degradation tendencies along the remainder of the study reach were evaluated by comparing the average annual bed-material load in each subreach with the upstream and tributary supply (**Figures 2.6 and 2.7**). The sediment-continuity analysis indicates that Subreach 2.1 is net degradational (about -0.03 feet per year) due to the high sediment-transport capacity compared to the upstream and arroyo sediment supply. This subreach is located below the Hatch Siphon, where approximately 10 feet of degradation has occurred since completion of the Canalization Project in the early-1940s. The degradation rate indicated by the continuity analysis is less than the historical, post-Canalization Project rate, which is reasonable since the channel has undergone substantial adjustment during the period and is likely approaching equilibrium with the existing upstream sediment supply. Subreach 2.2 is slightly aggradational (0.04 feet per year), consistent with historic aggradation observed in this subreach. Subreach 2.3 is net degradational (-0.13 ft/yr) due to the high sediment-transport capacity (103 ac-ft/yr) and little or no tributary supply to the reach. This subreach is located within the steeper and confined section between Bignell Arroyo and Selden Canyon. Compared to the degradation rates in the other subreaches (e.g., Subreach 2.1), the estimated rate in Subreach 2.3 may be unreasonably high. It is possible that the bed material in this relatively inaccessible reach is coarser than the gradation that was used in the analysis, but sufficient data are not available to confirm this. From Subreach 3 through the downstream end of the study reach, the transport capacity is approximately in balance with the supply, with a slight aggradational trend in Subreaches 5 and 6.1 (0.03 and 0.04 ft/yr, respectively) due to the lower transport capacities. Consistent with this trend, the USIBWC has removed sediment from this portion of the reach on multiple occasions since construction of the Canalization Project.

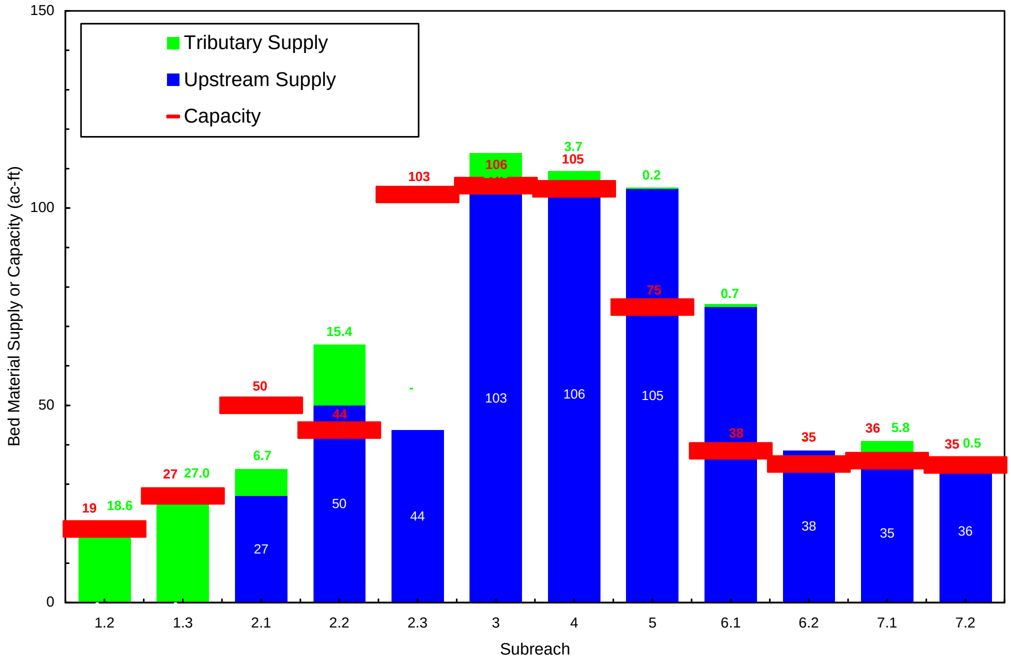

Figure 2.6. Comparison of average annual supply and bed-material transport capacity for each subreach.

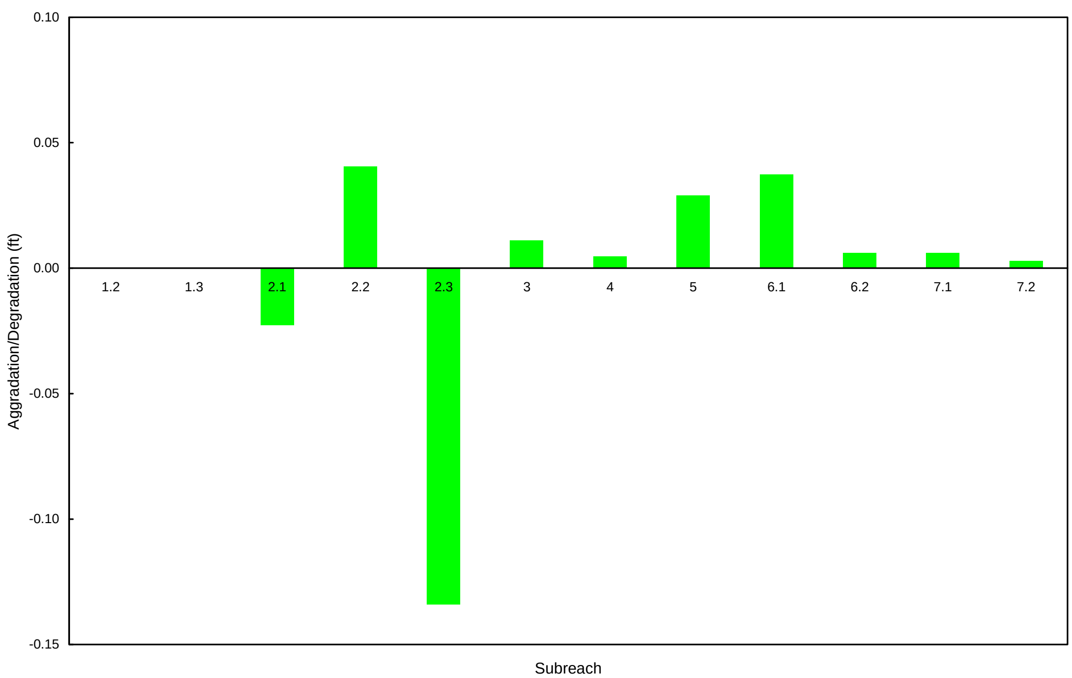

Figure 2.7. Estimated average annual aggradation/degradation depths for each subreach.

It is important to note that the above continuity analysis quantifies the relative balance between the transport capacity and supply that affects the overall aggradation/degradation tendencies along the reach. Local changes in bed elevation that differ from the subreach-averaged trends occur in specific areas due to a combination of local scour at structures, contraction scour in locally narrow reaches, and deepening on the outsides of bends. For example, according to EBID, about 18 inches of bed lowering has occurred at the Picacho Flume since the 1990s that required extensive work to protect the wooden piles. Sufficient information is not available to the project team to assess the specific causes of this bed lowering, but it does not appear to result from general degradation.

2.5. Baseline Ecological Conditions

2.5.1. General

The study area lies within the Chihuahuan Desert ecoregion (Bailey, 1976). The native upland plant community outside the Rio Grande floodway is dominated by a mosaic of semi-desert grasslands and shrublands. Common species include honey mesquite (*Prosopis glanulosa*), four-wing saltbush (*Atriplex canescens*), creosote-bush, and tarbush (*Flourensia cernua*) in shrublands; and tobosa (*Pleuraphis mutica*) and black grama (*Bouteloua eripoda*) in grasslands. Throughout the Rio Grande valley in the study area, agricultural lands predominate, often directly abutting the floodway. Two large urban areas occur at Las Cruces, New Mexico, and El Paso, Texas.

Historically, the floodplain of the Rio Grande through southern New Mexico supported a broad band of riparian vegetation consisting of a mosaic of woodland, shrub, and meadow communities (Dick-Peddie, 1975; sources cited in Scurlock, 1999 and Stotz, 2000). Linear gallery forests or widespread, but patchy, woodland stands were dominated by Rio Grande cottonwood (*Populus deltoides* subsp. *wislizeni*, Goodding's willow (*Salix gooddingii*), and peach-leaf willow (*S. amygdaloides*). Shrub communities, sometimes forming a moderately dense woodland understory, included coyote willow (*S. exigua*), seep-willow (*Baccharis salicina*), pale wolfberry (*Lycium pallidum*), and skunkbush sumac (*Rhus trilobata*). Common native grasses and forbs within the riparian corridor included alkali sacaton (*Sporobolus airoides*), sand dropseed (*S. cryptandrus*), vine mesquite (*Panicum obtusum*), sunflowers (*Helianthus* spp.), and asters (*Aster* spp.). Inland saltgrass (*Distichlis spicata* var. *spicata*) was the dominant grass species in the riparian zone, including areas too saline to support cottonwood and willow. [Scientific names for all plant species follow Allred (2008).]

The Rio Grande channel in the lower-perennial Mesilla Valley historically followed a sinuous path which meandered widely throughout the floodplain (**Figure 2.8**). The river frequently changed its course across the floodplain, creating new channels and abandoning old ones. Abandoned channels often contained sufficient groundwater discharge to support marshes (*cienegas*), sloughs (*esteros*), and oxbow lakes (*charcos*) (Dick-Peddie, 1975; Scurlock, 1998; Ackerly, 1999; Stotz, 2000). Marshes supported cattails (*Typha* spp.) and softstem bulrush (*Schoenoplectus tabernaemontani*) along with a variety of other sedge and rush (*Juncus*) species. The hydroperiod of these wetlands depended on their proximity to the Rio Grande channel and the depth to the water table. Ponds and marshes within abandoned channels or depressions deep enough to intersect the ground water table were likely permanently or semi-permanently flooded. Wetlands in shallower basins or further from the river were likely seasonally or temporarily flooded; that is, during the majority, or just a portion, of the growing

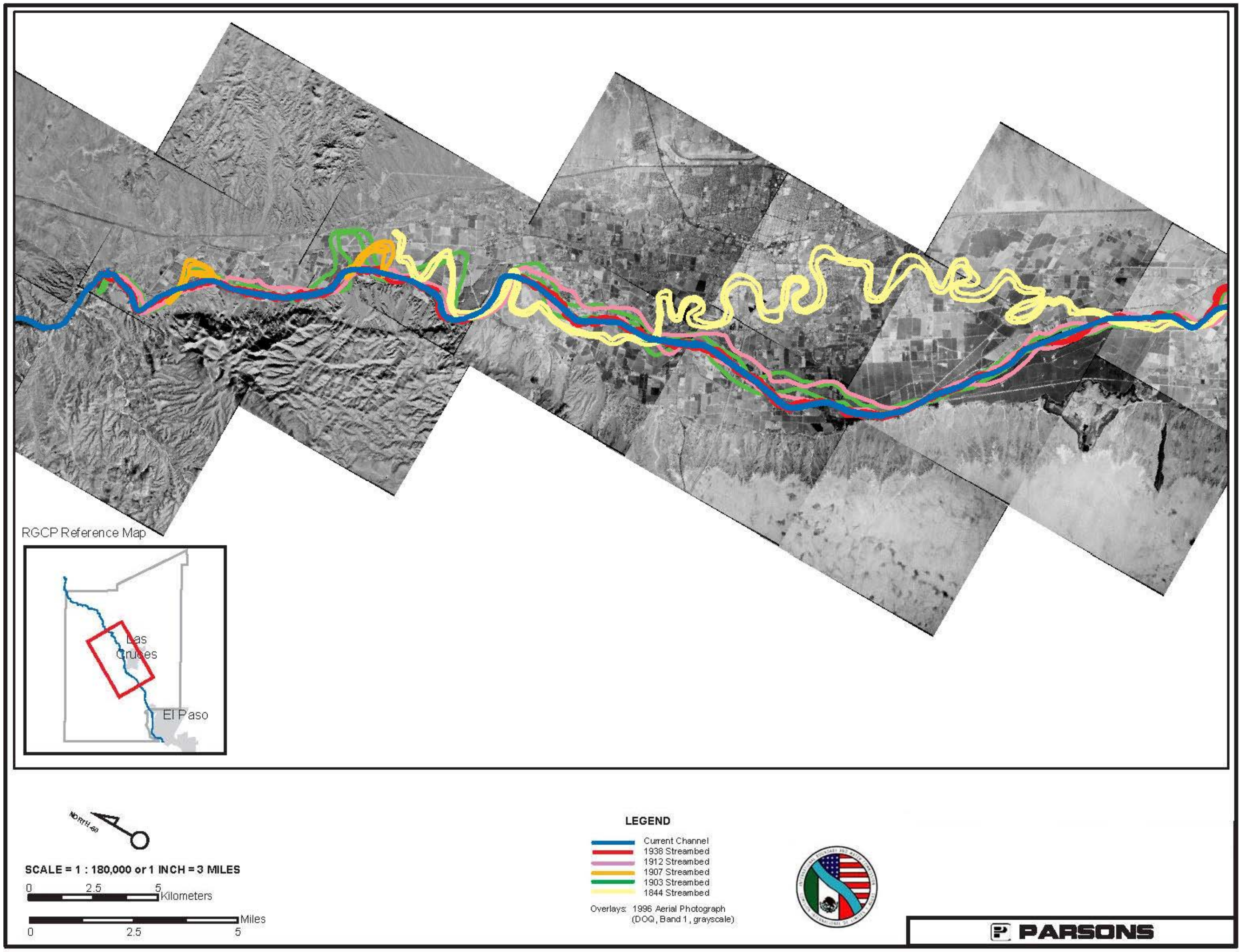

Figure 2.8. Comparison of current channel and historic streambeds in the Upper Mesilla Valley (from Parsons, 2003).

season, respectively. River flows during the spring runoff period elevated the regional water table sufficiently to discharge into these wetlands.

Currently, the extent of riparian and wetland plant communities in the historic floodplain of the study reach has been significantly reduced; however, little information is available to accurately quantify the reduction (see discussion in Stotz [2000]). In addition to direct replacement by agricultural and urban development throughout the reach, the ground water elevation in the valley was lowered by the construction of drains in the 1920s. In 1917, Elephant Butte Dam began operation for irrigation and flood control purposes. Several other dams and diversions (Caballo, Percha, Leasburg, Mesilla, and American Dams) were constructed beginning as early as 1912. Except for discharges from uncontrolled tributaries, the flow regime of the Rio Grande is entirely regulated. Irrigation and flood control operations have reduced the magnitude of discharges within the floodway, especially during the spring runoff period, limiting the extent of overbank flooding.

The Rio Grande Canalization Project (RGCP) was constructed between 1938 through 1943, and included river straightening, channelization, riparian vegetation removal, bank armoring, and levee construction from present-day Percha Dam downstream for approximately 105 river miles to American Dam. Earthen levees, constructed to provide protection for the 100-year (1-percent chance) flood, extend for 57 miles along the west side and 74 miles along the east side of the Rio Grande. Reaches with elevated bluffs or canyons walls adjacent to the river did not require levees to contain this event. Generally, the floodway is 750 to 800 feet wide north of Mesilla Dam and 600 feet wide downstream from that point. Large portions of the overbank areas within the floodway have been regularly mowed to assure flood conveyance, and this has limited the growth and distribution of riparian trees and shrubs.

Saltcedar (*Tamarix* spp.), a deciduous, needle-leaved tree, was introduced into the United States from Eurasia in the early 1800s (Robinson, 1965). Along large portions of the Rio Grande floodway downstream from Albuquerque, saltcedar has become established in the understory of existing cottonwood galleries, but, more extensively, has replaced broad expanses of riparian grassland and coyote willow communities.

2.5.2. Functions of Riparian and Wetland Vegetation

The riparian zone of a river or stream includes that portion of the terrestrial landscape from the water edge landward where vegetation may be influenced by river-associated water tables or flooding, and by the ability of soils to hold water (Mitsch and Gosselink, 1986). The following discussion highlights the major functions of riparian and wetland vegetation and is not intended to be an exhaustive summary. For concise reviews of riparian functions and values see Brinson et al. (1981); Davis et al. (1996); and other cited sources.

<u>Bank Stabilization</u>. Channel width, depth, and slope are influenced by bank stability. Vegetation stabilizes banks by directly reducing flow velocities and thus the erosive forces at the soil-water interface (Davis et al., 1996). Roots and rhizomes of bank vegetation bind soil material, increase cohesiveness, and reduce weakening and loosening processes which are often the precursors of entrainment (Thorne, 1990). The numerous fine roots of sedges and grasses provide greater binding strength than coarse roots of woody plants. A mixture of vegetation is generally preferred since the deeper rooting depth of trees and shrubs provide additional protection to tall banks. Vegetated banks are also drier than unvegetated slopes because soil water is removed by transpiration, effectively reducing the likelihood of mass failure. The net effect of these contributing forces is generally positive, however, in some rivers

or reaches (including the Rio Grande in the study area), dense bank vegetation (e.g., saltcedar) may exacerbate channel incision and narrowing.

Resistance to flood flows. Vegetation within the floodway presents an obstruction to water flow that tends to decrease flow velocities. Soil erosion is reduced in vegetated overbank areas and deposition of suspended sediment is enhanced. The magnitude of these effects depends upon the density and type of vegetation. Grasses and short herbaceous groundcover are flattened against the ground surface by flows and present relatively little resistance to flow. Shrubs provide higher resistance due to the stiff, less flexible branches and, if present, large leaf area. Dense mature trees have large cross-sectional areas and can withstand relatively high flows without breaking, therefore, providing the greatest resistance to flow (Vogel, 1984). Sparsely distributed trees can actually generate bank scour by accelerating flow around their trunks.

Floodwave attenuation. The flood peak discharge is a function of the available storage in the channel and on the floodplain. A small flood peak will occur when there is significant floodplain inundation and storage. Dense riparian vegetation can increase floodplain storage through the reduction of flow velocity through the vegetation.

Sediment load. Riparian vegetation affects stream morphology by impacting both sediment supply and deposition. As stated previously, overbank vegetation influences sediment transport by reducing flow velocities and causing deposition. Since the primary source of sediment in many streams is bank erosion (Dunne and Leopold, 1978), sediment load can be significantly limited by bank vegetation. In agricultural watersheds with significant sediment laden runoff, riparian vegetation can trap sediments before they reach the stream (Lowrance et al., 1984).

Nutrient trapping and removal. Riparian vegetation traps both suspended and dissolved materials and contributes significantly to the high fertility of floodplain soils. Suspended particles in overbank flow and upland runoff are deposited when flow velocities are decreased by vegetation. Most notably, carbon, nitrogen, and phosphorous concentrations in surface water are effectively reduced by floodway vegetation (Peterjohn and Correll, 1984). Additionally, riparian root systems uptake dissolved nutrients in subsurface water.

Importance to aquatic systems. Bank vegetation is also an important component of aquatic faunal habitat (Platts, 1983). Streamside vegetation provides shade and cover for fishes where it overhangs the water surface. The contribution of carbon to downstream aquatic habitats is one of the most widely recognized functions of riparian vegetation (Brinson et al., 1981).

Pollutant removal. Created wetlands have been used to improve water quality from agricultural or stormwater runoff at many locations in the United States. Pollutant removal is accomplished through several physio-chemical and biological processes. Wetland treatment systems substantially improve water quality for suspended solids, trace metals, fecal coliform (as indicators of potentially pathogenic organisms), pH, nitrate, phosphorus, and biological oxygen demand (Hammer, 1991; Reed et al., 1995).

Wildlife habitat. Riparian and wetland habitats provide breeding sites, wintering areas, and migratory stop-over areas for numerous wildlife species. The provision of food, cover, and shelter has long been an important, widely recognized function of these communities (Brinson et al., 1981). This is especially true in the central and western United States where riparian woodlands provide uncommon and structurally complex habitats relative to the surrounding grassland or shrub land. Riparian woodland occupies only a small percentage of land area in the Southwest, but more than 60 percent of the vertebrates found in theses systems are obligate to them (Ohmart and Anderson, 1982). Riparian plant communities serve as travel corridors for local mammal populations.

2.5.3. Plant Communities Within the Study Area

In 2001, Parsons (2001b) determined the extent of major physiognomic classes of vegetation within the RGCP area from color infrared orthoimagery. **Table 2.3** lists the acreage and relative distribution of these types throughout the study reach and within subreaches. The following discussion is based on this and other analyses by Parsons, Inc., field surveys conducted by the Corps, and inspection of the 2004 Doña Ana County and 2005 Corps aerial photography.

Herbaceous vegetation comprises 45 percent of the area within the floodway, and consists primarily of grasslands. The predominance of this community is likely the result of long-term mowing of the overbank areas to control weed, brush, and tree growth. Levee slopes are also mowed to prevent the root systems of woody vegetation from compromising their structural integrity. Mowing is conducted nearly annually on up to 4,657 acres, including vegetation types listed in Table 2.3 as herbaceous, exposed ground, levees, and, to some degree, shrublands (USIBWC 2003).

Table 2.3. Distribution of plant communities (acres and percent within reach) in the RGCP floodway (USIBWC 2003).

Plant community [1]	Upper Reach (Percha Dam to Leasburg Dam)		Middle Reach (Leasburg Dam to Mesilla Dam)		Lower Reach (Mesilla Dam to American Dam)		Total	
Woodland	584	23%	437	29%	424	26%	1,445	25%
Shrubland	611	24%	155	10%	73	4%	839	15%
Herbaceous	859	34%	738	48%	954	58%	2,551	45%
Exposed ground	377	15%	174	11%	151	9%	702	12%
Emergent wetland	75	3%	26	2%	39	2%	145	2%
Forested/shrub wetland	32	1%	3	<1%	2	<1%	37	1%
Total	2,537		1,533		1,643		5,714	

[1] Does not include herbaceous vegetation on levees (748 ac.) or cropland (66 ac.) within the floodway.

Throughout the entire reach, saltgrass is the principal species present in areas classified as herbaceous vegetation. While saltgrass stands are most vigorous in areas with a relatively shallow water table, this species has a long root system and can occupy drier portions of the floodway (BOR, 1997). Alkali sacaton frequently occurs (mixed with saltgrass) in a transitional zone between drier saltgrass-dominated stands and more moist areas supporting sedges and rushes. Bermudagrass (*Cynodon dactylon*), an introduced species, occurs in relatively large stands within the floodway downstream from Shalem Colony Bridge (River Mile 51.5). Watts (1998) found Bermudagrass to be common along the banks of the Rio Grande from Selden Canyon downstream to Fort Quitman, approximately 86 miles south of the current study area.

In addition to grass species, herbaceous communities also include a diverse variety of forbs; 84 species were documented by Parsons (2001a). These species are typical of early seral-stage communities and are tolerant of mowing. Common species that may dominate the floral composition in relatively large patches (0.5 acres or more) in the driest parts of the floodway include aster, nightshade (*Solanum* spp.), cocklebur (*Xanthium* spp.), red bladderpod, goosefoot (*Chenopodium* spp.), and non-native Russian–thistle (*Salsola* sp.). (Because of the low density of these species, many of these areas may have been classified as Exposed Ground by Parsons [USIBWC, 2003].)

Shrublands classified by Parsons (USIBWC, 2003) include woody vegetation less than 9-feet tall. The relative abundance of this vegetation type decreases from north to south, likely as a function of the flatter topography of overbank areas downstream from Leasburg Dam which facilitates mowing. Saltcedar is the most common shrub, often forming dense patches where mowing is not practical. The highest concentration of saltcedar within the floodway is in Selden Canyon (outside of the USIBWC right-of-way). Saltcedar seeds are viable for a longer period than cottonwood and willow (DiTomasso and Healy, 2003), and are able to germinate in drier soil conditions; therefore, this species has proliferated along the Rio Grande (Crawford et al., 1993) and throughout the western U.S. along regulated rivers. Once established, saltcedar has the capability to readily produce sprouts after fire or mowing. Much of the overbank areas dominated by saltgrass throughout the study area were observed to be populated by scattered saltcedar sprouts, which can attain a height of 3 to 5 feet between annual mowing cycles. (Many areas classified by Parsons [USIBWC, 2003] as herbaceous vegetation may also include saltcedar sprouts.) Coyote willow occurs in scattered to moderately dense patches in the floodway where the groundwater is relatively close to the surface during the growing season (usually within 3 feet). Coyote willow also readily produces sprouts following grazing or mowing. The practice of vegetation management in the RGCP reach (since the 1940s), coupled with decreased discharges following the closure of Elephant Butte Dam in 1917, has limited the distribution of coyote willow within the floodway.

In portions of the floodway with relatively drier soils (largely north of Selden Canyon), pale wolfberry and four-wing saltbush are scattered throughout the higher elevations of the overbank areas. Both species are capable of growing in semi-arid soil conditions and their distribution is not dependent on proximity to the water table. Their presence within the geographic area of the current floodway likely has been facilitated by the reduction of overbank inundation since the closure of Elephant Butte Dam. While typically classified as transitional or upland species, both shrubs provide food sources for many animals (Martin et al., 1951). Therefore, the presence of these two species within the floodway should be treated as indicators of areas which may not be cost effective for riparian restoration, yet provide additional wildlife habitat.

Other shrub species that commonly occur in the floodway are arrow-weed (*Pluchea sericea,* a semi-woody species found primarily north of Shalem Colony Bridge), and seep-willow and screwbean mesquite (*Prosopis pubescens*) (scattered throughout the study reach).

Both saltcedar and coyote willow occupy much of the banklines of the Rio Grande throughout the study reach. Saltcedar appears to be more prevalent upstream from Shalem Colony Bridge, and coyote willow is more common downstream from that point. Regardless of the dominant species, these shrubs appear to thrive in a 10- to 20-foot-wide strip along the bank. It is not clear if their lateral distribution is limited by soil moisture influenced by river stage or by mowing practices which avoid river bank disturbance; however, the root systems of both species provide bankline stabilization. The height of these shrubs ranges from 5 to 15 feet, and they are commonly, 8 to 10 feet tall.

Parsons, Inc. (in USIBWC, 2003) classified the Woodland vegetation type as containing woody vegetation greater than 9 feet tall, and listed saltcedar as the dominant species; therefore, much of this vegetation class includes shrub stands as traditionally defined. Rio Grande cottonwood is the principal tree species in the reach and occurs in small, scattered stands that rarely attain canopy closure greater than 75 percent, or as isolated trees. Goodding's or peach-leaf willow also occur as scattered, isolated individuals. Non-native Siberian elm (*Ulmus pumilla*) is occasionally present in the floodway, particularly near Hatch. The long-term absence of overbank inundation and soil disturbance has severely limited the germination of cottonwood and willows in the study reach.

Emergent wetlands are uncommon in the study reach. Only a few shallow marshes occur throughout the reach, usually dominated by cattail and bulrushes. More common are small patches of rarely inundated, wet meadow which occur where the depth to the water table is most shallow, often near or along the river banks. Meadow vegetation is dense and highly diverse. Common species include Baltic rush (*Juncus balticus*), three-square bulrush (*Schoenoplectus pungens*), cattail, and horsetail (*Equisetum*). Coyote willow or seep-willow are frequently scattered throughout, or adjacent to, wet meadows.

2.5.4. Relative Habitat Value

The value of various habitat types differs for each animal species. Generalizations can be made for larger taxonomic groups such as lizards, bird and small mammals. Because of their greater abundance and conspicuousness, birds are the subjects of the majority of studies analyzing habitat relationships.

Several studies (see below) have found that riparian areas are preferred habitat for a large proportion of the bird species in New Mexico, especially during the breeding season. Generally, the abundance of breeding birds increases with the complexity and density of vegetation structure, which is thought to be related to the increased food, cover, or nest substrate it provides. Along the Rio Grande, the highest breeding densities typically have been found in marshes, cottonwood stands with a well developed shrub understory, and in tall shrub stands (Hink and Ohmart, 1984; Hoffman, 1990; Thompson et al., 1994; Stahlecker and Cox, 1996; HAI, 2006). Saltcedar and woodland stands with a sparse understory generally support fewer breeding birds. Marshes, drains, and areas of open water contribute to the diversity of the riparian ecosystem as a whole because of their strong attraction to waterbirds.

For the RGCP study area, the most pertinent information on avian habitat relationships comes from a two-year study by graduate students from New Mexico State University (Thompson et al., 1994). Birds were surveyed in 1992 and 1993 along 72 500-m-long transects adjacent to the Rio Grande between Velarde and Mesquite, New Mexico (that is, over approximately 360 river-miles). Sixteen of the surveyed transects were downstream from Caballo Dam. This study includes detailed analysis and discussion of bird community patterns throughout the Rio Grande Valley and the specific value of riparian plant community types.

In an ancillary analysis (Leal et al., 1996), the same authors summarized relative habitat value through multivariate analyses relating bird species richness and abundance with vegetation structural characteristics (such as, vegetation height, stem density, tree size, ground cover, canopy closure, etc.). Their findings are summarized in **Table 2.4**. The relative ranked importance of the various habitat types was fairly similar for all bird species and Neotropical migrant (NTM) species across all seasons and for all bird species in summer; but rankings differed for NTM species in summer.

Table 2.4. Relative ranked importance (1=highest) of plant community types for all bird species and Neotropical migrant (NTM) species based on canonical variate scores (Leal et al., 1996). Community types are ordered in the table by their "All species–All seasons" rank. Communities commonly found downstream from Caballo Dam are in **bold** typeface.

Community (Overstory / Understory)	All seasons [a]		Summer	
	All species	NTM species	All species	NTM species
Cottonwood / NM olive	1	4	1	3
Cottonwood / Mesquite	**2**	**5**	**3**	**9**
Cottonwood / Saltcedar	**3**	**6**	**2**	**1**
Cottonwood / Willow	**4**	**2**	**9**	**12**
Russian olive shrubland	5	3	4	14
Emergent marsh	**6**	**1**	**6**	**16**
Cottonwood / sparse or no understory	**7**	**10**	**5**	**4**
Mesquite-Saltcedar shrubland	**8**	**8**	**11**	**6**
Cottonwood / Russian olive-Saltcedar	9	7	10	10
Cottonwood / Russian olive	10	11	8	11
Cottonwood / Exotic shrubs-Willow	**11**	**9**	**12**	**5**
Cottonwood / Russian olive-Juniper	12	13	7	2
Pecan orchard	**13**	**12**	**14**	**7**
Saltcedar shrubland	**14**	**16**	**13**	**8**
Saltcedar-Willow-Cottonwood shrubland	**15**	**14**	**15**	**13**
Mowed river edge	**16**	**15**	**16**	**15**

[a] Spring, summer, and fall.

The Rio Grande is a major migratory corridor for songbirds (Yong and Finch, 2002), waterfowl, and shorebirds. At various times of the year, riparian areas support the highest bird densities and species numbers in the Rio Grande basin. Both the river channel and the drains adjacent to the riparian zone provide habitat for species such as Mallards, Wood Ducks, Great Blue Herons, Snowy Egrets, Green Herons, Belted Kingfishers and Black Phoebes. Agricultural fields and grasslands with sparse woody vegetation are important food sources for sparrows and other songbirds during migration and winter.

As stated previously, there is little extensive analysis of other animal groups; however, some generalizations can be made regarding habitat preferences. Most amphibians depend on aquatic habitat for at least a portion of their life cycle. The presence of these species is limited in the project area by a lack of wet meadows or marshes. Amphibians likely common to the habitat types in the study area (riparian and immediately adjacent upland) include tiger salamander, Couch's spadefoot, Plains spadefoot, New Mexico spadefoot, Great Plains toad, Texas toad, Woodhouse's toad, bullfrog, and northern leopard frog (Degenhardt et al., 1996;

Stotz, 2000). Similarly, aquatic reptiles (painted turtle, yellow mud turtle, turtle, spiny softshell) are limited to the Rio Grande channel or adjacent ponds and marshes.

Reptiles (as well as the ornate box turtle) are most commonly found in grasslands and sparsely vegetated open areas within the riparian zone. These include species such as leopard lizard, collared lizard, greater earless lizard, horned lizards, prairie lizard, side-blotched lizard, whiptails, Great Plains skink, and several snake species (Degenhardt et al., 1996).

The most numerous and widespread small mammal species in Rio Grande riparian zones is the white-footed mouse, which, because of its arboreal habitats, is most numerous in dense woody vegetation. Similar to reptiles, many small mammal species (such as, western harvest mouse, Botta's pocket gopher, and Ord's kangaroo rat) are more abundant in grasslands and open areas than in denser woody vegetation (Campbell et al., 1997; Stotz, 2000). The preference for grassy and open areas by a large number of small mammals and lizards is contrary to the apparent preference of woody vegetation by birds, highlighting the need for a variety of interspersed habitat types within the riparian zone.

2.6. Implications for Restoration Potential

Results from the FLO-2D model were used to assess restoration potential along the RGCP. The model results indicate that the greatest potential for overbank flow under existing conditions occurs downstream from Mesilla Dam. For the baseline conditions analysis, the 20 sites that were identified as having restoration potential by Parsons/USIBWC (2003) were divided into those at which some overbank flooding would occur at flows between 3,500 and 5,000 cfs, and those at which no flooding would occur at these flows. At each of the sites where flooding would not occur for the existing conditions, the amount of bank lowering to attain a reasonable frequency of overbank flooding was estimated. This preliminary analysis indicated that one to four feet of lowering would be required at most of the sites. A review of available groundwater information was also conducted to determine whether the water table is sufficiently shallow to support riparian vegetation. Shallow groundwater elevations within the Mesilla Valley portion of the RGCP are generally controlled by the drain elevations, and the water table is typically between 8 and 10 feet below the existing ground surface in most locations (SSPA, 1987).

Comparison of the 1943 design thalweg profile of the RGCP with the thalweg profile developed from the 2004 Tetra Tech survey suggests that, since 1943, the channel has incised downstream of Percha Dam. The exceptions occur upstream from Bignell Arroyo in the lower part of Subreach 2.2 and in Subreaches 7.1 and 7.2 where up to 2 feet of aggradation has occurred since 1943. Localized aggradation is also occurring upstream of the Rincon Siphon. The results of the sediment-continuity analysis suggest that most of the subreaches are either armored (Subreaches 1.2 and 1.3), nearly in balance or locally degradational (Subreach 2.1), or slightly aggradational (Subreaches 3 through 7.2). In combination, the profile and sediment-continuity data suggest that there may be more hydraulic capacity in the RGCP than was initially designed, and that extensive removal of sediment from the river may not be necessary to maintain conveyance capacity. Review of the USIBWC O&M records indicates that most of the in-channel sediment removal since 1994 has occurred upstream from the American and Mesilla Diversion Dams. Construction of the NRCS sediment and flood detention structures in tributaries upstream from Selden Canyon has significantly reduced the sediment supply and need to remove sediment from the river (USIBWC, 2003).

The numerous arroyo confluences in the RGCP represent both channel maintenance challenges and restoration opportunities. Arroyo flooding and sediment loading, such as occurred during the 2006 monsoon season, can have significant local impacts on the Rio Grande, primarily in reaches upstream from Selden Canyon. Arroyo sediment deposition at the confluence and downstream in the Rio Grande can reduce channel conveyance capacity, increase flood water surfaces and erode banks by constricting the river flow against the bank opposite the mouth of the tributary. This may adversely impact local infrastructure such as levees, bridges and siphons. Conversely, variations in channel geometry and channel migration associated with this process may also provide restoration opportunities through enhanced riparian flooding and lateral adjustment to increase in-channel and overbank habitat diversity.

3. EVALUATION OF RESTORATION POTENTIAL

3.1. Restoration Objectives

The term and concept of "ecosystem restoration" has been applied to a diverse array of river projects designed to improve instream and riparian habitat and function. For the RGCP restoration study, the restoration concept might be best stated as "the partial improvement of degraded natural river functions and values". Restoration of riparian resources to pre-water resource development historical conditions, or even mimicking historical conditions to any significant degree, is beyond the scope of this project. Neither the water flow nor sediment supply are available to re-create historical riverine and riparian habitat functions that occurred in this reach. For this study, the restoration of historic habitat functions and values focuses on various methods (including flow augmentation and site-specific irrigation) to enhance the altered resource conditions. An understanding of existing geomorphic and ecological conditions and future trends were used to guide the planning process, site selection and project restoration techniques.

Restoration objectives for this study were determined in close coordination with the USIBWC, EBID, WWF and other interested parties throughout the study reach. Two stakeholder meetings were held in Las Cruces in December 2006 and July 2007, to discuss study objectives, baseline conditions, restoration methodology, and to solicit information on resource concerns and issues. Following is a brief discussion highlighting specific restoration objectives and measures that guided this study.

Enhance river-floodplain hydrologic connectivity: The functionality of the riparian system in the RGCP has been limited by channelization, channel incision, reduction in sediment supply and the elimination of seasonal high flows. The resulting marginal river-floodplain hydrologic connectivity does not adequately sustain or expand healthy native riparian ecology. The primary focus of this plan is to identify locations where the frequency and duration of overbank inundation can be enhanced through a combination of channel and floodplain restoration projects and potential flow augmentation without jeopardizing downstream water delivery requirements and public safety.

Bankline destabilization: Reworking of the channel topography and floodplain through erosion on the outsides of bends and deposition in the insides of the bends, as well as deposition and migration of alternate bars, is a key aspect of natural river function that helps to maintain healthy in-channel and riparian habitat. Along much of the RGCP reach, rock protection was installed along the toe of the riverbanks to prevent lateral migration of the channel. This strategy has been effective in maintaining the relatively straight channel alignment, but it has effectively prevented river migration which is an important aspect of natural river function. An objective of this plan was to identify locations where it might be possible to remove the existing toe protection and re-work the bankline to remove stabilizing vegetation in a manner that would encourage lateral migration without jeopardizing downstream water delivery requirements and public safety,

Reduction of Exotic Vegetation: A stated previously, saltcedar and other invasive species have become widely established throughout the study reach. Exotic woody species in the RGCP reach are much less extensive than in other portions of the Rio Grande in New Mexico and Texas (Crawford et al., 1994; CDM, 2005), in part, because of the past USIBWC mowing and maintenance program on the floodway. Continued expansion of exotic woody species is, however, expected from local seed sources. Large, dense tracts of saltcedar were a primary focus in selecting specific restoration projects.

Restoration of Southwestern Willow Flycatcher Habitat: In 1995, the U.S. Fish and Wildlife Service listed the Southwestern Willow Flycatcher (*Empidonax traillii extimus*, SWWF) as endangered in the southwestern United States (USFWS, 1995). The flycatcher also is classified as endangered by the State of New Mexico. The flycatcher is an obligate riparian species occurring in habitats adjacent to rivers, streams, or other wetlands characterized by dense growths of shrubs. Nesting habitat for the SWWF varies greatly by site and includes plant species such as willow, saltcedar, seep-willow, arrow-weed, box elder (*Acer* spp.), and Russian olive (Finch and Stoleson, 2000). Species composition, however, appears less important than plant and twig structure. Slender stems and twigs are important for nest attachment. Along the Middle Rio Grande, breeding territories have been found in young and mid-age riparian vegetation dominated by dense growths of willows at least 15 feet high as well as in mixed native and exotic stands dominated by Russian olive and saltcedar; however, the overall vegetation type of most of the flycatcher territories established in the Middle Rio Grande is dominated by native species (Moore and Ahlers, 2008). A critical component for suitable nesting conditions is the presence of water or saturated soil, usually provided by overbank flooding or some other hydrologic feature. Along the Middle Rio Grande, nests have been consistently found within 150 feet of surface water (usually a flowing channel) (Moore and Ahlers, 2008). In rare cases in Arizona, birds have nested over 300 feet from water.

While historic information is sparse on the specific occurrence of the SWWF in the study area, the historic condition of riparian vegetation in the RGCP reach (see Chapter 2.5, Baseline Ecological Conditions) likely provided suitable habitat for this species during the breeding season and migration. Over the past several years, two to six pairs of flycatchers have been known to nest in Selden Canyon (pers. comm., Deb Hill, USFWS, and Hira Walker, NM Dept. of Game and Fish). Development of SWWF breeding habitat within the RGCP was a primary riparian habitat restoration objective of this study. Stakeholders currently are coordinating with the USFWS to develop a Safe Harbor Agreement that limits new liabilities or restrictions on water deliveries as a result SWWF habitat creation.

Re-establishment of Riparian Habitat: For the USIBWC's Environmental Impact Statement, Parsons, Inc., developed restoration site plans from Percha Dam downstream to Mesilla Dam. Two primary objectives for the current study were the re-evaluation of restoration potential based on 2-D hydraulic modeling and the formulation of site plans throughout the 105-mile-long entire RGCP reach. Underlying principles in site design and location included the incorporation of diverse habitat types, a variety of restoration techniques (e.g., plantings, excavation, supplemental irrigation, cessation of mowing), and identification of sites throughout all subreaches, to the extent possible (i.e., the "string of pearls" concept discussed at stakeholders meetings).

In the site selection and restoration project design, it was the intent to address several related water-resource and management issues, including:

- Ensure flood control in accordance with regional and international obligations,
- Ensure water deliveries in accordance with regional and international obligations,
- Improve water quality,
- Provide recreational opportunities,

- Cost-effectiveness, and
- Facilitate interagency cooperation.

3.2. Restoration Implementation Methods

This section discusses general methods and considerations in implementing riparian restoration projects, and includes specific recommendations for the RGCP study area where appropriate. Approximate costs of recommended methods are also included.

Vegetation removal: Methods for removing existing vegetation prior to planting vary according to plant species, density, soil texture, and the size of the restoration area. Eradication of saltcedar requires special care to kill or remove the root crown just below the soil surface to prevent resprouting.

Stands of large, dense saltcedar can be cleared with a scraper or bulldozer, followed by root-plowing and raking of broken crown and root material ($1,800/acre). Excessive soil disturbance and appropriate disposal of raked material are important factors when considering this method.

Extraction of individual saltcedar plants with a front-end loader or backhoe equipped with a clasping "thumb" is an efficient method of removing exotic shrubs in sparse, moderately dense and very dense stands with less soil disturbance ($500 to $1,000/acre). The root crown is removed along with the above-ground portion of the plant, and the extracted debris can be immediately placed in piles or trucks to be hauled away. Filling of divots with suitable soil material or grading may be required in dense stands.

The use of tracked equipment can result in extensive ground cover and soil disturbance and compaction. Whenever, possible, the use of low-impact rubber tires on heavy equipment is recommended.

Saltcedar along banklines, in small monotypic stands, and in stands with mixed native shrubs can be removed by manual cutting with chainsaws ($1,500/acre). To prevent resprouting, saltcedar must be treated with herbicide to kill the root system. For stems with a basal diameter greater than 3 inches, the "cut-stump" method is recommended. Immediately after cutting, Garlon® 3A (or equivalent) is applied from a backpack sprayer to the exposed cut ($650/acre). For smaller stems, Garlon® 4 or Remedy® (Dow Elanco) can be applied to the cut surface and bark. These techniques must be performed during late-August and September so that herbicide is drawn into the root system of the plants. In some locations, specific plant removal on the banks with a backhoe or other specialty equipment may be necessary.

Most of the RGCP study area is regularly mowed and sparse to moderately dense resprouts of saltcedar are commonly present, often attaining heights of 5 to 6 feet between mowing. These plants can be eradicated by manually spraying the foliage in spring, or basal stem spraying in fall, with Garlon® (or equivalent). For relatively dense resprouting saltcedar, New Mexico State University and the Bureau of Reclamation have developed a method to apply herbicide (imazapyr) directly to stems with a tractor-mounted carpet roller and preserve existing ground cover (Franco, 2007). Regularly mowed and resprouting plants will have a larger root system than similarly sized seed-origin plants, and therefore, may require herbicidal treatment for 2 or 3 years to be successful.

Grubbing is generally recommended when clearing sites with herbaceous or light woody growth (not including saltcedar) ($800/acre). If exotic and/or noxious species are present at a site, the scraped topsoil should <u>not</u> be reserved and redistributed in order to avoid future germination.

Disposal of woody debris: At restoration sites with minor saltcedar removal, small piles of woody material can be left onsite to serve as cover for reptiles, birds and small mammals. Many of the restoration prescriptions in this report, however, would generate a larger amount of woody debris than can reasonably be disposed of on site. At sites with a moderate amount of debris, it was assumed that the material could be hauled from the site and disposed of at appropriate landfill facilities. At restoration sites distant from landfill facilities or with large amounts of woody debris, modern onsite burning technology may be less costly than hauling ($1,600 for burner rental). One example is the containerized, air-curtain burner developed by Blue Sky Environmental, Inc.

Native vegetation planting: Many riparian and wetland plant species are phreatophytic, necessitating their roots to reach the groundwater table or at least the capillary fringe just above the groundwater elevation. Depth to groundwater is an important determinant in the distribution of riparian plant species and in planning for revegetation planting. Following are general depths to the capillary fringe during the growing season required for successful establishment and maintenance of some common species in the study area (USDA, 2007 and other sources):

Rio Grande cottonwood	7 to 10 feet
Goodding's and peach-leaf willow	5 to 8 feet
Saltgrass	5 feet or less
Coyote willow	3 to 4 feet
Wet meadow species	2 feet or less

In the RGCP reach, woody riparian vegetation should primarily be established through plantings. Cottonwood and Goodding's willow have been successfully reestablished through pole plantings ($45/pole installed). Dormant, 15- to 20-foot tall poles are cut from natural stands or nurseries during the late winter. Holes to receive poles are drilled with a soil auger (often gas-powered and tractor-mounted) to a depth sufficient to reach the groundwater surface or at least the capillary fringe. Poles are inserted and the holes backfilled by hand. Poles will generate rapid root growth if they are planted before bud break and their lower ends are sufficiently wet. Supplemental irrigation usually is not required. Following successful establishment, the above-ground growth rate can be as much as 5 feet per year. Survival rates greater than 85 percent after the third growing season are commonly achieved. Plantings may require insecticidal treatment during the first year or two to control cottonwood beetle damage.

Coyote willows can be easily established through the planting of dormant whips (6 to 8 feet long) cut from existing stands during mid- to late-winter ($7.50/whip, installed). Whips are inserted into manually or mechanically prepared holes (e.g., auger, rotary drill, or backhoe with "stinger" attachment) sufficiently deep to reach the water table, and the hole is carefully back-filled. At sites with a relatively high water table, an array of shallow trenches can be excavated for the placement of whips, then carefully backfilled. This technique has been proven to be cost effective for dense willow planting in restoration projects conducted in the Middle Rio Grande reach. Willow planting is an excellent restoration activity to utilize volunteer labor.

Additional shrub species can be established by installing plants grown in small containers. Supplemental irrigation is usually required for successful establishment, either through irrigation or small-diameter PVC watering installed when planting. Many species may be grown in "tallpots" (6-inch diameter, 30-inch long tubes) in the nursery to develop long root systems and increase their likelihood of establishment. The NRCS Los Lunas Plant Materials Center also has developed "longstem" container-grown shrubs to facilitate deep planting. Longstem, tall-pot shrubs are recommended for all sites in the RGCP study area except those with a very shallow depth to the water table ($55 each, installed).

Several factors are crucial to the natural germination and survival of cottonwood and willows including available seed source(s); timing of seed release; competition; availability of suitable substrate; the depth, duration, expected frequency, and seasonal timing of inundation; and the rapidity of descending water levels (Mahoney and Rood, 1993). Within the RGCP study area, establishment of woody riparian vegetation may be accomplished through natural germination to a limited extent. After substrate preparation, inundation and the subsequent drawdown can promote the natural seeding of cottonwood and willow. The success of this technique will depend on the availability of wind-blown seeds from the surrounding area and the timing of drawdown to coincide with seed release. Due to the general dearth of these species in the study area, and the relatively late occurrence of the peak discharge (see Figure 3.2), this method is not recommended as a primary revegetation method. However, once seed-bearing species have developed at a restoration site, some degree of natural germination would be expected to occur in subsequent years, especially if augmented releases from Caballo Dam facilitate overbank flooding in late May to early June. At proposed restoration sites with additional water sources which can be utilized (such as from wasteways, or through pumping from the river or riverside drains), natural germination may be the most cost effective method of establishment if seed sources are nearby, or if seeds collected from other locations are sown artificially.

Soils with high salinity are not viable areas for the restoration of cottonwood and willows. Generally, soils with electro-conductivity levels greater than 4 deci-Siemens per meter (dS/m) are considered too saline for the successful establishment of these species. It may be possible to leach accumulated salts from the soil through periodic inundation. Sites with medium textured soils may be best suited for this, as soils with high clay content may impede infiltration, while coarse sands may be excessively well-drained. Additionally, if the soils in the target area are rich in clay and have a high sodium adsorption ratio, soils could seal and irrigation could increase soil salinity. Prior to implementation of the restoration prescriptions in this report, the soil texture, surface and subsoil salinity, and the depth to groundwater should be verified at each site.

Seeding is recommended for restoration sites to control erosion and the proliferation of noxious weeds. Establishment of riparian grasses and herbaceous vegetation usually follows standard agricultural practices. Areas intended for restoration planting may require disking, scarifying, or other seedbed preparation, especially if the area has been trafficked by heavy equipment. Only native plant species should be considered for establishment since these are best adapted to region's climate and hydrologic conditions. A cover crop of a rapidly germinating or sterile species can be included in the seed mix.

Seeding can be accomplished by a variety of methods. Mechanized methods (grass seed drill, range drill, or imprinter) facilitate seeding over large areas, but their use may be restricted in stands with numerous shrubs and trees. Hand-broadcasting and hydro-seeding methods are better suited for vegetated areas and on uneven topography and slopes. Mulching is recommended to retain moisture and protect the seeds and seedbed from wind erosion. Crimped hay mulch has been found to be the most successful method in groundcover planting efforts. The cost of grass seeding and mulching is approximately $1,900/acre for 10 pounds of pure-live-seed seed per acre. Supplemental irrigation may be necessary if reseeding is attempted during dry periods.

Meadow and wetland species may be established by seeding (some sedge and rush species), or by hand-planting from small containers ($3 each, installed).

Earthwork: Excavation and removal of soil material from the banks or floodplain can be performed with standard equipment such as excavators, scrapers or bulldozers. Due to the close proximity of proposed spoil waste disposal sites, an estimated cost of $5 per cubic yard (CY) was used for earthwork activities.

Section 404 of the Clean Water Act regulates the placement of fill material in waters of the United States and adjacent wetlands. Additionally, Section 401 of the Act requires State Water Quality Certification for these regulated activities.

Several restoration site prescriptions include relatively minor excavation for bank destabilization, channels to improve river-floodplain connectivity, or aquatic habitat improvement at the mouths of arroyo. At these sites—many of which are located in degraded reaches of the river—excavated waste material may be placed in the river channel along the foot of the bank pursuant to Nationwide Permit 27 (Aquatic Habitat Restoration, Establishment and Enhancement Activities). A Pre-construction Notification (PCN) for Nationwide Permit activities must be filled with the El Paso Regulatory Office of the U.S. Army Corps of Engineers, and State Water Quality Certification must be obtained from New Mexico or Texas, as appropriate.

At restoration sites where extensive floodplain excavation is proposed in this study, spoil waste material is recommended to be deposited above the Ordinary High Water Mark, usually adjacent to an existing levee or the upland edge; therefore, Section 404 and 401 permitting would not be required.

Use of supplemental water: In floodway locations near existing irrigation canals and drains, supplemental water may be applied to riparian restoration areas. Delivery methods would vary depending on site conditions and may include the installation of a gate, turnout, and ditch to service the restoration area; or pumping from the river or riverside drain.

The numerous drains and wasteways within the study reach provide opportunities for the application of acquired water to promote the development of riparian vegetation. Based on a preliminary EBID design for a specific drain that was modified by the study team for more generic application (**Figure 3.1**), a relatively simple check dam within the wasteway between the levee and the river can raise the water surface sufficiently to flow onto the overbank area through a standard irrigation turnout. To contain and route irrigation flow, the restoration site should be graded or slightly excavated. Scraped material should be used to create a low, central peninsula extending downstream from the wasteway bank to route flows through a 180-degree path back to the wasteway channel. Small berms may also be created to contain water within the desired footprint. Flow would return to the wasteway over a small armored or gated spillway located below the check dam. Optionally, flow may return to the river from the downstream portion of the irrigated cell. The inundated cell should not be constructed closer than 30 feet from a levee to facilitate continued mowing along the riverward levee toe. Infiltration seepage will also return some of the supplemental water to the river.

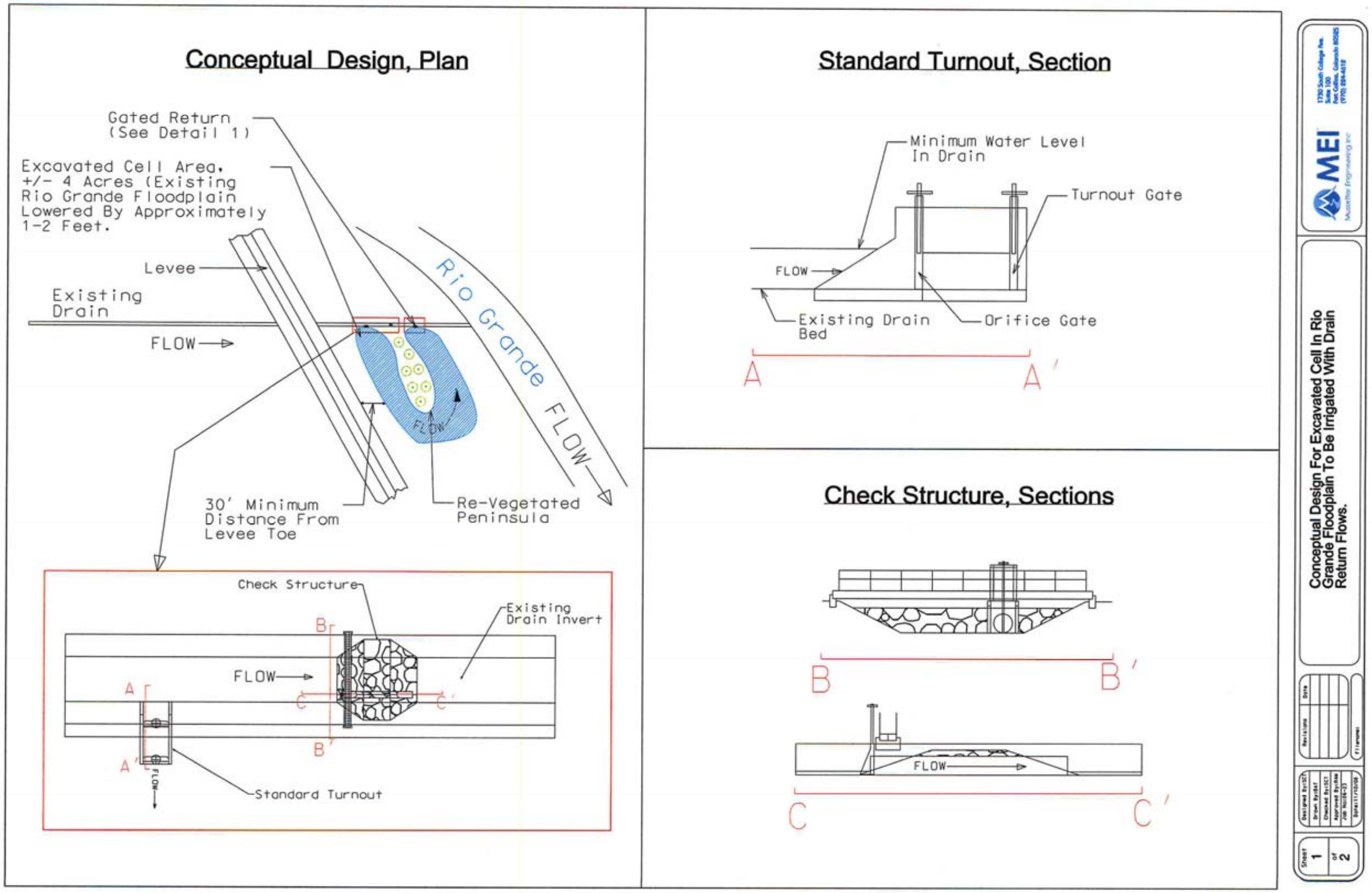

Figure 3.1. Conceptual design for check structure and turnout to provide overbank irrigation adjacent to irrigation wasteways and drains.

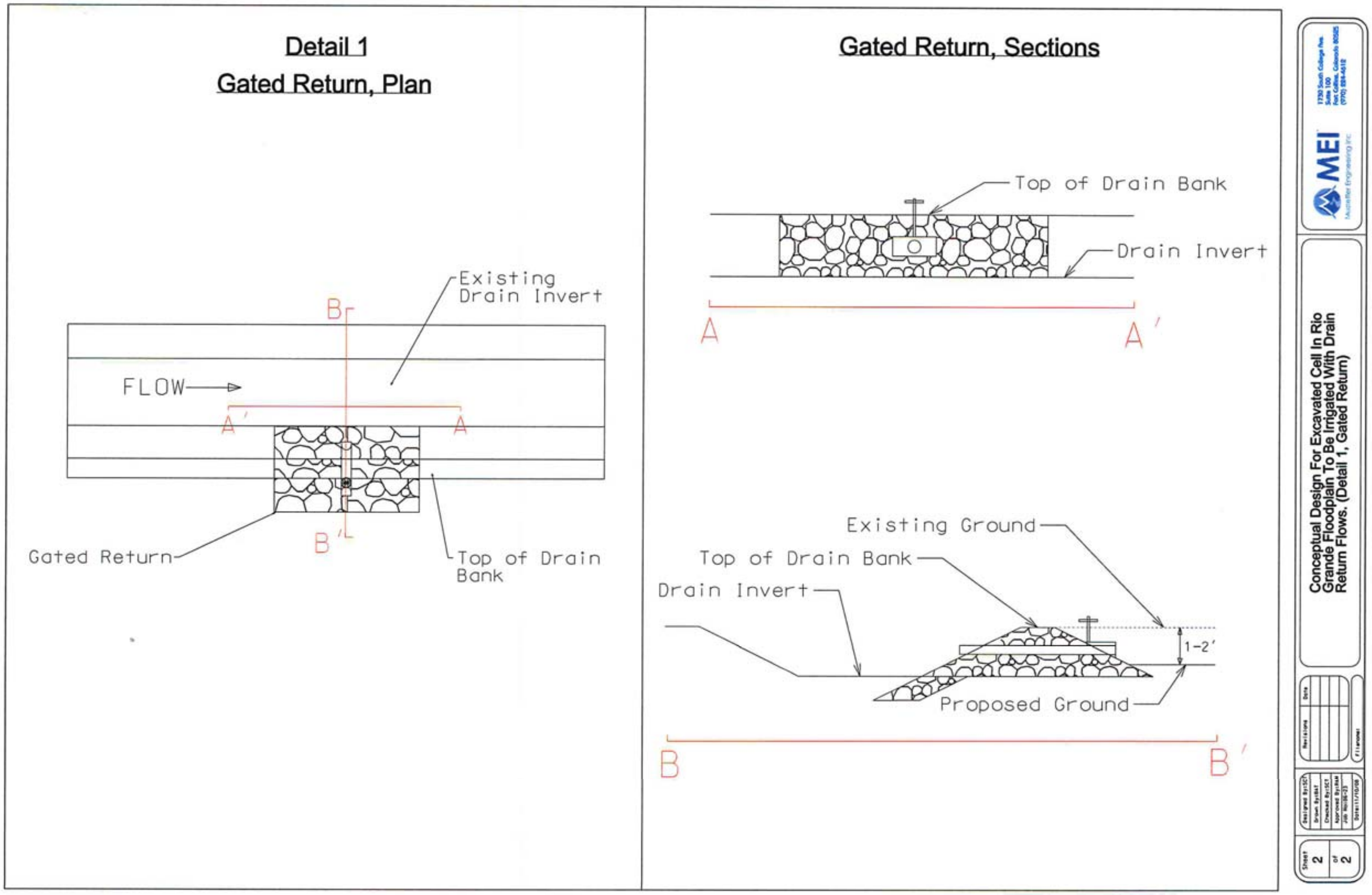

Figure 3.1. Conceptual design for check structure and turnout to provide overbank irrigation adjacent to irrigation wasteways and drains (continued).

In this restoration plan, three sites with suitable soil and groundwater conditions utilize variations of this portable design. Locations other than those selected may be better suited in terms of water quality, available flow, and the avoidance of problematic backwater conditions. The final location of these sites should be selected in coordination with EBID engineers.

With proper site conditions, the addition of supplemental water would be sufficient to maintain a variety of riparian habitat types, including dense willow stands. The irrigation requirement for dense willow habitat was estimated to be 0.5 feet per month from late April through September (3 ft/yr). Supplemental water can be provided through an acquired water right specifically delivered to the site. Alternatively, <u>all</u> wasteway discharges could be routed through the cell if the net evapotranspiration depletion is acceptable or otherwise compensated. In addition to providing habitat for wildlife, vegetation within the cell would improve the water quality of wasteway or drain outflow by the trapping and removing dissolved and suspended solids (see Chapter 2.5.2).

Currently, the cost to acquire a water right in the EBID service area is approximately $3,000 per water-righted acre (which includes 3 ac-ft). In this report, several specific site prescriptions include supplemental, annual irrigation, and it was assumed that a water right would be acquired for these sites. It was also assumed that such water rights were acquirable, and that the specific sites are within the legal boundary of the irrigation district. EBID establishes an annual assessment charge to users to cover the cost of reservoir operation, system maintenance, and delivery. Costs in this report were based on the 2008 assessment rates of $75 per acre for the first acre-foot per acre, plus $10 for each additional acre-foot per acre.

In addition to the site-specific application of acquired water, all restoration prescriptions were based on a restoration flow release from Caballo Dam totaling 3,500 cfs approximately every four years (see Section 3.3) Water for restoration flow release was assumed to be available for lease in a given year or for acquisition. The cost for either process was estimated to be $1,000 per ac-ft. Because all restoration prescriptions assume periodic restoration flow releases, each site prescription also includes a statement of the viability of the design should such releases <u>not</u> occur.

Evaluation of evapotranspiration: Evapotranspiration (ET) is water lost to the atmosphere from the ground surface, evaporation from the capillary fringe of the groundwater table, and the transpiration of groundwater by plants. For each proposed restoration site, the net change in water depletion on an annual basis due to changes in ET resulting from the replacement of one plant community type with another was assessed using available published ET rates for the various plant communities. Consumptive use estimates of saltcedar stands range from 4.2 ft/yr (USBR, 1997a) to 4.3 ft/yr (Bawazir et al., 2000), 4.8 ft/yr (Blaney and Hanson, 1965), and 4.9 ft/yr (Evapotranspiration Work Group, Bureau of Reclamation; Van Hylckama, 1974). Moderately dense stands not subject to flooding exhibit lower ET rates than dense flooded stands (2.4 vs. 4.0 ft/yr, respectively; Cleverly et al., 2002). The relatively high value of 4.9 ft/yr was used in the current analysis to reflect the longer and warmer growing season in the RGCP reach compared to the upstream Middle Rio Grande reach where many of the cited studies were conducted.

Estimates of consumptive use by cottonwood-dominated stands in the Socorro area range from 3.0 feet/year (Flannigan and Balleau, 1998) to 4.8 feet per year (USBR, 1997b). While the latter value may be high for that locale, it was used in the current analysis due to the higher temperatures and slightly longer growing season in the study reach. Consumptive use of cottonwood woodland habitat, with approximately 50 to 60 percent of the areal cover of trees and shrubs of a mature cottonwood forest, was assumed to be approximately 3.5 ft/yr.

ET rates for dense willow stands have not been calculated. Due to their lower leaf volume, willows may have a lower consumptive use than saltcedar; however, a value of 4.9 ft/yr was used in this analysis because the target habitat type often included dense willow stands suitable as SWWF breeding habitat.

The consumptive use for saltgrass stands is estimated to be 1.99 ft/yr (USBR, 1997b). In the current analysis, this rate was increased to 2.4 ft/yr (120 percent) to reflect warmer conditions in the study reach.

Summarizing, the following ET rates were used for common habitat types:

- Dense shrubs (saltcedar and willow): 4.9 ft/yr
- Riparian forest: 4.8 ft/yr
- Riparian woodland: 3.4 ft/yr
- Grassland: 2.4 ft/yr

Interpolated values were sometimes used for plant communities with varying amounts of vegetation than in these typical types. Although the ET rate of a newly planted stand would be low and would increase with maturity, a constant rate was used in this analysis for simplicity.

The change in consumptive use resulting from habitat restoration activities was calculated as the difference in rates between the existing and restored habitat types at each site. For example, conversion of grassland (2.4 ft/yr) to riparian woodland (3.5 ft/yr) would entail an additional 1.1 ft/yr in consumptive use. If this restoration site is 10 acres in size, the net depletion volume would be 11 ac-ft/yr. Conversely, if saltcedar (4.9 ft/yr) was proposed to be replaced by grassland (2.4 ft/yr), there would be a net decrease in ET by 2.5 ft/yr per acre.

3.3. Selection and Modeling of Potential Restoration Flows

Following the baseline, steady-state analysis of inundation potential in the RGCP reach (Figure 2.5) and subsequent discussions with the stakeholders, the project team determined that the target restoration flow should consist of a maximum discharge in the range of 2,250 to 3,500 cfs with a frequency of about once every 4 years and duration of 4 days including a 1-day ramp-up, 2 days of steady flows and 1-day ramp-down. An analysis of historical flow records was undertaken to justify the selection of a specific target restoration flow. The frequency analysis of historical irrigation releases from Caballo Dam indicates that the target restoration flows had recurrence intervals during the post-Caballo Dam period from WY1938 through WY2007 ranging from once in 2 years (2,250 cfs) to slightly less than one in 100 years (3,500 cfs) (**Table 3.1**). The mean daily flow release data for this period also demonstrate that the irrigation releases typically have two peaks, with the initial peak occurring between March 1 and April 15, and the summer maximums occurring between April 15 and June 30 (**Figure 3.2**).

Based on riparian ecology and biology, the primary target window for the restoration flows extends from April 24 to June 7, and the secondary target window extends from April 1 to June 15. Restoration flows outside this window were deemed by the plant ecologists to be undesirable for recruitment of native riparian vegetation. The mean daily flow records for the Caballo Dam releases were evaluated to further assess the frequency, duration, and volume of

Table 3.1. Summary of the target restoration releases from Caballo Dam.					
Target Restoration Release (cfs)	Recurrence Interval (yrs)[1]	Years Exceeded Without Augmentation	Number of Augmented Flow Years	Combined Number of Historical and Augmented Restoration Flows	
		Spring[2]	Spring[2]	Spring[2]	Target[3]
2,250	2.0	20	8	26	17
2,500	3.1	8	12	18	12
2,750	5.5	5	12	16	12
3,000	11.4	4	13	16	12
3,250	27.0	2	13	15	12
3,500	73.6	1	13	14	12

[1]Based on frequency analysis of releases between April 1 and June 15, WY1938 to WY2007
[2]Spring period from April 1 to June 15
[2]Target period from April 24 to June 7

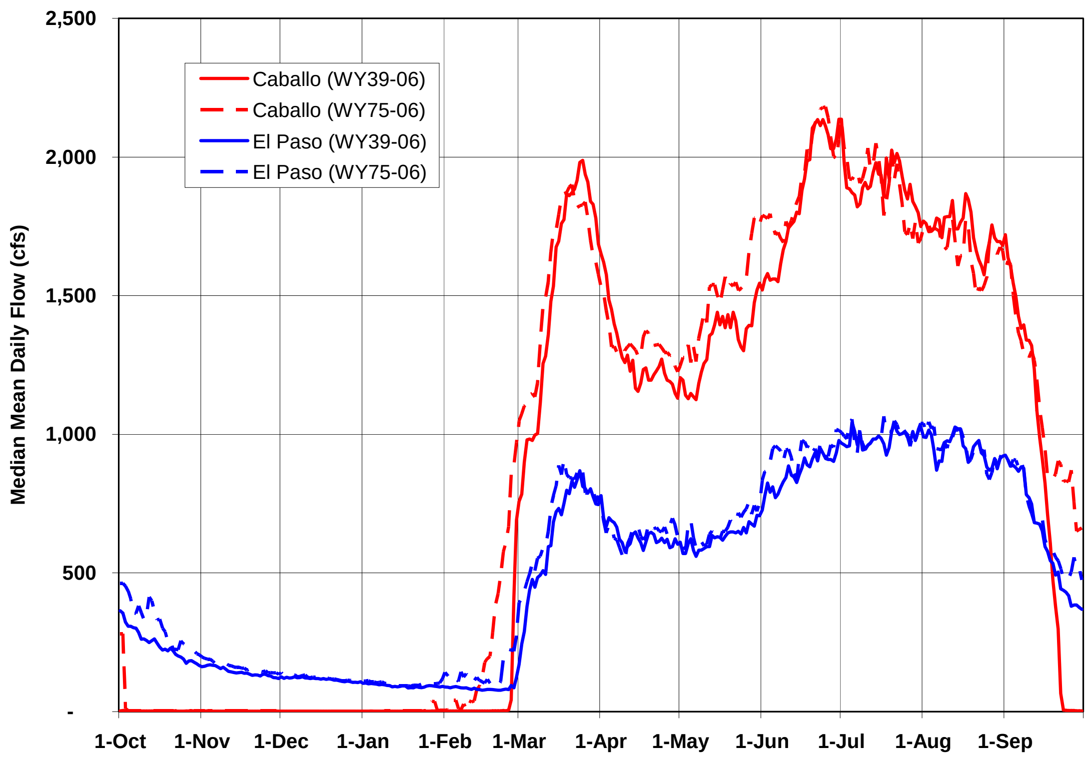

Figure 3.2. Median mean daily flows at Rio Grande at Caballo gage (USGS Gage No. 08362500) and the Rio Grande at El Paso gage (EBID gage) for the periods from WY1938 through WY2006 and WY1975 through WY2006.

historic releases between these time windows. Data from WY1951 through WY2007 were used in the analysis because it includes the dry period from WY1951 through WY1978, as well as the relatively wet period in the 1980s and 1990s, and because the systematic records improved after 1951. The lower target flow of 2,250 cfs was reached or exceeded during the primary window in 11 of the 57 years, with an average of about 5 years and longest period of 14 years between occurrences (**Figure 3.3**). During the longer, secondary window, the lower target flow was reached or exceeded in 20 of the 57 years, with an average of 2 to 3 years and longest period of 10 years between occurrences. In the years in which the releases exceeded the lower target flows during the primary window, the duration of these flows ranged from 1 to 44 days, and averaged about 10 days. The higher target flow of 3,500 cfs was reached or exceeded only once (WY1987) during the 57-year period and lasted a total of 26 days. From this analysis, it was apparent that the existing opportunities for restoration flows would be insufficient to support recruitment of native riparian vegetation and other associated attributes of restoration projects without flow augmentation. The volume of augmentation water that would be required was analyzed using the historical record to achieve the following objectives:

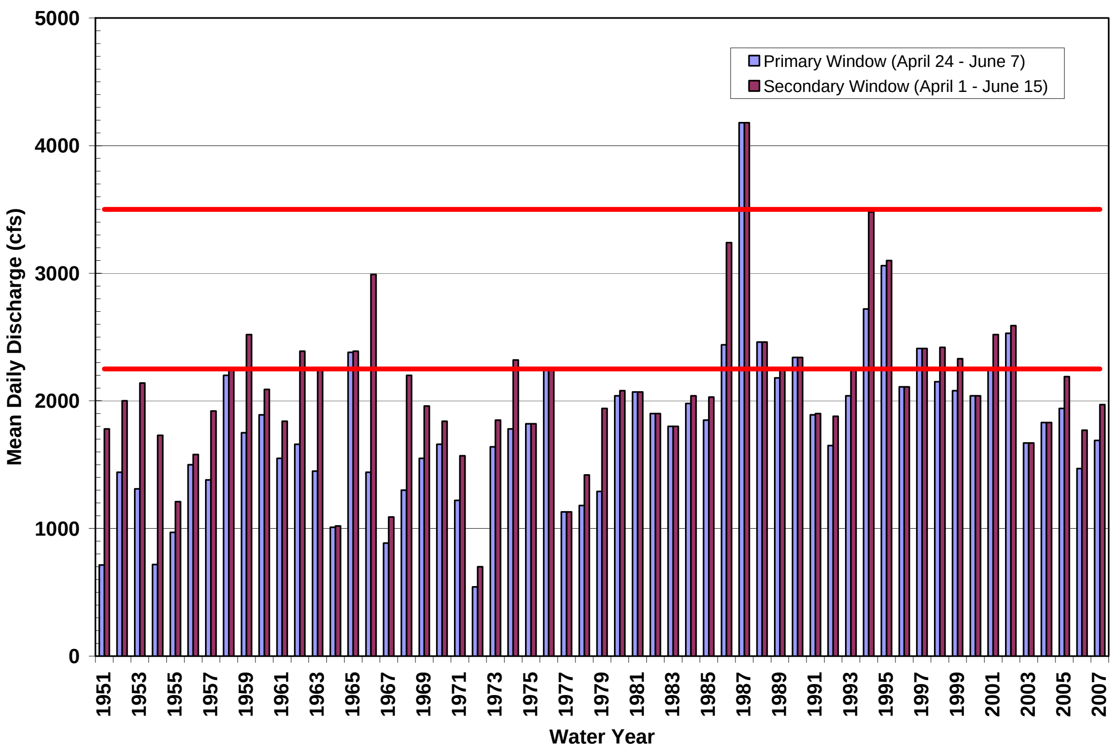

Figure 3.3. Maximum mean daily flow release from Caballo Dam in the primary and secondary target restoration release windows during the period from WY1951 through WY2007.

- A restoration flow once every three to five years (no more than four consecutive years without a restoration flow),
- Restoration flow of two days with one-day ramp up and ramp down,
- A minimum flow trigger for the restoration flow of 1,750 cfs,

- Primary target period (April 24 through June 7), and
- Secondary target spring period (April 1 through June 15).

In performing the evaluation, it was assumed, as a starting point, that 1950 was a wet year that met restoration flow criteria. The need for flow augmentation in any given year is determined by the magnitude of flows that occurred in previous years as well as a projection of the magnitude and timing of current year releases. Examples of how the augmentation criteria would be applied are provided in **Figures 3.4 through 3.7**. Based on this analysis, flow augmentation would be necessary in eight of the 57 years to meet the criteria for the lower target restoration release of 2,250 cfs (**Figure 3.8**), and in 13 of the 57 years for the higher target release of 3,500 cfs (**Figure 3.9**). The above criteria were applied over the 57-year period to estimate the per-event, average annual and total volume of the augmentation flows for discharge between the lower- and upper-limit target restoration flows. The average volume per augmentation event ranges from about 1,900 ac-ft for a target restoration release of 2,250 cfs to about 9,300 ac-ft for a target release of 3,500 cfs (**Figure 3.10**). This represents average annual volumes of augmentation flow ranging from about 500 to about 2,500 ac-ft (**Figure 3.11**). A summary of the above analysis is provided in Table 3.1.

This analysis indicates that all the target restoration flow criteria can be achieved within the historical flow regime if average water augmentation volume 9,500 ac-ft per restoration flow event can be acquired. The project team selected 3,500 cfs as the target restoration flow to be used in further analysis of the restoration site design. This selection was made considering a wide range of factors, including potential site restoration options, historical river flows, site inundation (or lack thereof) under existing conditions, future opportunities for flow augmentation, necessary methods to secure additional water volume for flow augmentation, desired restoration techniques, and cost of restoration and water augmentation. The sites being designed for hydrologic connectivity with the river were tested for potential site inundation assuming a one-day ramp-up from the irrigation operation flow (typically 2,350 cfs) to 3,500 cfs, two days of relatively constant flow at 3,500 cfs and a one day ramp-down duration back to the irrigation operation flow.

Based on the above information, the analyses contained in the following chapters evaluate the restoration potential for a periodic release of 3,500 cfs from Caballo Dam, and its ecologic, hydrologic, and sediment-transport effects. It was assumed that water for such a release would be available through acquisition or system operation or from storm-generated events downstream from Caballo Dam. Issues associated with the contractual or legal authority for such a scenario are outside the scope of this study. The results of this study will serve to inform stakeholders and decision-makers within the RGCP reach in their continuing discussion and evaluation of the availability and use of water for restoration purposes."

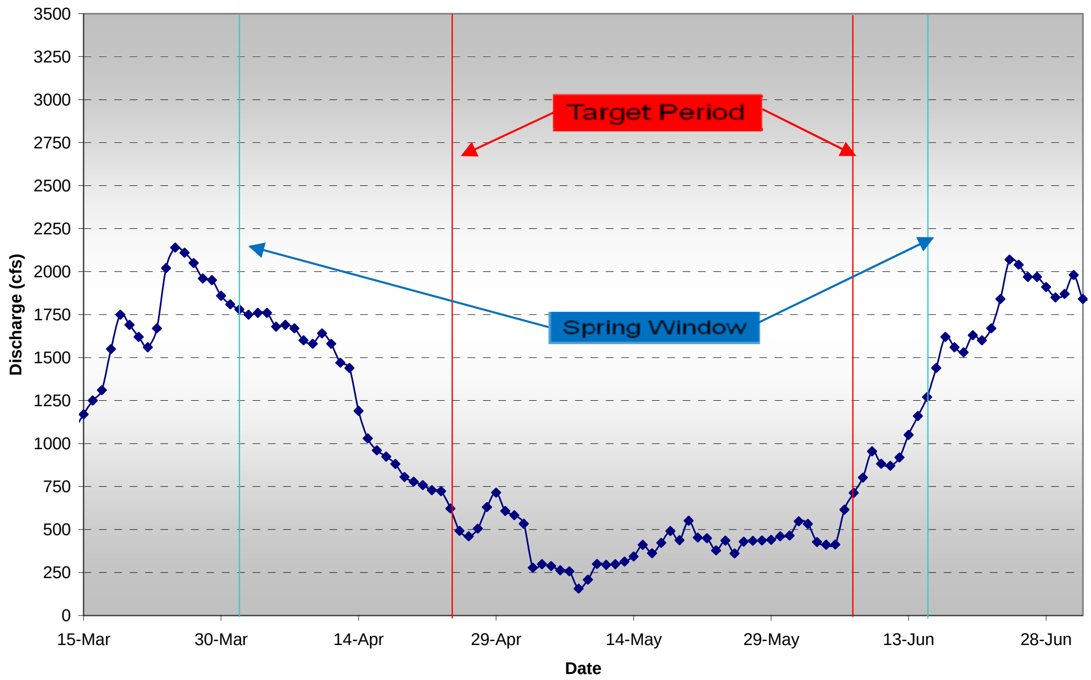

Figure 3.4. Recorded Caballo Dam releases during 1951. No augmentation is shown, but augmentation is possible within the spring window.

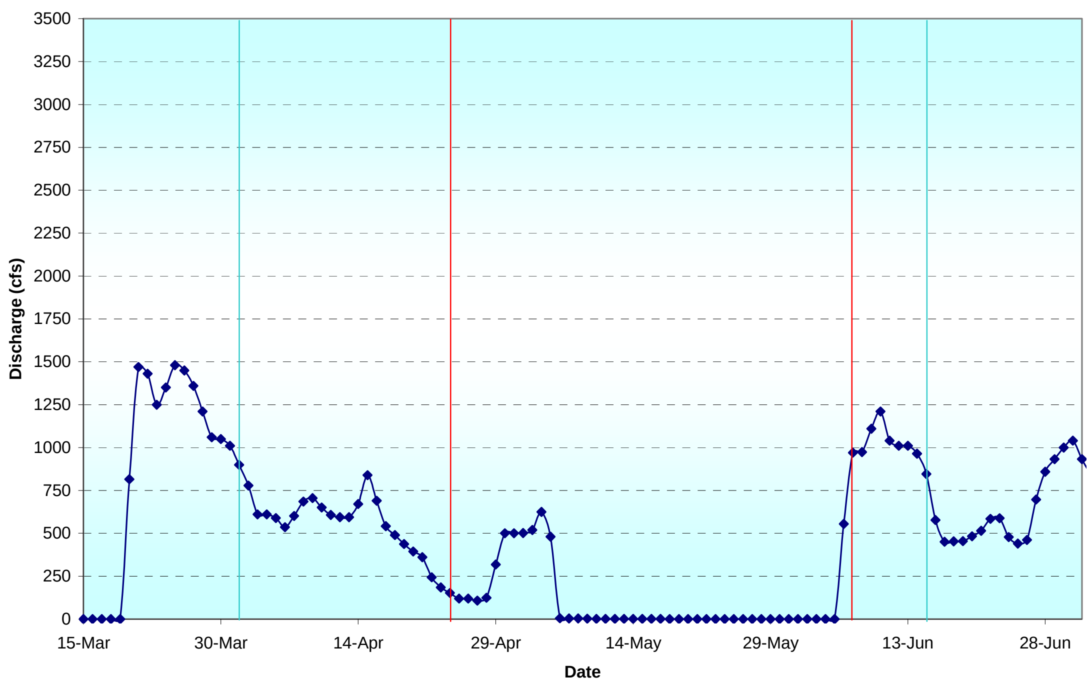

Figure 3.5. Recorded Caballo Dam releases during 1955. Dry year with no augmentation.

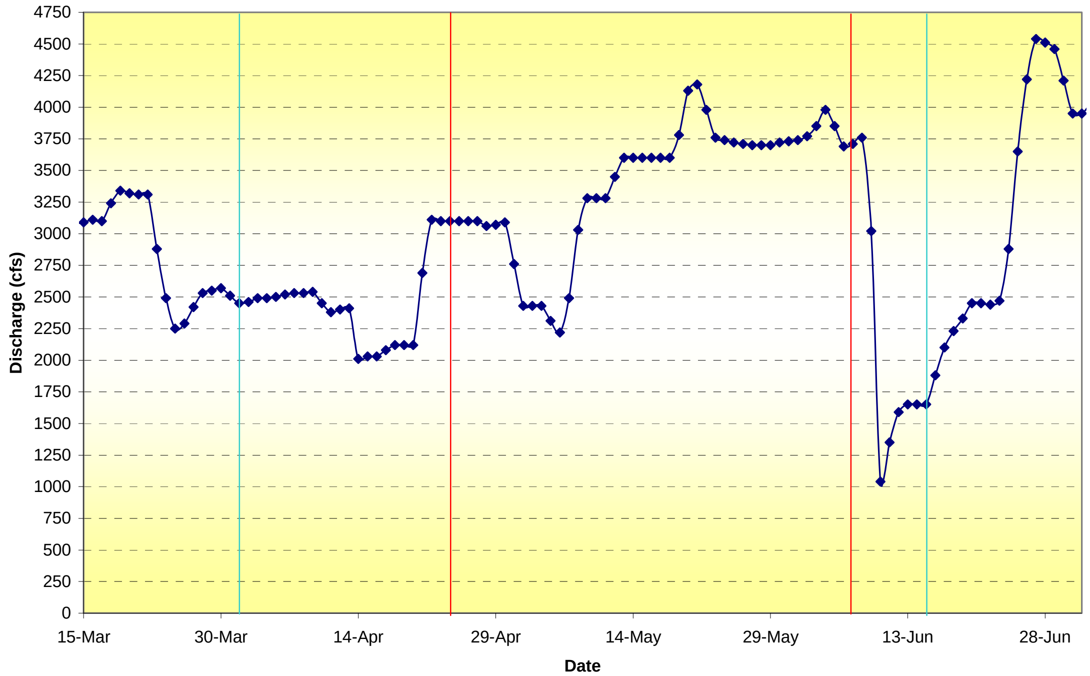

Figure 3.6. Recorded Caballo Dam releases during 1987. Highest target restoration flow was met; no augmentation is necessary.

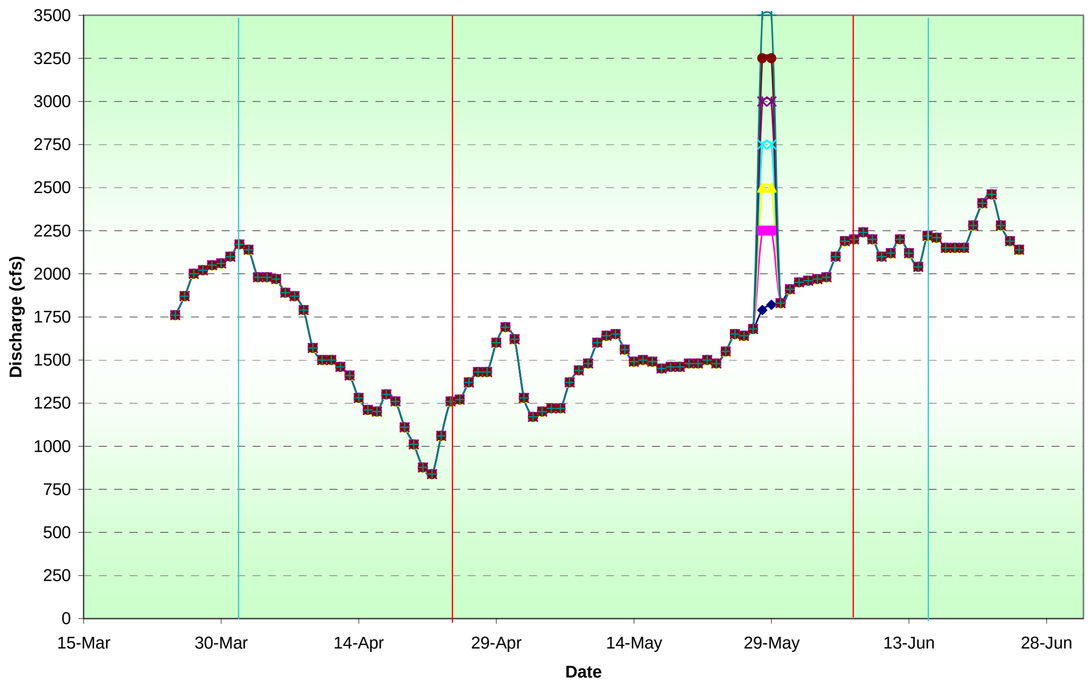

Figure 3.7. Recorded Caballo Dam releases during 1958. Wet year, in which augmentation is possible within the target period.

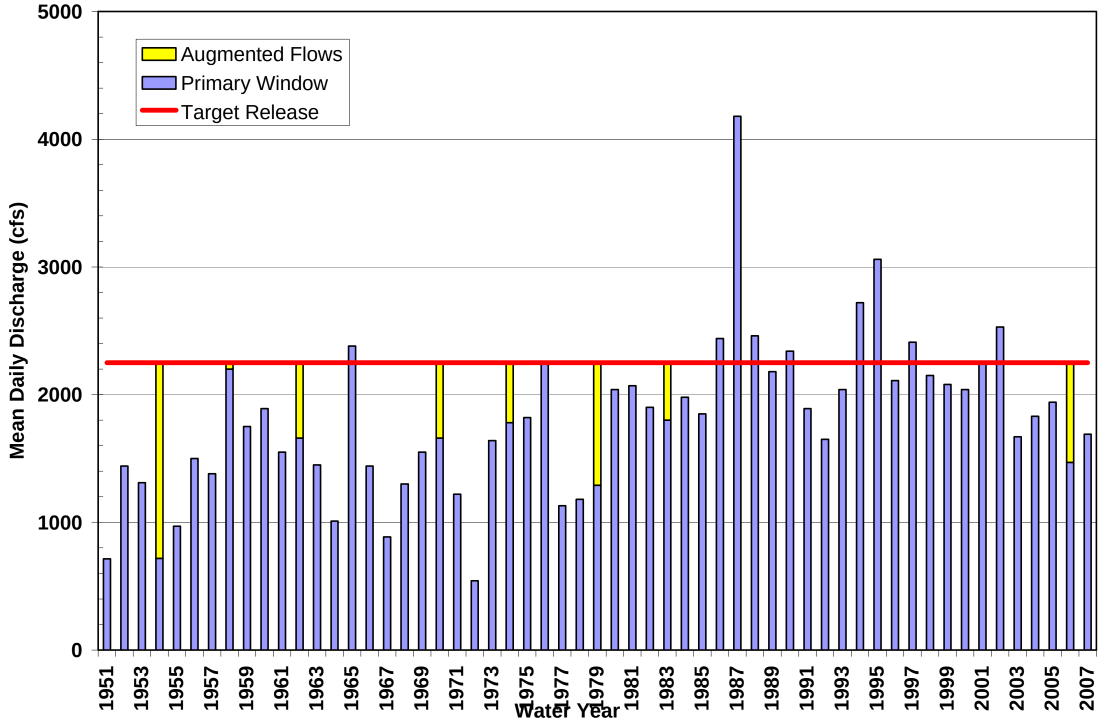

Figure 3.8. Maximum historical flow during the primary restoration release window and the flow augmentation required to meet the restoration objectives for a target release of 2,250 cfs.

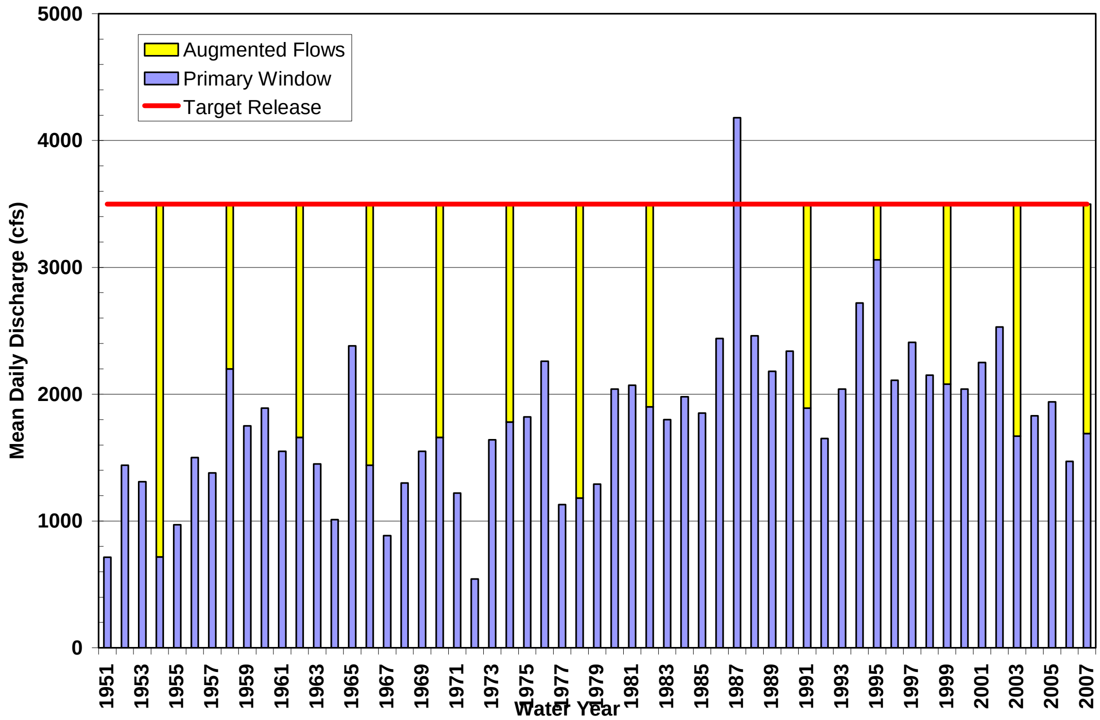

Figure 3.9. Maximum historical flow during the primary restoration release window and the flow augmentation required to meet the restoration objectives for a target release of 3,500 cfs.

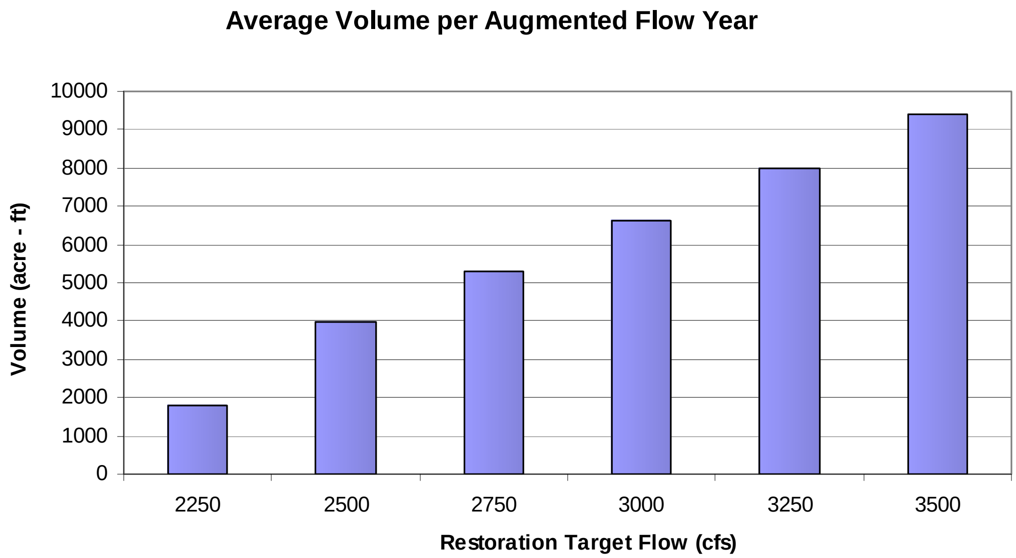

Figure 3.10. Average volume of augmentation flows per event.

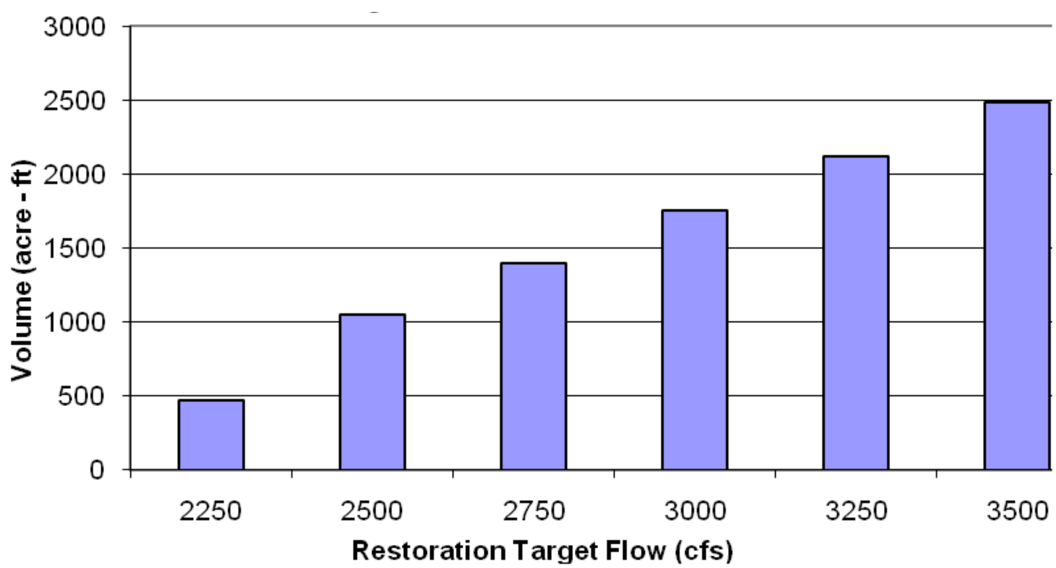

Figure 3.11. Average annual volume of augmentation flows over the 57 years on which the analysis was based.

4. DESCRIPTION AND ANALYSIS OF RGCP RESTORATION SITES

4.1. Site Selection Criteria

Selection criteria were developed to provide a basis for identifying sites at which it may be possible to meet the restoration objectives of enhancing ecological diversity, improving riparian and channel functionality, and expanding native habitat in a manner that does not jeopardize water delivery requirements and public safety. In this regard, it is not the intent of this project to restore pre-water development historical conditions, but rather to create a more functional riparian system and ecologically diverse environment while considering infrastructure and operational constraints. It is anticipated that the long-term response will also enhance the quality of life in the river corridor in terms of water quality, recreational opportunities and aesthetic values.

The potential for riparian and channel restoration throughout the study reach was evaluated by conducting analyses of the existing and potential future channel and floodplain morphology, main channel and floodplain hydraulic conditions (including possible river-floodplain connectivity), and ecological conditions. The specific criteria that were evaluated for the preliminary site selection included:

1. Potential for overbank flood inundation,
2. Land ownership,
3. Existing vegetation,
4. Depth to groundwater during the growing season,
5. Access to supplemental water,
6. Soil conditions,
7. Areal extent of the site (very small sites were excluded),
8. Adjacent land use,
9. Site location and contribution to reach-wide restoration objectives, and
10. Potential restoration costs.

In conjunction with the above restoration factors, potential impact to local infrastructure (levees and bridges), endangered species habitat, fire protection, recreational access, and distribution of sites along the system (i.e., the “string-of-pearls” concept discussed at the stakeholder meetings) were also considered.

4.2. Preliminary Site Evaluation

Potential restoration sites were selected for preliminary evaluation using a variety of techniques. The study team conducted an initial reach-wide reconnaissance in December 2006. Additional fieldwork was conducted by individual team members, and included all areas where inundation was predicted by the baseline conditions FLO-2D model (**Appendix B**). The restoration sites recommended for implementation in the 2004 River Management Plan (Parsons, 2004) were also reviewed and re-evaluated for their inundation potential based on the initial FLO-2D modeling (MEI/Riada, 2007). Additionally, several locations specifically suggested by stakeholders and participating agencies were visited and evaluated. The list of potential sites was subjected to several levels of examination and eventually pared down to a preferred group of 24 sites for more extensive investigation and flood inundation modeling.

4.3. Site Selection

The preferred list of 24 proposed restoration sites was critically reviewed by the study team, USIBWC, EBID and WWF in July 2007. This evaluation included a specific FLO-2D-model analysis of a 3,500-cfs restoration flow release from Caballo Dam. Model results from this analysis were used to assess water-surface elevations and areas of inundation at each site. Based on the modeling results, information from the soil surveys, supplemental water considerations, and a more detailed examination of the site selection criteria, a number of the initially selected sites were eliminated from further analysis.

By refining the site selection criteria during the review process, the study team was able to identify additional sites for consideration. Assistance in specific site selection was also provided by Mr. Henry Magallenez, EBID Chief Engineer and the soil and vegetation investigations in Selden Canyon by Parametrix, Inc. and Soil Water West, Inc. (Caplan and Landers, 2008).

Based on the combined results from the above work, a final list of 30 restoration sites was selected for more detailed evaluation (**Table 4.1**). **Table 4.2** summarizes the area of each habitat type and supplemental water requirements by geomorphic subreach.

4.4. Analysis of Restoration Site Design Techniques

An analysis of the restoration design techniques at each individual site was carried out by modifying the baseline conditions FLO-2D model to include the passive or active restoration techniques at the restoration sites presented in Table 4.1. The restoration site design techniques include the following specific elements:

1. Removal of exotic vegetation,
2. Native vegetation plantings,
3. Bank shavings to enhance channel-floodplain connectivity,
4. Floodplain excavation to increase the area of inundation and flow depths,
5. Floodplain area connections with small excavated channels,
6. Bank destabilization to encourage river migration,
7. Development of channel constrictions to raise the overbank flooding water surface,
8. Construction of inset floodplains,
9. Flow augmentation from irrigation canals and drains, and
10. Reconfiguration of wasteways to enhance wetland areas.

Table 4.1 Index and summary of recommended restoration sites.

Site Number	Site Name	River Mile and Bank	Acres	Riverine Features	River-floodplain Connection	Supplemental water (ac-ft/yr)	Target Riparian habitat(s)	ET difference (ac-ft\yr)	Discontinue Mowing (acres)	Ownership / Management	State	Restoration Cost
1	Trujillo	103 W	14.0	Bank destabilization & Channel widening		42.0	Dense riparian shrubs (SWWF)	0.0	(Not mowed currently)	USIBWC	NM	$115,225
2	Jaralosa	94.9 E	4.5	Bank destabilization & Channel widening		13.5	Open riparian woodland	n/a	4.5	USIBWC	NM	$157,350
3	Yeso Arroyo	94 W	10.6	Arroyo mouth mgmnt.			Aquatic Habitat	-26.5	(Not mowed currently)	USIBWC	NM	$5,165
4	Yeso East	93.7 E	9.7	Bank destabilization & Channel widening		29.1	Open riparian woodland	n/a	11.6	USIBWC	NM	$171,610
5	Yeso West	93.5 W	2.5	Inset floodplain			Aquatic Habitat	-6.3	(Not mowed currently)	USIBWC	NM	$12,260
6	Crow Canyon A	92 E	90.0				Riparian savanna & shrubland	81.4	89.0	USIBWC	NM	$213,925
7	Crow Canyon B	90.5 E	25.6		Bank cut		Dense riparian shrubs (SWWF) & meadow	17.0	18.0	USIBWC	NM	$69,980
8	Placitas Arroyo	85 W	21.8	Arroyo mouth mgmnt.			Aquatic Habitat	-14.0	(Not mowed currently)	USIBWC	NM	$4,010
9	Rincon Siphon	82.5 E	16.3		Bank cut		Dense riparian shrubs (SWWF)	31.0	16.3	USIBWC	NM	$193,225
10	Angostura Arroyo	80 W	15.4	Arroyo mouth mgmnt.			Aquatic Habitat	-16.9	(Not mowed currently)	USIBWC	NM	$5,100
11	Lack Property	71.5 E	51.0		Bank cut	(optional)	Dense riparian shrubs (SWWF)	86.7	N/A	Private	NM	$831,905
12	Pasture 18	69.5 E	0.0		Bank cut & channel		N/A	n/a	N/A	Private	NM	$0
13	Broad Canyon Ranch Middle	67 W	13.8		Breach channels		Saltgrass meadow	0.0	N/A	Private	NM	$64,500
14	Broad Canyon Ranch South	66.8 W	20.6		Breach channels		Saltgrass meadow	0.0	N/A	Private	NM	$80,420

Table 4.1 Index and summary of recommended restoration sites (continued).

Site Number	Site Name	River Mile and Bank	Acres	Riverine Features	River-floodplain Connection	Supplemental water (ac-ft/yr)	Target Riparian habitat(s)	ET difference (ac-ft\yr)	Discontinue Mowing (acres)	Ownership / Management	State	Restoration Cost
15	Selden Point Bar	66 E	6.9		Bank cut		Dense riparian shrubs (SWWF)	0.0	N/A	Private	NM	$201,345
16	Bailey Point Bar	64 E	16.6		Bank cut		Dense riparian shrubs (SWWF)	0.0	N/A	Private	NM	$229,570
17	Shalem Colony	50.5 E	14.2				Screwbean mesquite & riparian grassland	5.0	9.2	USIBWC	NM	$5,000
18	Leasburg Extension Lateral WW 8	47.8 E	4.1			9.3	Dense riparian shrubs (SWWF)	n/a	4.1	USIBWC	NM	$117,600
19	Clark Lateral	43.5 E	6.0			13.5	Dense riparian shrubs (SWWF)	n/a	6.0	USIBWC	NM	$147,335
20	Mesilla Valley Bosque State Park	41.5 W	31.8				Riparian forest, shrubland, meadow & grassland	14.4	31.8	IBWC / State of NM	NM	$112,710
21	Mesilla East	41 E	15.8		Overbank lowering		Dense riparian shrubs (SWWF)	39.5	22.1	USIBWC	NM	$486,370
22	Berino West	25.5 W	10.3		Overbank lowering		Dense riparian shrubs (SWWF)	25.8	13.4	USIBWC	NM	$282,720
23	Berino East	24.5 E	9.5		Overbank lowering		Dense riparian shrubs (SWWF) & forest	23.3	12.0	USIBWC	NM	$221,035
24	Vinton A	17 W	14.7				Riparian forest	25.7	14.7	USIBWC	TX	$171,228
25	Vinton B	16 W	20.0				Riparian woodland	22.0	20.0	USIBWC	TX	$201,500
26	Valley Creek	9 W	22.0				Riparian woodland	22.9	22.0	USIBWC	TX	$179,150
27	Nemexas Siphon	7 W	16.7		Bank cut & channels		Dense riparian shrubs (SWWF)	0.0	(Not mowed currently)	USIBWC	NM	$276,690
28	Country Club East	6.8 E	29.0		Bank cut & channels		Riparian forest & woodland	51.4	29.0	USIBWC	NM & TX	$330,815
29	Sunland Park	4 E	28.8				Riparian woodland	31.7	28.8	USIBWC	NM	$236,570
30	Anapra Bridge	3 E	11.0				Open riparian woodland	5.5	11.0	USIBWC	NM	$35,050
	Total:		**553.2**			**107.4**		**419.6**	**363.5**			**$5,159,363**
				7 sites	13 sites	5 sites		29 sites	18 sites			

Table 4.2. Summary of habitat areas and supplemental water requirements by subreach.													
Subreach	Area (acres)												Supplemental Water (ac-ft/yr)
	Aquatic Habitat	Dense Riparian Shrubs (SWWF)	Dense Riparian Shrubs (SWWF) and Forest	Dense Riparian Shrubs (SWWF) and Meadow	Open Riparian Woodland	Riparian Forest	Riparian Forest and Woodland	Riparian Forest, Shrubland, Meadow and Grassland	Riparian Savanna and Shrubland	Riparian Woodland	Saltgrass Meadow	Tornillo and Riparian Grassland	Total	
1.2		14.0											14.0	42.0
1.3	13.1			25.6	14.2				90.0				142.9	42.6
2.1	21.8	16.3											38.1	
2.2	15.4												15.4	
2.3		51.0											51.0	
3.0		23.5									34.4		57.9	
4.0		4.1										14.2	18.3	9.3
5.0		21.8						31.8					53.6	13.5
6.2		10.3	9.5			14.7							34.5	
7.1										42.0			42.0	
7.2		16.7			11.0		29.0			28.8			85.5	
Total	50.3	157.7	9.5	25.6	25.2	14.7	29.0	31.8	90.0	70.8	34.4	14.2	553.2	107.4

The design techniques were incorporated into the FLO-2D model at each of the restoration sites by modifying the model channel geometry and floodplain attributes. Simulation of bank shaving involved lowering roughness values to represent removal of exotic vegetation. Native vegetation plantings were modeled by revising floodplain roughness where appropriate. Floodplain excavation was modeled by lowering the floodplain elevation by an appropriate amount to increase the frequency and extent of overbank inundation. Modeling bank destabilization involved modification of roughness values to represent removal of exotic vegetation and modification of the cross-sectional geometry to represent excavation laterally into the bank by 15 to 25 feet. The construction of inset floodplains was simulated by extending a bar approximately 100 feet into the channel at an elevation 0.5 feet below the 3,500-cfs water-surface elevation. Some bank-lowering and excavation of the existing floodplain was also necessary.

4.5. Individual Site Prescriptions and Analysis

The following sections present restoration prescriptions and analysis results for the individual sites. A cumulative effects analysis of the overall restoration plan represented by these sites is presented in Chapter 5.

Note: For sites where spoil waste from excavation must be placed near or in the river, Clean Water Act compliance can be fulfilled by a Pre-construction Notification (PCN) for Nationwide Permit (NWP) 27 (Aquatic Habitat Restoration, Establishment and Enhancement Activities), and State Water Quality Certification.

1. Trujillo (RM 103)

The Trujillo Arroyo restoration site covers 18 acres bordered by the Rio Grande to the east and Trujillo Arroyo to the north (**Figure 4.1**). On the average, the site is about 1.5 feet above the 3,500-cfs Caballo release water surface elevation and inundation does not occur downstream of the arroyo confluence.

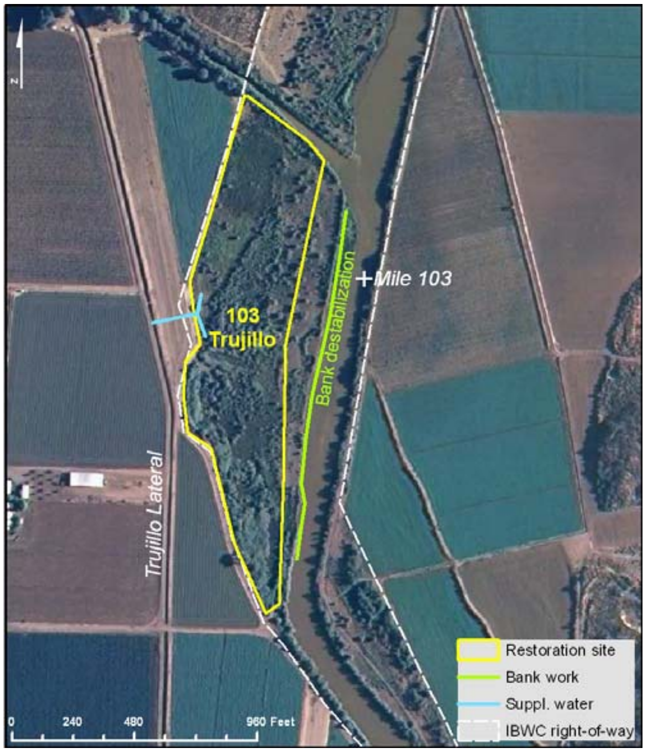

Figure 4.1. Trujillo restoration site.

A sparsely vegetated, gravelly, alluvial terrace occupies the area within 75 to 150 feet of the west bank of the river. The western 14 acres of the site is extensively vegetated with mixed stands of coyote willow, saltcedar, arrow-weed and native grassland. Judging by the existing vegetation and the water surface in the channel for the 1,500-cfs Caballo release, groundwater throughout most of the site during the growing season is within 3 to 4 feet of the surface. Seepage from irrigated fields (primarily chili) and the Trujillo Lateral immediately west of the site likely have contributed to the maintenance of riparian vegetation; however, the Trujillo Lateral was recently lined with pipe and future seepage will be reduced.

Also, the arroyo confluence was recently reconstructed to join the river at a less abrupt angle to reduce erosion into the narrow east overbank. Sediment from Trujillo Arroyo will continue to deposit at the confluence, which may require continued periodic sediment management.

Soils at the site are mapped as Brazito loamy fine sand (NRCS,2007c).

Restoration Prescription

Following is a brief description of the proposed prescription for this site, and a summary of the estimated quantities, costs and evapotranspiration (ET) loss rates is provided in **Table 4.3**.

Table 4.3. Trujillo site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Bank destabilization	25 ft wide x 1,400 ft long x 0.5 ft deep	650 CY	$ 3,250
Saltcedar removal	Mechanical extraction Selective manual extraction Cut-stump herbicidal treatment	3 ac. 7 ac. 7 ac.	$ 1,950 $ 10,500 $ 2,275
Irrigation	Turnout valve, 100 ft piping, installation		$ 11,000
Plantings	Coyote willow whips Longstem riparian shrubs Tree poles	3,100 300 100	$ 23,250 $ 16,500 $ 4,500
		Implementation cost	**$ 73,225**
Water right	Acquisition Annual assessment (14 ac. at 3 ft/yr)	14 ac. 42 ac-ft	$ 42,000 $ 1,330[a]
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	79.4 79.4 0	 $ 0
		Implementation + Water Cost	**$115,225**

[a]*In this and all subsequent summary tables, the Annual assessment cost is <u>not</u> included in the "Implementation + Water Cost."*

Bank destabilization, to encourage river migration and channel diversity, is recommended along approximately 1,400 feet of the west bank. Bank vegetation (saltcedar and, to a lesser extent, willow) can be removed by extraction or grubbing. During winter, the bank should be shaved at a slope with a bulldozer or excavator, and bank riprap material, if present, removed. Spoils placement is described below.

The site is expected to be inundated by Caballo releases of 4,000 cfs or greater, but cannot be inundated by a 3,500-cfs release without extensive overbank lowering which would remove existing riparian vegetation.

Supplemental irrigation*:* from the Trujillo Lateral could sustain and improve coyote willow stands. A turnout valve and pipe could provide water to the site, which is as much as 10 feet lower than the Trujillo Lateral. Interior perforated pipe and small berms may be necessary to distribute water throughout the site. A low containment berm built from bank-shaved material along the eastern edge of the 14-acre irrigated area (yellow polygon) would contain irrigation flows. The irrigation requirement would be 0.5 feet per month from late April through September.

Target habitat: Dense riparian shrubs. With supplemental irrigation, the site is expected to become suitable breeding habitat for the Southwestern Willow Flycatcher [SWWF], although slightly less than the optimal condition.

Exotic vegetation removal: About 3 acres of low-density saltcedar can be removed by mechanical extraction of entire plants. Selective manual extraction within mixed coyote willow stands would be required throughout approximately 7 acres, using the cut-stump method of herbicidal treatment.

Native vegetation plantings: Following removal of saltcedar, some root colonization by coyote willow is expected. Coyote willow whips throughout 7 acres of formerly mixed stands is recommended at approximately 100per acre, and at 1,000 per acre throughout 3 acres of mechanically cleared area. Scattered small clumps of riparian shrubs (seep-willow, sumac, etc.) can be planted at an average density of 30 per acre over 10 acres of the entire site. Likewise cottonwood and/or Goodding's willow poles can be sparsely planted over 10 acres at 10 poles per acre for additional vegetation structure. Because plantings essentially replace removed saltcedar, pre- and post-treatment evapotranspiration rates would not differ significantly.

Revegetation is not recommended for the gravelly terrace within 75 to 150 feet of the riverbank to allow for bank erosion, channel migration, or the option to reposition the Trujillo Arroyo confluence in the future.

Prescription viability without supplemental water*:* Even without the application of supplemental irrigation, some improvement to riparian vegetation would be expected following saltcedar removal and additional plantings. The recent pipe-lining of the Trujillo Lateral likely has decreased seepage to the site, therefore, additional information on groundwater and vegetation should be collected before considering a restoration option without irrigation. In this case, the recommended extent and density of plantings should be reduced accordingly.

2. Jaralosa (RM 94.9)

The Jaralosa site includes an abandoned meander bend of approximately 4.5 acres (**Figure 4.2**). Most of the floodplain surface in the abandoned channel is about 4 feet higher than the 3,500-cfs release water-surface elevation, and the remainder of the overbank surface is about 9 feet higher.

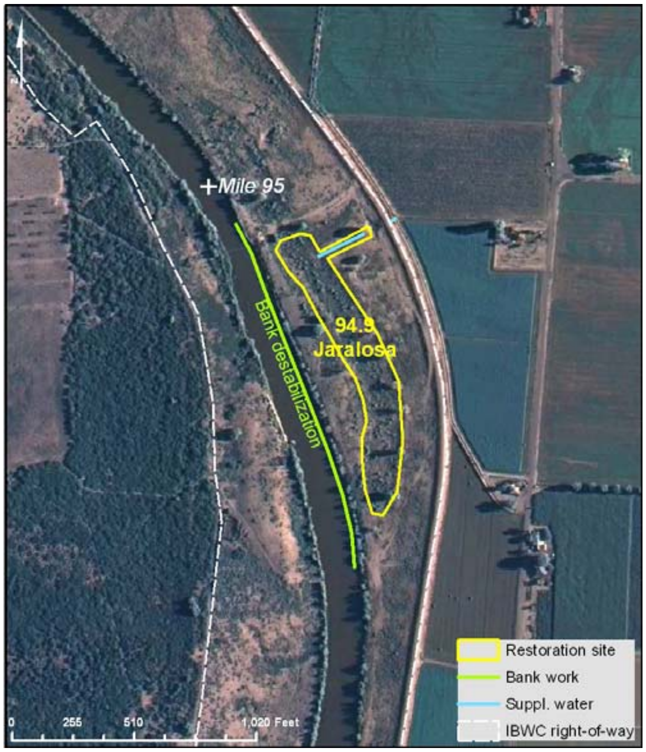

Figure 4.2. Jaralosa restoration site.

The site is vegetated by native and non-native herbaceous vegetation, arrow-weed, and scattered saltcedar that resprouts between mowing cycles. A few remnant but senescent cottonwood trees are present.

The soil is mapped as Anapra clay loam with low (2-4 dS/m) salinity values (NRCS, 2007a).

Restoration Prescription

Following is a brief description of the proposed prescription for this site, and a summary of the estimated quantities, costs and evapotranspiration (ET) loss rates is provided in **Table 4.4**.

Bank destabilization is recommended along 1,400 feet of the east bank. Bank vegetation (saltcedar and, to a lesser extent, willow) can be removed by extraction or grubbing. The bank should be shaved at a slope with a bulldozer or excavator, and bank riprap, if present, removed. The spoil waste from the bank destabilization would not be excessive and can be placed at the riverward toe of the bank for removal by high flows.

Table 4.4. Jaralosa site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Bank destabilization	25 ft wide x 1,400 ft long x 0.5 ft deep	650 CY	$ 3,250
Irrigation	Irrigation gate, turnout and pipe (concrete-encased through levee		$110,000
Saltcedar removal	Mechanical extraction (light-density)	4.5 ac.	$ 2,250
Site preparation	Grubbing and grading	4.5 ac.	$ 3,600
Discontinue mowing		4.5 ac.	
Plantings	Coyote willow whips (400/ac. over 2 ac.) Longstem riparian shrubs with watering tubes (2.5 ac.) Tree poles (avg. 50 ft apart along 3,000 ft) Grass & forb seeding (broadcast)	800 125 60 4.5 ac.	$ 6,000 $ 7,500 $ 2,700 $ 8,550
Implementation cost			**$143,850**
Water right	Acquisition Annual assessment (4.5 ac. at 3 ft/yr)	4.5 ac. 13.5 ac-ft	$ 13,500 $ 428
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	10.8 15.8 5.0	 $ 0
Implementation + Water Cost			**$157,350**

The site cannot be inundated without extensive excavation; thus, the *hydrologic connectivity* between the river and floodplain will not be enhanced.

Target habitat: Open riparian woodland.

Supplemental irrigation: The ground surface within the old meander is nearly level and slopes gently in the downstream direction. Near the upstream end of the site, a ditch extends from the landward toe of the levee to the meander, indicating that the site was likely irrigated in the past (perhaps pre-canalization). Supplemental water could be provided to the site from the Gonzalez Lateral via a private ditch (requiring an appropriate use and maintenance-sharing agreement with the private party). An irrigation gate, turnout, and appropriate piping through the existing levee would be required. The pipe should be encased in concrete for the entire cross-section of the levee, and that material be compacted in lifts when rebuilding the levee after pipe installation. The irrigation requirement would be 0.5 feet per month from late April through September. Light salt deposits are evident in scattered areas throughout the site, but irrigation should leach the surface salts; however, additional soil and irrigation water salinity levels should be verified before implementing the prescribed restoration plan.

Exotic vegetation removal: The sparse, resprouting saltcedar on the site likely has extensive root systems as a result of regular mowing and regrowth. Saltcedar plants should be individually extracted to remove the root crown and eliminate the potential for regrowth. Grubbing is recommended to clear noxious weeds from the site, and minor grading would be required. If possible, irrigation of the site after grubbing but before planting is recommended to germinate remnant weeds, which can then be disked before they develop seeds.

Native vegetation plantings: Although the depth to the growing season water table is approximately 5 feet, riparian shrubs can be established and maintained through supplemental irrigation. Coyote willow whips and other riparian shrubs should be planted at a moderate density in patches throughout the site. Watering tubes are recommended with shrub plantings in order to establish sufficient growth over the first growing season. (An alternative to the use of watering tubes is the application of irrigation water—for instance, pumped from the channel—immediately after planting.) Cottonwood poles along the periphery of the irrigated depression would provide additional habitat structure and shade for shrubs. The existing dead and senescent cottonwoods should be retained to provide wildlife snags and nesting cavities. Current mowing practices can be discontinued.

Prescription viability without supplemental water: This prescription is entirely dependent on irrigation. The ground surface elevation is sufficiently high that the site is only suitable for upland vegetation (even with restoration flow releases of 3,500 cfs from Caballo Dam).

3. Yeso Arroyo (RM 94)

The Yeso Arroyo site is one of three arroyos that is proposed to be treated with a natural restoration approach. The restoration techniques to be used under this approach include removal of the existing riprap toe protection along the left (north) bank opposite the mouth of the arroyo, destabilization and lowering of the left bank and termination of future dredging, to allow channel migration during future arroyo flooding (**Figure 4.3**). As channel conveyance capacity is lost over time due to deposition of tributary-derived sediment, more frequent overbank flooding may in the area just upstream from the mouth of the tributary.

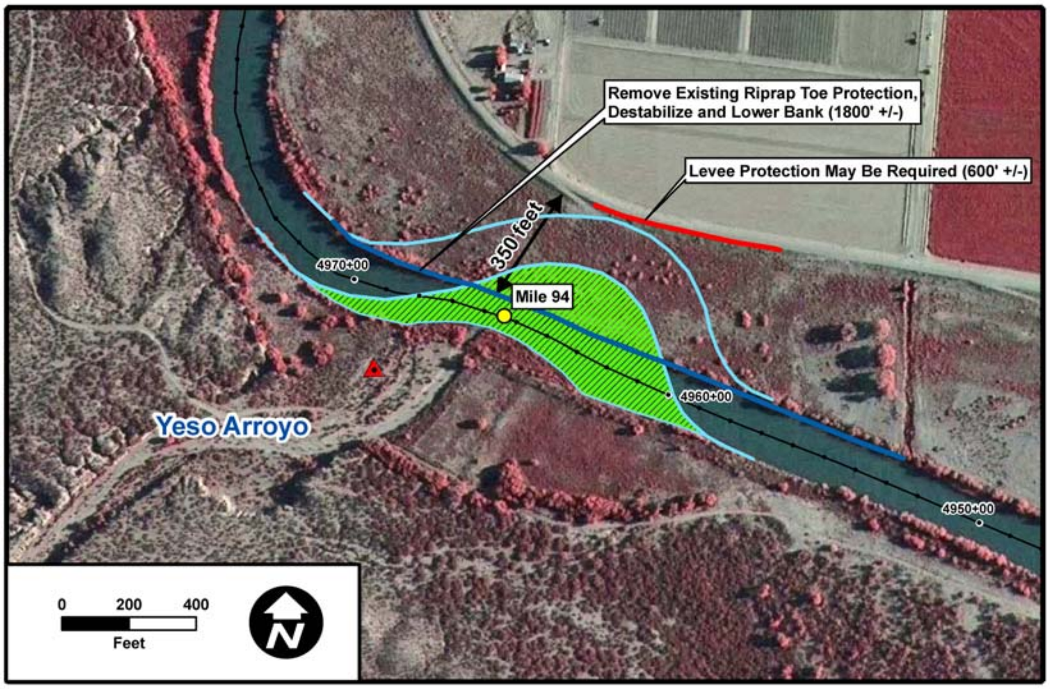

Figure 4.3. Yeso Arroyo Restoration site showing the channel alignment and boundaries of the tributary mouth bar at maximum anticipated channel migration.

Bank destabilization was simulated in the FLO-2D model by rounding off and lowering the left banks approximately 0.5 feet for approximately 1,800 feet along the site to simulate vegetation removal and removal of bank riprap. Excavation spoil waste could be left on the bank of the channel to be eroded during high flows. The area of new tributary mouth bar (indicated by the green cross-hatched pattern) at the maximum migration distance shown in Figure 4.3 is about 4.5 acres, and the indicated migration would erode about 5.3 acres of the left overbank. Erosion protection may be required along 600 to 700 feet of the levee to avoid damage if the left bank ultimately migrates to the extent shown in Figure 4.3.

Restoration Prescription

***Target habitat**:* Improved in-channel aquatic habitat due to increased in-channel topographic, hydraulic and substrate diversity.

Exotic vegetation removal: Saltcedar along the bank would be removed during excavation.

***Bank destabilization**:* Bank destabilization was simulated in the FLO-2D model by rounding off and lowering the left bank approximately 0.5 feet for approximately 1,800 feet along the site to simulate vegetation removal and removal of bank riprap. Excavation spoil waste could be left on the bank of the channel to be eroded during high flows. The total area that would be re-worked at the maximum migration distance shown in Figure 4.3, including the river channel, is 10.6 acres of which about 4.5 acres would be new tributary mouth bar (green cross-hatched area) and about 5.3 acres of the left overbank would be eroded. Erosion protection may be required along about 600 feet of the levee to avoid damage if the left bank ultimately migrates to the extent shown in Figure 4.3. The cost of the erosion protection shown in Figure 4.3 is not included in the cost estimate because such protection will likely not be required for several years to a few decades, depending on the frequency and magnitude of flows from the arroyo, and it is assumed that the protection would be installed as part of future levee upgrade/maintenance activities.

Table 4.5. Yeso Arroyo site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Bank destabilization	25 ft wide x 1,800 ft long x 0.5 ft deep	833 CY	$ 4,165
Saltcedar removal	Mechanical extraction (high density)	1 ac.	$ 1,000
		Implementation cost[1]	**$ 5,165**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	36.1 9.6 -26.5	$ 0
		Implementation + Water Cost	**$ 5,165**

[1] Excluding levee protection

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases.

4. Yeso East (RM 93.7)

The Yeso East site is situated on the east bank of a river bend (**Figure 4.4**) and the floodplain is an average of 5 feet higher than the 3,500-cfs Caballo release water-surface elevation. As a result, inundation at this discharge is not possible without substantial excavation.

Figure 4.4. Yeso East restoration site.

A 9.7-acre, shallow depression (likely a former channel meander) through the center of the site is primarily vegetated by non-native weeds (mostly amaranth), and alkali sacaton, aster, and arrow-weed that resprout between mowing cycles. The surrounding area (outside of the yellow polygon) is vegetated by saltgrass, and sparse alkali sacaton and arrow-weed.

The soil series is mapped as Brazito loamy fine sand (NRCS, 2007a).

Restoration Prescription

Following is a brief description of the proposed prescription for this site, and a summary of the estimated quantities, costs and evapotranspiration (ET) loss rates is provided in **Table 4.6.**

Bank destabilization is recommended along approximately 1,800 feet of the outside of the bend (i.e., east bank) to widen the channel and encourage river migration. Saltcedar along the bank can be removed by extraction or scrapping. During the low-flow period, the bank should be shaved at a slope with a bulldozer or excavator, and bank riprap material, if present, removed. The excavation from the bank destabilization would not be excessive and can be placed at the riverward toe of the bank for removal by high flows. Waste deposition should be less than 1 acre in extent below the Ordinary High-water Mark (OHWM).

Table 4.6. Yeso East site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Bank destabilization	25 ft wide x 1,800 ft long x 0.5 ft deep	833 CY	$ 4,165
Irrigation	Check dam and turnout		$50,000
Saltcedar removal	Mechanical extraction al bank (high density)	1 ac.	$ 1,000
Site preparation	Excavation (1 ft over 3.3 ac.) Grubbing & grading	5,324 CY 5 ac.	$ 7,990 $ 4,000
Discontinue mowing		9.7 ac.	
Plantings	Coyote willow whips (patches covering the downstream 2 ac. at 400 stems/ac.) Longstem riparian shrubs with watering tubes over 9.7 ac. Cottonwood poles (50/ac. over 9.7 ac.) Grass & forb seeding (broadcast)	800 485 485 9.7 ac.	$ 6,000 $29,100 $21,825 $18,430
		Implementation cost	**$142,510**
Water right	Acquisition Annual assessment (9.7 ac. at 3 ft/yr)	9.7 ac. 29.1 ac-ft	$29,100 $ 922
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	23.3 34.0 10.7	$ 0
		Implementation + Water Cost	**$171,610**

Target habitat: Open riparian woodland.

Supplemental irrigation can be provided from the Palmer Lateral Wasteway which traverses the overbank at the upstream end of the site. A simple check dam in the wasteway would raise the water surface sufficiently to allow inundation of the lowered overbank area (see Figure 3.1 for a prototype design). Excavation of approximately one-third of the 9.7 acres to a depth of 1 foot to elevation 4,091 would be required to facilitate irrigation. Spoil waste could be placed along the riverward slope of the levee for up to 2,500 linear-feet. A small amount of spoil waste can be used to raise the banks of the wasteway above the check dam, if needed. The irrigation requirement would be 0.5 feet per month from late April through September.

Exotic vegetation removal: (discussed under Bank destabilization above)

Native vegetation plantings: Although the depth to the water table during the growing season is 4 to 6 feet, riparian shrubs can be established and maintained through supplemental irrigation. Coyote willow whips and other riparian shrubs should be planted at a moderate density in patches throughout the site. Watering tubes are recommended with shrub plantings in order to establish sufficient growth over the first two growing seasons. Cottonwood poles should be planted at 50 per acre.

Site preparation is anticipated to be necessary in the downstream 1.5 acres of the site. Grubbing is recommended to clear noxious weeds from areas where excavation is not conducted, and minor grading would be required. If possible, irrigation of the site after grubbing but before planting is recommended to germinate remnant weeds, which can then be disked before they develop seeds.

Prescription viability without supplemental water: This prescription is entirely dependent on irrigation. The ground surface elevation is sufficiently high that the site is only suitable for upland vegetation (even with restoration flow releases of 3,500 cfs from Caballo Dam).

5. Yeso West (RM 93.5)

The restoration design would consist of a small (approximately 1.6-acre) inset floodplain along the right (west) bank just upstream from the mouth of the small unnamed arroyo (**Figure 4.5**). The inset floodplain is a feature that, if successfully implemented, can be considered for future restoration sites.

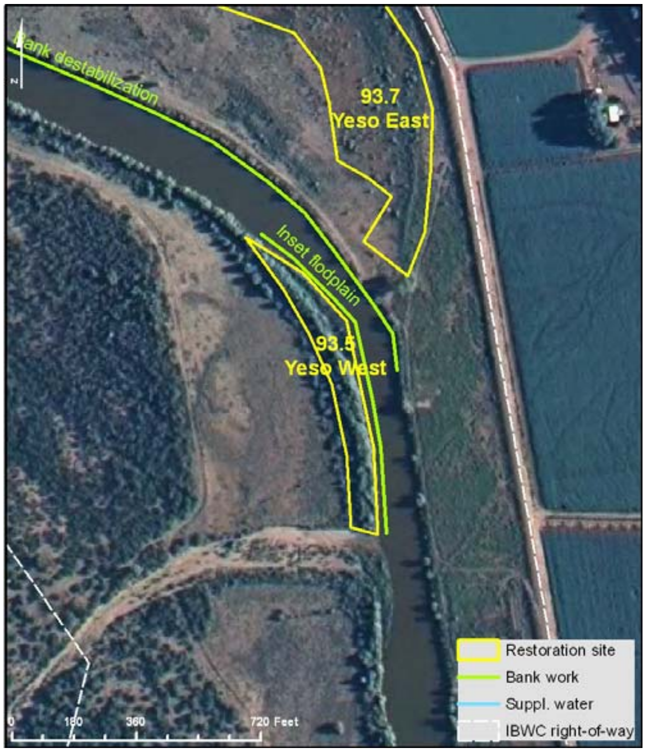

Figure 4.5. Yeso West restoration site.

The inset floodplain was simulated by lowering an approximately 40-foot wide strip along the right bank elevation to 0.5 feet below the 3,500-cfs water-surface elevation (about 4 feet total lowering), and extending the cross section width from 240 to 300 feet (**Figure 4.6**). The excavation spoil waste could be placed into the river channel downstream to at least temporarily constrict the flow and raise the upstream water-surface elevations, helping to force water onto the inset floodplain. The inset floodplain should be designed for inundation during the restoration or operation flows at the time of construction.

Restoration Prescription

Following is a brief description of the proposed prescription for this site, and a summary of the estimated quantities, costs and evapotranspiration (ET) loss rates is in **Table 4.7**.

Construction of an inset floodplain is recommended along approximately 1,100 feet on the west bank to increase the overbank area subject to inundation under the restoration flows. Saltcedar along the bank can be removed by extraction or scrapping. During the low-flow period, the overbank in the specified area should be graded to about 0.5 feet below the 3,500-cfs water-surface elevation with a bulldozer or excavator. The excavation would not be excessive and can be placed at the riverward toe of the bank for removal by high flows.

Site work area west: 2.5 acres
Inset floodplain: along 1,100 feet of bank
Site excavation east and west: minimal spoil waste to be eroded by high flows

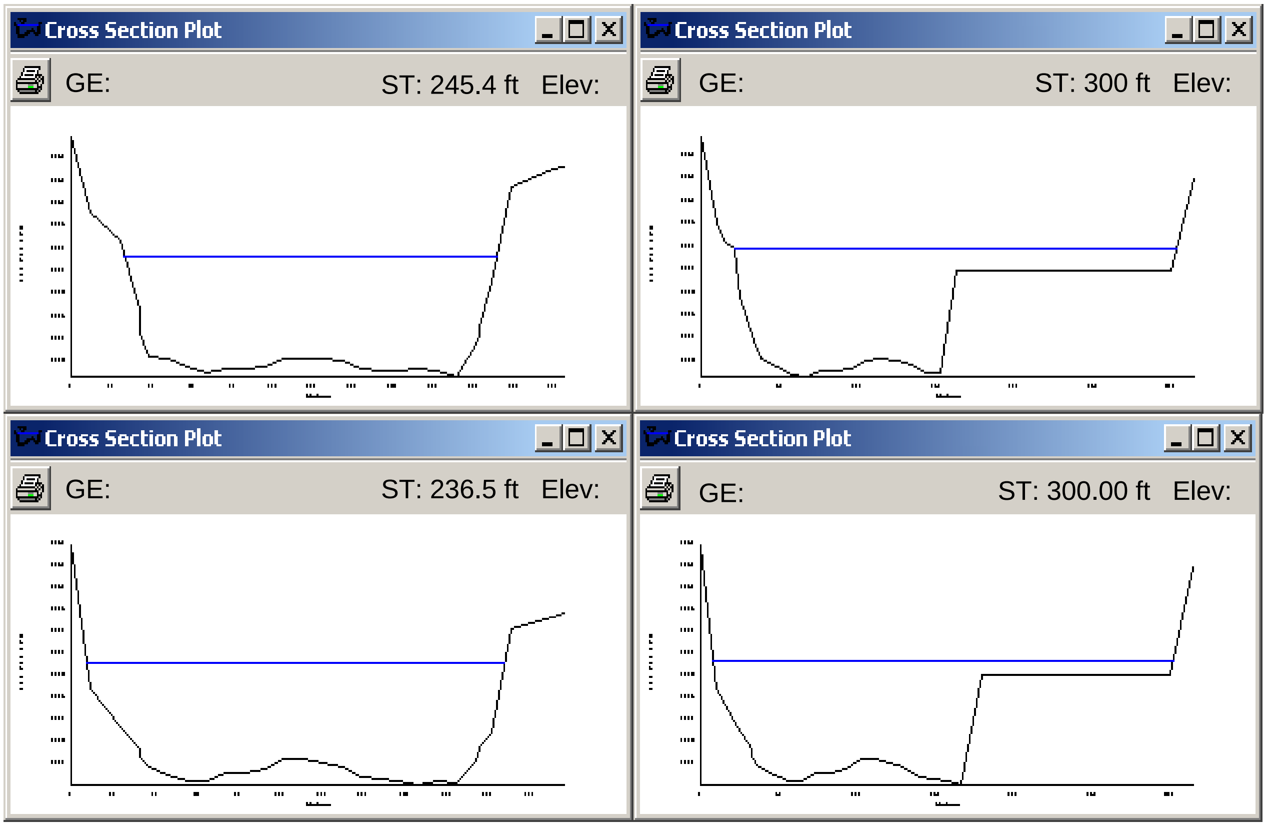

Figure 4.6. Existing (left) and restored (right) Inset floodplain cross sections.

Table 4.7. Yeso West site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Inset floodplain	Excavation (40 ft wide x 1,100 ft long x 4 ft deep)	6,500 CY	$32,500
Bank vegetation removal	Bulldozed (1,100 x 100 feet)	2.5 ac.	$ 2,500
		Implementation cost	**$12,260**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	12.3 6.0 -6.3	$ 0
		Implementation + Water Cost	**$12,260**

Prescription viability without restoration flow releases: This prescription is almost entirely dependent on restoration flow releases of 3,500 cfs from Caballo Dam considering the relative rarity of storm flows of the same magnitude.

6. Crow Canyon A (RM 92)

A large former river meander dominates the eastern overbank area opposite the mouth of the outlet wash channel from Crow Canyon Dam (**Figure 4.7**). The potential for reconnection of river flow through this meander was investigated; but the Rio Grande channel is significantly incised and overbank flooding for the 3,500-cfs restoration discharge is not practical for the upstream 1.4 miles of the 2-mile-long meander.

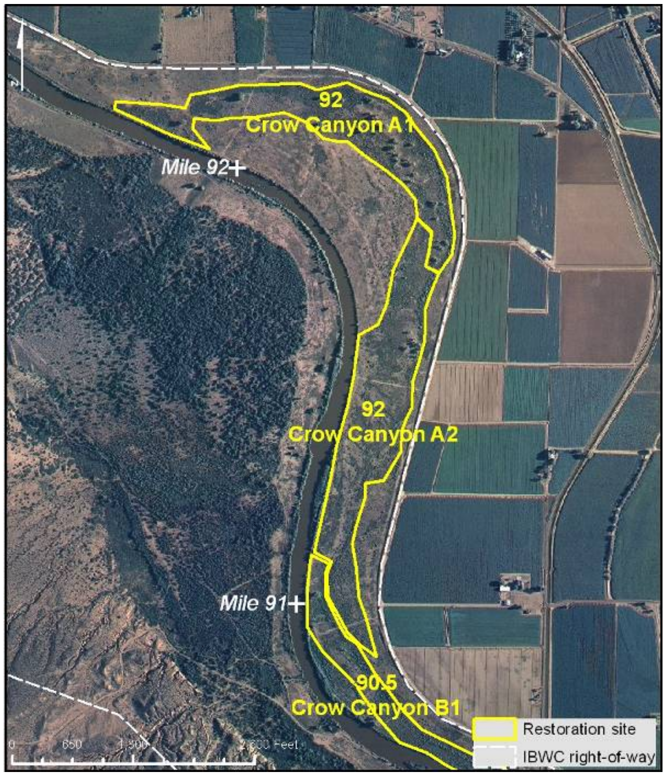

Figure 4.7. Crow Canyon A restoration site.

The entire 90-acre site (yellow polygons in Figure 4.7) and the surrounding area has been periodically mowed in the past. Vegetation within the upstream 41 acres of the meander bottom (Parcel A1) is primarily alkali sacaton with several remnant cottonwoods. Parcel A2 (49 acres) is vegetated by alkali sacaton, saltgrass, and sprouts of screwbean mesquite and arrow-weed. Resprouting saltcedar is also scattered throughout Parcel A2, and to a lesser extent in Parcel A1.

The soil series at this site is mapped as Agua Variant, moderately wet (AJ) with typical salinity levels of 4 to 16 dS/m (NRCS, 2007a). The presence of healthy cottonwoods and shrubs throughout the site, however, indicates that subsurface salinity is not a deterrent to the growth of woody riparian vegetation.

Restoration Prescription

Target habitat: Riparian "savanna" (41 acres) and riparian shrubland (49 acres).

Cessation of mowing: Significant improvement in habitat quality would be realized by the cessation of maintenance mowing, subsequent to which native shrubs and grasses would mature and spread through the site. Native grass and herbaceous growth would also improve in Parcel A1, and Parcel A2 would develop into a moderately dense screwbean mesquite and arrow-weed shrubland.

Exotic vegetation removal: To avoid ground disturbance, resprouting saltcedar should be controlled by manual foliar or basal stem herbicidal spraying. Herbicidal treatment may be required for 2 to 3 years before producing desirable results because the root systems of regularly mowed shrubs are larger than those of seed-origin plants,

Native vegetation planting: Limited plantings are recommended to improve wildlife habitat quality. If additional subsurface soil salinity levels in Parcel A1 are suitable, cottonwood pole plantings could increase the tree density to 15 per acre. In Parcel A2, additional riparian shrub species could also be added to increase density and diversity.

Table 4.8. Crow Canyon A site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Discontinue mowing		99 ac.	
Saltcedar removal	Herbicidal treatment of sparse resprouts, 2 years	40 ac.	$ 24,000
Plantings	Longstem riparian shrubs over 49 ac. (40/ac.) Cottonwood poles (15/ac. over 41 ac.)	1,470 615	$ 80,850 $ 27,675
		Implementation cost	**$132,525**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	237.6 319.0 +81.4	 $ 81,400
		Implementation + Water Cost	**$ 213,925**

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

7. Crow Canyon B (RM 90.5)

This site includes a 20-acre meander depression that is about 3 feet lower than the rest of the site (**Figure 4.8**, yellow polygon). FLO-2D modeling indicated that the southern portion of this depression would be inundated by discharges equivalent to a 4,500-cfs Caballo release, and the depression would be entirely inundated by a 5,000-cfs release.

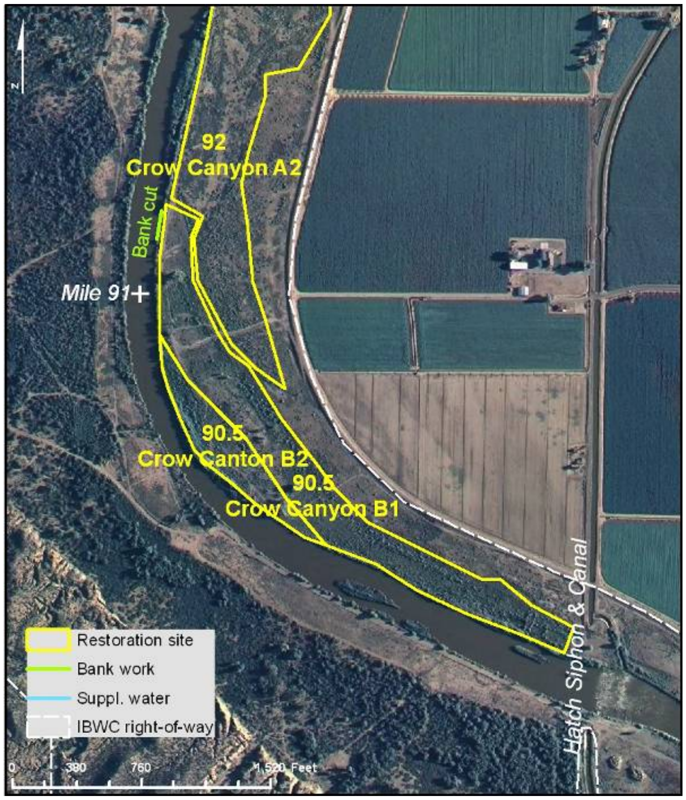

Figure 4.8. Crow Canyon B restoration site.

Vegetation at this site entails one of the best stands of meadow vegetation that was found throughout the entire RGCP reach. Alkali sacaton and saltgrass predominate, and scattered clumps of arrow-weed, rush, three-square bulrush, and cattail are present. The latter species indicate that soil moisture is relatively high and their limited distribution is believed to be the result of repeated mowing. Bank vegetation is predominantly saltcedar with some intermixed coyote willow. Coyote willow extends landward from the bank in the 5.6-acre Parcel B2, and a portion of this stand has been periodically mowed as part of the USIBWC floodway maintenance program.

Soils in this site are mapped as Agua Variant, moderately wet (AJ), and Brazito loamy fine sand (NRCS 2007a). Although Aqua Variant soils can have elevated salinity, existing vegetation at the site indicates that soil salinity levels are suitable for the growth of willows and other shrub species.

Restoration Prescription

Target habitat: Riparian meadow (15 acres) and dense riparian shrubs (10.6 acres; SWWF habitat).

Enhanced floodplain hydrologic connection: Inundation of 20 acres of the relict channel (Parcel B1) by the 3,500-cfs Caballo release restoration flow is possible by lowering a portion of the left (east) bank near RM 91.1. Excavating a 50-foot length of the bank by 1.6 feet will permit flooding of the overbank (**Figure 4.9**).

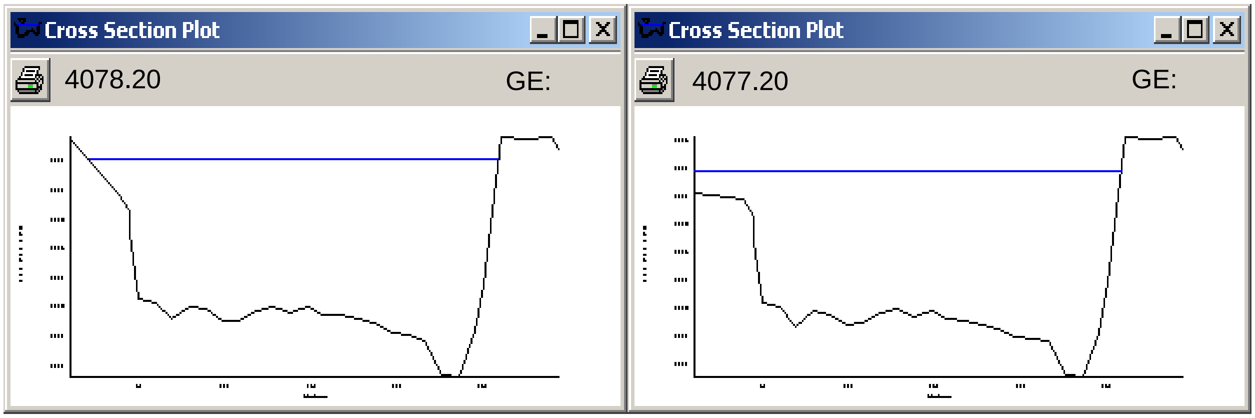

Figure 4.9. Before and after cross-section plot of river connection near RM 91.

Immediately downstream from this site, the Hatch Siphon crosses the Rio Grande channel and is protected by riprap fill over the buried conduit. The elevated bottom functions as a grade-control, stabilizing the channel bed immediately upstream. The addition of 0.5 feet of riprap to the siphon crossing was evaluated as a means of raising the upstream water-surface and enhancing potential inundation at the Crow Canyon B site; however; the backwater effect from this action would be negligible at the bank excavation near RM 91.1.

Exotic vegetation removal: A relatively small amount of resprouting saltcedar is present at this site that may be controlled by foliar or basal stem herbicidal treatment. Relatively large saltcedars are mixed with mature coyote willow along the bank, and can be controlled by manually cutting and cut-stump herbicidal treatment.

Native vegetation planting: Within the inundated portion of the site (Parcel B1), additional vegetation plantings would not be required. The cessation of mowing and periodic flooding would suffice to allow existing vegetation to fully colonize this 20-acre portion of the site that can be inundated with the target restoration flow release. It is expected that up to 25 percent of this area may be naturally colonized by woody vegetation (coyote willow and seep-willow).

In Parcel B2, located between the river and the old meander channel, additional Goodding's willow, coyote willow and riparian shrub plantings would enhance habitat diversity. While not expected to be inundated, soil moisture would increase to some degree from adjacent flooding. Plantings and the development of existing vegetation should result in suitable breeding habitat for the SWWF.

Table 4.9. Crow Canyon B site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Floodplain connection	20 ft wide x 50 ft long x 1.6 ft deep	60 CY	$ 300
Saltcedar removal	Mechanical extraction at the lowered bank Herbicidal treatment of minor resprouts, 2 years Selective manual, cut-stump removal	0.2 ac. 10 ac. 1,200 ft	$ 500 $ 5,000 $ 800
Discontinue mowing		23.6 ac.	
Plantings	Coyote willow whips (800/ac. over 2 ac.) Longstem riparian shrubs (40/ac. over 3.6 ac.) Goodding's willow poles (100/ac. over 5.6 ac. Cottonwood poles (5/ac. over 5.6 ac.)	1,600 144 560 28	$12,000 $ 7,920 $25,200 $ 1,260
		Implementation cost	**$52,980**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	66.4 83.4 17.0	 $17,000
		Implementation + Water Cost	**$69,980**

NOTE: Even without periodic inundation by a 3,500-cfs release, vegetation improvement at this site is still sustainable and recommended. Without inundation, the extent and vigor of woody growth would be somewhat less than discussed above.

Prescription viability without restoration flow releases: Cessation of mowing and removal of exotic vegetation would improve meadow habitat without restoration flow releases of 3,500 cfs from Caballo Dam; however, the development of dense riparian shrubs is dependent on higher flows. The cessation of mowing would improve shrub habitat to some degree, but planting densities should only be about 25 percent of those recommended with restoration flow releases.

8. Placitas Arroyo (RM 85)

The Placitas Arroyo site is the second of three arroyos where it may be possible to employ a natural restoration approach by minimizing site maintenance activities. The restoration techniques to be used under this approach include removal of the existing riprap toe protection along the left (north) bank opposite the mouth of the arroyo, destabilization and lowering of the left bank and termination of future dredging, to allow channel migration during future arroyo flooding (**Figure 4.10**). As channel conveyance capacity is lost over time due to deposition of tributary-derived sediment, more frequent overbank flooding in the area immediately upstream from the mouth of the arroyo may ensue. Based on discussions with EBID staff, the overbank area into which the river would erode may be privately owned. At the time of this report, EBID is researching this issue. The rate at which the channel migration would occur is highly uncertain, and dependent primarily on the frequency of occurrence of large, sediment-laden tributary flows. At least several such events would be required to achieve the maximum migration indicated in Figure 4.10; thus, the erosion protection indicated in the figure would most likely not be necessary for several years to a few decades.

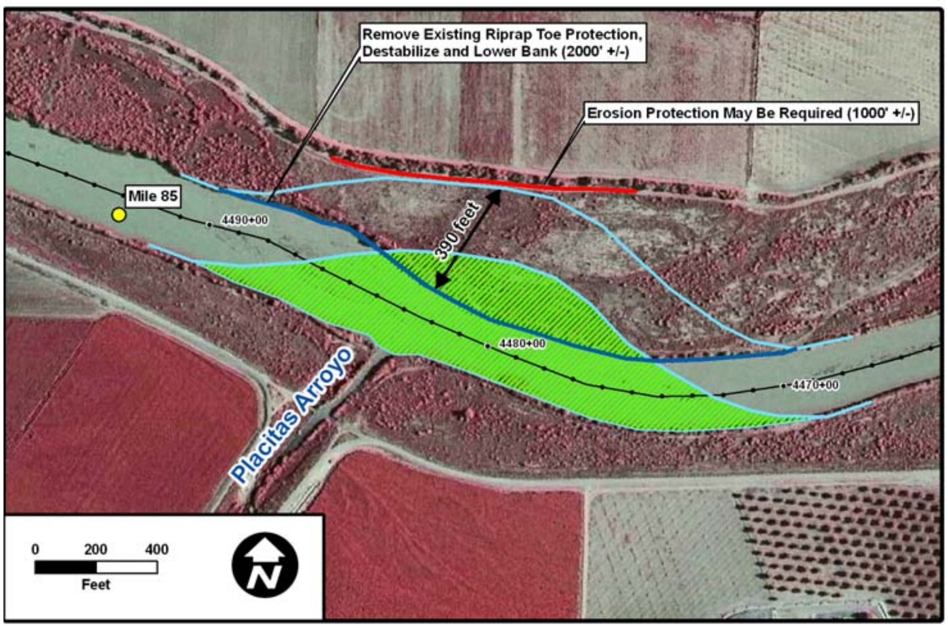

Figure 4.10. Placitas Arroyo restoration site.

Restoration Prescription

Target habitat*:* Improved in-channel aquatic habitat due to increased in-channel topographic, hydraulic and substrate diversity.

Exotic vegetation removal*:* Saltcedar along the bank would be removed during excavation.

Bank destabilization, potential river migration to the east*:* Bank destabilization was simulated in the FLO-2D model by rounding off and lowering the left bank approximately 0.5 feet for approximately 2,000 feet along the site to simulate vegetation removal and removal of bank riprap. Spoil waste from the excavation could be left on the bank of the channel to be eroded during high flows. The total area that would be re-worked at the maximum migration distance shown in Figure 4.10, including the river channel, is 21.8 acres. The area of new tributary mouth bar (green cross-hatched area) is about 10.7 acres, and the indicated migration would erode about 9.7 acres of the left overbank. Erosion protection may be required along about 1,000 feet of the levee to avoid damage if the left bank ultimately migrates to the extent shown in Figure 4.13. The cost of the erosion protection is not included in the cost estimate because such protection will likely not be required for several years to a few decades, depending on the frequency and magnitude of flows from the arroyo, and it is assumed that the protection would be installed as part of future maintenance activities.

Enhanced channel diversity*:* Channel migration will modify the channel geometry and should increase the habitat diversity for aquatic species.

Table 4.10. Placitas Arroyo site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Bank destabilization	25ft wide x 1,300 ft long x 0.5 ft deep	602 CY	$ 3,010
Saltcedar removal	Mechanical extraction (high density)	1 ac.	$ 1,000
		Implementation cost	**$ 4,010**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	26.0 12.0 -14.0	$ 0
		Implementation + Water Cost	**$ 4,010**

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

9. Rincon Siphon (RM 82.5)

This site consists of two parcels, 4.5 and 11.8 acres in size that could potentially be inundated by the target restoration releases (**Figure 4.11**). An intervening area of higher ground separates the parcels where an unnamed arroyo empties onto the floodplain.

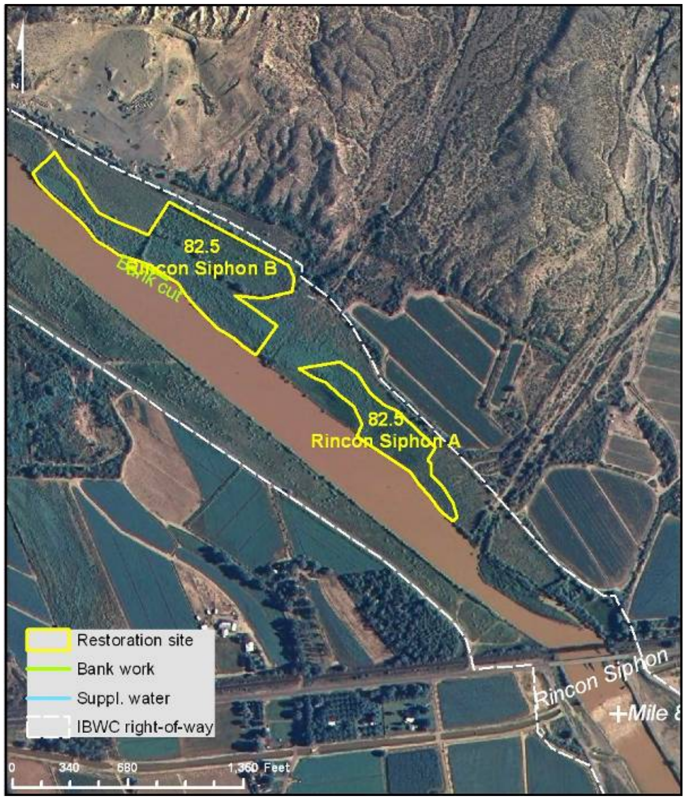

Figure 4.11. Rincon Siphon restoration site.

FLO-2D modeling indicates that overbank areas at this site would begin to be inundated by a 4,000-cfs release from Caballo Dam. The water surface elevation for the 3,500-cfs Caballo release is just below the bank elevation and much of the overbank area is slightly lower than the riverbank.

Existing vegetation consists of dense saltcedar that is periodically mowed. Some native shrubs (screwbean mesquite, willow, arrow-weed) may be mixed with saltcedar.

Soils series within the site are mapped as Brazito loamy fine sand (Br) and Brazito very fine sandy loam (Bs), with a small area of Anapra silt loam (NRCS, 2007a). (While these soil series typically exhibit low salinity levels, the predominance of saltcedar at this site emphasizes the need for additional soil salinity information before implementing the planting prescription described below.)

Restoration Prescription

Target habitat: Dense riparian shrubland (SWWF habitat).

Enhanced floodplain hydrologic connection: Inundation of most of the site would be possible by lowering a portion of the east bank to 0.5 feet below the predicted water surface elevation for the 3,500-cfs Caballo release (**Figure 4.12**). Accumulation of sediment at the arroyo mouth may reduce the inundated area over time, especially in Parcel A. Limited sediment removal or a small connecting channel between the parcels should be considered for future site maintenance.

Exotic vegetation removal: The relatively dense but small-diameter saltcedar present at the site would be difficult to eradicate through mowing and basal herbicidal treatment. It is recommended that saltcedar be removed by a scraper or bulldozer, followed by root-plowing and raking of the debris. The work area should be scarified before revegetation. If the resprouting stand is entirely saltcedar rather than mixed with coyote willows, herbicidal treatment with a carpet-roller would be more cost-effective and avoid the need for root-plowing.

Native vegetation planting: The site is sufficiently wet to promote the vigorous growth of willows that should develop into suitable SWWF breeding habitat. Coyote willows should be planted throughout the site, with scattered patches of Goodding's willows, especially near the bankline. Cottonwoods, sumac, and seep-willow should be planted in clumps throughout the site.

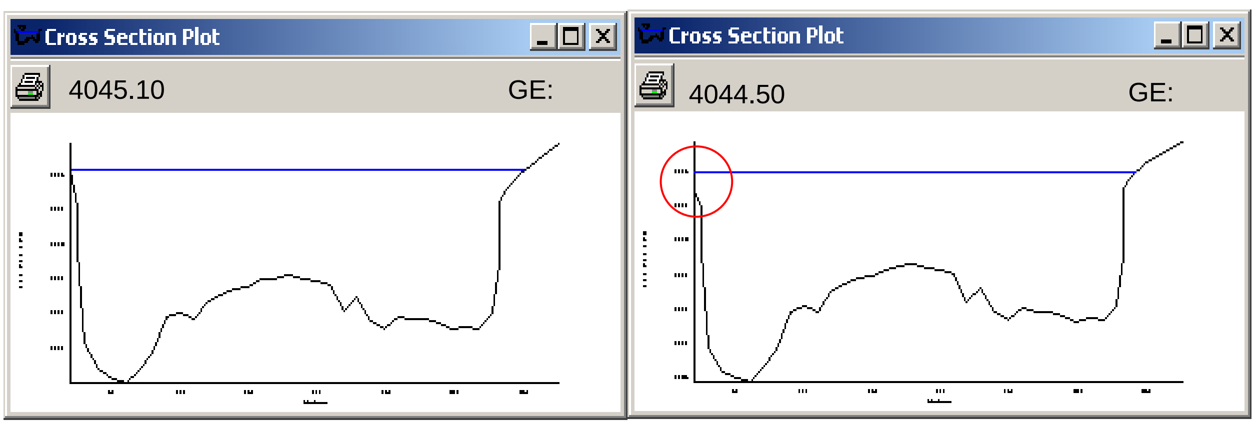

Figure 4.12. Before and after cross-section plot of river connection.

Table 4.11. Rincon Siphon site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Floodplain connection	20 ft wide x 50 ft long x 1 ft deep	37 CY	$ 250
Saltcedar removal	Mechanical removal and root-plowing	16.3 ac.	$ 29,340
Discontinue mowing		23.6 ac.	
Plantings	Coyote willow whips (1,000/ac. over 12 ac.) Riparian shrubs (40/ac. over 8 ac.) Goodding's willow poles (patches of 100/ac. over 5 ac. Cottonwood poles (10/ac. over 16.3 ac.)	12,000 320 500 163	$ 90,000 $ 12,800 $ 22,500 $ 7,335
		Implementation cost	**$162,225**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	48.9 79.9 31.0	 $ 31,000
		Implementation + Water Cost	**$193,225**

NOTE: Even without periodic inundation by a 3,500-cfs release, vegetation improvement at this site is still sustainable and recommended. Without inundation, the extent and vigor of woody growth would be somewhat less than discussed above. Raising the elevation of the rip rap over the Rincon Siphon would also enhance inundation at the restoration site.

Prescription viability without restoration flow releases: Even without periodic inundation by a 3,500-cfs release, vegetation improvement at this site is still sustainable and recommended. Without inundation, the extent and vigor of woody growth would be somewhat less than discussed above. Raising the elevation of the rip rap over the Rincon Siphon would also enhance inundation at the restoration site.

10. Angostura Arroyo (RM 80)

The Angostura is proposed to be treated with a natural restoration approach by minimizing site maintenance. The restoration techniques to be used under this approach include removal of the existing riprap toe protection along the left (north) bank opposite the mouth of the arroyo, destabilization and lowering of the left bank and termination of future dredging, to allow channel migration during future arroyo flooding (**Figure 4.13**). As channel conveyance capacity is lost over time due to deposition of tributary-derived sediment, more frequent overbank flooding may ensue.

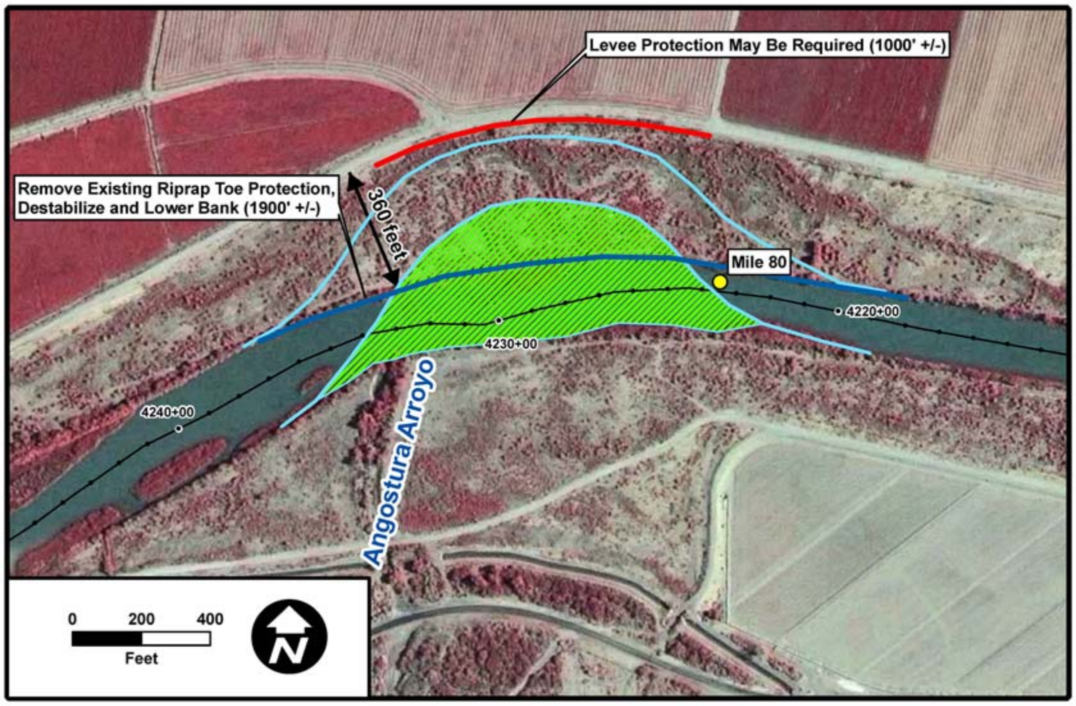

Figure 4.13. Angostura Arroyo restoration site.

Bank destabilization was simulated by shaving 1,200 feet along the left bank of the site. The cross section banks were rounded off and lowered by approximately 0.5 feet. The bank destabilization also requires bank vegetation removal. The spoil waste from the bank destabilization can be used to reinforce the levee on the west side of the river.

Restoration Prescription

***Target habitat**:* Improved in-channel aquatic habitat.

***Exotic vegetation removal**:* Saltcedar will be removed during bank excavation.

***Bank destabilization will encourage river widening to the east**:* Bank destabilization was simulated in the FLO-2D model by rounding off and lowering the left bank approximately 0.5 feet for approximately 1,900 feet along the site to simulate vegetation removal and removal of bank riprap. Spoil waste from the excavations could be left on the bank of the channel to be eroded during high flows. The total area that would be re-worked at the maximum migration distance shown in Figure 4.13, including the river channel, is 15.4 acres. The area of new tributary mouth bar (green cross-hatched area) is about 7.5 acres, and the indicated migration would erode about 9.0 acres of the left overbank. Erosion protection may be required along about 1,000 feet of the levee to avoid damage if the left bank ultimately migrates to the extent shown in Figure 4.13. The cost of the erosion protection is not included in the cost estimate because such protection will likely not be required for several years to a few decades, depending on the frequency and magnitude of flows from the arroyo, and it is assumed that the protection would be installed as part of future levee upgrade/maintenance activities.

Enhanced channel diversity by eliminating dredging*:* Aquatic habitat will benefit from enhanced diversity of channel geometry.

Table 4.12. Angostura Arroyo site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Bank destabilization	25 ft wide x 1,900 ft long x 0.5 ft deep	880 CY	$ 4,400
Saltcedar removal	Mechanical extraction (high density)	0.7 ac.	$ 700
		Implementation cost[1]	**$ 5,100**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	26.5 9.6 -16.9	$ 0
		Implementation + Water Cost	**$5,100**

[1]Excluding levee protection

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

11. Lack Property (RM 71.5)

The Lack Property is a privately owned site on the east bank of the river at the upstream end of the Selden Canyon reach. FLO-2D modeling indicated that the Lack Property begins to inundate by a 4,500-cfs Caballo release, and is entirely inundated by a 5,000-cfs release (**Figure 4.14**).

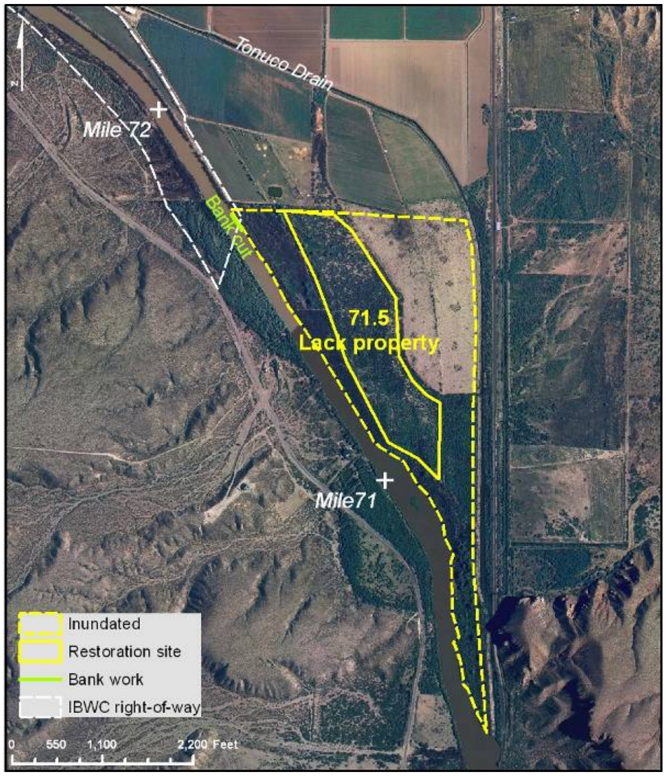

Figure 4.14. Lack Property restoration site.

Soils are mapped as Agua variant and Belen variant soils (AK) and Agua Variant, moderately wet (AJ)—both of which typically exhibit soil salinity of 4 to 16 dS/m—and a smaller area of Brazito loamy fine sand (NRCS, 2007a). A more detailed soil evaluation was conducted in 2008 by Soil and Water West, Inc. (Caplan and Landers 2008) and is discussed below.

The northwest portion of the site contains Gila clay loam and very fine sandy loam with salinity ranging from 8-16 dS/mm on the surface and 4 to 8 dS/m in the subsurface. Belen Variant clay with relatively high salinity (8 to 18 dS/m) occupies the southeast portion of the site. Vegetation within these soil types consists of relative dense stands or mixtures of saltcedar and screwbean mesquite.

The large (51-acre) central portion of the site was characterized as Brazito Variant loamy sand and Anthony Variant loamy sand with very low salinity levels (solid-line polygon in Figure 4.14). Vegetation consists of sparse to moderately dense screwbean mesquite with saltgrass, Bermuda grass, and alkali sacaton.

The northeastern portion of the site has been cleared and is anticipated to be put into production as a nursery.

Restoration Prescription

Target habitat: Dense riparian shrubs. Due to soil conditions described above, only the central 51 acres of the site was considered suitable for restoration of riparian trees and shrubs. At other restoration sites in this study, the enhancement of screwbean mesquite stands has been recommended. With periodic inundation, the Lack Property site presents a rare opportunity to create a large tract of suitable breeding habitat for the SWWF in place of lower-value screwbean mesquite stands.

Enhanced river floodplain hydrologic connectivity: The floodplain is lower than the riverbank and inundation may be possible with relatively minor bank excavation (**Figure 4.15**). Over the entire site, about 160 acres of floodplain would be inundated by the 3,500-cfs Caballo Dam release (dashed line in Figure 4.14).

The inundated area includes the northeast portion of the property where a production nursery is planned. To protect this area from inundation by the introduction of periodic flows, a low berm would be required along approximately 3,325 feet. This berm could be created from excavated material in the area of proposed inundation.

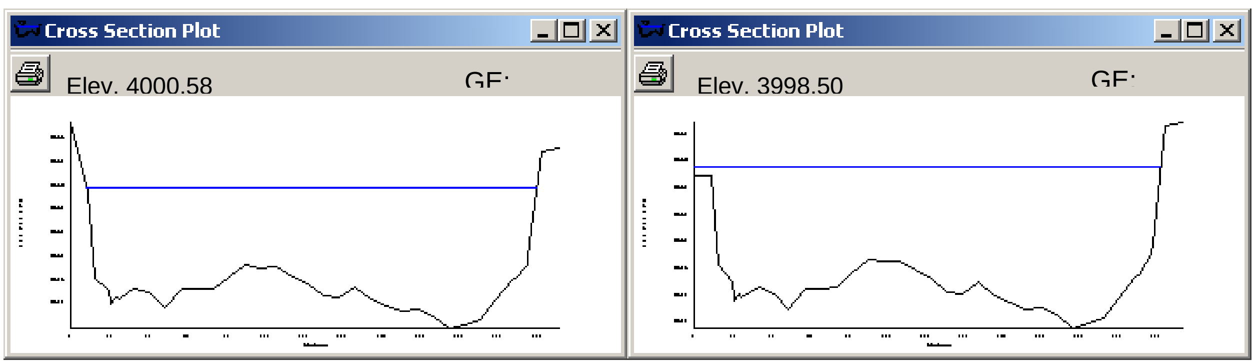

Figure 4.15. Before and after cross-section plots of river connection.

Vegetation removal: Existing woody vegetation can be removed by scraping or extraction. Burning debris onsite with an air-curtain burner would likely be less expensive than hauling it from the site.

Native riparian vegetation plantings: Although soils are fairly well-drained, the water table is expected to be within 3 to 4 feet of the surface during the growing season. Dense Goodding's and coyote willow plantings are recommended throughout the 51-acre site, with more sparse, complementary plantings of cottonwood and other riparian shrubs. Periodic inundation (every 3 to 5 years) is believed to be essential to sustain the target habitat.

Table 4.13. Lack Property quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Bank cut	20 ft wide x 50 ft long x 2.5 ft deep	93 CY	$ 465
Vegetation removal	Vegetation removal (scraping or extraction) Air-curtain burner rental	51 ac. Each	$ 51,000 $ 1,600
Plantings	Coyote willow whips (1,000/ac.) Longstem riparian shrubs (40/ac. over 26 ac.) Goodding's willow poles (100/ac.) Cottonwood poles (10/ac.)	51,000 2,040 5,100 510	$382,500 $ 57,200 $229,500 $ 22,950
		Implementation cost	**$745,205**
Protection berm	3,235 ft long x 3 ft high x 20 ft base-width	4,493 CY	$ 6,740
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	163.2 249.9 86.7	 $ 86,700
		Implementation + Water Cost	**$831,905**

Optional Restoration

The design described above would only be viable with restoration flow releases. Rather than rely on inundation by river flow, supplemental water from the Tonuco Drain ordering the property can be utilized to establish dense riparian shrubs. A smaller, 40-acre area was selected for irrigation based on site topography (**Figure 4.16**). Vegetation removal and native vegetation plantings in the irrigated area would be similar to that described above.

Supplemental water: A check gate and turnout structure in the Tonuco Drain at the north end of the site should raise the water surface sufficiently to provide flow to an earthen canal to the 40-acre parcel (see Figure 3.1 for conceptual sketch of the structure). The irrigation requirement would be 0.5 feet per month from late April through September. A protection berm would not be required.

Table 4.14. Alternate Lack Property quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Irrigation	Irrigation gate and turnout 1,550-ft canal (3 ft deep x 8 ft wide)	 1,380 CY	$ 2,000 $ 6,900
Vegetation removal	Vegetation removal (scraping or extraction) Air-curtain burner rental	40 ac. Each	$ 40,000 $ 1,600
Plantings	Coyote willow whips (1,000/ac.) Longstem riparian shrubs (40/ac. over 20 ac.) Goodding's willow poles (100/ac.) Cottonwood poles (10/ac.)	40,000 800 4,000 400	$300,000 $ 44,000 $180,000 $ 18,000
		Implementation cost	**$592,500**
Water right	Acquisition Annual assessment (40 ac. at 3 ft/y)r	40 ac. 120 ac-ft	$120,000 $ 3,800
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	128 196 +68	 $ 0
		Implementation + Water Cost	**$712,500**

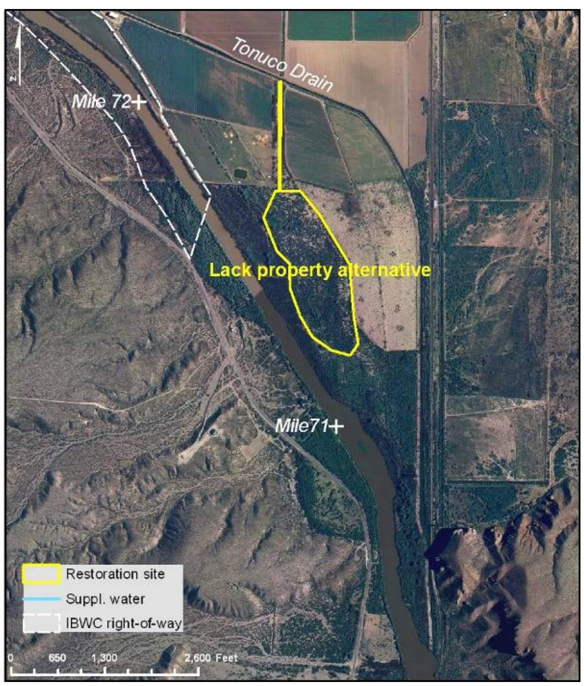

Figure 4.16. Alternative restoration at Lack Property.

12. Pasture 18 (RM 69.5)

The 52-acre Pasture 18 site is owned by the State of New Mexico and managed by New Mexico State University (**Figure 4.17**). FLO-2D modeling indicated that the site would not be inundated by a 5,000-cfs release from Caballo Dam. The overbank area is slightly higher than the water surface elevation from the 3,500-cfs Caballo Dam release. The elevated Burlington, Northern & Santa Fe (BNSF) railroad track lies along the eastern edge of the site.

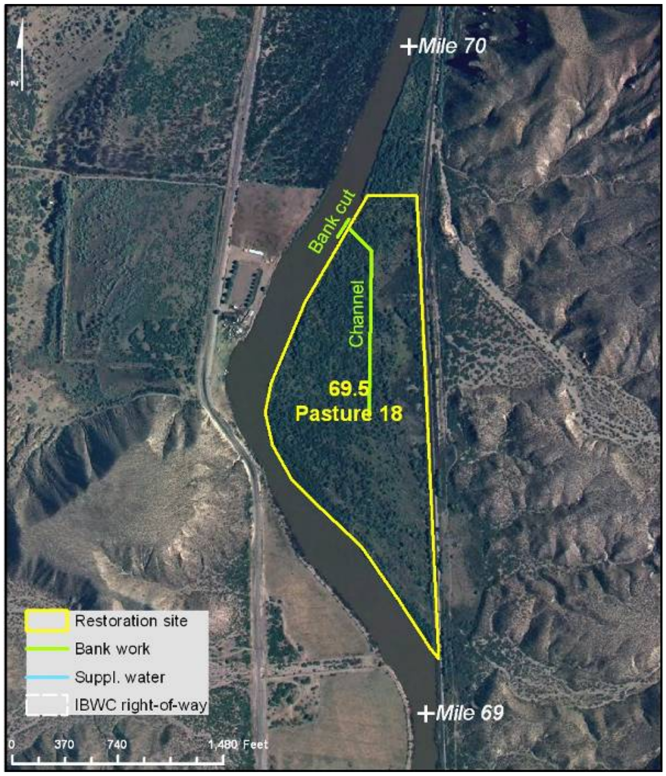

Figure 4.17. Pasture 18 restoration site.

Existing vegetation consists of a variety of plant communities (Caplan and Landers, 2008). Screwbean mesquite occupies about 14 acres (mixed with coyote willow in four of those acres). Drier portions of the site (22 acres) consist of wolfberry, often mixed with screwbean mesquite, alkali mallow, and arrow-weed. Approximately 10 acres of alkali meadow (saltgrass and alkali sacaton) are present along the eastern edge and southern portions of the site. A narrow band of saltcedar occupies the entire river bank. Most of the site was burned in spring 2007, but both herbaceous and woody vegetation is vigorously resprouting.

The soil series at the site is mapped as Agua Variant, moderately wet (AJ) which typically exhibits soil salinity of 4 to 16 dS/m (NRCS 2007a). A more detailed soil evaluation was conducted in 2008 by Soil and Water West, Inc. (Caplan and Landers, 2008). The predominant soil series are Armijo clay and Gila Variant clay loam. Soil salinity is greater than 4 dS/m throughout the site, with concentrations frequently in the 8 to 16 dS/m range or greater.

The potential for enhanced river floodplain hydrologic connectivity was evaluated with the FLO-2D model. Lowering the bank elevation would facilitate flooding by the 3,500-cfs Caballo release. Approximately 14 acres at the southern end of the site has topography suitable for inundation with an excavated channel from the north end of the site (**Figure 4.18**). A gated weir should be constructed to control the overbank water surface to the target elevation. Between periodic flooding events, the interior channel would have ponded water.

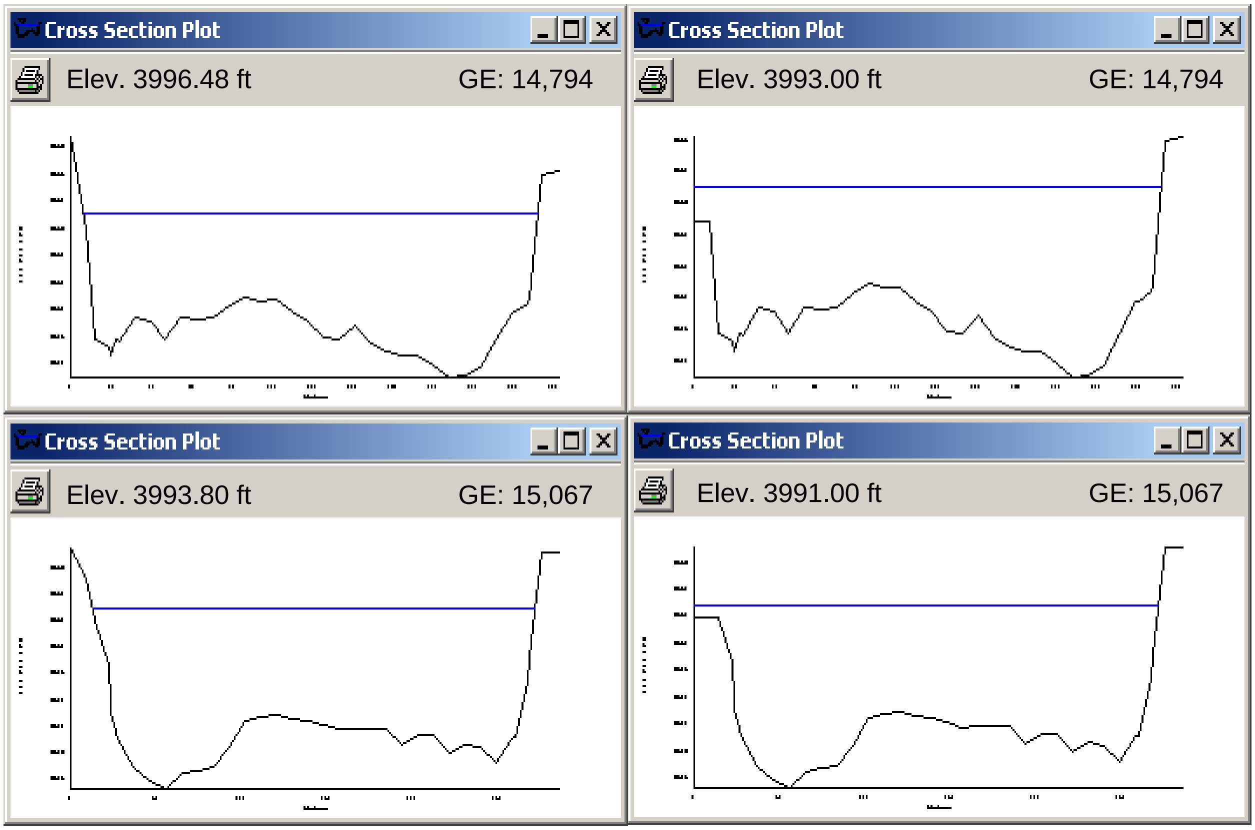

Figure 4.18. Baseline condition (left) and restored cross section with lowered bank (right).

The 14 acres inundated by the river connection and channel consist of alkali meadow and wolfberry-screwbean mesquite communities. Because of the high soil salinity and clay content, periodic inundation would not be expected to improve soil conditions sufficiently to support appreciable willow growth.

Restoration Prescription

Due to the low potential for developing riparian communities that meet the study objectives, no restoration activities are recommended for the Pasture 18 site.

Table 4.15. Pasture 18 site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Floodplain connection	Bank cut (20 ft wide x 50 ft long x 6 ft deep) Channel excavation (20 ft wide x 1,400 ft long x 4 ft deep) Weir at inlet (to prevent drainage)	222 CY 4,148 CY	$ 1,100 $ 20,740 $50,000
Saltcedar removal	Mechanical extraction at the lowered bank	0.2 ac.	$ 200
Site preparation	Grubbing for channel (50 ft x 1,400 ft)	1.6 ac.	$ 1,280
		Implementation cost	**$ 0**

13. Broad Canyon Ranch Middle (RM 67)

The privately owned Broad Canyon Ranch Middle restoration site covers 13.8 acres (**Figure 4.19**). A low berm (approximately 3 feet high) is present along the entire bankline. FLO-2D modeling indicated that the berm is sufficiently high to prevent inundation by a 5,000-cfs release from Caballo Dam.

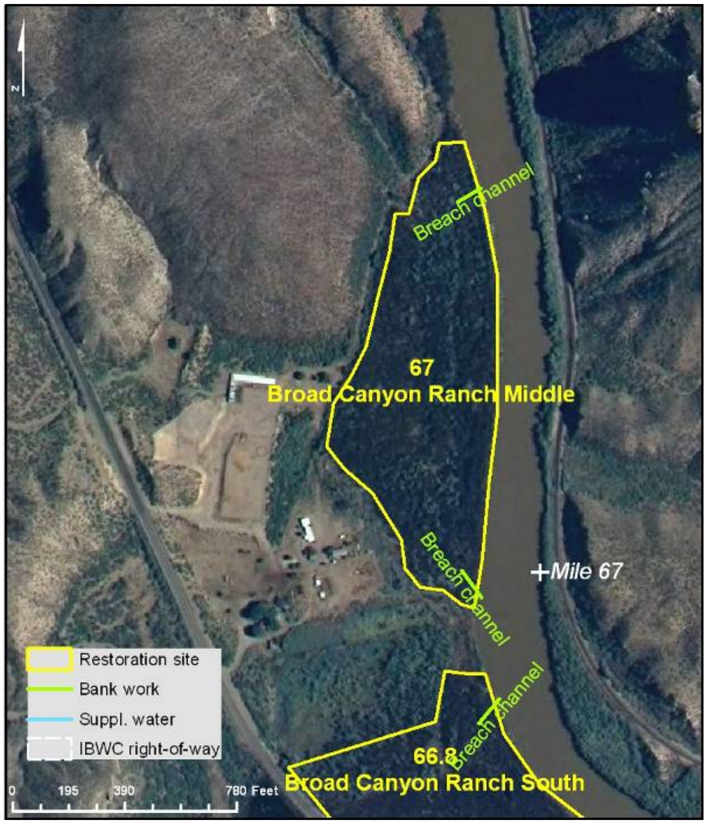

Figure 4.19. Broad Canyon Ranch Middle restoration site.

Several years ago, the dense saltcedar which occupied the entire site was aerially sprayed with herbicide, and standing dead material was removed in winter 2007-2008. Currently, the site is vegetated by saltcedar resprouting from remnant root crowns and perhaps from seeds.

The soil series at the site is mapped as Agua Variant, moderately wet (AJ) which typically exhibits soil salinity of 4 to 16 dS/m (NRCS, 2007a). Two soil samples taken at the site in March 2008 were determined to consist of clay and sandy clay loam with salinity levels of 12 to 13 dS/m in the upper 12 inches (pers. comm., Todd Caplan, Parametrix, Inc., and Cliff Landers, Soil and Water West, Inc.). Salinity levels below 12 inches were lower, ranging from 1.9 to 4.4 dS/m. The water table is relatively shallow and surface ponding after precipitation has been evident.

Restoration Prescription

Target habitat: Saltgrass meadow.

Enhanced river floodplain hydrologic connection: There is a small 3-foot berm developed by the landowner that extends along the river bank. By breaching the berm at the northern end, the site can be inundated by a 3,500-cfs Caballo release. A similar breach at the south end of the site would allow the water to flow through the site. The existing berm is about 3 feet high and 30 feet wide. Excavation of the banks would include a small connecting channel 20 feet wide by 3 feet deep by 60 feet long in each of the two locations (**Figure 4.20**). The spoil waste would be minimal and can either be placed along the small levee or in an adjacent upland area.

Removal of exotic vegetation: Remnant sprouting saltcedar must be removed prior to revegetation. Due to the clay soils, root-plowing and subsequent debris removal would be difficult at this site. Manual herbicidal spraying by either foliar or basal stem application is recommended to control the residual growth. If resprouting saltcedar is relatively dense, herbicidal application with tractor-mounted carpet roller would be more economical. Application may need to be repeated for two to three years to be effective. The residual stems can then be removed by mowing or light grubbing.

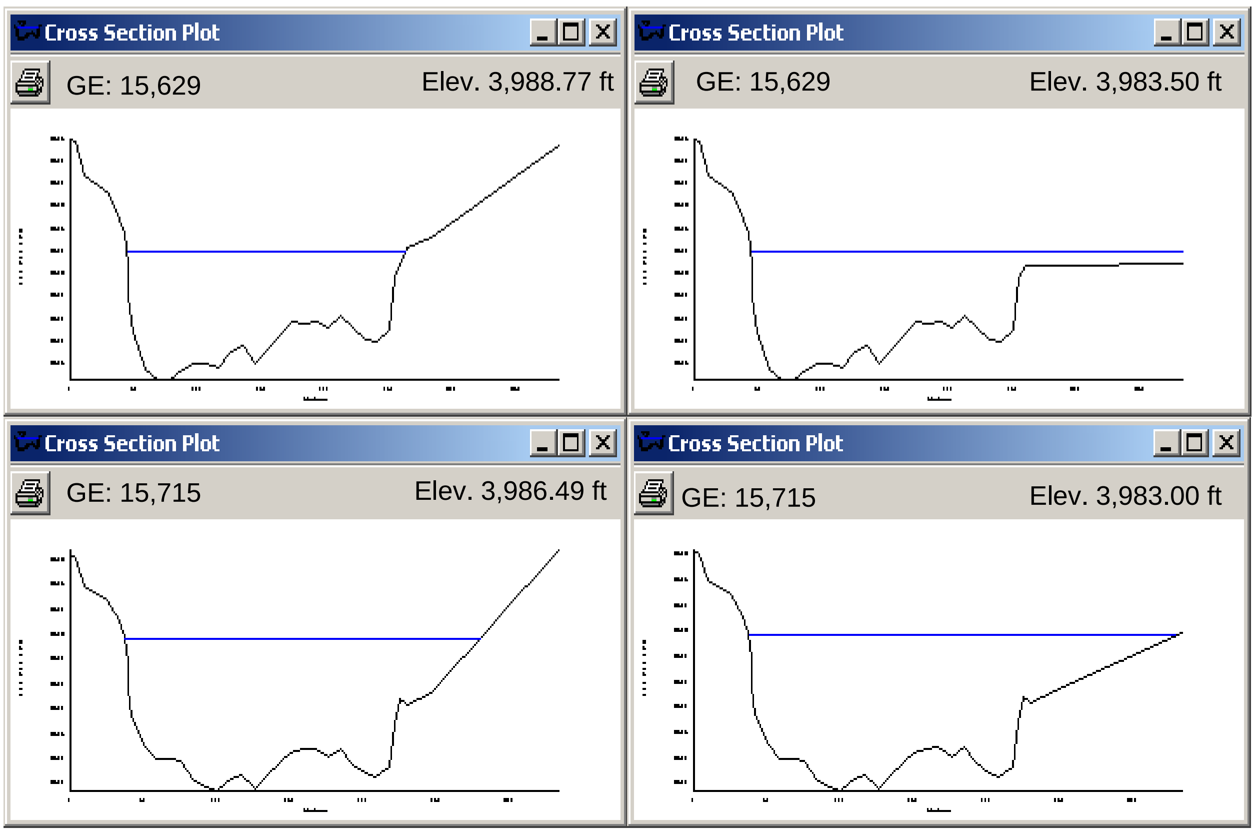

Figure 4.20. Baseline condition (left) and restored cross-section with lowered bank (right). The floodplain element elevations were adjusted to more accurately reflect the DTM data set and the proposed bankline lowering.

Native vegetation plantings: The heavy soils and high salinity are not conducive to the establishment of willows and riparian shrubs. The site is best suited for restoration as a saltgrass and alkali sacaton meadow, including relatively salt-tolerant forbs such as yerba mansa, Baltic rush, and three-square bulrush.

Table 4.16. Broad Canyon Ranch Middle site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Bank cut and channel	Two channels (20 ft wide x 30 ft long x 3 ft deep plus 20 ft wide x 30 ft long x 6 ft deep)	200 CY	$ 1,000
Saltcedar removal	Mechanical extraction along bank Foliar / basal spray herbicidal treatment of resprouts, 2 years	0.8 ac. 13.8 ac.	$ 800 $17,940
Site preparation	Grubbing	13.8 ac.	$11,040
Plantings	Grass seeding (seed drill or range drill) Herbaceous vegetation plugs	13.8 ac. 2,500	$26,220 $ 7,500
		Implementation cost	**$64,500**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	33.1 33.1 0	 $ 0
		Implementation + Water Cost	**$64,500**

Prescription viability without restoration flow releases: Considering the relatively shallow groundwater at this site, this prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam; however, the extent and vigor of planted grasses may be reduced.

14. Broad Canyon Ranch South (RM 66.8)

This 20.6-acre, privately owned parcel is similar to the Broad Canyon Ranch Middle site in that a low berm prevents the 5,000-cfs Caballo release from inundating the site (**Figure 4.21**).

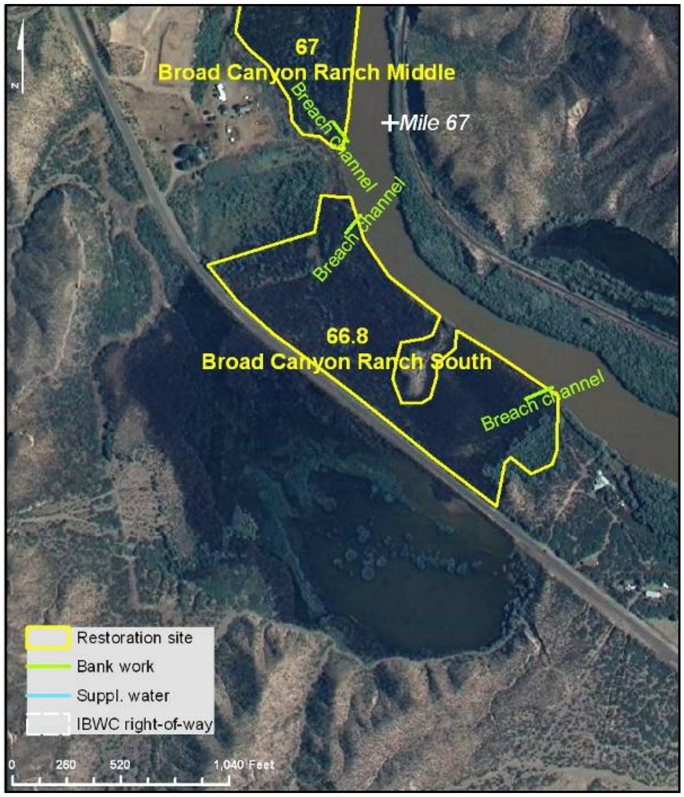

Figure 4.21. Broad Canyon Ranch South restoration site.

Existing vegetation is primarily standing dead saltcedar that was aerially sprayed with herbicide several years ago. Screwbean mesquite occupies a portion of the site at the northern end. A large rock outcrop is present in the center of the site (Figure 4.21).

The soil series at the site is mapped as Agua variant and Belen variant soils (AK) which typically exhibits soil salinity of 4 to 16 dS/m (NRCS, 2007a). A soil sample taken at the north end of the in March 2008 consisted of clay loam over sandy clay loam with salinity levels of 15 dS/m in the upper 12 inches and 4.6 dS/m in the 12- to-24-inch depth (pers. comm., Todd Caplan, Parametrix, Inc., and Cliff Landers, Soil and Water West, Inc.). The water table is relatively shallow and surface ponding after precipitation has been observed.

Restoration Prescription

Target habitat: Saltgrass meadow.

Enhanced river floodplain hydrologic connection: By breaching the levee near the upstream end of the site, the 3,500-cfs Caballo release will inundate most of the area (**Figure 4.22**). The levee is about 3 feet high and about 30 feet wide at the base, and the excavated breach channels through the levee are estimated to be 20 feet wide by 3 feet deep by 60 feet long in two locations. The spoil waste would be minimal and can either be placed along the small levee or in an adjacent upland area.

Removal of exotic vegetation: The standing dead saltcedar needs to be removed from the site. Relatively light equipment should be used to collect and pile the material to avoid severe compaction of the heavy soils. Burning debris onsite with an air-curtain burner would likely be less expensive than hauling it from the site. Some resprouting of saltcedar is expected and subsequent manual herbicidal spraying by either foliar or basal stem application is recommended to control the residual growth.

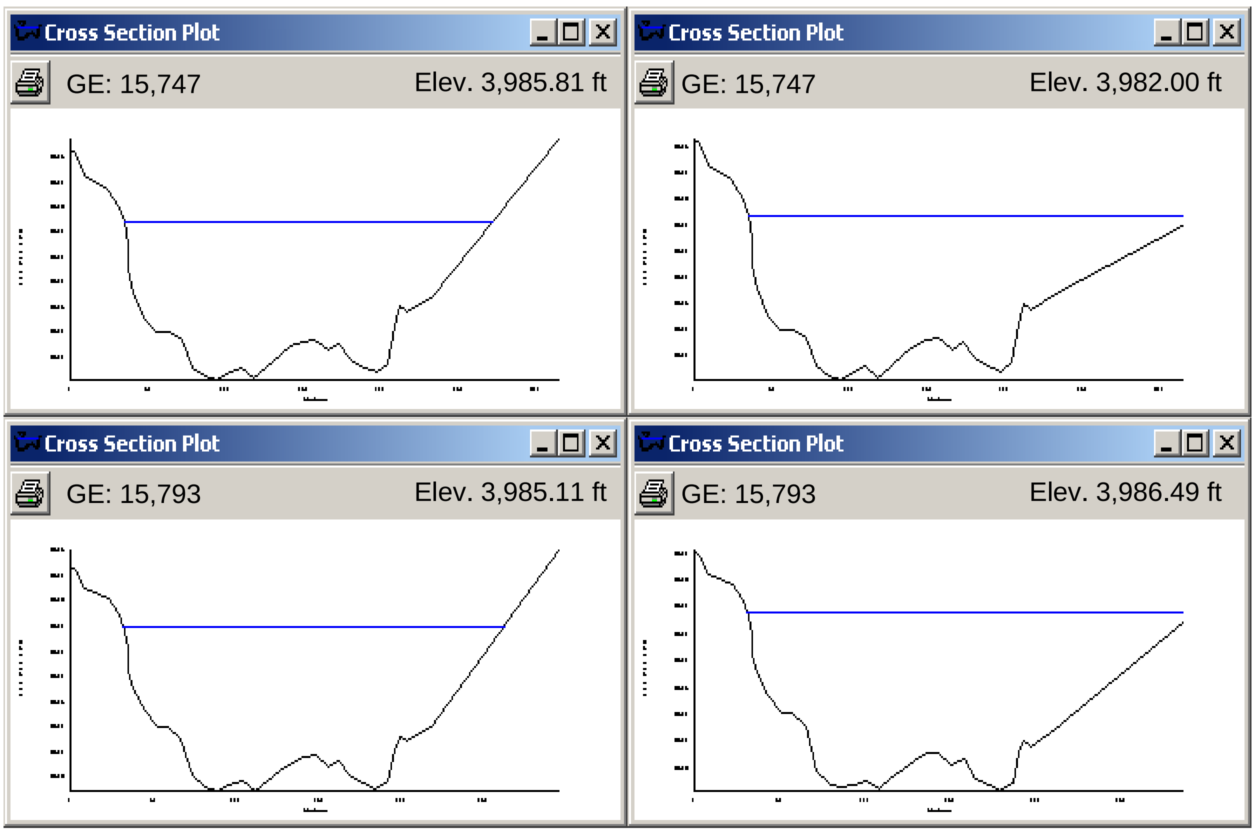

Figure 4.22. Baseline condition (left) and restored cross-section with lowered bank (right). The floodplain element elevations were adjusted to more accurately reflect the DTM data set and the proposed bankline lowering.

Native vegetation plantings: Based on limited soil texture and salinity information, this site may not be conducive to the establishment of willows and riparian shrubs. The site may be best suited for restoration as a saltgrass and alkali sacaton meadow, including relatively salt-tolerant forbs such as yerba mansa, Baltic rush, and three-square bulrush. (Additional soil and groundwater information should be obtained prior to implementing a revegetation plan for this site.)

Table 4.17. Broad Canyon Ranch South site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Bank cut & channel	Two channels (20 ft wide x 30 ft long x 3 ft deep plus 20 ft wide x 30 ft long x 6 ft deep)	200 CY	$ 1,000
Saltcedar removal	Mechanical extraction along bank Mechanical removal Air-curtain burner rental Foliar / basal spray herbicidal treatment of resprouts, 2 years	0.8 ac. 20.6 ac. Each 20.6 ac.	$ 800 $20.600 $ 1,600 $ 6,180
Plantings	Grass seeding (seed drill or range drill) Herbaceous vegetation plugs	20.6 ac. 3,700	$39,140 $11,100
		Implementation cost	**$80,420**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	49.4 49.4 0	 $ 0
		Implementation + Water Cost	**$80,420**

Prescription viability without restoration flow releases: Considering the relatively shallow groundwater at this site, the recommended prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam; however, the extent and vigor of planted grasses may be reduced.

Optional Restoration

Outflow from a 42-acre marsh/open-water complex immediately west of the restoration site traverses the southern end of the Broad Canyon Ranch South site. Additional emergent wetland—and, perhaps SWWF habitat—could be created within the southern 7 acres of the Broad Canyon Ranch South site with relatively simple earthwork and detention structures. Additional site information, including soil structure, soil and water salinity, and the hydrologic regime and water budget of the marsh/open-water complex, would be required to recommend this alternative.

15. Selden Point Bar (RM 66)

The Selden Point Bar site is on privately owned land on the north bank of the Rio Grande. Inundation by a 5,000-cfs Caballo release was not predicted by FLO-2D modeling (**Figure 4.23**). Portions of the overbank are about a foot lower than the water surface elevation of a 3,500-cfs release.

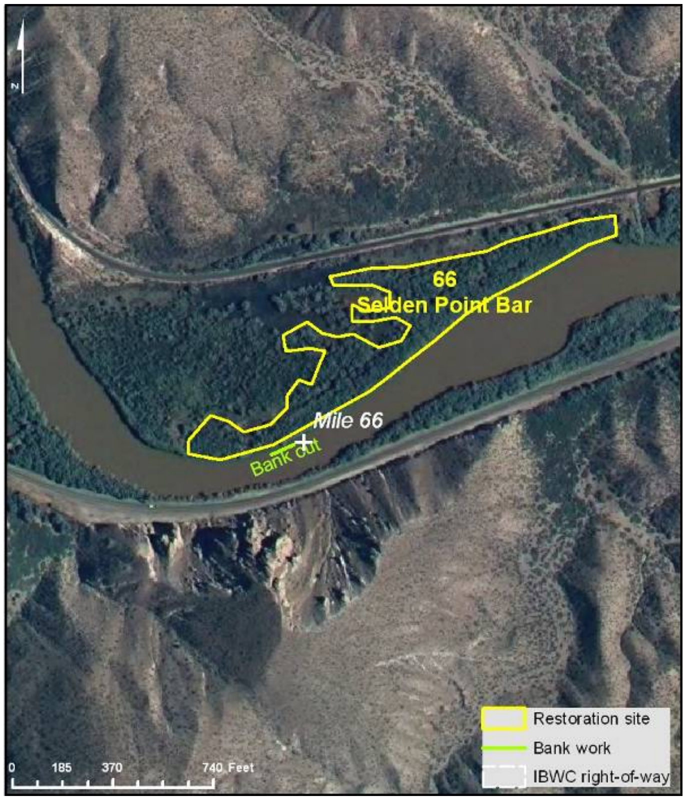

Figure 4.23. Selden Point Bar restoration site.

A band of very dense saltcedar borders the bankline and moderately dense saltcedar occupies the interior portions of the site. Well developed wet meadow vegetation forms the ground cover in some saltcedar dominated stands, and a small emergent marsh is present adjacent to the BNSF railroad tracks (Caplan and Landers, 2008).

Soils are mapped as Bluepoint-Caliza-Yturbide complex (BP) in the interior of the point bar and Agua Variant and Belen Variant soils (AK) along the outer edge (NRCS, 2007a). A more detailed soil evaluation was conducted on the downstream half of the bar in 2008 (Caplan and Landers, 2008). Clay loam overlying sandy loam occupies the interior, and loamy sand overlying clay loam occurs along the bankline. The soil surface and subsoil are low in salinity concentrations (0 to 4 dS/m).

Restoration Prescription

Target habitat: Dense riparian shrubs. Figure 4.23 depicts the 6.9-acre restoration target area which avoids marsh and saltcedar/meadow complexes.

Enhanced river floodplain hydrologic connection: By lowering the bank near RM 66, the downstream 8 acres of the bar can be inundated by a 3,500-cfs Caballo release.

Exotic vegetation removal: Removal of saltcedar by extraction is recommended to minimize disturbance of the well developed ground cover. Burning debris onsite with an air-curtain burner would likely be less expensive than hauling it from the site.

Native vegetation planting: The low-salinity and relatively moist soils at the site are conducive to development of suitable SWWF habitat. Goodding's and coyote willow plantings are recommended throughout the site, with higher densities along the bankline. Cottonwood and other riparian shrub plantings should also be included for floral and structural diversity.

Access: Access to the site from the upland side is difficult due to the presence of the railroad track and adjacent wetlands. The transport of equipment to—or spoil waste from—the Selden Point Bar site could be facilitated by building a railroad siding adjacent to the site. This was not considered to be cost-effective, nor environmentally desirable because it would entail the non-essential placement of fill in adjacent jurisdictional wetlands as defined in Section 404 of the Clean Water Act. The temporary placement of fill and culverts across the unvegetated Rio Grande channel was considered to be the preferred alternative. During the late winter low-flow period, a temporary river crossing could provide access to the site.

Table 4.18. Selden Point Bar quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Bank cut	50 ft wide x 60 ft long x 2.3 ft deep	256 cy	$ 1,280
Saltcedar removal	Extraction (high density)	3.0 ac.	$ 3,000
	Extraction (moderate density)	3.9 ac.	$ 2,535
	Air-curtain burner	Each	$ 1,600
Plantings	Coyote willow whips (1,000/ac.)	6,900	$ 51,750
	Longstem riparian shrubs (40/ac.)	276	$ 15,125
	Goodding's willow poles (50/ac.in bankline 3 ac.)	150	$ 6,750
	Goodding's willow poles (100/ac. in interior 3.6 ac.)	360	$ 16,200
	Cottonwood poles (10/ac.)	69	$ 3,105
River crossing	Six 60-inch diam. x 30-ft long culverts; 2,500 CY fill		$100,000
		Implementation cost	**$201,345**
ET estimate (ac-ft/yr)	Pre-treatment	33.8	
	Post-treatment	33.8	
	Difference	0	$ 0
		Implementation + Water Cost	**$201,345**

Prescription viability without restoration flow releases: Considering the relatively shallow groundwater at this site, the recommended prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam; however, the extent and densities of woody vegetation plantings should be reduced.

16. Bailey Point Bar (RM 64)

This site entails a 1.1-mile long point bar that is located on private land on the east bank of the river (**Figure 4.24**). The FLO-2D model predicts that about half of the site will be inundated by a Caballo Dam release of 4,000 cfs, and all of the bar would be inundated by a 5,000-cfs release.

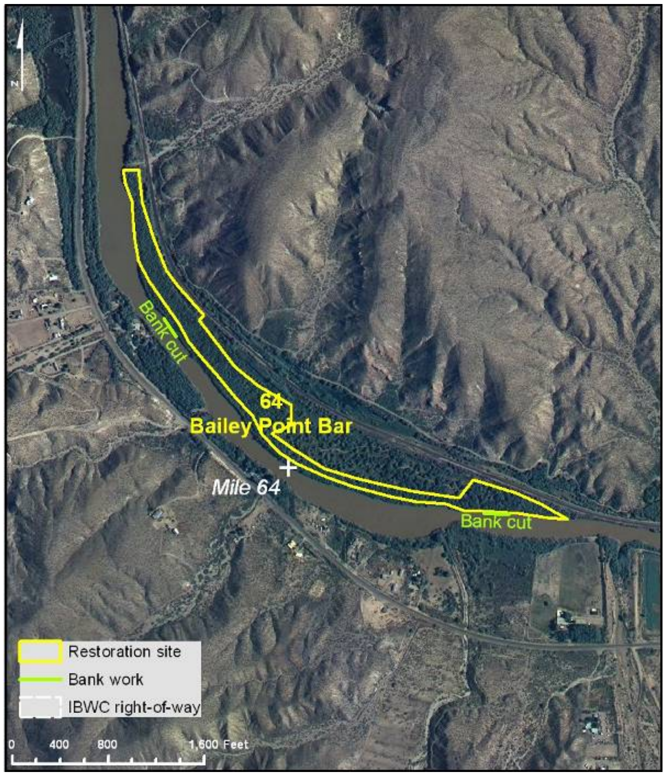

Figure 4.24. Bailey Point Bar restoration site.

Saltcedar dominates the plant species composition at the site (Caplan and Landers, 2008); however, willow also was present in mixed stands. This site has the largest concentration of Goodding's willow that was found throughout the 105-mile-long study area. Screwbean mesquite and wet meadow also occupy central portions of the site.

Soils are mapped Agua Variant and Belen Variant soils (AK) which typically exhibit salinity levels of 8-16 dS/m. A more detailed soil evaluation was conducted at the site in 2008 (Caplan and Landers, 2008). The recent study verified the high salinity levels in the portions of the site along the railroad embankment and the bankline, but a large central area of loam and loamy sand had lower salinity levels in the 2 to 4 dS/m range.

Access to the site is possible from the upland side (Figure 4.24).

Restoration Prescription

Target habitat: Dense riparian shrubs (suitable SWWF habitat).

Enhanced river floodplain hydrologic connection: If the bank is lowered near the upstream end, the site can be inundated with the 3,500-cfs Caballo release. Lowering the bank in two locations may enable the water to flow through the site under some flooding conditions. The bank elevations are close to the 3,500-cfs release water surface and the required excavation may be minimal (**Figure 4.25**). The excavation required for the connection is assumed to be 1 foot deep by 20 feet wide by 50 feet long at both ends of the site. The spoil waste could either be used to line the railroad embankment or placed along the river channel bank for removal during high flows.

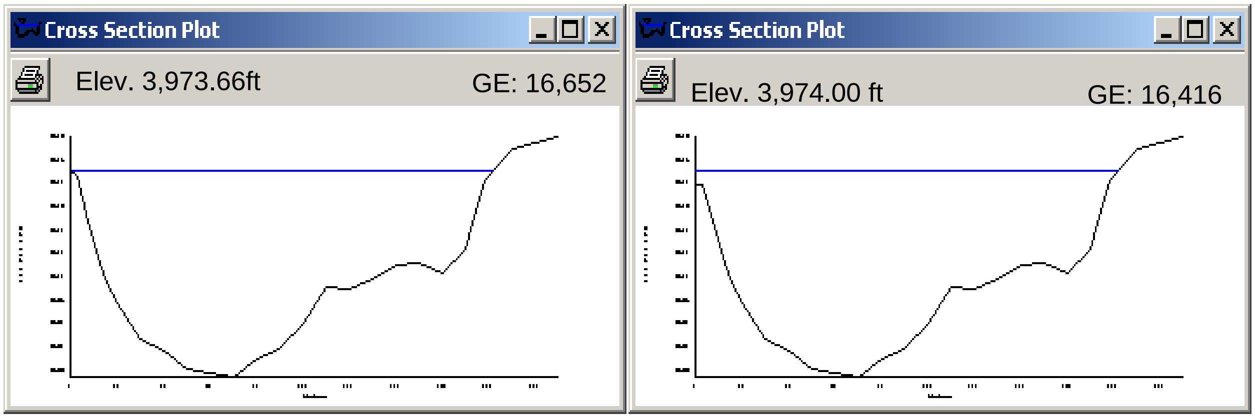

Figure 4.25. Baseline condition (left) and restored cross-section with lowered bank (right).

Exotic vegetation removal: About 16.6 acres that avoid areas of Goodding's willow and well developed wet meadow were selected for restoration. Removal of saltcedar by extraction is recommended to minimize disturbance of the well developed ground cover. (Alternatively, vegetation can be knocked down with a bulldozer and the area can be root-plowed for a moderate additional cost.) Burning debris onsite with an air-curtain burner would likely be less expensive than hauling it from the site.

Native vegetation plantings: Coyote willow and, especially, Goodding's willow plantings are recommended throughout the selected area. Cottonwood and other riparian shrub plantings are also included for floral and structural diversity.

Table 4.19. Bailey Point Bar quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Bank cut	Two cuts at 20 ft wide x 50 ft long x 1 ft deep	74 CY	$ 370
Saltcedar removal	Extraction (mod. - high density) Air-curtain burner rental	16.6 c. Each	$ 14,110 $ 1,600
Plantings	Coyote willow whips (1,000/ac.) Longstem riparian shrubs (40/ac.) Goodding's willow poles (100/ac.over 10 ac.) Cottonwood poles (10/ac.)	16,600 664 1,000 166	$124,500 $ 36,520 $ 45,000 $ 7,470
		Implementation cost	**$229,570**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	81.3 81.3 0	 $ 0
		Implementation + Water Cost	**$229,570**

Prescription viability without restoration flow releases: Considering the relatively shallow groundwater at this site, the recommended prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam; however, the extent and densities of woody vegetation plantings should be reduced.

17. Shalem Colony (RM 50.5)

This 14.2-acre site is about a mile downstream from the Shalem Colony Bridge on the east bank of the river (**Figure 4.26**). The riverward half of the site consists of the largest stand of screwbean mesquite observed in the study area downstream from Leasburg Dam. In a Memorandum of Understanding between the USIBWC and the Southwest Environmental Center dated March 22, 1999, the USIBWC agreed to refrain from vegetation management in a 35-foot-wide band along the river channel. In practice, mowing has been discontinued in a much wider band, such that screwbean mesquite now occupies approximately 5 acres. Alkali sacaton, saltgrass, and spike dropseed (*Sporobolus contractus*) form a well developed ground cover under the maturing trees and throughout the rest of the site. Resprouting coyote willow is scattered throughout the regularly mowed areas.

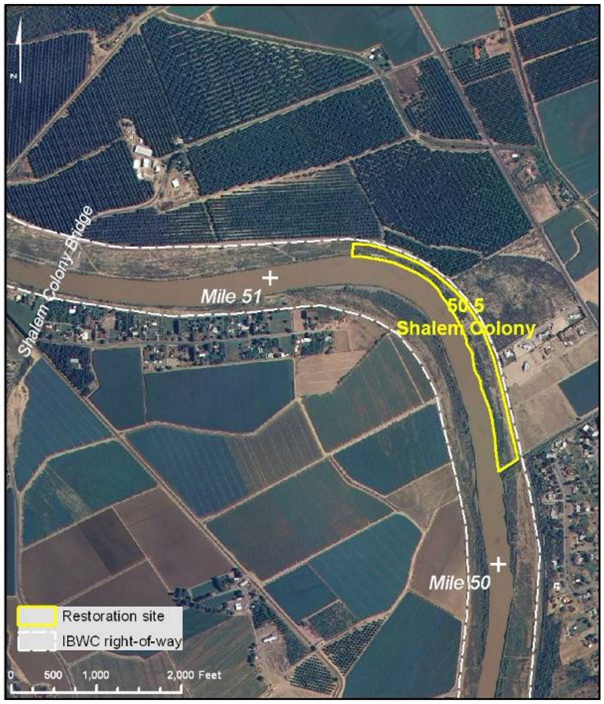

Figure 4.26. Shalem Colony restoration site.

Restoration Prescription

Discontinue mowing: Cessation of mowing throughout the site would allow native trees, shrubs and grasses to mature and spread. To avoid encroachment of woody vegetation on the adjacent levee, mowing should be continued in a 15- to 25-foot-wide strip adjacent to the riverward toe of the levee.

Table 4.20. Shalem Colony site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Discontinue mowing		9.2 ac.	$ 0
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	41.9 46.9 5.0	 $ 5,000
		Implementation + Water Cost	**$ 5,000**

18. Leasburg Extension Lateral Wasteway 8 (RM 47.8)

In the 34 river miles between Leasburg Dam and the Vado Bridge, the FLO-2D model predicted very little overbank inundation, even for the 5,000-cfs release from Caballo Dam. Enhancing overbank flooding conditions to support native riparian vegetation generally involves lowering the bank elevations or lowering the floodplain surface, both of which are relatively expensive. Another option would be to use supplemental water to inundate the site. The numerous wasteways or drain returns within this reach provide opportunities for the application of acquired water to promote the development of riparian vegetation. A site at the Leasburg Extension Lateral Wasteway 8 (RM 47.8) (**Figure 4.27**) and the Clark Lateral (RM 43.5) (described in the next section) were selected as example locations at which the conceptual check structure and overbank grading design illustrated in Figure 3.1 could be applied. This design could also be applied elsewhere throughout the reach, and other locations may be better suited in terms of water quality, available flow, and the avoidance of problematic back-water conditions. The final location of these sites should be selected in coordination with EBID engineers.

Figure 4.27. Leasburg Extension Lateral Wasteway 8 restoration site.

Vegetation at the Wasteway 8 site consists of mowed grassland with scattered, resprouting saltcedar (Figure 4.27). The ground surface is nearly level and is about 4 feet above the water surface of the 1,500-cfs release from Caballo Dam, the usual lower discharge under existing conditions during the growing season).

Soils are mapped as Brazito loamy fine sand (Br) and very fine sandy loam (Bs) (NRCS, 2007a).

Restoration Prescription

Target habitat: Dense riparian shrubs (3.1 acres) and riparian forest (1 acre).

Supplemental irrigation: The relatively simple check structure and turnout shown in Figure 3.1 in the wasteway between the levee and the river could raise the water surface sufficiently to force flow into the overbank area. Flow would return to the wasteway over the small armored or gated spillway located below the check dam. To contain and route irrigation flow, the restoration site should be slightly excavated or graded. Scraped material should be used to create a peninsula extending downstream from the wasteway bank to route flows through a 180-degree path back to the wasteway channel. Small berms may also be created to contain water within the desired footprint. The inundated cell should not be closer than 30 feet from the levee to facilitate continued mowing along the riverside levee toe.

The irrigation requirement for the target habitat would be 0.5 feet per month from late April through September.

Removal of exotic vegetation: At the Wasteway 8 site, the minor saltcedar sprouts can be removed during grubbing and grading.

Native vegetation planting: The relatively shallow groundwater and supplemental irrigation at this site would be conducive to development of dense riparian shrubs and suitable SWWF breeding habitat. Dense coyote and Goodding's willow plantings are recommended, along with the complementary inclusion of other shrub species. Cottonwoods and Goodding's willow poles would be planted on the central raised peninsula (about 25 percent of the total restoration site area).

Table 4.21. Leasburg Extension Lateral Wasteway 8 quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Site preparation	Grubbing and grading	4.1 ac.	$ 3,280
Irrigation	Check dam with turnout		$ 50,000
Plantings	Coyote willow whips (1,000/ac., 3.1 ac.) Longstem riparian shrubs (40/ac., 4.1 ac.) Goodding's willow poles (100/ac., 4.1 ac.) Cottonwood poles (75/ac. over 1 ac.)	3,100 164 410 75	$ 23,250 $ 9,020 $ 18,450 $ 4,125
		Implementation cost	**$108,125**
Water right	Acquisition Annual assessment (3.1 ac. at 3 ft/y)r	3.1 ac. 9.3 ac-ft	$ 9,300 $ 295
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	9.8 20.1 10.3	 $ 0
		Implementation + Water Cost	**$117,600**

Prescription viability without supplemental water: This prescription is almost entirely dependent on irrigation. The ground surface elevation is sufficiently high that lower density shrub and whip plantings nearest the river would be successful without supplemental irrigation or a restoration flow release from Caballo Dam.

19. Clark Lateral (RM 43.5)

The Clark Lateral site is on the east bank of the river halfway between the I-10 and Mesilla bridges (**Figure 4.28**).

Figure 4.28. Clark Lateral restoration site.

Vegetation at this 6-acre site consists of mowed grassland with scattered resprouting saltcedar. The ground surface is nearly level and is about 3 feet above the water surface of the 1,500-cfs release from Caballo Dam, the usual lower discharge during the growing season.

Soils are mapped as Brazito very fine sandy loam (Bs) (NRCS, 2007a).

Restoration Prescription

Target habitat: Dense riparian shrubs (4.5 acres) and riparian forest (1.5 acres).

Supplemental irrigation: This site design is similar to that for Wasteway 8. A check dam and turnout within the Clark Lateral outfall channel would facilitate water delivery to a 6-acre cell, and surface flow would return to the wastewater outflow channel. Scraped material should be placed in to form a central peninsula comprising about 25 percent of the cell's area.

The irrigation requirement for the target habitat would be 0.5 feet per month from late April through September.

Removal of exotic vegetation: Minor saltcedar sprouts can be removed during grubbing and grading.

Native vegetation planting: The relatively shallow groundwater and supplemental irrigation at this site would be conducive to development of dense riparian shrubs and suitable SWWF breeding habitat. Dense coyote and Goodding's willow plantings are recommended, along with the complementary inclusion of other shrub species. Cottonwoods and Goodding's willow poles would be planted on the central raised peninsula (about 25 percent of the total restoration site),

Table 4.22. Clark Lateral quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Site preparation	Grubbing and grading	6 ac.	$ 4,800
Irrigation	Check dam with turnout		$ 50,000
Plantings	Coyote willow whips (1,000/ac., 4.5 ac.) Longstem riparian shrubs (40/ac., 6 ac.) Goodding's willow poles (100/ac., 6 ac.) Cottonwood poles (75/ac. over 1.5 ac.)	4,500 240 600 113	$ 33,750 $ 13,200 $ 27,000 $ 5,085
		Implementation cost	**$133,835**
Water right	Acquisition Annual assessment (4.5 ac. at 3 ft/yr)	4.5 ac. 13.5 ac-ft	$13,500 $ 428
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	14.4 29.3 14.9	 $ 0
		Implementation + Water Cost	**$147,335**

Prescription viability without supplemental water: This prescription is almost entirely dependent on irrigation. The ground surface elevation is sufficiently high that lower density shrub and whip plantings near the river would be successful without supplemental irrigation or a restoration flow release from Caballo Dam.

20. Mesilla Valley Bosque State Park (RM 41.5)

The Mesilla Valley Bosque State Park site entails 31.8 acres within the USIBWC right-of-way west of the levee (**Figure 4.29**). The FLO-2D model predicted that a small (about 6 acres) area in the central part of the site would be inundated by a 5,000-cfs Caballo release.

Figure 4.29. Mesilla Valley Bosque State Park restoration site.

Existing vegetation within the footprint shown in Figure 4.29 is a mixture of mowed grassland and wet meadow, robust coyote willow bordering the bankline, scattered cottonwoods, and, in the downstream portion, saltcedar.

Soils in the restoration site as mapped as Brazito loamy fine sand (Br) and Brazito very fine sandy loam (Bs) with smaller areas of Belen clay (Bg) and Anapra clay loam (Ao), all of which typically have salinity levels less than 4 dS/m (NRCS, 2007a).

Restoration Prescription

Target habitat: Riparian forest (8.6 acres), shrubland (6.2 acres), wet meadow (2 acres), and grassland (15 acres).

This prescription incorporates the specific vegetation features and locations detailed in the Mesilla Valley Bosque State Park Resource Management Plan (Blue Earth Ecological Consultants, 2008) within the USIBWC right-of-way. Specific stands (e.g., "H-7") refer to designations in the management plan.

Discontinue mowing on 31.8 acres. To prevent encroachment of woody vegetation on the levee, mowing should continue in a 25-foot-wide strip adjacent to the riverward toe of the levee.

Removal of exotic vegetation: Removal of minor residual saltcedar that sprouts after cessation of mowing could be achieved by mechanical extraction of individual plants, or foliar (spring) and/or basal stem (fall) herbicidal treatment of individual plants. While not extensive, the remnant saltcedar would have well-developed root systems; therefore, herbicidal treatment may be required for 2 to 3 years. Dense saltcedar should be removed by extraction from 6.5 acres (stands H-7 and H-8).

Native vegetation planting: Wet meadow vegetation (alkali sacaton, Baltic rush, three-square bulrush) occupies about an acre in the northern portion of the site and can be expanded to 2 acres with additional herbaceous plantings. [The management plan prescribed excavating a shallow, 2-foot deep cell for developing meadow vegetation. Field observations indicate that this area is sufficiently wet to support meadow vegetation once mowing ceases, without the need for excavation.]

Trees would be planted in three stands (C-2, C-14 and C-13) totaling 8.62 acres. Poles should not be planted within 25 feet of the riverward toe of the levee. Coyote willow would be planted in four stands (W-1, W-14, W-15, and about two-thirds of W-2) totaling 6.24 acres. Additional riparian shrub species should be planted throughout cottonwood and willow stands for floral and structural diversity.

Table 4.23. Mesilla Valley Bosque State Park site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Discontinue mowing		30.2 ac.	
Saltcedar removal	Extraction (high density) Extraction / herbicidal treatment	6.5 ac. 20 ac.	$ 6,500 $ 10,000
Plantings	Coyote willow whips (400/ac., 6.2 ac.) Longstem riparian shrubs (30/ac., 14.8 ac.) Goodding's willow poles (8.6 ac.) Cottonwood poles (8.6 ac.)	2,480 444 183 679	$ 18,600 $ 24,420 $ 8,235 $ 30,555
		Implementation cost	**$ 98,310**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	98.1 112.5 +14.4	 $ 14,400
		Implementation + Water Cost	**$112,710**

Except for the wet meadow, the locations and sizes of the prescribed plantings can be altered to conform to revised park management planning. The final revegetation plan should be formulated in conjunction with New Mexico State Parks to accommodate and be complementary with ongoing restoration planning for adjacent portions of the park.

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

21. Mesilla East (RM 41)

The Mesilla East site covers 15.8 acres on the east bank of the river, opposite Mesilla Valley Bosque State Park (**Figure 4.30**). The site is an average of 1.5 feet higher than the water-surface elevation of the 3,500-cfs Caballo release. At the southern end of the site, the FLO-2D model predicted that Caballo releases of 3,250 to 5,000 cfs would inundate approximately 6.6 acres. A backwater effect from the downstream Mesilla Dam tends to elevate the water surface at the restoration site.

Figure 4.30. Mesilla East restoration site.

Vegetation consists of mowed grassland with minor saltcedar resprouts and a few native shrubs.

Soils are mapped as Brazito loamy fine sand (Br) and Brazito very fine sandy loam (Bs) (NRCS, 2007a).

Restoration Prescription

Target habitat: Dense riparian shrubs (SWWF habitat).

Enhanced river floodplain hydrologic connection: The proposed restoration site design includes excavation of the floodplain to an elevation approximately 0.5 feet below the water-surface elevation of the 3,500-cfs Caballo release within the project site. The approximate volume of excavated material was estimated as 2 feet average depth over a 689,000 ft^2 area, based on the proposed site shapefile. Spoil waste from excavation can be placed along the riverward face of the existing levee.

Saltcedar removal: The minor resprouts present would be removed during site excavation.

Native vegetation plantings: Dense riparian shrubs were selected as the target habitat for this site because overbank inundation will occur more frequently with the proposed restoration. The restored site would serve as complementary habitat to the Mesilla Valley Bosque State Park directly across the river. Dense Goodding's and coyote willow plantings, and supplemental cottonwoods and shrub species are recommended for planting.

Pedestrian trail: The existing pedestrian trail through the site can be rerouted to the levee or riverbank edge of the site after restoration. The re-located trail can cross a portion of the planted area, but should not traverse the entire stand.

Table 4.24. Mesilla East site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Floodplain excavation	2 ft deep over 15.8 ac.	51,000 CY	$255,000
Plantings	Coyote willow whips (1,000/ac.)	15,800	$118,500
	Longstem riparian shrubs (40/ac.)	632	$ 34,760
	Goodding's willow poles (100/ac. over 7 ac.)	700	$ 31,500
	Cottonwood poles (10/ac.)	158	$ 7,110
		Implementation cost	**$446,870**
ET estimate (ac-ft/yr)	Pre-treatment	37.9	
	Post-treatment	77.4	
	Difference	39.5	$39,500
		Implementation + Water Cost	**$486,370**

Prescription viability without restoration flow releases: Without restoration flow releases of 3,500 cfs from Caballo Dam, excavation would still provide viable growth conditions for riparian tress and shrubs, but in lower densities than those prescribed.

22. Berino West (RM 25.5)

The Berino West site is located on the west river bank approximately one mile upstream from the Berino Bridge (**Figure 4.31**). The baseline FLO-2D model predicted that the 10.3-acre site would be inundated by Caballo Dam releases of 4,500 cfs and greater. This site is the first overbank area larger than 10 acres that would be inundated by this range of flows in the 34-mile reach below Leasburg Dam. The site is an average of one foot higher than the water-surface elevation for the 3,500-cfs Caballo release.

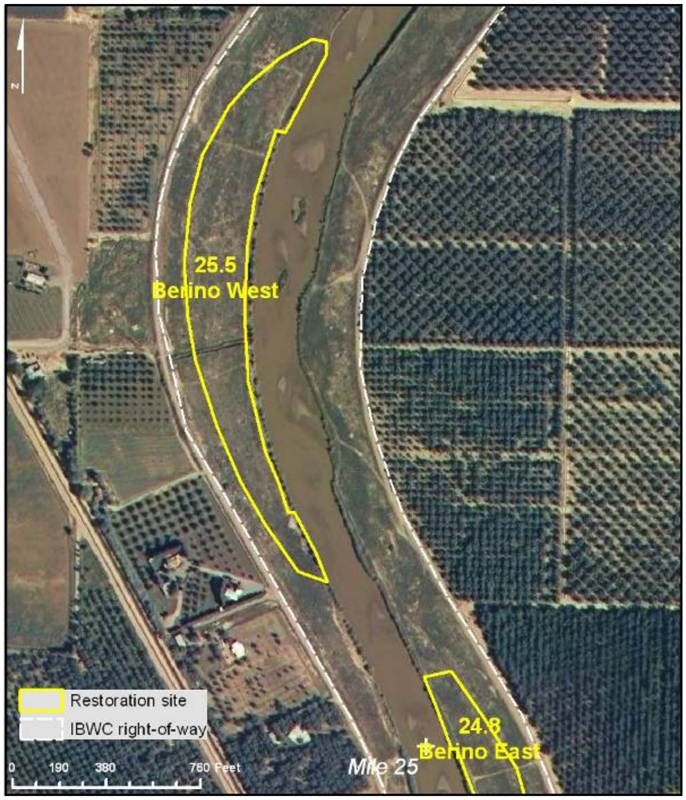

Figure 4.31. Berino West restoration site.

Vegetation consists of regularly mowed grasses, and exotic and native herbaceous species.

Soils at the site at the site are mapped as Anthony-Vinton fine sandy loam (Ap) and Brazito very fine sandy loam (Bs) (NRCS, 2007a).

Restoration Prescription

Target habitat: Dense riparian shrubs (SWWF habitat).

Enhanced river floodplain hydrologic connection: Excavating the bank and floodplain surface by 1.5 feet would induce inundation by the 3,500-cfs Caballo Dam release. The spoil waste can be placed on the river side of the levee. The site is located on the outside of a channel bend and the existing bank vegetation (regardless of species) should be kept intact along most of the bankline to prevent erosion of the restored area.

Native vegetation plantings: Dense riparian shrubs were selected as the target habitat for this site because of the potential for inundation at relatively low flows and the surrounding agricultural (rather than residential) land use. Dense Goodding's and coyote willow plantings, and supplemental cottonwoods and shrub species are recommended.

A wasteway crossing the overbank area near the center of the site may require additional maintenance after the site is periodically flooded. An additional 650 coyote willow whips have been included in the planting prescription for installation along the wasteway banks to help stabilize them following floodplain excavation.

Table 4.25. Berino West site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Floodplain excavation	1.5 ft deep over 10.3 ac.	25,000 CY	$125,000
Plantings	Coyote willow whips (1,000/ac.) Coyote willow whips along wasteway banks Longstem riparian shrubs (40/ac.) Goodding's willow poles (100/ac. over 5 ac.) Cottonwood poles (10/ac.)	10,300 650 412 500 103	$ 77,250 $ 4,875 $ 22,660 $ 22,500 $ 4,635
		Implementation cost	**$256,920**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	24.7 50.5 25.8	 $ 25,800
		Implementation + Water Cost	**$282,720**

Prescription viability without restoration flow releases: Without restoration flow releases of 3,500 cfs from Caballo Dam, excavation would still provide viable growth conditions for riparian tress and shrubs, but in lower densities than those prescribed.

23. Berino East (RM 24.8)

The Berino East site is on the east bank of the Rio Grande approximately 0.6 miles upstream from the Berino Bridge, and immediately downstream from the Berino West restoration site (**Figure 4.32**). The FLO-2D model predicted that this 9.5-acre site would be entirely inundated by Caballo releases of 4,500 cfs or more. The site is an average of 0.7 feet higher the water-surface elevation of the 3,500-cfs Caballo release.

Figure 4.32. Berino East restoration site.

Vegetation consists of regularly mowed grasses, and exotic and native herbaceous species.

Soils at the site at the site are mapped as Anthony-Vinton fine sandy loam (Ap) and Agua loam (Ag) (NRCS, 2007a).

Restoration Prescription

Target habitat: Dense riparian shrubs (5 acres; SWWF habitat) and cottonwood forest (4.5 acres).

Enhanced river floodplain hydrologic connection: Excavating the bank and floodplain surface by 1.3 feet should induce inundation by the 3,500-cfs Caballo release. Spoil waste from the excavation can be placed on the riverside of the levee. This site is also located on the outside of a channel bend and the existing bank vegetation (regardless of species) should be kept intact along most of the bankline to prevent erosion of the restored area.

Native vegetation plantings: This site is complementary to the Berino West site in that target habitat includes a similar dense willow stand, but Berino East will also include cottonwood forest for local plant community diversity. The site averages about 200 feet wide. The five acres of SWWF habitat should occupy the 100-foot wide band closest to the channel, and cottonwood forest plantings would form a parallel band to the immediate east.

Table 4.26. Berino East site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Floodplain excavation	1.3 ft deep over 9.5 ac.	15,330 CY	$ 76,650
Plantings	SWWF habitat (5 ac.):		
	Coyote willow whips (1,000/ac.)	5,000	$ 37,500
	Goodding's willow poles (100/ac.)	500	$ 22,500
	Longstem riparian shrubs (40/ac.)	200	$ 11,000
	Cottonwood forest (4.5 ac.):		
	Coyote willow whips (300/ac.)	1,350	$ 10,125
	Longstem riparian shrubs (100/ac.)	450	$ 24,750
	Cottonwood poles (75/ac.)	338	$ 15,210
		Implementation cost	**$197,735**
ET estimate (ac-ft/yr)	Pre-treatment	22.8	
	Post-treatment	46.1	
	Difference	23.3	$ 23,300
		Implementation + Water Cost	**$221,035**

Prescription viability without restoration flow releases: Without restoration flow releases of 3,500 cfs from Caballo Dam, excavation would still provide viable growth conditions for riparian tress and shrubs, but in lower densities than those prescribed.

24. Vinton A (RM 17)

Downstream from RM 17, floodplain elevations are lower relative to the 3,500-cfs Caballo restoration flow, and inundation will be more frequent than in the upstream reaches. Overbank flooding was observed at many locations in the lower reach in 2006 and 2008. The Vinton A site (**Figure 4.33**) and the succeeding six restoration sites were selected for treatment primarily of their potential for frequent inundation.

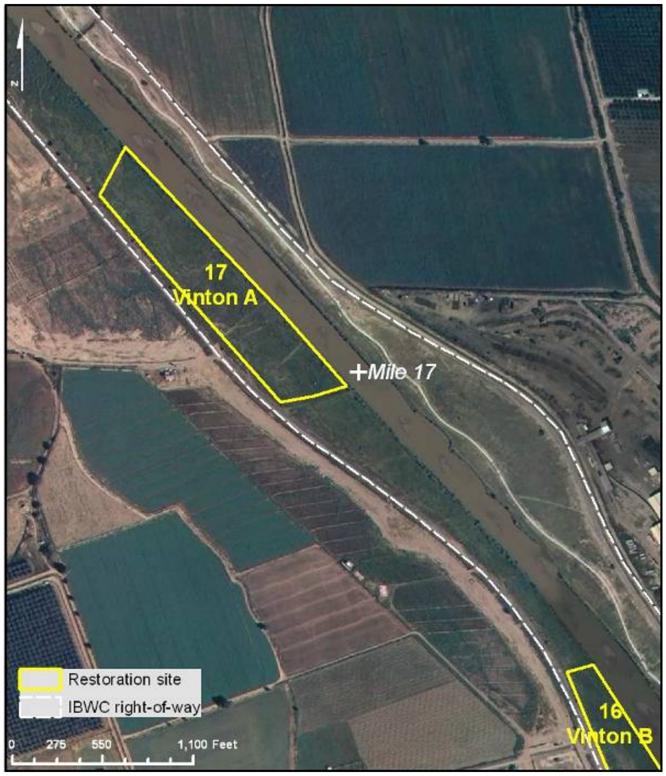

Figure 4.33. Vinton A restoration site.

The 14.7-acre Vinton A site is on the west bank of the river approximately 1.25 miles upstream from the Vinton Bridge (Figure 4.33). This site is predicted by the FLO-2D model to begin flooding at a 3,250-cfs Caballo release and be fully inundated by the 4,000-cfs release.

Vegetation consists of regularly mowed grasses, and native and non-native herbaceous vegetation. Scattered, resprouting saltcedar and some willows are present.

Soil series at the site are mapped as Made land, Gila soil material (NRCS, 2007b).

Restoration Prescription

Target habitat: Riparian forest.

Exotic vegetation removal: Individual resprouting saltcedar can be removed by extraction (eliminating the need for follow-up herbicidal treatment).

Native vegetation planting: A cottonwood forest with canopy cover ranging from 50 to 100 percent is prescribed. Shrubs (coyote willow, sumac, seep-willow, etc.) would form the understory strata. Additional grass and herbaceous species should be seeded throughout about 10 acres of the site.

Table 4.27. Vinton A site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Discontinue mowing		14.7 ac.	
Saltcedar removal	Mechanical extraction (light density)	5 ac.	$ 2,500
Plantings	Coyote willow whips (200/ac.) Longstem riparian shrubs (100/ac.) Goodding's willow poles (30/ac., avg.) Cottonwood poles (70/ac., avg.) Grass seeding	2,940 1,470 441 1,029 7 ac.	$ 22,050 $ 80,850 $ 19,845 $ 46,305 $ 13,300
		Implementation cost	**$145,528**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	35.3 61.0 +25.7	 $ 25,700
		Implementation + Water Cost	**$171,228**

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

25. Vinton B (RM 16)

The 20-acre Vinton B site is also on the west bank of the river approximately 0.25 miles upstream from the Vinton Bridge (**Figure 4.34**). This site is predicted by the FLO-2D model to begin flooding with a 2,500-cfs Caballo release and be fully inundated by the 4,000-cfs release.

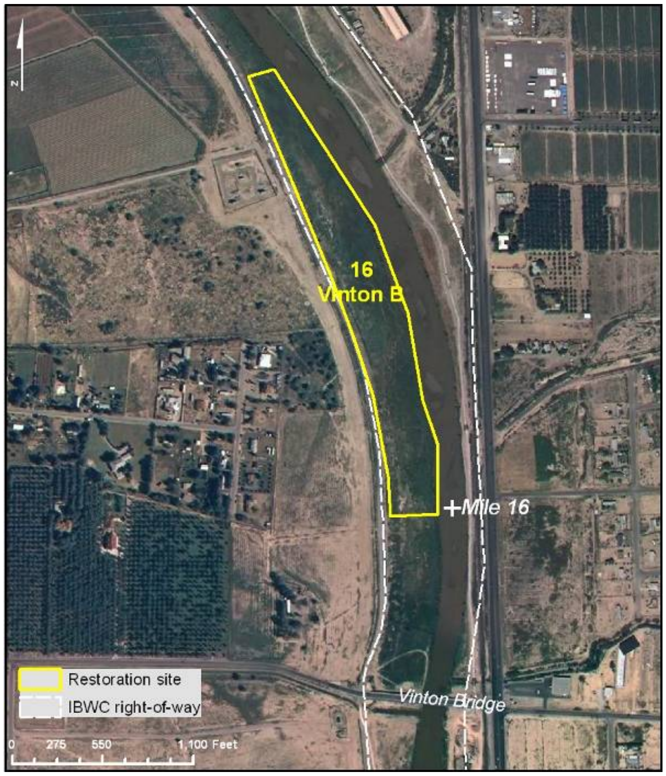

Figure 4.34. Vinton B restoration site.

Vegetation consists of regularly mowed grasses, and native and exotic herbaceous vegetation. Scattered resprouting saltcedar and some willows are present.

Soil series at the site are mapped as Made land, Gila soil material (NRCS, 2007b).

Restoration Prescription

Target habitat: Riparian woodland.

Exotic vegetation removal: Individual resprouting saltcedar can be removed by extraction (eliminating the need for follow-up herbicidal treatment).

Native vegetation planting: To complement the forest prescribed for the Vinton A site, open riparian woodland is recommended for this location. Scattered patches and individual trees should be planted with an overall canopy cover of about 50 percent. Shrubs (coyote willow, sumac, seep-willow, etc.) would form the understory strata. Additional grass and herbaceous species should be seeded throughout about 10 acres of the site.

Table 4.28. Vinton B site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Discontinue mowing		20 ac.	
Saltcedar removal	Mechanical extraction (light density)	10 ac.	$ 5,000
Plantings	Coyote willow whips (150/ac.) Longstem riparian shrubs (80/ac.) Goodding's willow poles (10/ac., avg.) Cottonwood poles (40/ac., avg.) Grass seeding	3,000 1,600 200 800 10 ac.	$ 22,500 $ 88,000 $ 9,000 $ 36,000 $ 19,000
		Implementation cost	**$179,500**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	48.0 70.0 22.0	 $ 22,000
		Implementation + Water Cost	**$201,500**

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

26. Valley Creek (RM 9)

The 22-acre Valley Creek site is on the west bank of the river beginning approximately 0.7 miles upstream from the Country Club bridge and extending 1.1 miles to the north (**Figure 4.35**). A portion of the Rio Grande Trail System traverses this long, narrow site, and Valley Creek Park lies immediately to the west. This site is predicted by the FLO-2D model to begin flooding with the 2,750-cfs Caballo release and would be fully inundated by the 3,500-cfs release.

Figure 4.35. Valley Creek restoration site.

Vegetation consists of regularly mowed grasses, and native and exotic herbaceous vegetation. Scattered, resprouting saltcedar and some willows are present.

Soil series at the site are mapped as Made land, Gila soil material (NRCS, 2007b).

Restoration Prescription

Target habitat: Open riparian woodland. Because of frequent recreational use, additional plantings of woody vegetation are recommended, rather than a fully stock, closed canopy forest.

Exotic vegetation removal: Individual resprouting saltcedar can be removed by extraction (eliminating the need for follow-up herbicidal treatment).

Native vegetation planting: Gooding's willow and cottonwood trees can be planted with an overall canopy cover of about 30 percent. Shrubs (coyote willow, sumac, seep-willow, etc.) would form scattered patches throughout the area. Additional grass and herbaceous species should be seeded throughout about 10 acres of the site.

Table 4.29. Valley Creek site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Discontinue mowing		22 ac.	
Saltcedar removal	Mechanical extraction (light density)	5 ac.	$ 2,500
Plantings	Coyote willow whips (50/ac., avg.) Longstem riparian shrubs (80/ac.) Goodding's willow poles (10/ac., avg.) Cottonwood poles (20/ac., avg.) Grass seeding	1,100 1,760 220 440 10 ac.	$ 8,250 $ 96,800 $ 9,900 $ 19.800 $ 19,000
		Implementation cost	**$156,250**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	49.9 72.8 22.9	 $ 22,900
		Implementation + Water Cost	**$179,150**

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

27. Nemexas Siphon (RM 7)

This 16.7-acre site is a triangular area on the west bank immediately downstream from the Nemexas Siphon (**Figure 4.36**). The FLO-2D model predicts that the site will be inundated by Caballo Dam releases of 4,500 cfs and larger. The water surface elevation of the 3,500-cfs Caballo release is very near the bank elevation.

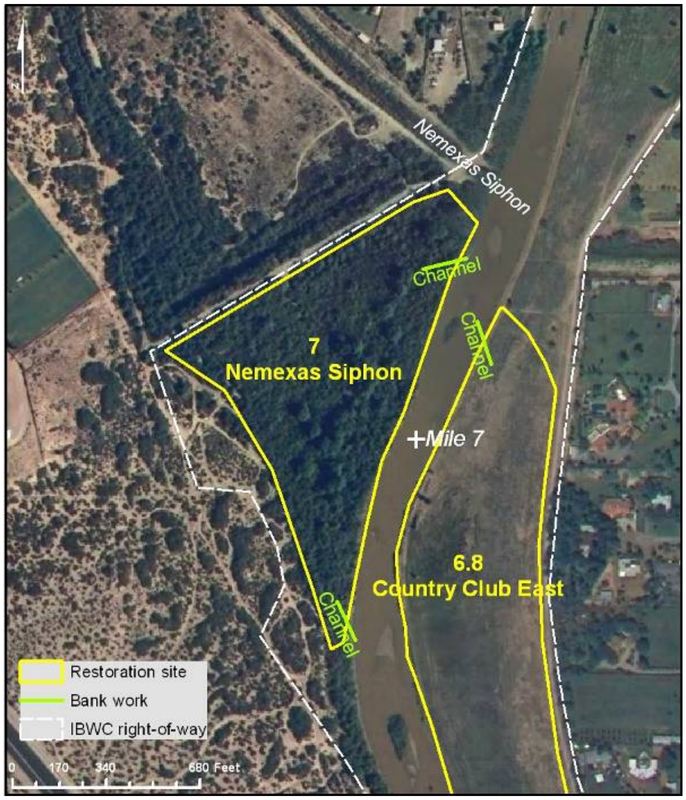

Figure 4.36. Nemexas Siphon restoration site.

The site is vegetated by a dense stand of the saltcedar, one of the largest stands found along the river downstream from Selden Canton. Several mature cottonwoods are present and coyote willow occurs in small patches, mixed with saltcedar.

Soils are mapped as Agua variant and Belen variant soils (AK) which typically has salinity levels of 4-16 dS/m (NRCS, 2007a). The presence of cottonwood and willow at the site indicate that at least subsurface salinity may be in the range of 4 dS/m or less.

Restoration Prescription

Target habitat: Dense riparian shrubs (SWWF habitat).

Enhanced river floodplain hydrologic connection: The FLO-2D model indicates that shaving the bank in two locations may enable water to flow through the site (**Figure 4.37**). Excavation of the banks would include a small (20 feet wide by 1.5 feet deep by 25 feet long) channel area in two locations. The spoil waste would be minimal and can either be placed along the levee or on the river bank for removal during high flows.

Exotic vegetation removal: This stand of large, dense saltcedar should be removed by a bulldozer or scraper, and the area can be root-plowed to remove the root crowns. Debris can be burned onsite with an air-curtain burner to avoid hauling. Near the existing cottonwoods and willows, saltcedar should be removed by extraction or manual cutting.

Native vegetation planting: Soil texture and salinity should be verified before planting. If soil salinity is sufficiently low, willows, cottonwood, and other riparian shrubs can be densely planted to develop into potential Willow Flycatcher breeding habitat.

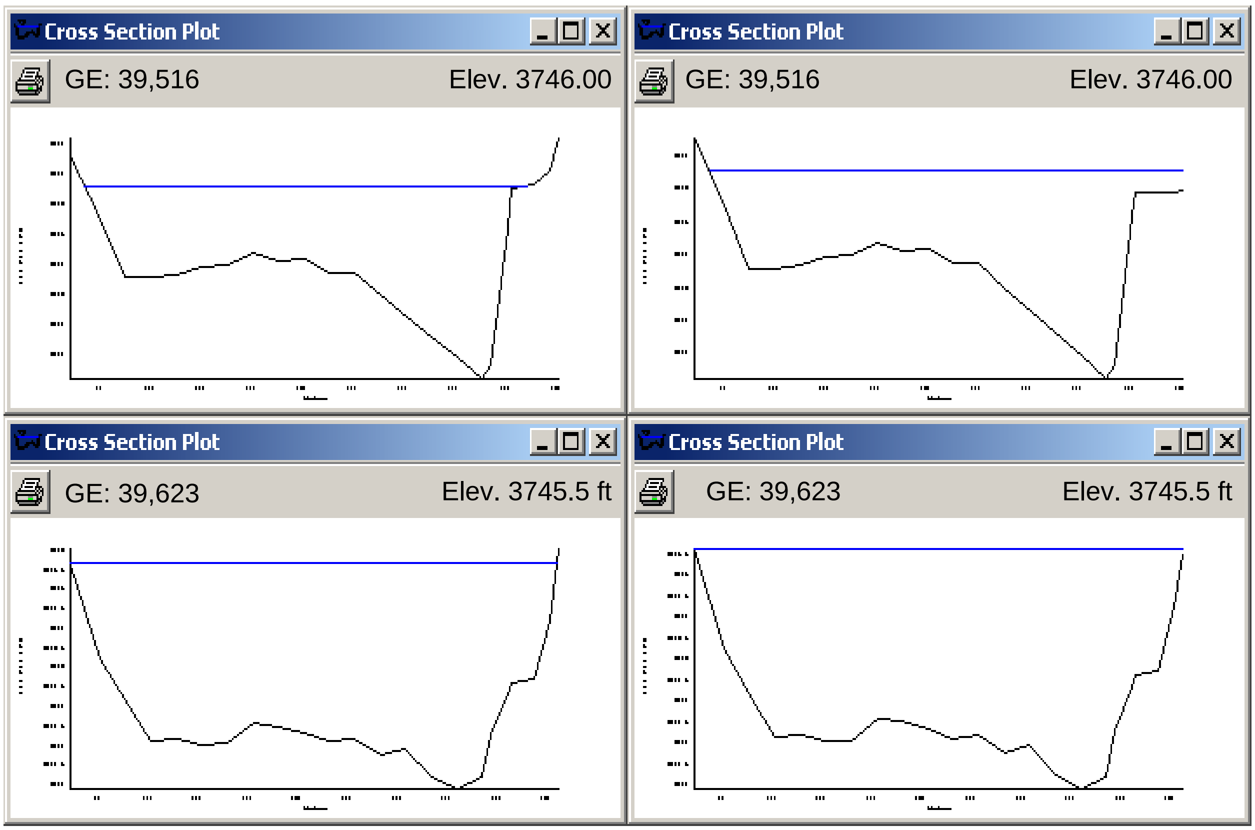

Figure 4.37. Baseline condition (left) and restored cross section with lowered bank (right).

Table 4.30. Nemexas Siphon site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Bank cut and channels	Bank cut plus 2 channels (20 ft wide x 25 ft long x 1.5 ft deep)	75 CY	$ 375
Saltcedar removal	Mechanical removal & root-plowing Air-curtain burner rental	16.7 ac. Each.	$ 30,060 $ 1,600
Plantings	Coyote willow whips (1,000/ac.) Longstem riparian shrubs (40/ac.) Goodding's willow poles (100/ac.) Cottonwood poles (10/ac.)	16,700 668 1,670 137	$125,250 $ 36,740 $ 75,150 $ 7,515
		Implementation cost	**$276,690**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	81.8 81.8 0	$ 0
		Implementation + Water Cost	**$276,690**

Note: Mixed saltcedar stands in the study area have been shown to support relatively high breeding bird abundance and species richness compared to grassland areas (Thompson et al., 1994). If soil conditions are not conducive to the establishment of cottonwoods and willows at this site, retention of the existing vegetation would likely provide higher quality habitat than would its conversion to saltgrass and alkali sacaton.

Prescription viability without restoration flow releases: Without restoration flow releases of 3,500 cfs from Caballo Dam, excavation would still provide viable growth conditions for riparian tress and shrubs, but in lower densities than those prescribed.

28. Country Club East (RM 6.8)

This 29-acre site is on the east bank of the river, opposite and extending downstream from the Nemexas Siphon site (**Figure 4.38**). The northern 21 acres are within New Mexico and the southern 8 acres are in Texas. FLO-2D modeling indicates that overbank inundation begins near RM 6.3 at a 3,000-cfs Caballo release, and flooding extends both upstream and downstream with increasing discharges. The site would be fully inundated by Caballo releases of 4,000 cfs and higher.

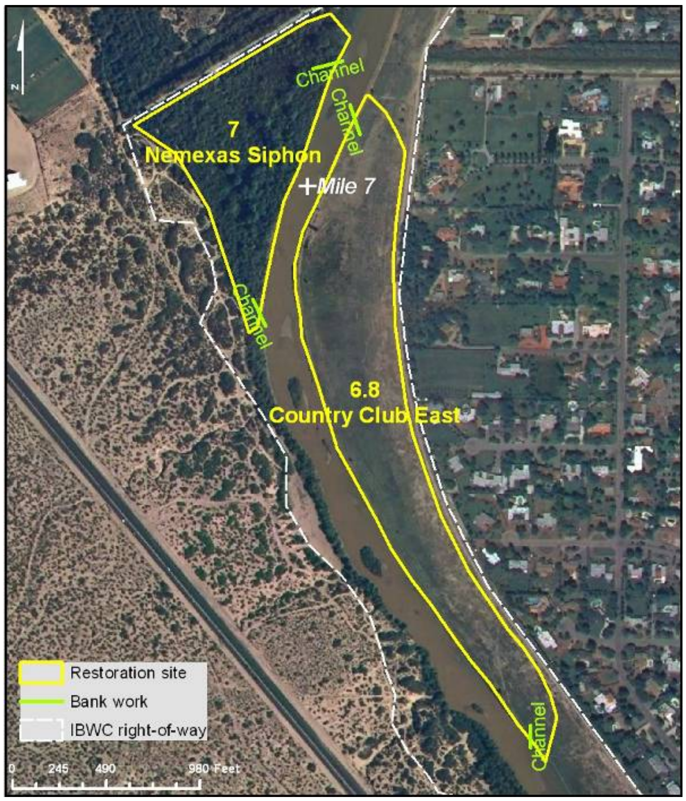

Figure 4.38. Country Club East restoration site.

Vegetation consists of mowed grassland with scattered resprouting saltcedar. In March 2008, a fire burned about half of the site and vegetation subsequently returned.

Soil series at the site are mapped as Agua loam (Ag) (NRCS, 2007a) and Made land, Gila soil material (NRCS, 2007b).

Restoration Prescription

Target habitat: Riparian forest (15 acres) and woodland (14 acres).

Enhanced river floodplain hydrologic connection: The proposed restoration techniques include bank shaving for enhanced overbank inundation. Lowering the bank in two places may enable the water to flow through the site under some conditions. Excavation of the banks would establish a small (20 feet wide by 2.25 feet deep by 25 feet long) channel in two locations (**Figure 4.39**). The spoil waste would be minimal.

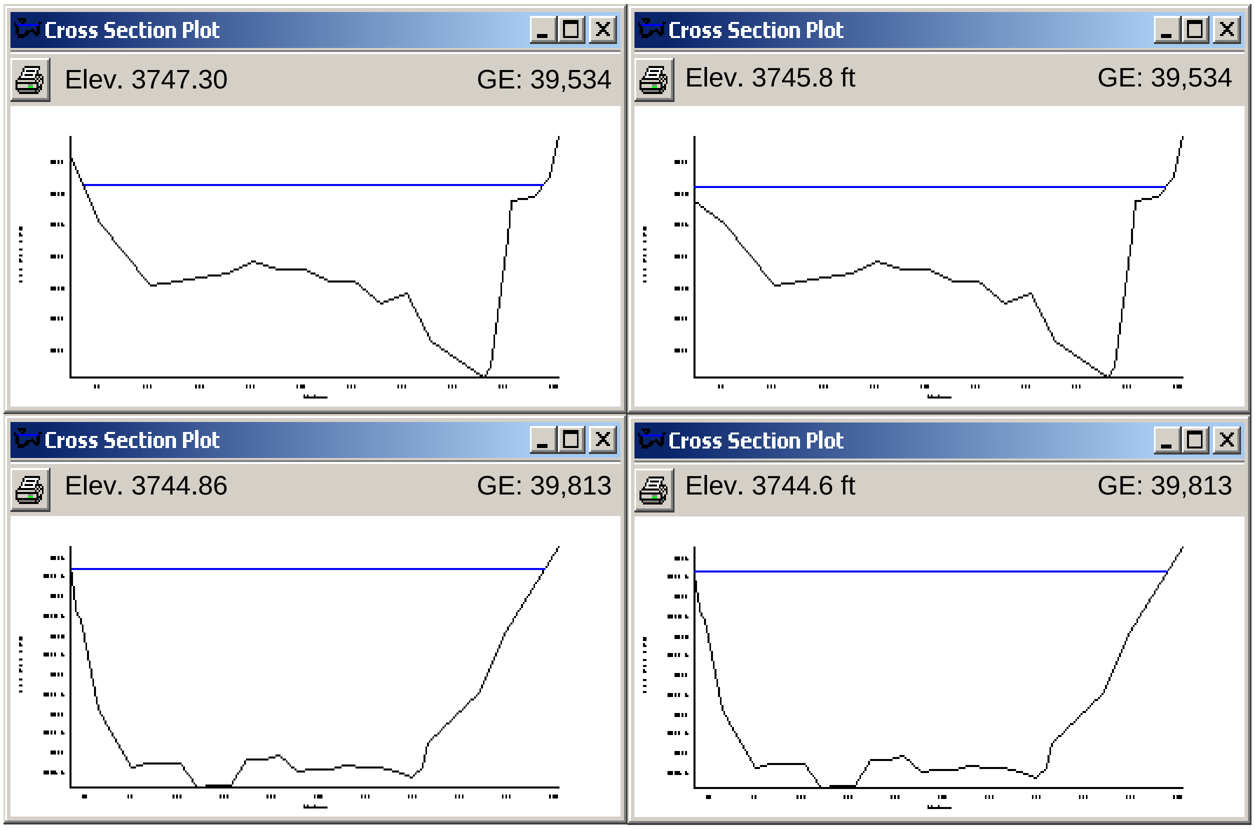

Figure 4.39. Baseline condition (left) and restored cross-section with lowered bank (right).

Exotic vegetation removal: Individual resprouting saltcedar can be removed by extraction (eliminating the need for follow-up herbicidal treatment).

Native vegetation planting: This site offers the possibility of creating a large tract of riparian forest and woodland. Cottonwood and Goodding's willow can be planted at fully stocked densities (100 per acre) in 2 or 3 patches to create about 15 acres of closed-canopy forest. The understory of these patches would consist of coyote willow and other shrubs. The remaining 14 acres of the site would be more open woodland, with approximately 50-percent canopy cover and scattered clumps of shrubs. Existing grasses and ground cover would improve with enhanced inundation, but seeding additional species within the woodland portion is recommended.

Table 4.31. Country Club East site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Bank cut and channels	Two channels (20 ft wide x 50 ft long x 2.25 ft deep)	83 CY	$ 415
Discontinue mowing		29 ac.	
Saltcedar removal	Mechanical extraction (light density)	15.0 ac.	$ 6,000
Plantings	Riparian forest (15 ac.):		
	Coyote willow whips (120/ac.)	1,800	$ 13,500
	Longstem riparian shrubs (80/ac.)	1,200	$ 66,000
	Goodding's willow poles (20/ac.)	300	$ 13,500
	Cottonwood poles (80/ac., avg.)	1,200	$ 54,000
	Riparian woodland (14 ac.)		
	Coyote willow whips (120/ac.)	1,680	$ 12,600
	Longstem riparian shrubs (80/ac.)	1,120	$ 61,600
	Goodding's willow poles (10/ac.)	140	$ 6,300
	Cottonwood poles (30/ac.)	420	$ 18,900
	Grass seeding	14 ac.	$ 26,600
		Implementation cost	**$279,415**
ET estimate (ac-ft/yr)	Pre-treatment	69.6	
	Post-treatment	121.0	
	Difference	51.4	$ 51,400
		Implementation + Water Cost	**$330,815**

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

29. Sunland Park (RM 4)

The Sunland Park restoration site covers 28.8 acres on the east bank (**Figure 4.40**).This site is predicted by the FLO-2D model to begin flooding with the 3,250-cfs Caballo release, and be fully inundated by the 3,500-cfs release.

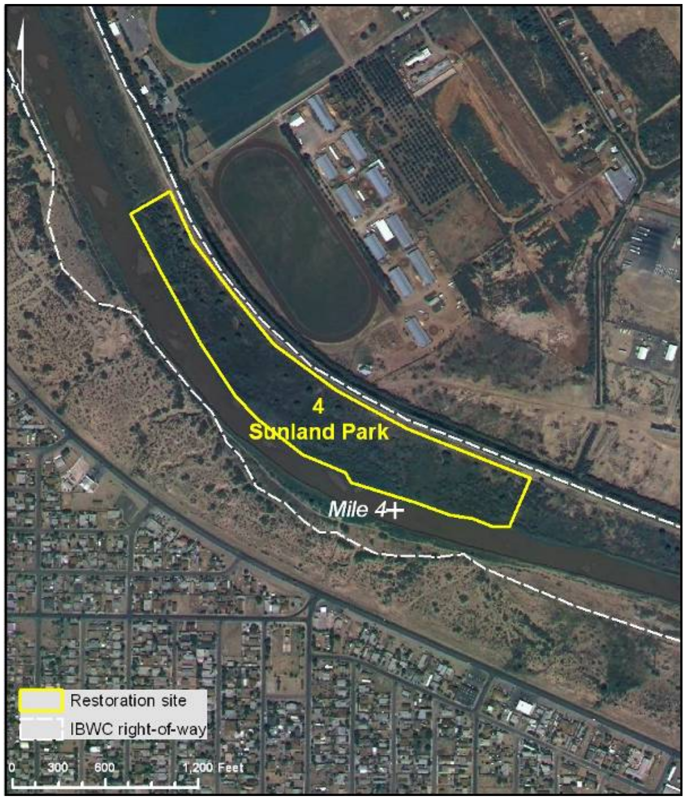

Figure 4.40. Sunland Park restoration site.

Existing vegetation consists of relatively dense grasses (primarily saltgrass) and scattered cottonwoods and shrubs. Minor saltcedar resprouting occurs between mowing.

Soils at the site at the site are mapped as Anthony-Vinton fine sandy loam (Ap) (NRCS, 2007a).

Restoration Prescription

Target habitat: Open riparian woodland.

Exotic vegetation removal: Individual resprouting saltcedar can be removed by extraction (eliminating the need for follow-up herbicidal treatment).

Native vegetation planting: Scattered patches and individual trees should be planted with an overall canopy cover of about 50 percent. Shrubs (coyote willow, sumac, seep-willow, screwbean mesquite, etc.) would form the understory strata and areas between clumps of trees.

Table 4.32. Sunland Park site quantities, costs, and evapotranspiration (ET) estimates.			
Activities	Items	Quantities	Costs
Discontinue mowing		28.8 ac.	
Saltcedar removal	Mechanical extraction (light density)	10 ac.	$ 2,500
Plantings	Coyote willow whips (50/ac.) Longstem riparian shrubs (80/ac.) Goodding's willow poles (10/ac., avg.) Cottonwood poles (40/ac., avg.)	1,440 2,304 288 1,152	$ 10,800 $126,720 $ 12,960 $ 51,890
		Implementation cost	**$204,870**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	69.1 100.8 31.7	 $ 31,700
		Implementation + Water Cost	**$236,570**

Upstream storm events are expected to inundate this site at an average frequency of less than five years. Considering this and the relatively shallow groundwater at this site (which is likely enhanced by seepage from the riverside drain), the prescribed vegetation improvements should be sustainable without augmented releases from Caballo Dam. Alternatively, the riverside drain is an optional source of supplemental water. Temporary pumps for periodic inundation of the overbank are recommended in this case, as pumping would be significantly cheaper than a permanent check gate and concrete-encased pipe through the levee (approximately $150,000).

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

30. Anapra Bridge (RM 3)

The last restoration site spans the crossing of the new Anapra Bridge (**Figure 4.41**). A public parking area is located at the southern end of the site and trails extend to north. The 11-acre site is predicted to be inundated by a 2,750- to 3,500-cfs release from Caballo Dam.

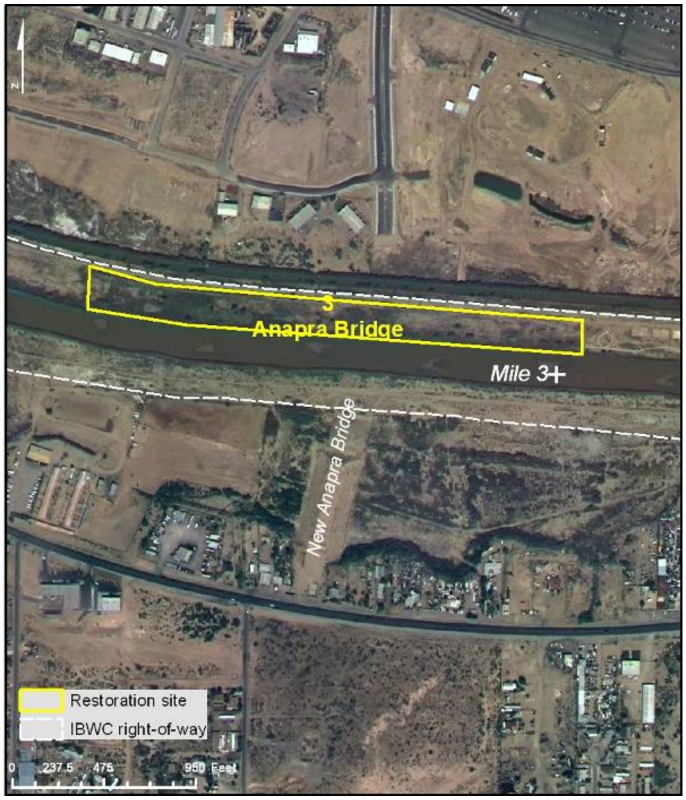

Figure 4.41. Anapra Bridge restoration site.

The site is moderately vegetated with grasses (primarily saltgrass) and mature cottonwoods, coyote willow, and screwbean mesquite.

Soils are mapped as Agua variant and Belen variant soils (AK) which typically exhibit salinity levels of 4 to 16 dS/m (NRCS, 2007a). The presence of cottonwood and willow at the site indicate that at least subsurface salinity may be in the range of 4 dS/m or less.

Restoration Prescription

Target habitat: Open riparian woodland. Because of frequent recreational use, additional plantings of woody vegetation are recommended, rather than a fully stock, closed canopy forest.

Exotic vegetation removal: The relatively few scattered saltcedar and Russian olive trees can be removed by extraction.

Native vegetation planting: Cottonwood, willows, screwbean mesquite, and other shrubs should be added in small patches to complement the existing vegetation.

Table 4.33. Anapra Bridge site quantities, costs, and evapotranspiration (ET) estimates.

Activities	Items	Quantities	Costs
Discontinue mowing		5 ac.	
Saltcedar removal	Mechanical extraction (light density)	3 ac.	$ 1,500
Plantings	Coyote willow whips (30/ac.) Longstem riparian shrubs (30/ac.) Goodding's willow poles (5/ac., avg.) Cottonwood poles (10/ac., avg.)	330 330 55 110	$ 2,475 $18,150 $ 2,475 $ 4,950
		Implementation cost	**$29,550**
ET estimate (ac-ft/yr)	Pre-treatment Post-treatment Difference	33.0 38.5 5.5	 $ 5,500
		Implementation + Water Cost	**$35,050**

Upstream storm events are expected to inundate this site at an average frequency of less than five years. Considering this and the relatively shallow groundwater at this site (which is likely enhanced by seepage from the riverside drain), the prescribed vegetation improvements should be sustainable without augmented releases from Caballo Dam. Alternatively, the riverside drain is an optional source of supplemental water. Temporary pumps for periodic inundation of the overbank are recommended in this case, as pumping would be significantly cheaper than a permanent check gate and concrete-encased pipe through the levee (approximately $150,000).

Prescription viability without restoration flow releases: This prescription is not dependent on restoration flow releases of 3,500 cfs from Caballo Dam.

5. CUMULATIVE EFFECTS ANALYSIS

After completion of the individual site analyses described in the previous chapter, a series of analyses were performed to assess the cumulative effects of all of the proposed restoration activities. The cumulative effects analysis was performed by completing the following specific tasks:

1. Modifications were made to the baseline-conditions FLO-2D model to represent restoration conditions.
2. The restoration conditions model was used to assess the following issues:
   a) Potential water depletion at American Dam during both normal irrigation releases when the discharge averages about 2,350 cfs and the target restoration flows of 3,500 cfs,
   b) effects of the restoration activities on water-surface elevations and flood wave attenuation during the 10- and 100-year flood events, and
   c) changes in local hydraulic conditions that could affect sediment-transport conditions and channel stability along the reach.
3. An evaluation of the potential net change in annual ET loss due to the restoration activities.
4. An evaluation of changes in the relative sediment-transport balance along the reach due to the proposed restoration activities, and the potential effects of these changes on channel stability and sustainability of the individual restoration sites.

5.1. Modifications to FLO-2D Model to Simulate Cumulative Effects

As discussed in the previous chapter, the FLO-2D model was modified at each of the sites to represent physical changes (i.e., topography, hydraulic roughness and infiltration characteristics) that would occur under the proposed restoration conditions. The sites were tested individually with the model for the restoration target flow of 3,500 cfs. In some cases, a number of simulations were necessary with subsequent adjustments to achieve the desired overbank flood inundation.

After completion of the individual site analysis, a comprehensive FLO-2D restoration conditions model was developed by incorporating all of the restoration site attributes into a single model to test the cumulative impacts on flood water-surface elevations and operational flow depletions. The flood simulations included the 10- and 100-year floods and the operational flow releases included a 2,350-cfs typical irrigation release and the 3,500-cfs target restoration release. A Caballo release of 2,350 cfs was also used for the 10- and 100-year floods. Input hydrographs for flood analysis were the same as those developed by Tetra Tech (2004) in re-evaluating the arroyo tributary flood inflows between Caballo Dam and American Dam. A Caballo Dam release of 2,350 cfs represents the mean irrigation operation for the flood models. Infiltration and evaporation were simulated as initially defined in the 2004 FLO-2D model. For the operation releases, mean diversion rates during the irrigation season were assumed to be 244 cfs at Percha Dam, 395 cfs at Leasburg, and 203 cfs at Mesilla Dam. These diversion flows were not applied to the 10- and 100-year floods because these facilities are typically shut down during flooding.

Infiltration loss was simulated using the Green-Ampt infiltration model which uses hydraulic conductivity, soil suction and soil moisture deficiency parameters. Channel seepage was assumed to be minor and was simulated using a 0.01-inch per hour hydraulic conductivity. In all baseline simulations, the floodplain infiltration was uniform with a hydraulic conductivity of 0.07 inches per hour. Application of this low infiltration parameter assumes wet conditions during the infrequent flood events. For the operational flows, the same infiltration values were used in the absence of spatially variable data. Combined floodplain and channel infiltration ranged from about 1 to 6 percent of the inflow hydrograph (range: 116 ac-ft for the 2,350-cfs simulation to 6,140 ac-ft for the 100-year flood). For the operational flows of 2,350 and 3,500 cfs, the infiltration loss was 1 and 2 percent of the inflow hydrograph. For the restoration project conditions, the hydraulic conductivity was assumed to increase by 100 percent on disturbed sites (0.14 inches per hour). Each site with some proposed construction activity was assigned spatially variable infiltration parameters.

Infiltration losses are not necessarily a complete loss of water from the river system. Infiltration loss is divided into groundwater storage and ET. Groundwater storage can eventually become return flow to the channel or it could increase the groundwater tables outside the levees. Groundwater storage is not considered a net depletion from the river system. Plant ET is water that is lost to the river. The portion of the groundwater infiltration that goes into groundwater storage versus ET is highly spatially variable depending on water table, soil conditions, season, plant species and density, and other factors. FLO-2D only reports on infiltration loss and the infiltrated water proportion distribution between groundwater storage and ET can only be qualitatively assessed.

All FLO-2D flow routing simulations for this project applied the same evaporation parameters. Diurnal variation in evaporation parameters for mean monthly conditions was modeled for the period from April through June. The evaporation was computed for both channel surface and floodplain wetted area and is dependent on the duration of the simulation as well as the surface area of inundation. The evaporation constituted approximately 0.8 to 1.6 percent of the inflow hydrograph (range: 130 ac-ft for the 2,350-cfs operational flow to 1,550 ac-ft for the 100-year flood). Evaporation is a loss from the system.

To insure that model results for baseline and restoration conditions are directly comparable, the baseline model was re-run for the two operational flows and the two flood events with some minor modifications to the original model that were necessary during the detailed investigation of the sites. These modifications included:

- Shifting the channel over by one grid element to better represent position of the river.
- Modification of *n*-values where necessary.
- Changes in grid element elevations where the elevations appeared to poorly represent the DTM point topography.

The number of overall changes to the model affected less than 20 grid elements, and the impact on the baseline results are negligible except in the local area of the modifications.

5.2. Effects on Cumulative Water Losses

5.2.1. Impact on Losses During Operational and Restoration Flow Releases

The simulations for the irrigation operational flow included a six-hour ramp-up period followed by a constant flow of 2,350 cfs for 74 hours and a total release volume of about 15,000 ac-ft (**Figure 5.1**). The model duration for this hydrograph was selected to provide a 10 hour peak discharge at American Dam. The attenuated hydrograph at American Dam for this release had a peak discharge of about 1,400 cfs. The 3,500-cfs target restoration release hydrograph consisted of a 6-hour increase from no-flow to the irrigation operational flow of 2,350 cfs that was maintained for 18 hours, a 1-day ramp-up from 2,350 cfs to the peak release of 3,500 cfs that was maintained for 2 days, followed by a 1-day ramp-down period to 2,350 cfs that was maintained for 1 day (**Figure 5.2**). The duration of this hydrograph was selected to enable the peak discharge to pass American Dam and the flow to return to the irrigation release operation discharge. The total release volume at the end of the 6-day simulation was about 34,200 ac-ft. The resulting attenuated hydrograph at American Dam for the restoration flows has a peak discharge of about 2,400 cfs and a peak duration of about 30 hours.

Tables 5.1 and 5.2 summarize the total inflow and outflow volumes and the volumes lost to infiltration, evaporation, and storage in the floodplain and channel at the end of the simulations.[1] The results in Table 5.1 indicate that there is essentially no difference in net depletions between baseline and restoration conditions for the 2,350-cfs operation release. Under restoration conditions, there is a small increase in the volume of water lost to infiltration, evaporation, and storage in the floodplain (2.4, 0.11, and 0.9 ac-ft, respectively) due to the small increase in floodplain inundation over baseline conditions, but these losses are essentially offset by the reduced channel storage that results from the small local decreases in channel capacity.

The results in Table 5.2 indicate a net increase in depletions under restoration conditions over the 144-hour simulation for the 3,500-cfs target restoration release of approximately 436 ac-ft attributed to an increase in infiltration, evaporation, and floodplain storage losses of about 347, 17, and 72 ac-ft, respectively. These depletions result in an approximately 450-ac-ft decrease in the flow volume at American Dam. The changes in depletion shown in the table do not represent the real net depletion from the system; however, because over a longer duration, part of the floodplain storage and some infiltrated water would return to the channel. It is also important to note that the total infiltration indicated in Table 5.2 represent both an increase in groundwater storage and water lost to ET. Some of the groundwater may return to the channel while the ET is lost to the system. The net depletion is the sum of the evaporation and ET. Both volumes would increase until the entire floodplain storage is eliminated. To assess the actual net depletion (i.e., determine the percentage of total 436-ac-ft gross depletion), groundwater monitoring and a more detailed ET analysis would be required. If it is assumed that about 50 percent of floodplain storage remaining at the end of the simulation (72 ac-ft) is infiltration and 50 percent of that volume goes to ET, and then roughly 208 acre-ft would be lost from the flow at American Dam.

[1] The volumes in Tables 5.1 and 5.2 are reported to the nearest 0.01 acre-ft to reveal any small differences between the two modeled conditions.

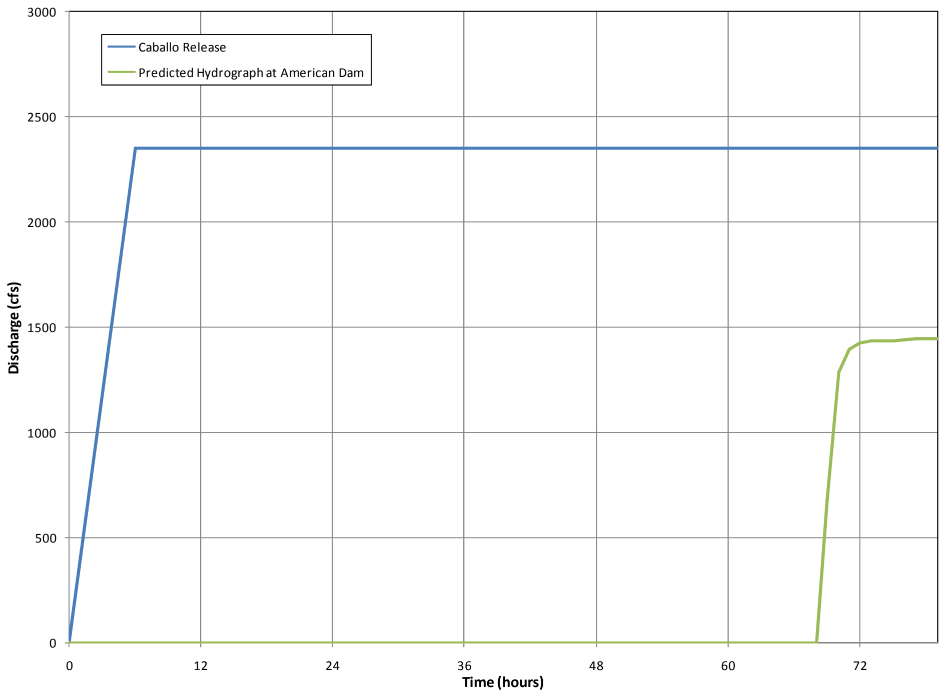

Figure 5.1. Modeled release hydrograph from Caballo Dam for the irrigation operational flow of 2,350 cfs and the predicted hydrograph at American Dam under restoration project conditions.

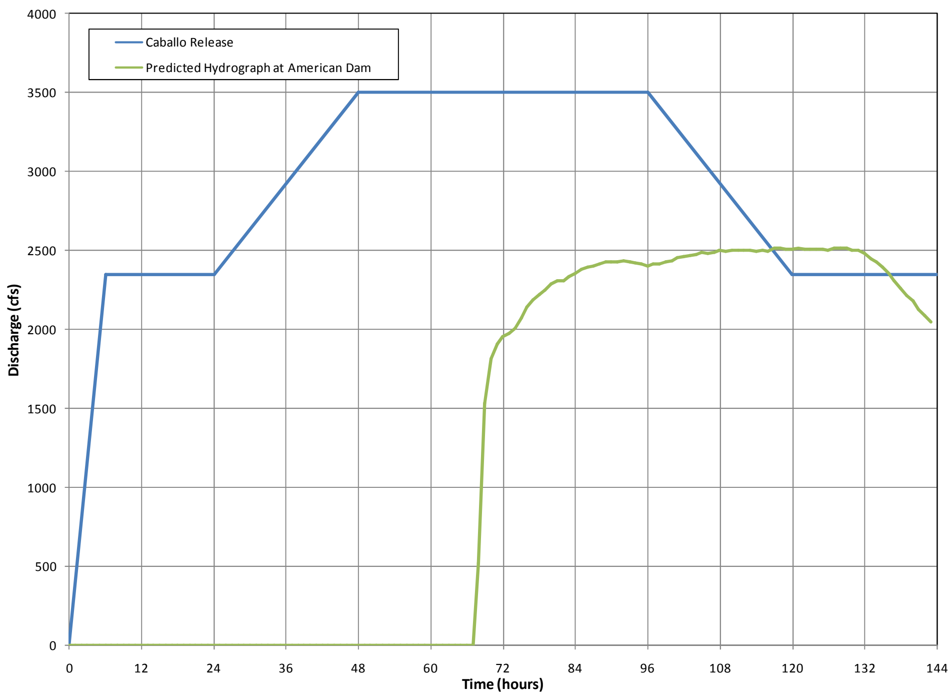

Figure 5.2. Modeled release hydrograph from Caballo Dam for the restoration flow of 3,500 cfs and the predicted hydrograph at American Dam under restoration project conditions.

Table 5.1. Comparison of FLO-2D results for the baseline and restoration volumes for the 2,350-cfs irrigation operational flow.			
	Baseline Flow 2,350 cfs	Restoration Flow 2,350 cfs	Difference (Baseline–Restoration)
	ac-ft	ac-ft	ac-ft
Inflow	14,955.10	14,954.91	+0.19
Floodplain Infiltration	0.00	2.42	-2.42
Floodplain Evaporation	0.00	0.11	-0.11
Floodplain Storage[1]	0.01	0.89	-0.88
Floodplain Outflow	0.00	0.00	0.00
Channel Infiltration	113.70	113.95	-0.24
Channel Evaporation	131.45	131.52	-0.07
Channel Storage[2]	9,631.01	9,626.76	4.25
Channel Outflow[3]	5,078.93	5,079.27	-0.30
		SUM	0.00

[1]Volume left on the floodplain at the end of the simulation
[2]Volume left in the channel at the end of the simulation
[3]Volume of flow at American Dam

Table 5.2. Comparison of FLO-2D results for the baseline and restoration volumes for the 3,500-cfs irrigation operational flow.			
	Baseline Flow 3,500 cfs	Restoration Flow 3,500 cfs	Difference (Baseline–Restoration)
	ac-ft	ac-ft	ac-ft
Inflow	34,227.26	34,227.13	0.13
Floodplain Infiltration	134.79	481.69	-346.90
Floodplain Evaporation	16.06	32.84	-16.78
Floodplain Storage[1]	95.44	167.26	-71.82
Floodplain Outflow	0.00	0.00	0.00
Channel Infiltration	290.98	291.49	-0.51
Channel Evaporation	374.00	373.99	0.01
Channel Storage[2]	10,014.23	10,030.59	-16.36
Channel Outflow[3]	23,301.76	22,849.26	452.50
		SUM	0.27

[1]Volume left on the floodplain at the end of the simulation
[2]Volume left in the channel at the end of the simulation
[3]Volume of flow at American Dam

5.2.2. Net Change in Annual ET Loss

The net change in water depletion on an annual basis due to changes in ET resulting from the replacement of one plant community type with another was assessed using available published ET rates for the various plant communities (see Chapter 3.2). The change in consumptive use resulting from habitat restoration activities was calculated as the difference in rates between the existing and restored habitat types at each site. For example, conversion of grassland (2.4 ft/yr) to riparian woodland (3.5 ft/yr) would entail an additional 1.1 ft/yr in consumptive use. If this restoration site is 10 acres in size, the net depletion volume would be 11 ac-ft/yr.

The net depletion due to ET for all 29 restoration sites was estimated to be 420 ac-ft/yr. Consumptive use is expected to decrease by 64 ac-ft/yr at the three arroyo-mouth sites and the Yeso West inset floodplain because existing vegetation would be replaced by river channel and sparse pioneering vegetation. The estimated net depletion at six riparian restoration sites having a cumulative area of 88.8 acres was zero primarily because dense native shrubs and trees would replace existing dense saltcedar stands. For the 25 sites with extensive riparian plantings, the total increase in depletion was estimated to be 484 ac-ft/yr. Over the total 503 acres of proposed restoration at these 25 sites, the average increase in consumptive use was 1 ft/yr for per acre.

5.3. Effects on 10- and 100-year Floods

The effects of the proposed restoration projects on the 10- and 100-year floods was evaluated by comparing the maximum water-surface elevations along the channel and in the overbank areas predicted by the restoration and baseline conditions models. The 10- and 100-year floods were simulated by using a steady state release from Caballo Dam of 2,350 cfs and inflowing hydrographs from Tetra Tech (2004) for the appropriate recurrence interval to represent the 40 major tributaries along the RGCP. For both flood events, the peak discharge varies significantly along the reach due a combination of routing effects and local inflows from the tributaries. For the 10-year flood, the routed peak discharge increases from the operational release of 2,350 cfs at Caballo Dam to about 9,500 cfs in the vicinity of Yeso Arroyo, remains relatively steady at that level, except for the local influence of the tributaries, to about the head of Seldon Canyon where it decreases rapidly to below 7,500 cfs, and then continues to gradually decrease through the remainder of the reach (**Figure 5.3**). The 100-year hydrograph shows more variability, with the peak discharge increasing to over 20,000 cfs between Angostura Arroyo and the head of Selden Canyon, abruptly decreasing to less than 15,000 cfs through Seldon Canyon, and then continuing to decrease to about 10,300 cfs at American Dam. Under baseline conditions, the channel capacity decreases in the downstream direction, with the channel capacity below Mesilla Dam being less than 2,000 cfs in some reaches. Most of the flood conveyance downstream from Leasburg Dam occurs on the floodplain for flood events greater than the 10-year flood.

The restoration design may result in raising or lowering the local maximum water surface within the project site by up to several feet depending on the restoration techniques. Some of the restoration projects involve excavated floodplains and channel widening. These projects increase the channel flood conveyance and the floodplain storage, which would tend to lower the flood water-surface elevations. Projects that include bank lowering, inset floodplains, and increased riparian vegetation density may cause an increase in the flood water-surface elevations. In addition, the predicted maximum water surface varies laterally across the

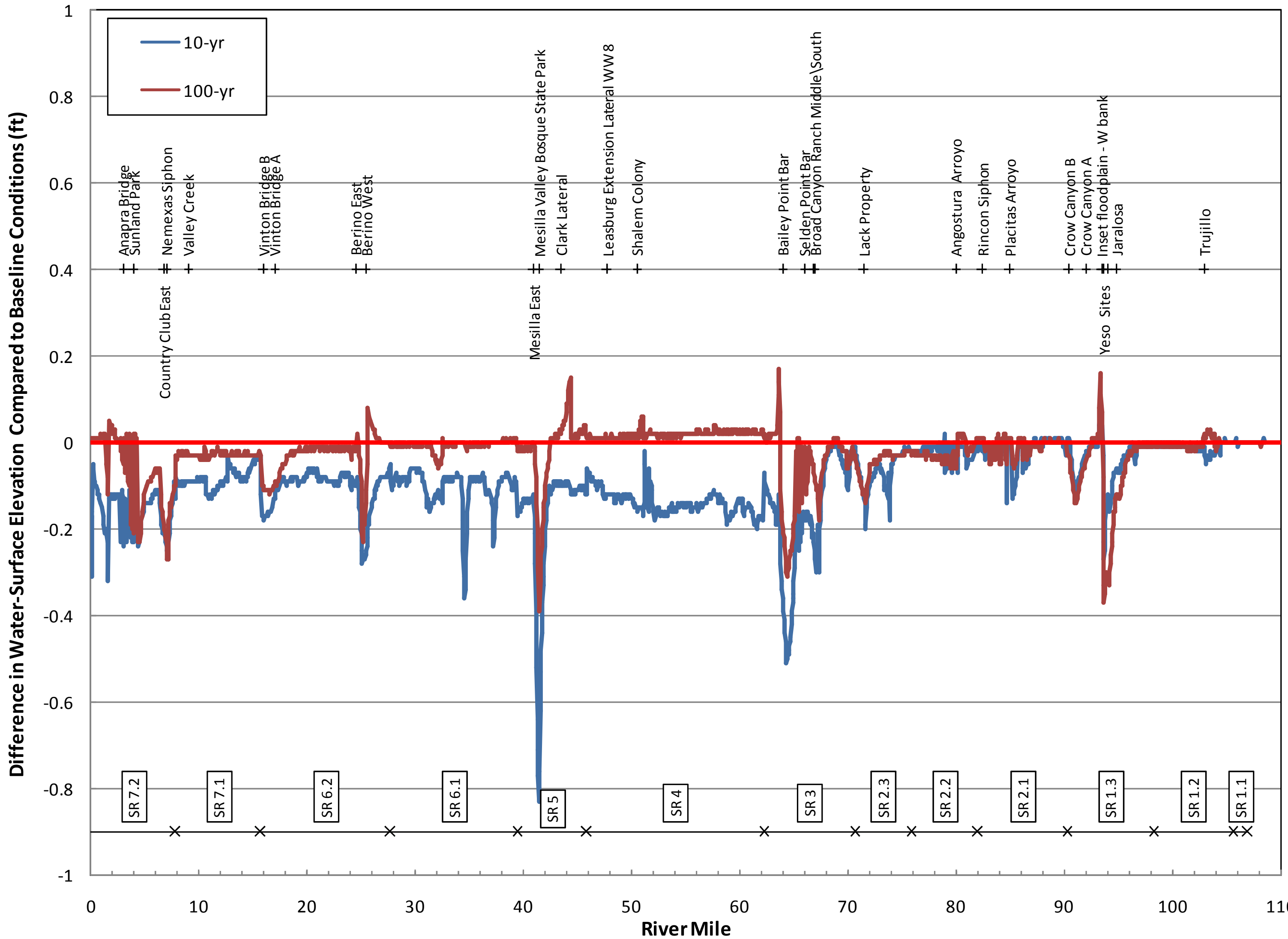

Figure 5.3. Routed peak discharge profiles for the 10- and 100-year hydrographs under baseline and project conditions.

floodplain. The FLO-2D model predicts spatially variable water-surfaces on the floodplain at the 250-foot grid resolution.

The model results show that the proposed restoration projects would generally result in a reduction in the maximum water-surface elevation during both flood events. For the 10-year event, the water-surface decreases in 1,846 of the 2,031 channel grid elements, with a median change of about -0.1 feet and maximum change of about -0.8 feet (**Figure 5.4**). Most of the reduction occurs below the head of Selden Canyon, and is caused by flow attenuation associated with increased floodplain storage, although locally larger reductions also result from project excavation. The largest 0.8-foot reduction occurs upstream from the Mesilla Valley restoration sites, and significant reductions also occur in the vicinity of the Yeso West Inset Floodplain, Broad Canyon Ranch, Bailey Point Bar, Berino, Nemexas Siphon and Sunland Park sites. An increase in water-surface elevation occurs at only 31 out of 2,045 channel elements, with a maximum increase of less than 0.1 feet occurring downstream from the Inset Floodplain Site.

The changes in water-surface elevation for the 100-year event generally follow the same trend as the 10-year event, but the reductions are typically less significant because the attenuation caused by overbank flooding is similar under baseline and restoration conditions. In general, the relationship between the flood volume in the channel and the flood volume on the floodplain at a specific location determines the response to the restoration projects. Throughout most of the RGCP the conveyance capacity is only a small percentage of the 100-year flood discharge, so the maximum water surface response to flooding at specific restoration to either 10-year or the 100-year flood can vary according to the flood volume in the channel versus the flood volume on the floodplain and the hydraulic characteristics and controls for each. The model predicts a reduction in water-surface in 1,107 of the 2,031 channel grid elements for the 100-year event. The largest reductions typically occur in the same locations as the 10-year event (Messilla Valley, Yeso West Inset Floodplain, Broad Canyon Ranch, Bailey Point Bar, Berino, Nemaxas Siphon and Sunland Park sites) with the maximum reduction of about 0.4 feet upstream from the Mesilla Valley sites. A minor increase in the maximum water-surface elevation occurs in the reach between Leasburg Dam and the Mesilla Valley sites due to the small increase in peak discharge under project conditions. The maximum water-surface elevation increases at 588 channel grid elements during the 100-year event, with maximum increases of 0.16, 0.17, and 0.15 feet downstream from the Yeso West Inset Floodplain, Bailey Point Bar, and Mesilla Lateral sites, respectively. The median increase in these 588 grid elements is, however, negligibly small (0.02 feet).

5.4. Potential Long-term Channel Impacts

An initial assessment of the potential effects of the proposed restoration projects on long-term sediment-transport conditions and channel stability in the RGCP reach were assessed by repeating the baseline conditions sediment-continuity analysis with hydraulic results from the restoration conditions FLO-2D model. The analysis was conducted by re-computing subreach-averaged hydraulic conditions for the 13 subreaches, developing project conditions bed-material sediment-transport capacity rating curves, and integrating those rating curves over the appropriate flow duration curves to estimate average annual bed-material loads. Consistent with the baseline conditions analysis, long-term aggradation/degradation tendencies were evaluated only for the portion of the project reach downstream from Geomorphic Subreach 1 (i.e., downstream from the Hatch Siphon) by comparing the computed bed-material capacity in each subreach with the upstream and tributary supply volumes. The reaches upstream from the Hatch Siphon were not considered because the bed is effectively armored for the range of flows

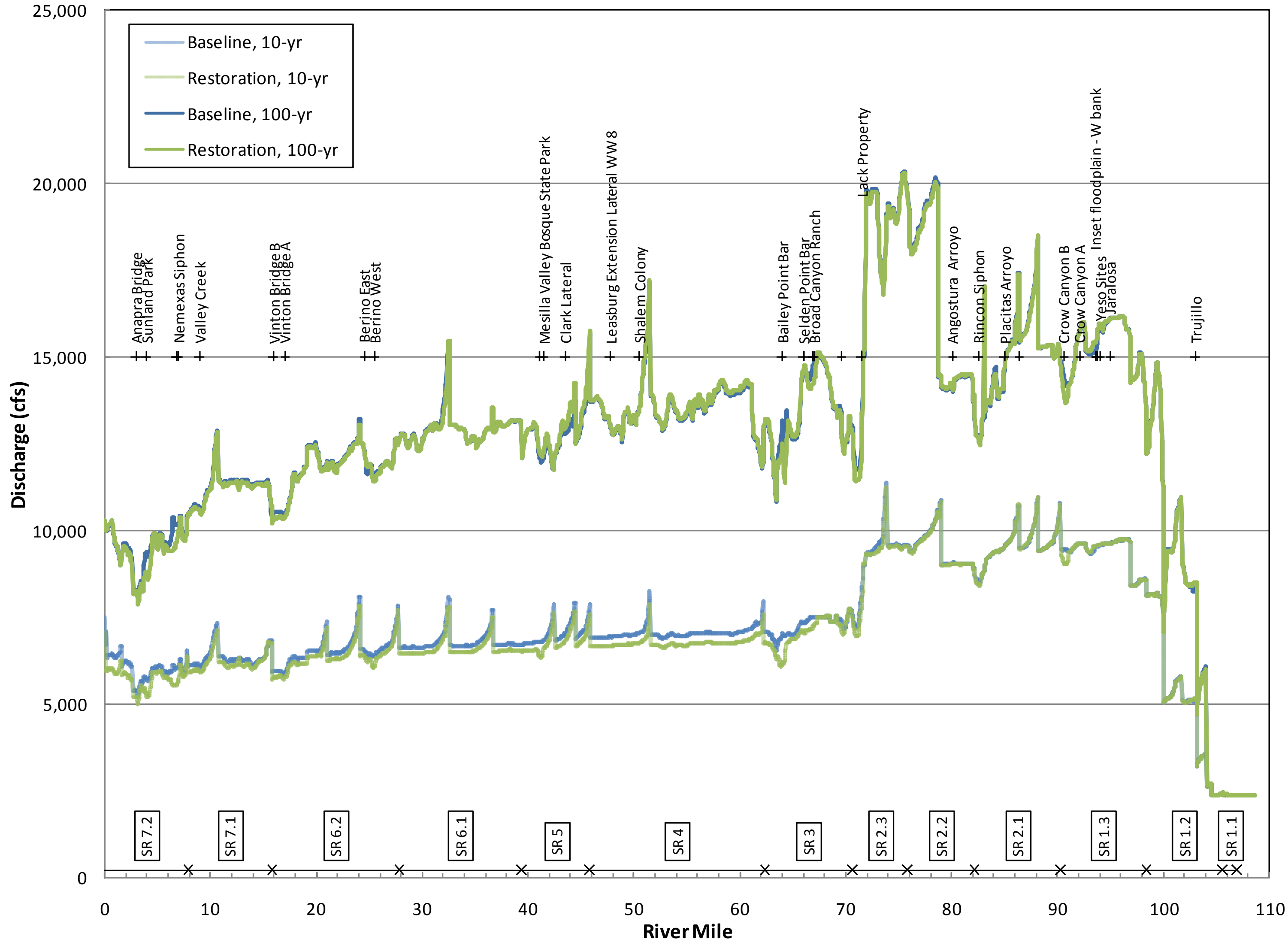

Figure 5.4. Difference in maximum computed water-surface elevation under project conditions (compared to baseline conditions) for the 10- and 100-year events.

in the target restoration releases (MEI/Riada, 2007). Results from the sediment-continuity analysis indicate that the aggradation/degradation volumes predicted under project conditions are nearly identical to those values for baseline conditions (**Figure 5.5**). This is to be expected, since the project conditions FLO-2D model grid elements were modified only at the restoration sites, and these grid elements represent a relatively small proportion of each subreach. In general, this analysis indicates that the proposed restoration projects would have an insignificant effect on the overall sediment-transport characteristics and stability of the RGCP reach. Restoration releases that exceed the current operation flows would increase the total sediment load in the reach due to the non-linear nature of the sediment-transport capacity versus discharge relationships. This is not expected to significantly change the relative sediment balance along the overall reach. It may, however, increase the rate of erosion at destabilized banklines.

The proposed plan may, however, affect these processes at the local scale of the individual restoration projects. These potential local-scale effects were evaluated using methods similar to those employed for the reach-wide sediment-continuity analysis by performing the following steps:

1. Average hydraulic conditions were computed using results from the baseline and project conditions FLO-2D models at the channel grid elements adjacent to each restoration site.

2. Sediment-rating curves for baseline and project conditions were developed for each site using the representative bed-material gradation for the appropriate subreach and Yang's (Sand) sediment-transport equation (Yang, 1973).

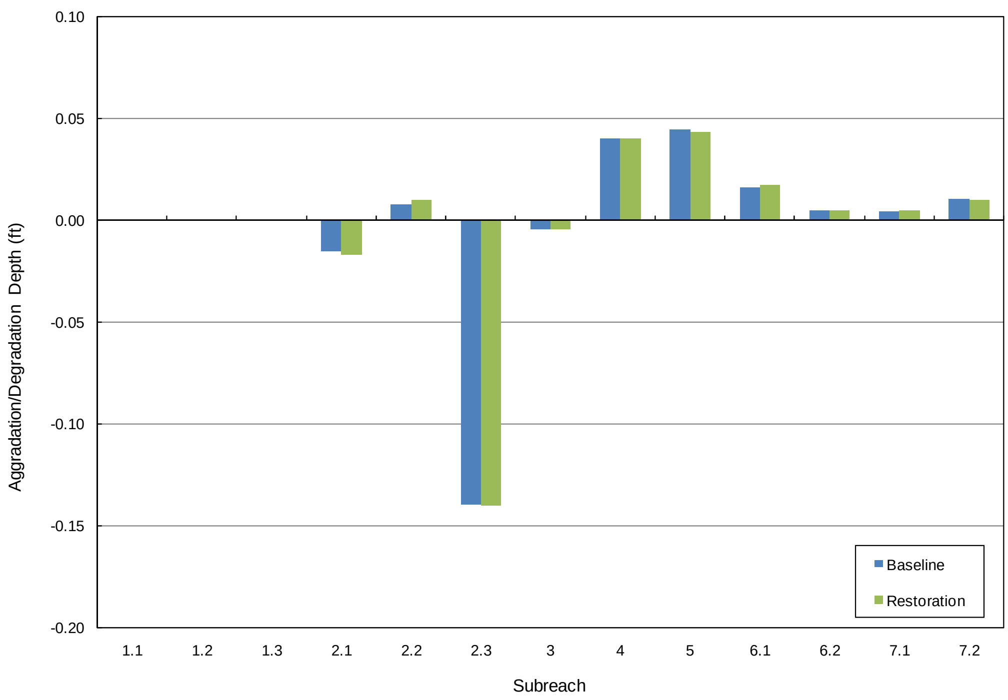

Figure 5.5. Comparison of computed average annual aggradation/degradation depths from the sediment-continuity analyses of baseline and restoration project conditions.

3. The sediment-rating curves were integrated over the applicable mean daily flow duration curve to estimate the average annual bed-material transport capacity in the vicinity of each site.

4. The local, average annual bed-material loads under baseline and project conditions were compared to identify locations where the restoration techniques could cause a significant change in the aggradation/degradation patterns, or bed-material characteristics.

The analysis indicates that the annual bed-material transport capacity at the sites is generally consistent with subreach-averaged transport capacities, and the differences from baseline to restoration conditions are relatively small (**Figures 5.6 and 5.7**). Differences between the local site values and the subreach-averaged values reflect the hydraulic variability along the reach. In most cases, the computed differences from the subreach-averaged values are much greater than would actually occur because local sorting of the bed-material and channel adjustments that cannot be accounted for at this level of analysis would occur under the modeled conditions.

The continuity analysis indicates that the local transport capacity would increase by a small amount at 10 of the sites, decrease by a small amount at five sites, and remain about the same at the remainder of the sites. At those sites where the transport capacity is predicted to increase, the change is caused by a small increase in the amount of flow in the channel due to increased overbank roughness due to the new vegetation and an associated, relatively small increase in the energy gradient at high flows. At the sites where the transport capacity decreases, the change is caused primarily by a decrease in in-channel flows due to the increased overbank conveyance associated with the site excavation. The channel would respond to these changes through subtle adjustments to the cross-sectional shape and bed-material gradations. Except for the three tributary-mouth sites (Yeso, Placitas and Angostura), the effect of the individual site prescriptions on local hydraulic and sediment-transport conditions over the range of anticipated flows will be relatively small. The river will respond to these changes through minor adjustments to the cross-sectional shape and bed-material characteristics, with no perceptible change in channel stability. At the tributary mouth sites, the prescriptions envision significant changes in cross-sectional shape and channel alignment that could affect the local sediment-transport balance. These sites should be monitored closely to insure that the changes do not adversely affect the levees and other infrastructure.

Monitoring at the tributary mouth sites should include the bankline alignment along eroding left bank, and cross section profiles in the area that is directly affected by the tributary-derived sediment after each significant tributary event. The purpose of the bankline monitoring is to the provide data that can be used to assess the rate of channel migration to determine whether and when it will be necessary to install the indicated erosion protection. The purpose of the cross sections is to provide data that can be used to assess impacts to the local flood carrying capacity of the reach. This can be accomplished by incorporating the cross sections into either the 1-D HEC-RAS or 2-D FLO-2D model, and re-running the model with the design flows.

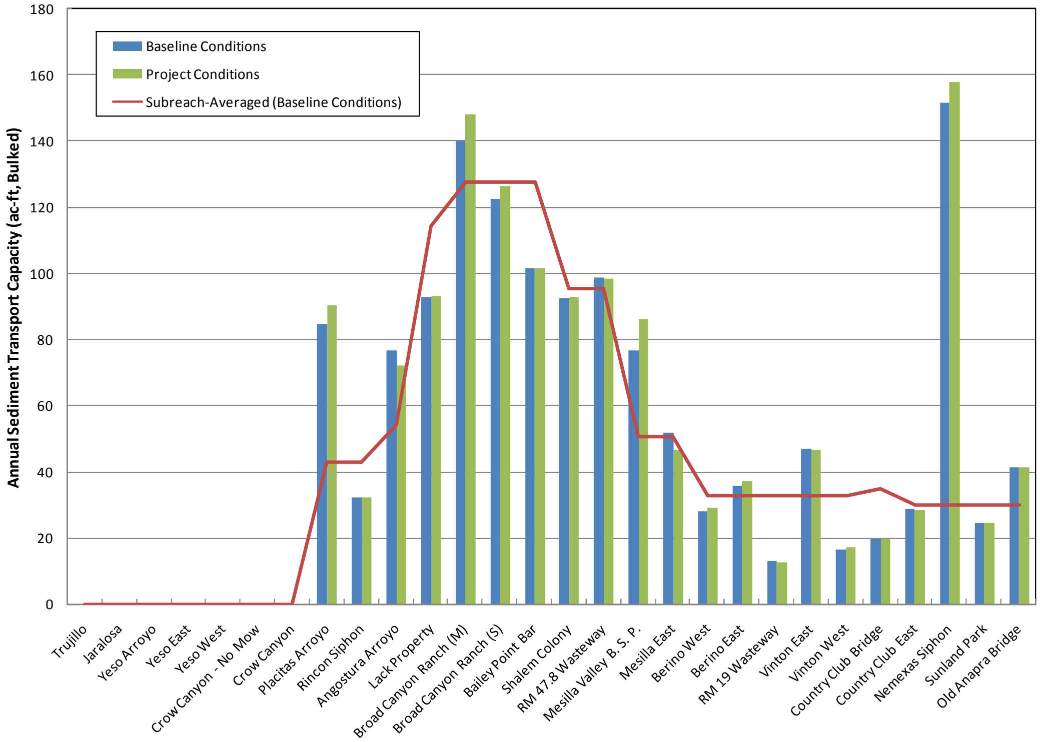

Figure 5.6. Comparison of the annual transport capacity at each of the restoration sites under baseline and project conditions. Also shown is the subreach-averaged annual transport capacity under baseline conditions.

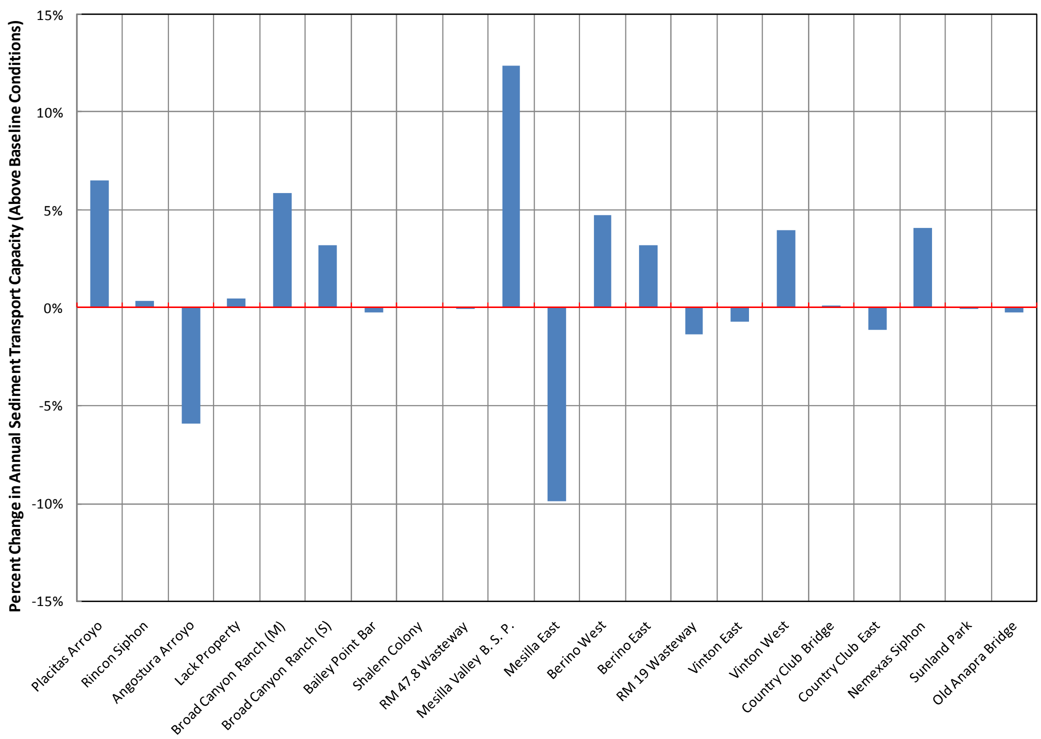

Figure 5.7. Percent change in annual sediment-transport capacity over baseline conditions at each of the restoration sites below Geomorphic Subreach 1.

6. SUMMARY AND CONCLUSIONS

A conceptual restoration plan was developed for the Rio Grande Canalization Project (RGCP) reach that includes 30 individual restoration sites. This plan provides conceptual designs for the sites that, if implemented, would enhance riparian functions, support natural riverine processes and improve terrestrial wildlife habitat. These objectives would be accomplished through various restoration methods and techniques which focus on enhancing river-floodplain hydrologic connectivity, improving riparian ecology, restoring some channel morphology and processes, and increasing channel aquatic habitat diversity. Over the long-term, restoring sites that will sustain native riparian habitat and establish trends for improved channel-floodplain hydrologic interaction while minimizing potential adverse impacts to infrastructure and water depletion was the focus of the study team.

The sites were selected based on a variety of restoration-related criteria that included the following:

- potential for overbank flood inundation without extensive topographic modifications,
- land ownership,
- character of the existing vegetation,
- depth to groundwater,
- access to supplemental water,
- soil conditions,
- size of the site and adjacent land use,
- site location and contribution to the reach-wide restoration objectives, and
- potential restoration cost.

Non-restoration related factors that were considered in the site selection included potential impact to existing infrastructure, endangered species habitat, fire protection, and recreational access.

Prescriptions for the individual sites ranged from removal of existing bank protection, bank destabilization and cessation of maintenance dredging activities to encourage future channel migration to overbank excavation and re-vegetation to increase the frequency of overbank flooding and improve the mix of riparian species. After completing the site analysis, the study team recommended that no restoration activities be conducted at one of the sites (Pasture 18) because there is low potential for developing riparian communities that meet the study objectives at this location. The selected sites are located throughout the RGCP reach, with 11 sites in the Rincon Valley between Percha Dam and the head of Seldon Canyon, 5 sites within Seldon Canyon, and the remaining 14 sites spread throughout the approximately 62-mile Mesilla Valley between Seldon Canyon and American Dam. The area that would be directly affected by the proposed prescriptions ranges from 2.5 to 90 acres, with a total area of about 553 acres. The sites in the Rincon Valley represent about 233 acres (~42 percent of the total), those in Seldon Canyon about 58 acres (~10 percent of the total) and those in Mesilla Valley about 261 acres (~47 percent of the total). Eight habitat types were targeted in the conceptual designs and the cumulative area of the individual types range from 31 acres (Screwbean mesquite) to 171 acres (Dense shrubs/SWWF Habitat) (**Table 6.1**). The total estimated cost to implement the proposed designs is approximately $5.16M, ranging from only a few thousand dollars at the sites where a limited amount of site work would be required (e.g., the mouths of

Yeso, Placitas and Angostura Arroyos) to about $834,000 at the Lack Property site (RM 71.5) where extensive re-vegetation would be required.

Table 6.1 Summary of target habitat types.

Target Habitat	Area (acres)	Number of Sites[1]	Percent of Total Acres (%)
Forest	43.0	4	8.0
Woodland	98.5	7	18.2
Dense shrubs (SWWF)	173.7	12	32.1
Shrubs	31.4	2	5.8
Screwbean mesquite	31.3	2	5.8
Meadow	51.7	4	9.6
Grassland & savanna	63.4	3	11.7
Aquatic habitat	47.8	3	8.8
Total	540.7		

[1]More than one target habitat is present at some sites.

An analysis of the historical flow records indicates that an average of about 9,300 ac-ft of supplemental water would be required for each 3,500-cfs restoration release that would consist of a 1-day ramp up from the irrigation operational release, 2 days of steady flows at 3,500 cfs and a 1-day ramp-down. The frequency of these events that would be required to sustain the restoration sites depends on future hydrologic and runoff conditions. Based on the historical flow records for the period from WY1951 through WY2007, the 3,500-cfs release would have been necessary in 13 of the 57 years (about 22 percent). Based on this relative frequency, about 2,500 ac-ft of supplemental water would be required on an average annual basis.

The changes in vegetation communities associated with the restoration activities would result in a net increase in annual depletions due to evapotranspiration (ET) of about 420 ac-ft. The change in net depletions along the reach during the 2,350-cfs operational irrigation release after implementation of the plan would be negligible. For the 3,500-cfs target restoration release, there would be an estimated 200 ac-ft net loss of flow at American Dam compared to baseline conditions.

Full implementation of the restoration plan would result in a small net decrease in water-surface elevations in the vicinity of many of the sites during the 10- and 100-year floods, and the effects on the reach-wide sediment-transport balance would be negligible. Except for the three tributary-mouth sites (Yeso, Placitas and Angostura), the effect of the individual site prescriptions on local hydraulic and sediment-transport conditions over the range of anticipated flows is relatively small. The river would respond to these changes through minor adjustments to the cross-sectional shape and bed-material characteristics, with no perceptible change in channel stability. At the tributary mouth sites, the prescriptions envision significant changes in cross-sectional shape and channel alignment that could affect the local sediment-transport balance. These sites should be monitored closely to insure that the changes do not adversely affect the levees and other infrastructure.

The 30 sites recommended in this report represent a diverse cross section of the riverine and riparian restoration potential in the RGCP reach. These 30 sites should not be construed as the only viable restoration sites in the river system. There may be opportunities to revise the designs, expand the sites, or investigate new locations during implementation as more data becomes available. River restoration planning requires a long-term commitment and should evolve as success or failure of implemented sites is experienced.

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APPENDIX A
Brief Overview of the RGCP FLO-2D Model

Brief Overview of the RGCP FLO-2D Model

The original FLO-2D RGCP model was developed in 2004 by Tetra Tech, Inc. for the Corps of Engineers to predict the potential flood inundation associated with the 100-year design flood event. The FLO-2D model development and results for riparian restoration baseline conditions were presented in the 2007 baseline report. The Corps'1996 report, *Rio Grande Canalization Improvement Project, Hydrologic and Hydraulic Analyses*' for the USIBWC provided the background information to assess the return period and project design flooding.

The RGCP FLO-2D model consists of 43,937 grid elements (250 square feet) and 2,046 channel elements. The grid system topography was generated from a 2005 LIDAR digital terrain model of Doña Ana County, New Mexico administered by the Doña Ana County Flood Commission (DACFC). High resolution aerial photography prepared with the LIDAR database was rectified into 1-foot pixels provided floodplain details. Channel cross sections from Caballo Dam to American Diversion Dam in El Paso were surveyed for the original model development. There were a total of 145 cross sections located about every one-half mile with more cross sections surveyed in the vicinity of hydraulic structures. These cross sections were distributed and interpolated to 2,046 channel elements.

Various floodplain details were added to the model including levees, hydraulic structures, evaporation and infiltration. There are approximately 65 miles of levee on the east side and 56 miles of levee on the west side of the river and generally the levees are set back from the active river channel less than 700 feet. A total of 27 bridges, two siphons and four diversion dams were added to the model as hydraulic structures with stage-discharge rating tables. Water losses due to evaporation and infiltration (using the Green-Ampt) are simulated. River flow is diverted from the river at three diversion dams. Water diversion can be modeled as historical flow or as average steady diversions. Only a few selected wasteways have been monitored for return flows. While some return flows were simulated in the original flood model, no return flows were modeled in the restoration analysis.

Model calibration encompassed three flood routing characteristics: hydrograph shape (volume), hydrograph timing and water surface elevation. The flood hydrograph shape is primarily defined by inflow discharge, irrigation diversions, and system losses (infiltration and evaporation). Peak discharge or discharge spike timing (arrival) at various locations in the system is primarily a function of volume, but is also dependent on resistance to flow. Historical hydrographs were replicated and the water surface elevation surveys were matched. The final calibration had differences in predicted and surveyed water surfaces that ranged from -0.45 to 0.49 feet with an average of 0.034-foot difference per cross section. Typical calibration hydrograph simulations at one of the RGCP gages are shown in **Figures A.1 thru A.3**.

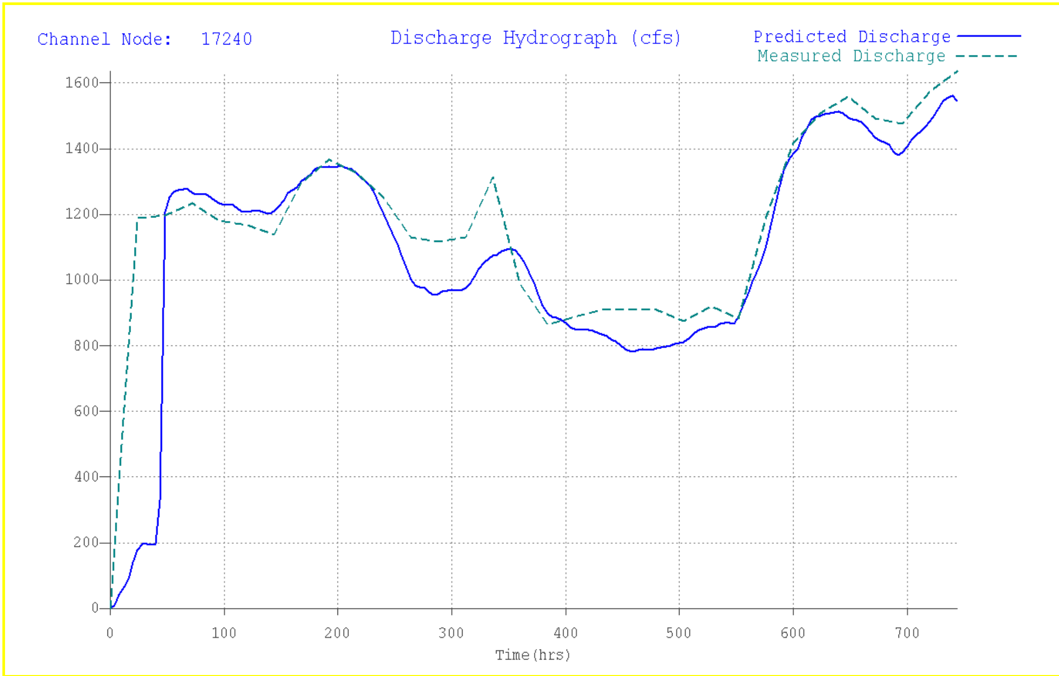


Figure A.1. 2004 Leasburg Gage vs. FLO-2D predicted hydrograph.

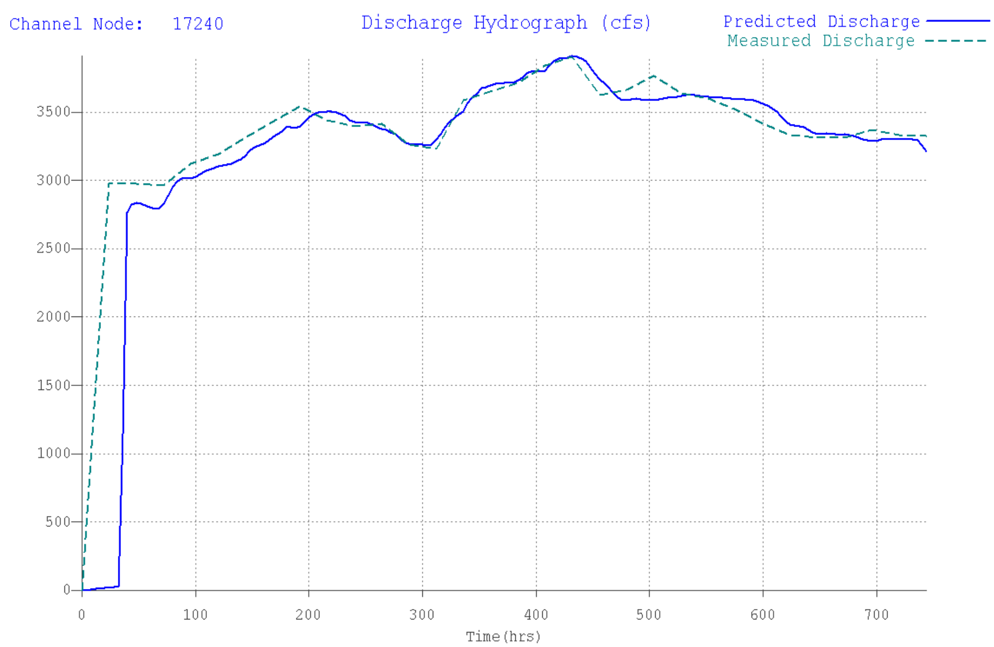


Figure A.2. 1995 Leasburg Gage vs. FLO-2D predicted hydrograph.

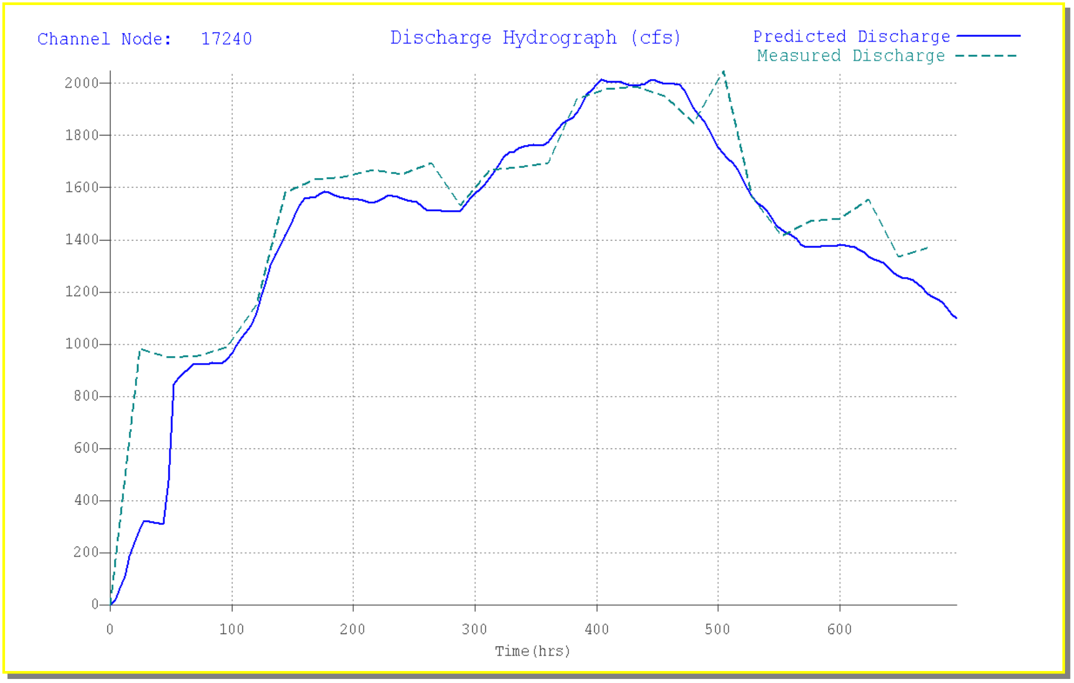
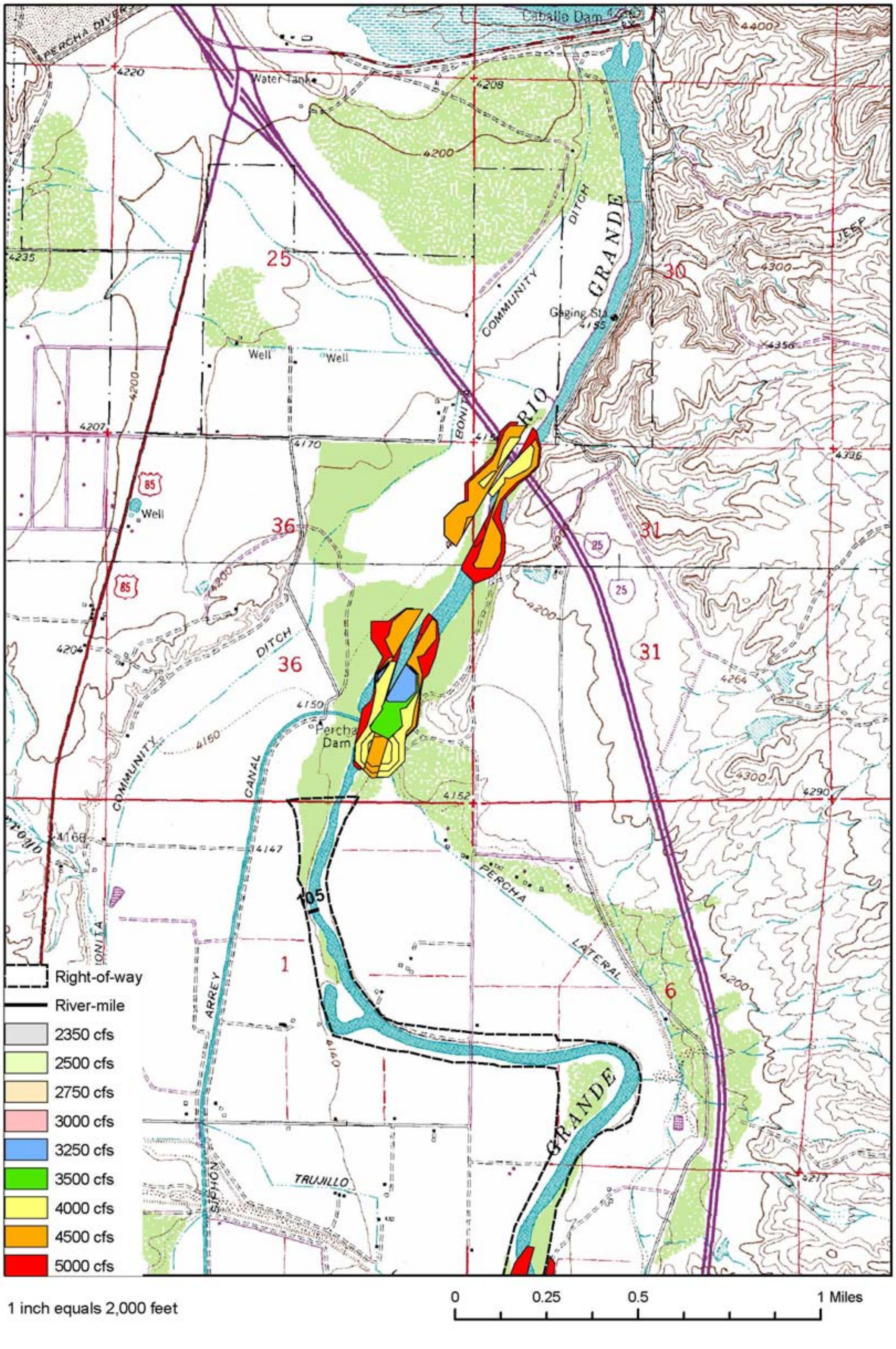


Figure A.3. 1998 Leasburg Gage vs. FLO-2D predicted hydrograph.

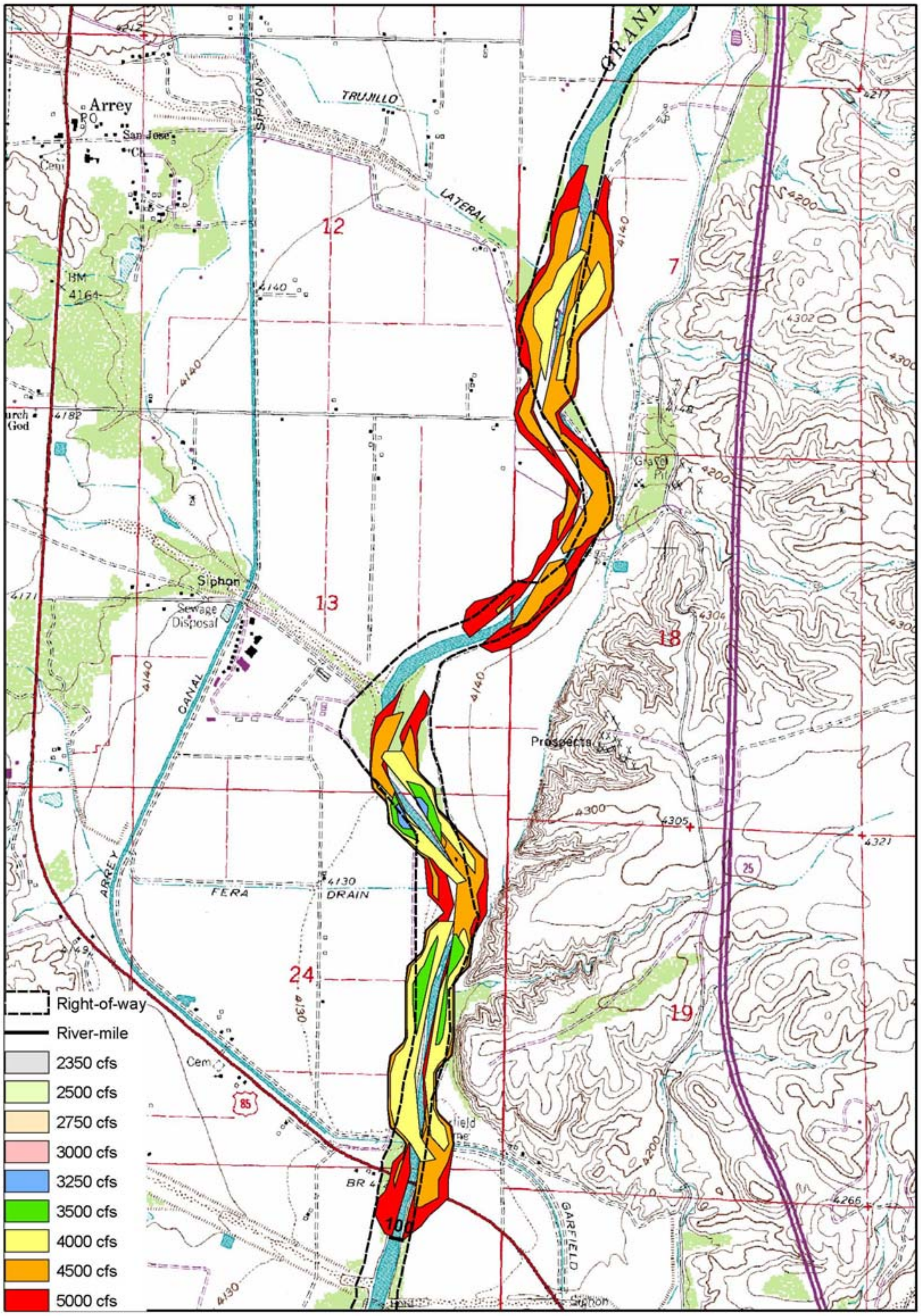
APPENDIX B
Baseline Conditions Inundation Locations

Table B.1. Summary of overbank inundation locations by subreaches in the study area.		
Subreach	Rive Mile	Area Description (discharges refer to Caballo release)
Upper Rincon (Percha Dam – Hatch Siphon)	106	Two areas outside of the USIBWC right-of-way were inundated beginning at 3,250 and 4,000 cfs, respectively.
	103 - 100	Between Trujillo Arroyo and the Garfield Bridge, small areas are flooded at 3,250 to3,500 cfs, becoming more extensive at 4,000 cfs and higher.
	90	A small area at the Hatch siphon began flooding at 3,250 cfs. A more extensive upstream area was involved at 4,500 to 5,000 cfs.
Lower Rincon (Hatch Siphon – Head of Selden Canyon)	83	Upstream from the Rincon Siphon, a large zone on the east bank was inundated at 3,250 cfs and higher; a smaller area on the west bank is involved at 5,000 cfs.
	76	A very small area at the confluence of Bignell Arroyo was flooded at 4,500 to 5,000 cfs.
Selden Canyon (Head of Selden Canyon – Leasburg Dam)	71	Large area outside of the right-of-way on east bank was inundated at 4,500 to 5,000 cfs.
	63	Both banks upstream from Leasburg Dam (and outside of the right-of-way) were inundated at 4,000 cfs and higher.
Upper Mesilla (Leasburg Dam – Picacho Bridge)	--	No overbanking indicated in this subreach.
Las Cruces (Picacho Bridge – Mesilla Dam)	41	A small area on the east bank began to be flooded at 3,250 cfs. A second small area on the west bank (near NMDGF lands) was flooded at 5,000 cfs.
Lower Mesilla (Mesilla Dam – Vinton Bridge)	25	Both banks upstream from Berino Bridge were involved at 4,500 to 5,000 cfs.
	23 - 21	Both banks in this 3-mile portion were inundated beginning at 3,500, and increasing at 4,500 to 5,000 cfs.
El Paso (Vinton Bridge – American Dam)	19 - 0	Overbank inundation was indicated nearly continuously in the lower 19 miles of the study area. Inundation began at several points at relatively low discharges (2,350 to 3,000 cfs), and increased dramatically with higher flows.

Inundation areas from FLO-2D model
River-mile 106



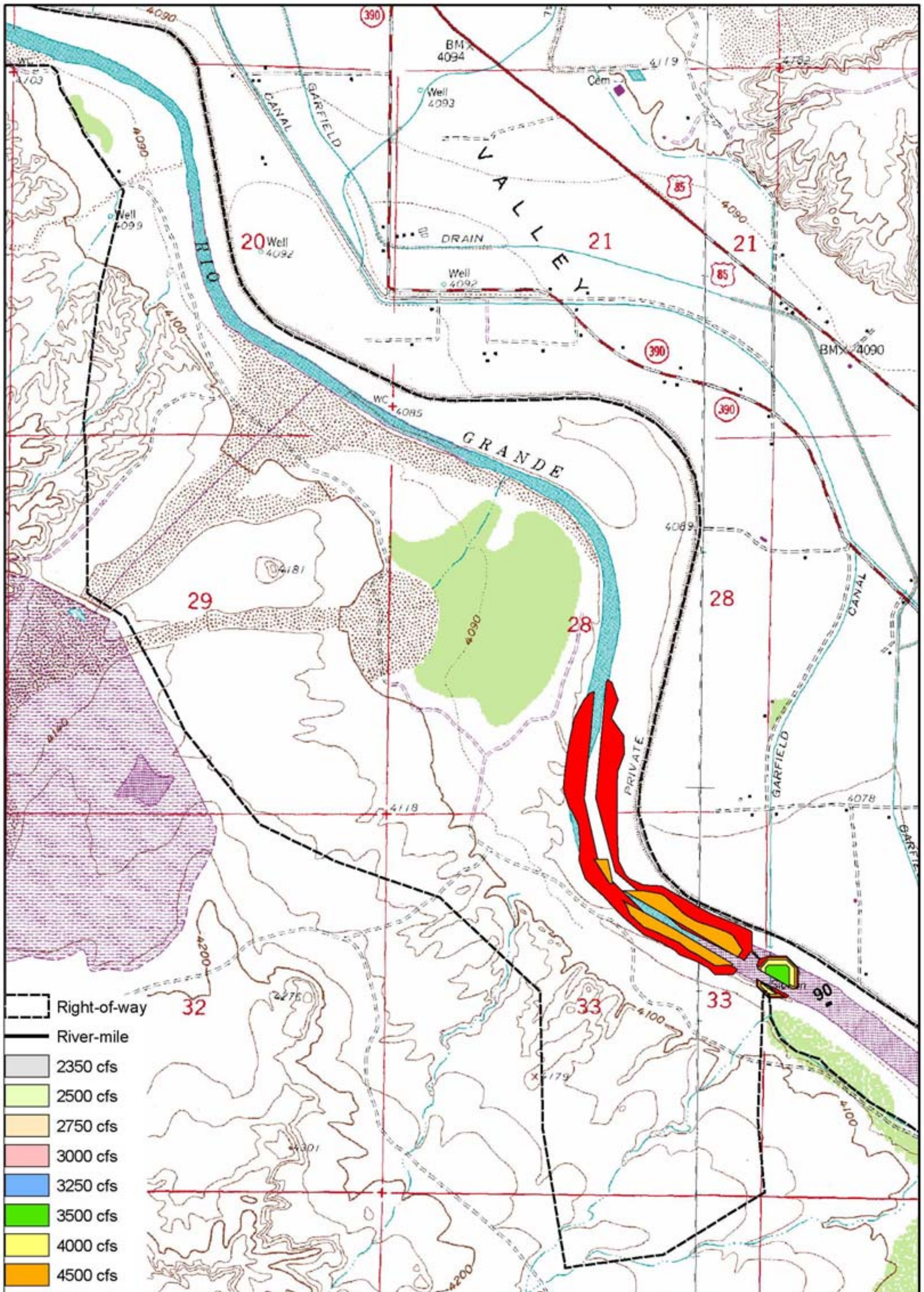
Inundation areas from FLO-2D model
River-mile 103 - 100



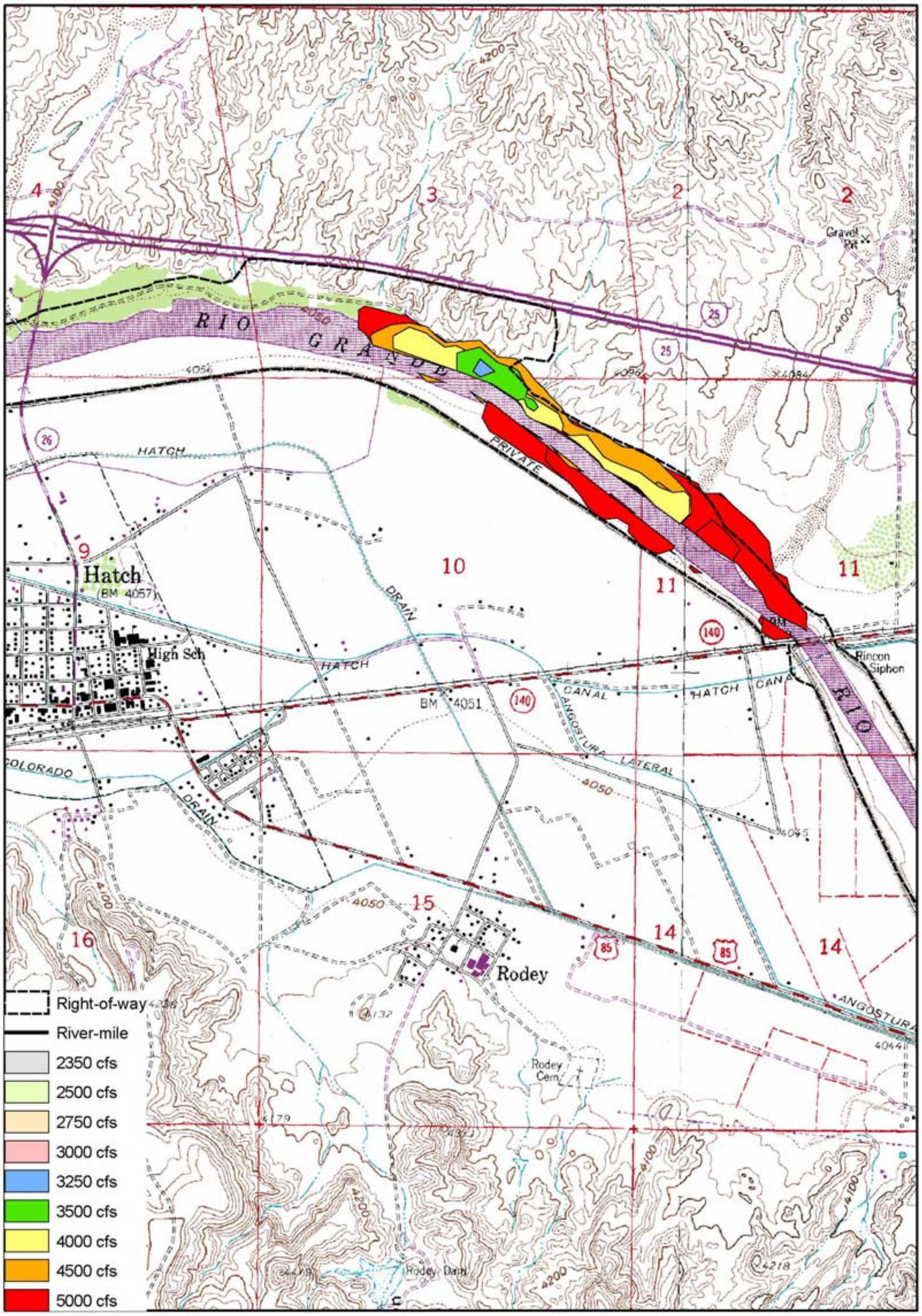
1 inch equals 2,000 feet

0 0.25 0.5 1 Miles

Inundation areas from FLO-2D model
River-mile 90



Inundation areas from FLO-2D model
River-mile 83



1 inch equals 2,000 feet

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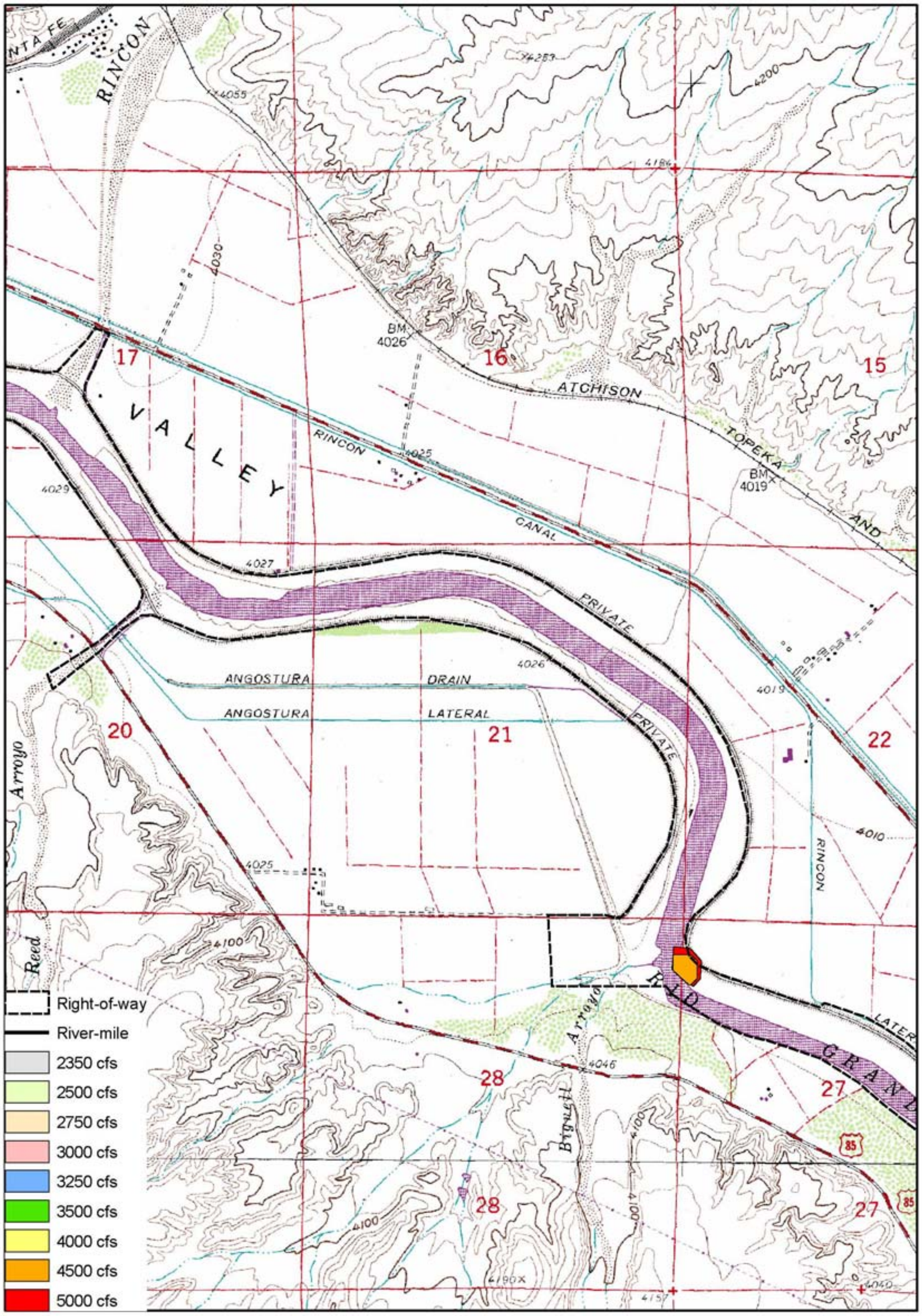
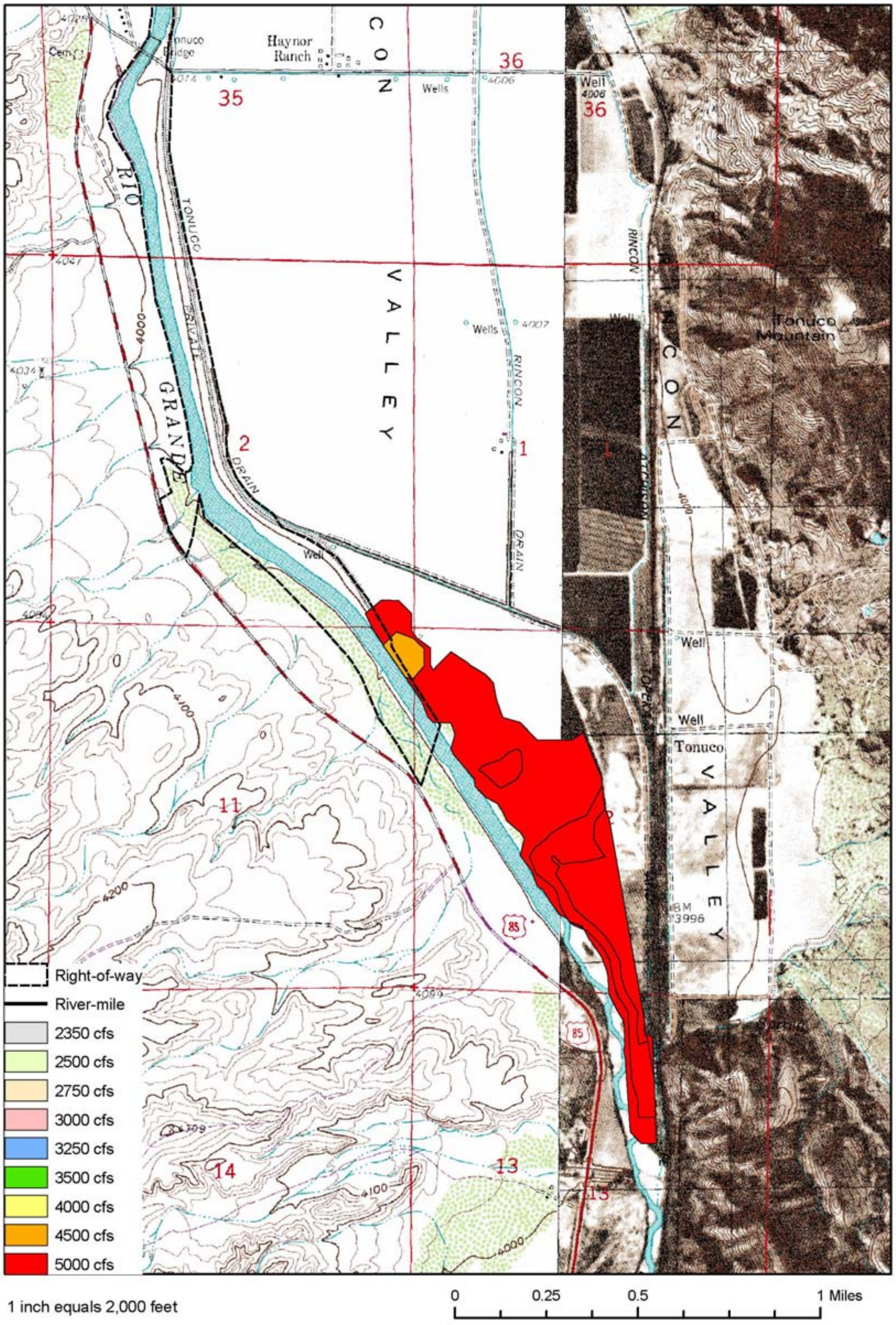
Inundation areas from FLO-2D model
River-mile 76



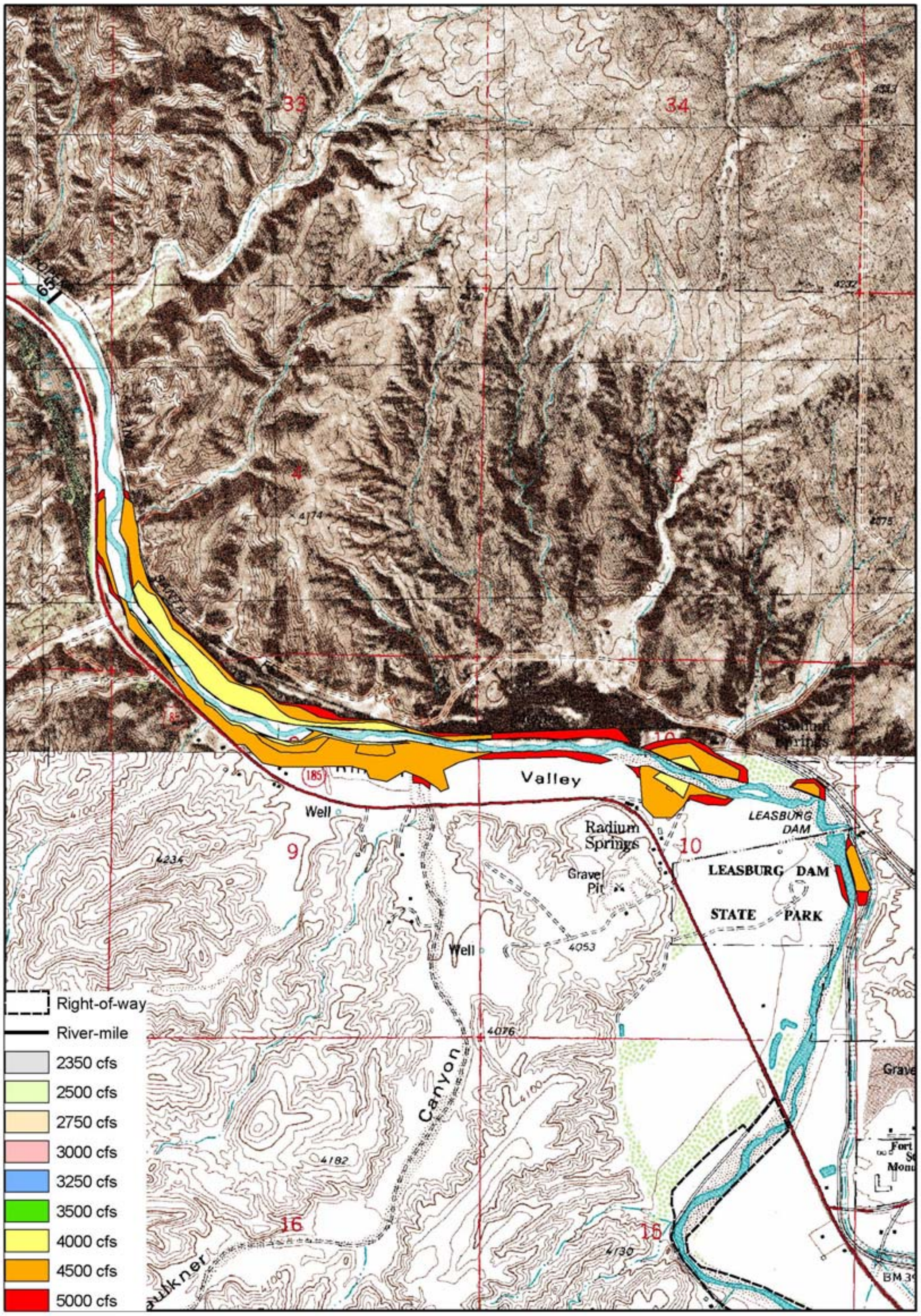
1 inch equals 2,000 feet

0 0.25 0.5 1 Miles

Inundation areas from FLO-2D model
River-mile 71



Inundation areas from FLO-2D model
River-mile 63



1 inch equals 2,000 feet

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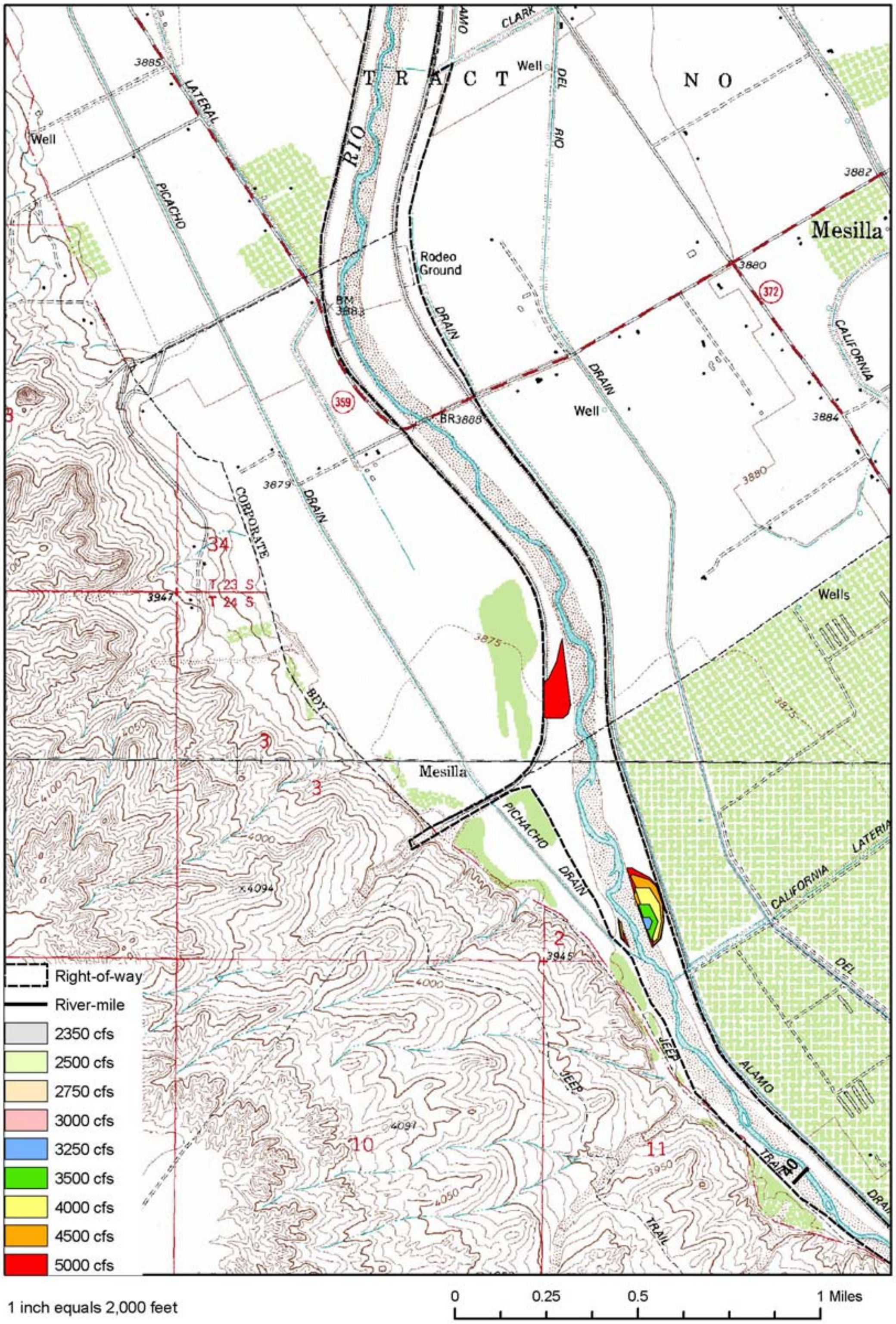
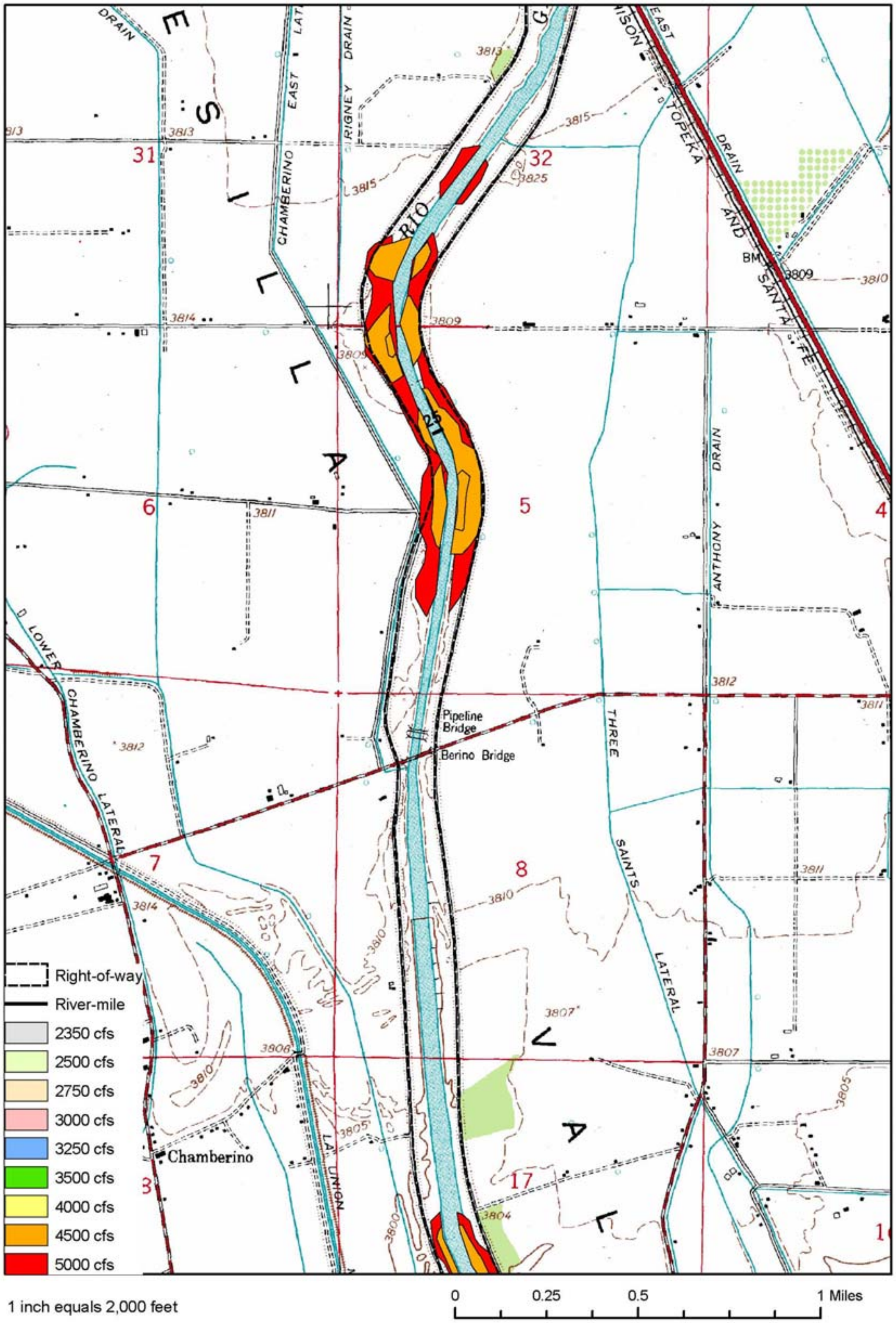
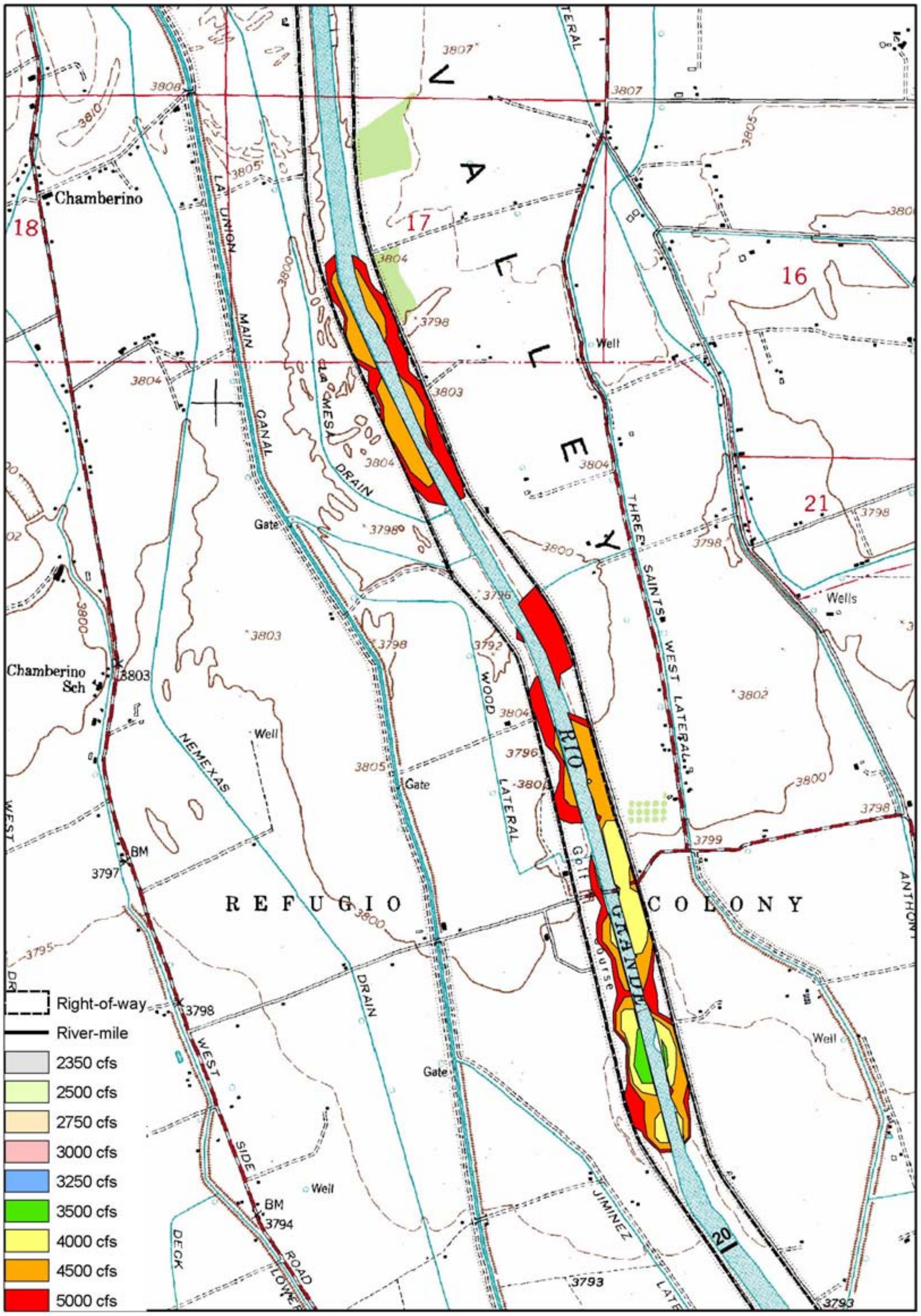
Inundation areas from FLO-2D model
River-mile 41



Inundation areas from FLO-2D model
River-mile 25



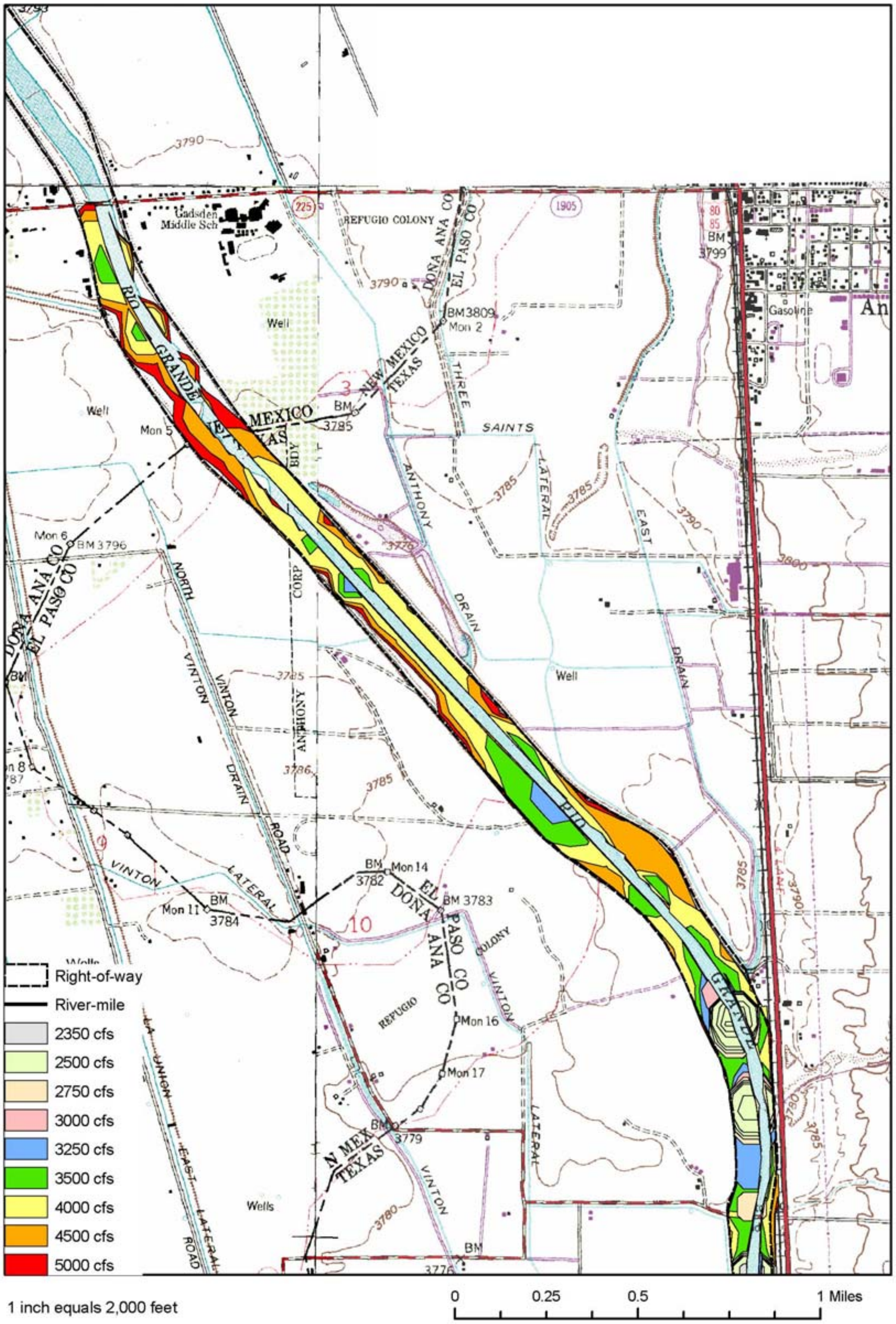
Inundation areas from FLO-2D model
River-mile 23 - 21



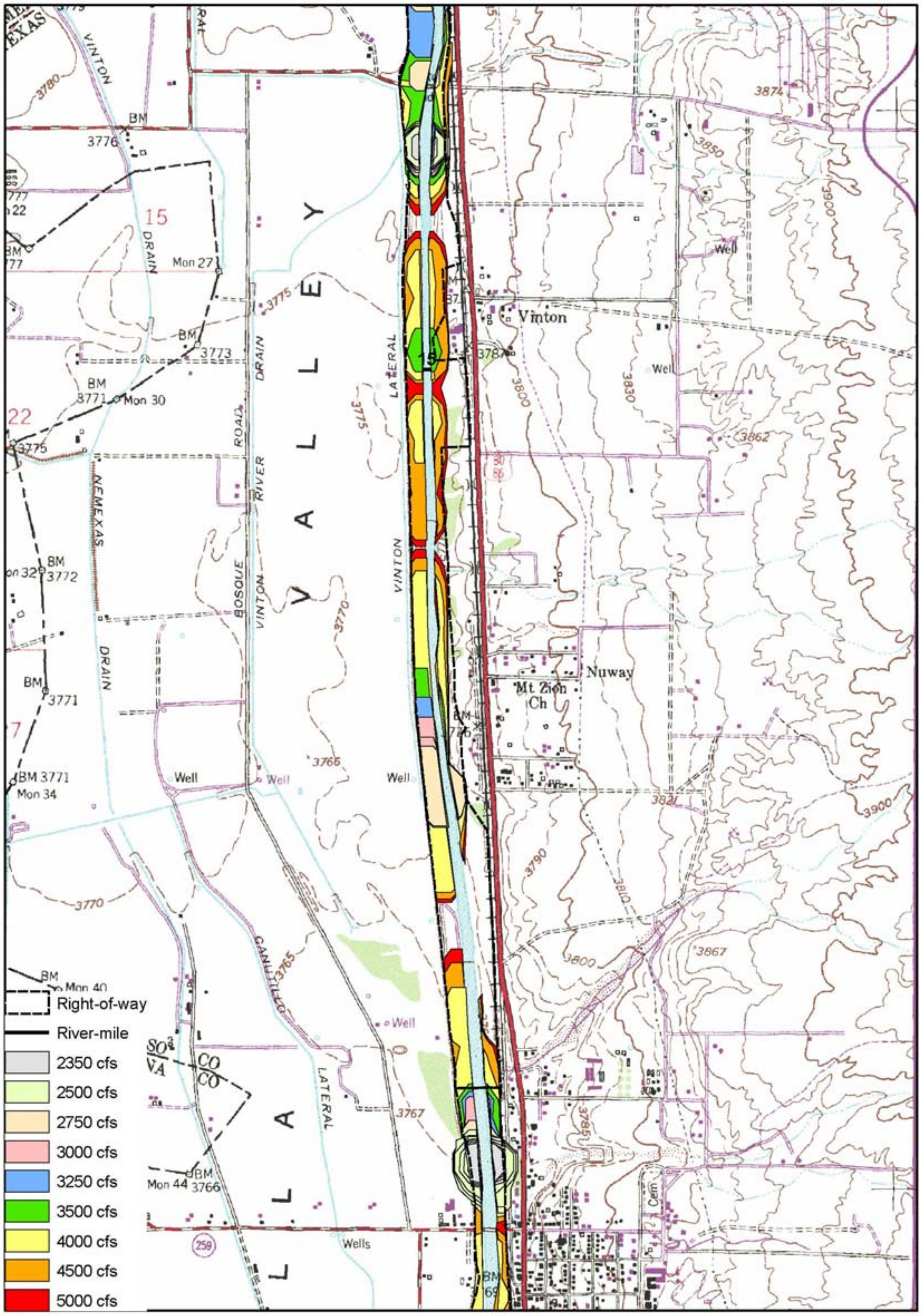
1 inch equals 2,000 feet

0 0.25 0.5 1 Miles

Inundation areas from FLO-2D model
River-mile 19 - 15.5



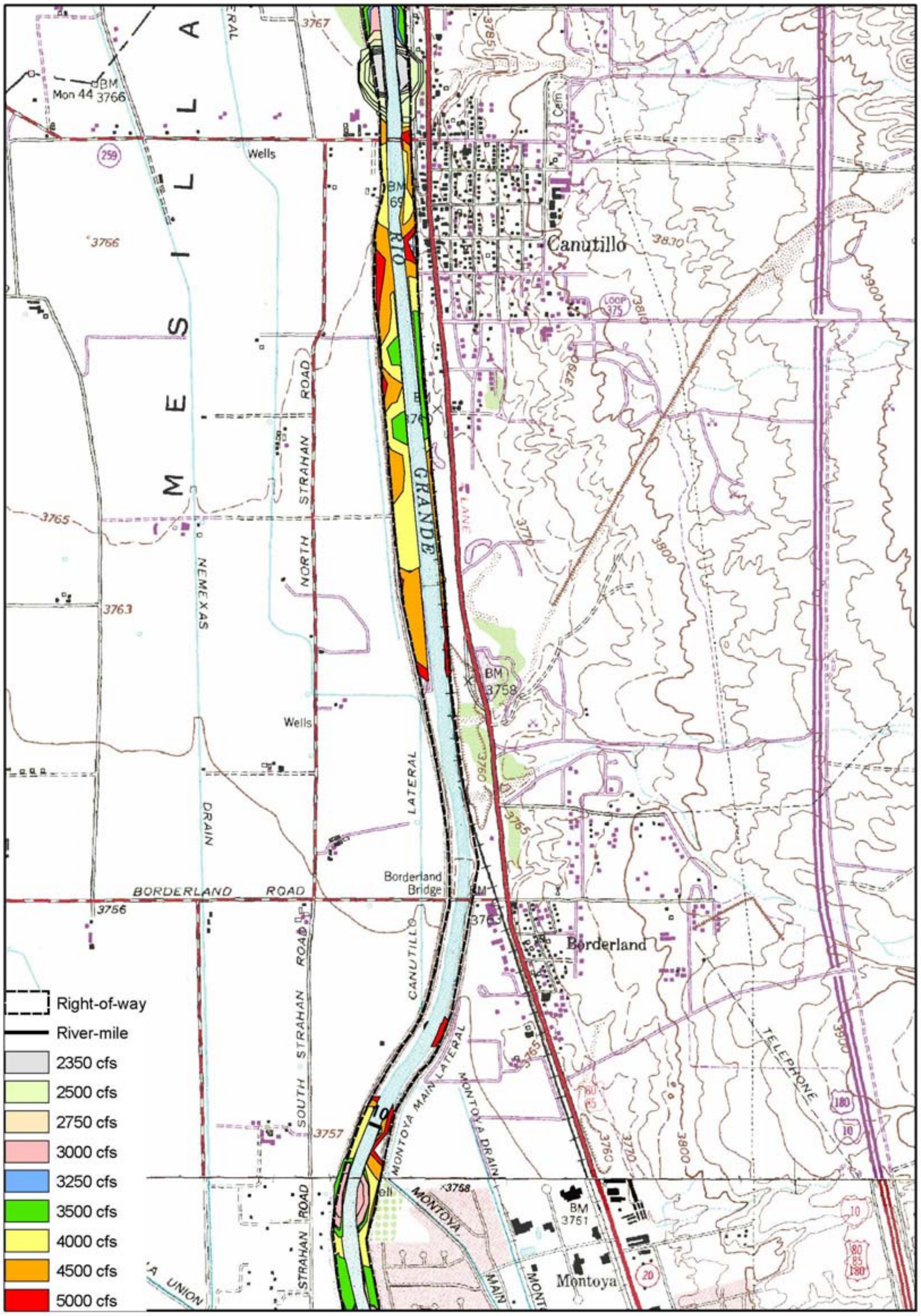
Inundation areas from FLO-2D model
River-mile 15.5 - 13



1 inch equals 2,000 feet

0 0.25 0.5 1 Miles

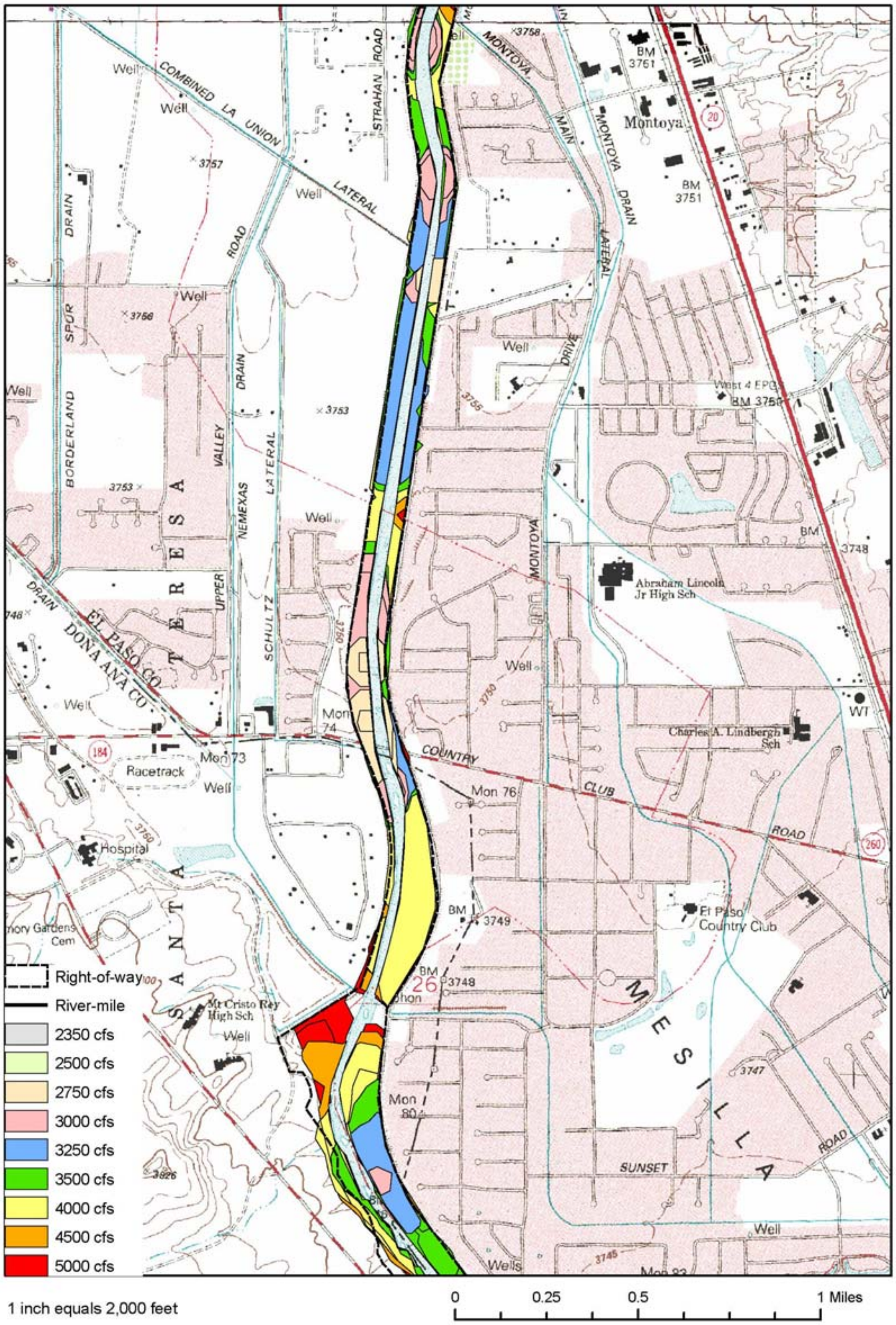
Inundation areas from FLO-2D model
River-mile 13 - 10



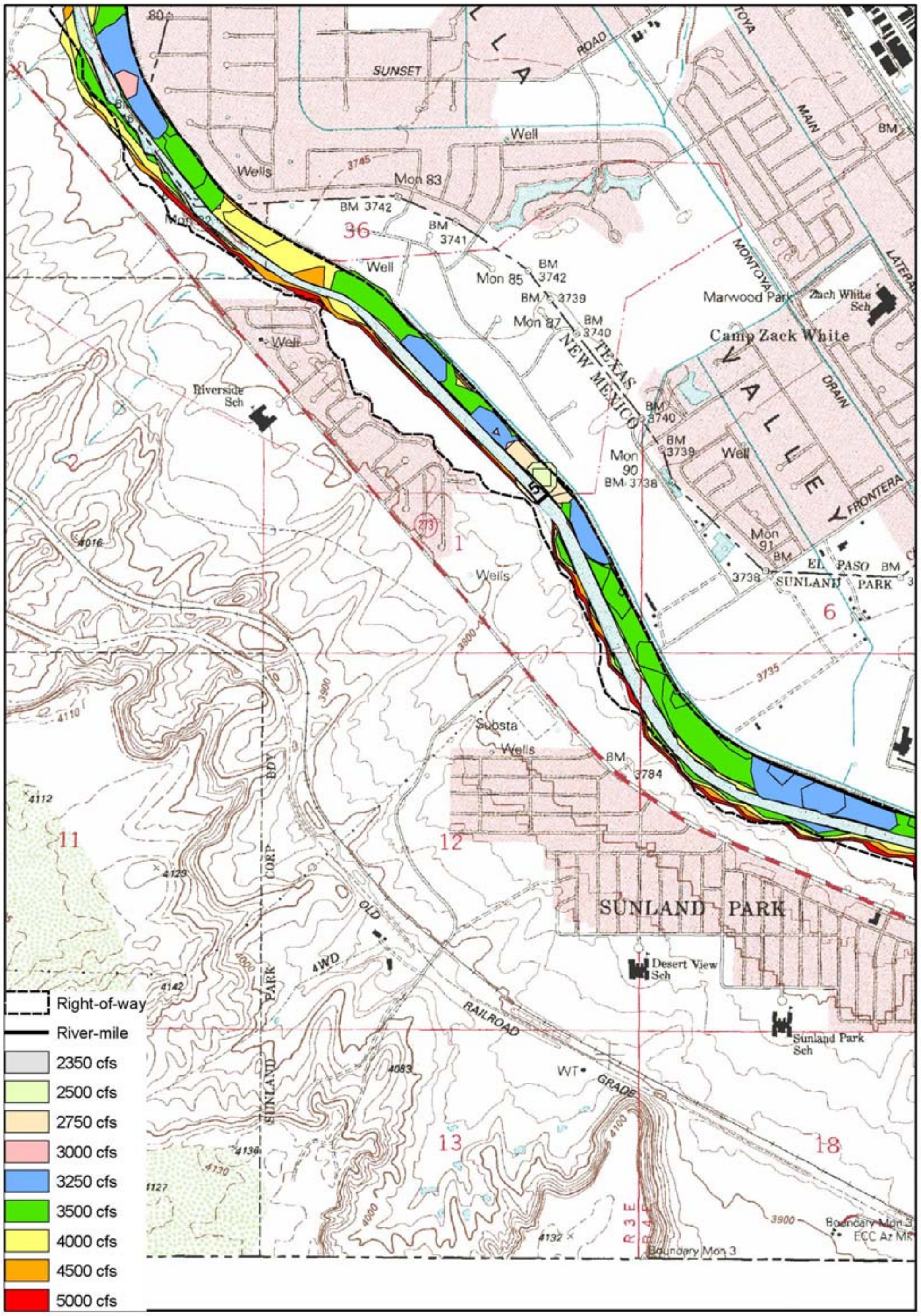
1 inch equals 2,000 feet

0 0.25 0.5 1 Miles

Inundation areas from FLO-2D model
River-mile 10 - 6.5



Inundation areas from FLO-2D model
River-mile 6.5 - 3



1 inch equals 2,000 feet

0 0.25 0.5 1 Miles

Inundation areas from FLO-2D model
River-mile 3 - 0