Chapter IV

Impacts of Water Operations Alternatives

4.1 Introduction

This chapter describes the impacts of the water operations alternatives on the resources discussed in Chapter 3. Analysis of impacts is conducted to estimate the amount of potentially significant change that a given resource might experience. Changes to a resource are considered from multiple perspectives including: 1) how much change is expected, 2) whether the change is beneficial or detrimental, 3) the understanding of complex relationships in the system, and 4) the reliability of the results of the analysis.

The upper Rio Grande basin is a complex system composed of interdependent relationships. Water present in the river at any given time is the result of many factors, including influences from snow pack, precipitation, drought, moisture deficit, evaporation, seepage, river bed geometry and composition, local geology, surface and groundwater diversion, return flows from irrigation and municipal uses, and other factors. Factoring in analyses of aquatic and riparian ecosystems adds further layers of complexity. Because such a large number of variables are possible, several computer models and spatial analysis tools (described in Chapter 2) were used to evaluate the amount of change that might be expected by implementing a proposed alternative. However, the results of these analyses can present conflicting impacts—for example, extremely high flows may benefit riparian habitat while potentially destroying cultural resource sites. When competing objectives and conflicting resource management goals occur, selecting an alternative that provides the best balance is a complicated process.

Decisions made in partnership are more complex than those made by individuals, as different objectives, agency missions, facility purposes, legal requirements, and management goals must be reconciled with human and ecosystem needs. The joint lead agencies (JLA) and cooperating agencies recognize that important decisions about Federal facility operations along the Rio Grande should not be made in isolation, but should involve an open, participatory, and consensus-building process. The JLA decided to implement a formal decision structure for evaluating alternatives in this Water Operations Review (Review) and Environmental Impact Statement (EIS). The decision structure is described in this section and detailed in Appendix P.

4.2 Methods, Tools, and General Assumptions

Decision-support software was selected to facilitate the documentation, analysis, and sharing of decision-making information for this Review and EIS. Criterium Decision Plus™ (CDP) 3.0 (InfoHarvest 2001), available as a free model reader from www.InfoHarvest.com, was selected based on its ease of use. The graphical depiction of decision structure, tradeoff analyses, and uncertainty evaluations enable interested stakeholders to understand the reasons for the ranking of alternatives.

Structuring a formal decision process forces discipline in framing the problem and allows a complex decision to be broken down into manageable parts. The CDP software assists in analyzing the important and sensitive elements of a decision, in evaluating the robustness of the choice made, and in identifying the tradeoffs made in selecting the top-ranked alternative. When the decision results are finalized, there is a record of how and why a decision was made. **Figure 4-1** depicts the elements in a multi-criterion decision process.

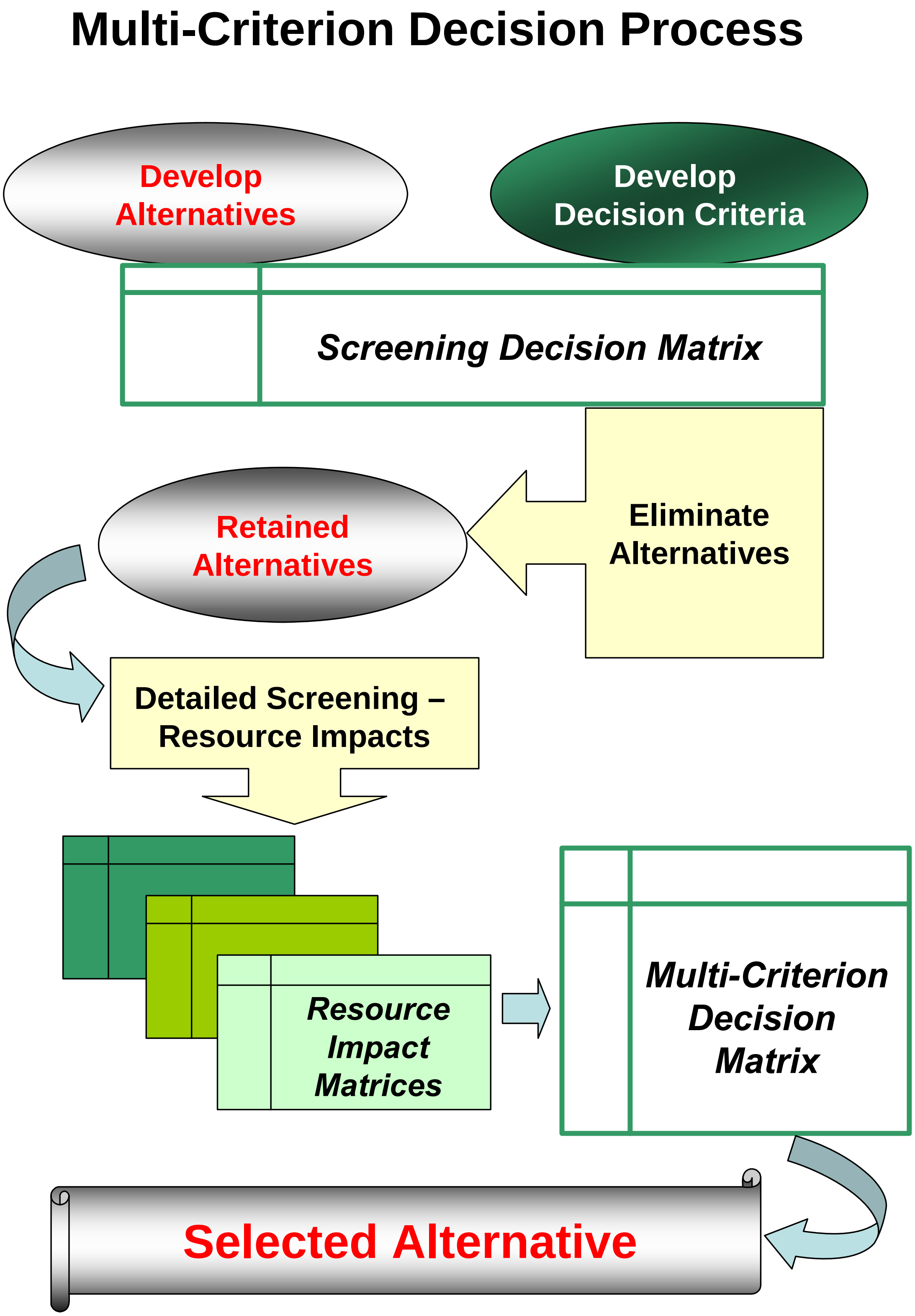


Figure 4-1. Elements in a Multi-Criterion Decision Process

Decision criteria and the relative importance of these criteria were established by the JLA, cooperating agencies, Steering Committee (see Figure 1-1), and other stakeholders prior to the analysis of alternatives and resource impacts. It was hoped that constructing and valuing the decision hierarchy as the first step minimized bias or prejudgment of alternatives. The resource teams then conducted the performance analysis of each alternative in accordance with the technical performance measures supporting the established decision structure. In order to maintain objectivity in resource team evaluation, alternatives were not identified by subjective names, but were instead identified only by letter and number. CDP was then used to document the alternative that best fit the stated hierarchy of decision criteria.

Effective decision criteria are directional, concise, clear and comprehensive, yet not redundant. The selected decision criteria considered the multitude of JLA requirements for environmental and regulatory compliance; multiple objectives in water management; multiple purposes for which facilities are authorized and operated; and stakeholder comments concerning resource impacts and issues. The JLA, Executive Committee, and the Steering Committee had opportunities to review, comment, and assign values to the proposed decision criteria.

The JLA identified three threshold criteria which an alternative needed to satisfy in order to be among those considered for implementation. The three overarching threshold criteria were:

- Meets Flood Control and Safe Dam Operations
- Meets Interstate Compact and Treaty Requirements
- Meets Water Storage and Delivery Needs

Nine decision criteria (**Table 4-1**) were then established for detailed analysis of the six action alternatives and the No Action Alternative. These decision criteria were developed from the Purpose and Need Statements for this Review and EIS and are based on the often competing regulatory requirements concerning natural and human environmental quality and health, cultural and tribal resources protection, and land use and socioeconomic considerations. These decision criteria were ranked in importance by the JLA, Steering Committee, and stakeholders. Three techniques for eliciting preferences among criteria were used. The first technique allocated 100 points across the nine criteria. The second technique established independent values for each criterion on a scale of 1 (low) to 10 (high). The final technique ranked the relative importance of each criterion compared to the others from high (1) to low (9). The average results across all three methods were used to establish the ordinal criteria rankings with the results from the JLAs and Steering Committee shown in **Table 4-1**.

Table 4-1. Ranking EIS Decision Criteria

AGENCY or STAKEHOLDER: JLA & Steering Committees Combined
Date: 11/13/2003
Participants: COE, BOR, ISC & Steering Committee Participants

FINAL RANKINGS	DECISION CRITERION	Fixed Point Criterion Score (Numerical)			Scaled Criterion Rating (Independent)			Ordinal Criterion Rank (Relative)			OVERALL RANK
		JLAs	SC	RANK	JLAs	SC	RANK	JLAs	SC	RANK	
A	Meets Water Storage & Delivery Needs	Threshold			Threshold			Threshold			EQUAL
B	Meets Interstate Compact & Treaty Requirements										EQUAL
C	Meets Flood Control & Safe Dam Operations										EQUAL
1	Meets Ecosystem Needs	15	20	2	7.7	8.8	2	1.7	1	1	1
4	Provides Sediment Management	13	12	4	6.0	6.4	4	3.3	3	3	4
3	Preserves Water Quality	17	15	1	6.7	8.6	3	4.0	2	4	3
2	Provides System Operating Flexibility	15	12	3	8.7	8.1	1	2.7	5	2	2
7	Preserves Desirable Land Uses	4	8	8	4.7	6.9	6	7.7	4	7	7
8	Preserves Recreational Uses	9	6	7	4.0	5.4	8	7.3	9	8	8
6	Preserves Cultural Resources	12	7	5	4.7	4.8	7	6.0	8	6	6
9	Alternative is Fair and Equitable	4	9	9	3.3	5.4	9	8.7	7	9	9
5	Preserves Indian Trust Assets	11	9	6	5.3	6.3	5	3.7	6	5	5

4.3 Scope of Analysis

There are physical, biological, and economic variations and uncertainties inherent in the operation of Federal facilities on the Rio Grande. The needs of a natural ecosystem are not necessarily the same as, or on the same schedule as, the delivery and use of water for human needs. Interrelationships in the ecosystem are not well understood. Attempts to improve or maximize a single resource can be too narrowly focused and can have unintended consequences, resulting in variable success for a given solution. Other factors that can contribute to uncertainty include extremes in precipitation and stream flow, seasonal and annual changes in water demand, and the various temporal and spatial scales available for measurement.

Limited modeling resources confined the Upper Rio Grande Water Operations Model (URGWOM) runs to exploring operating impacts that maximize available flexibility within the framework of the alternatives analyzed. For example, when native storage in Abiquiu Reservoir was allowed to reach a maximum of 180,000 acre-feet (AF), URGWOM was set up to allow storage to be maximized whenever possible. Similarly, if the diversion capacity for the Low Flow Conveyance Channel (LFCC) was 2,000 cubic feet per second (cfs) under a specific alternative, URGWOM allowed water to be diverted to the LFCC whenever it was available beyond the 250 cfs assumed bypass at the San Acacia Diversion dam. Thus, initial planning model results afforded a view of the maximum possible impacts of storage and diversion under a given alternative.

An initial analysis was performed modeling the No Action Alternative with zero diversions to the LFCC. These zero diversion data from the No Action modeling were used as input to other models including the aquatic habitat, riparian vegetation inundation, and hydraulic analyses. Sensitivity analyses were subsequently performed for the No Action Alternative that evaluated several diversion capacities including 500, 1,000, and 2,000 cfs to allow direct comparison with action alternative performance associated with LFCC diversions in the San Acacia Section. While the 40-year URGWOM runs were not completed for each variation of diversions to the LFCC under the No Action Alternative, the sensitivity analyses on the San Acacia section facilitate comparisons with the action alternatives.

The analyses performed by each resource team considered resource impacts in the context of available data and our current understanding of ecosystem dynamics. Expanding on the three threshold and nine decision criteria shown in Table 4-1, the decision hierarchy used in the decision support software for selecting the top-ranked alternative is shown in **Figure 4-2**. Alternatives were ranked according to how well they met each of the criteria to the left.

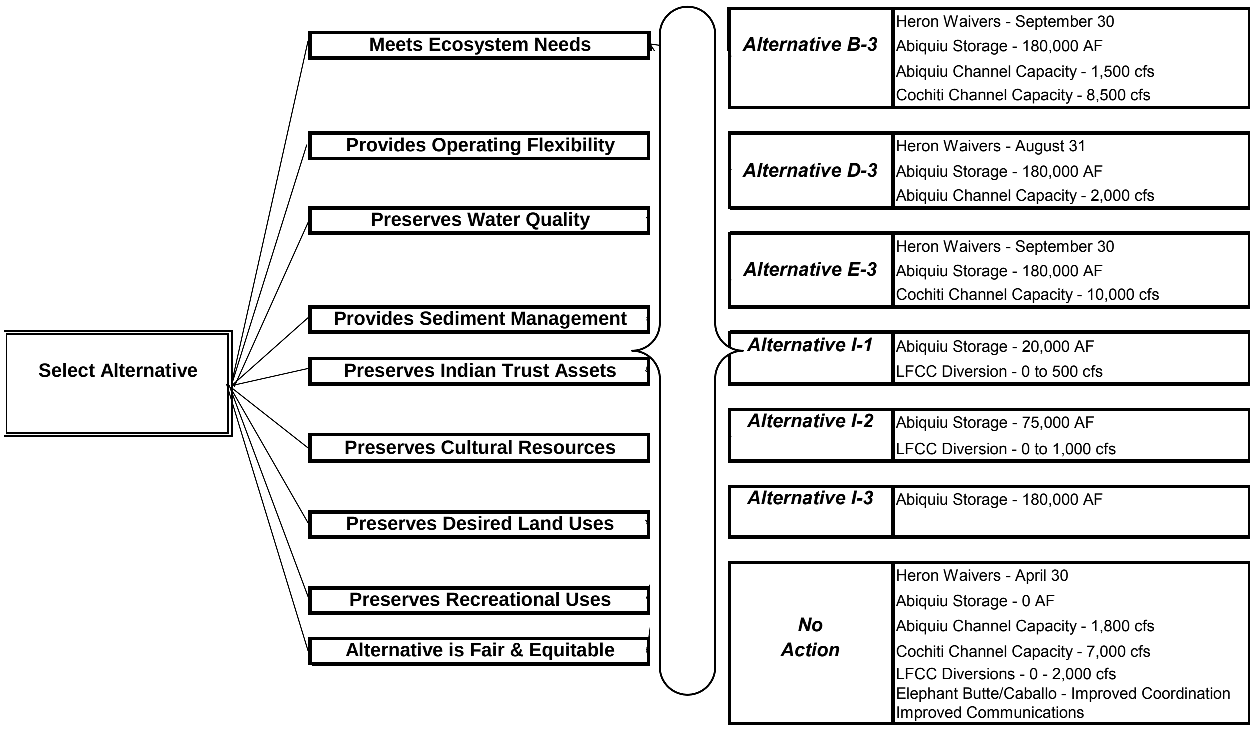


Figure 4-2. Decision Hierarchy

An evaluation of the quality of the data was used to supplement the decision criteria, effects analyses, and resource- and reach-specific conclusions. Each technical team documented datasets used, the corresponding metadata (data about the data, such as who, what, where, how collected, etc.), and rated the relative quality of each dataset within the applicable river reaches. This information was imported into a database to facilitate organizing the data quality by resource, reach, river section, or other parameters. The intent of the data quality database is to disclose the individual and overall quality of the datasets used in the evaluation of alternatives, to identify areas where data are insufficient or lacking, to identify data that may require adaptive management or future study, and to assist decision makers in understanding the comparison of alternatives in the context of the limitations of the data. The data quality, uncertainties, and gaps are further explored in Appendix P.

Each resource team was responsible for conducting a technical evaluation of the condition of the resource; establishing performance measures and analyses to evaluate alternative impacts; performing an assessment of the relative importance among competing criteria describing their resource; performing an assessment of the spatial and temporal variability, data gaps, and other sources of uncertainty inherent in their analysis; and developing and scoring the decision matrix for criteria. The results of these analyses are described by alternative and resource at the end of this chapter.

4.4 Affected Resources

The impacts of proposed water operations alternatives were analyzed by the resource teams using information from various sources: 1) URGWOM-planning model simulation of each alternative, assuming the most conservative implementation (i.e., if LFCC diversion or conservation storage was allowed up to a given limit, the model always simulates diversions up to that limit); 2) URGWOM planning model sensitivity analyses that evaluated alternative performance under a subset of the allowable range (i.e., No Action under various LFCC diversions); 3) database and spatial analysis via the GIS tools; and 4) specialized models specific to each resource, such as the aquatic habitat model, the San Acacia surface water/groundwater flow model (MODBRANCH), and 5) simple analytical and empirical models or calculations. For all cases, the same 40-year hydrograph and starting reservoir conditions were used.

Resources evaluated for changes included hydrologic and geomorphologic variation; aquatic and riparian ecosystem, water quality, Indian trust assets, cultural resources, various land uses – including agricultural and recreational uses; hydropower; flood control; and the regional economy. Alternative impacts by resource are discussed in the following sections.

4.4.1 Hydrology and Geomorphology

The primary changes that occur with alternative water operations are expressed as changes in water flow and reservoir storage. The changes in flow can also cause changes in geomorphology as sediments are moved and deposited along the river channel.

4.4.1.1 Issues

The primary goal for this EIS was to evaluate alternative operations within the constraint of existing authorities in order to better coordinate and manage water in the river system. Consequently, the alternative selected must meet minimum standards for three threshold criteria: safe operations, ability to meet water deliveries, and ability to meet Compact and Treaty obligations.

Safe dam operations were modeled using existing operating rules. These rules prevent water releases or storage that could exceed operating practices. Days at channel capacity (normal maximum flow) were used to evaluate the relative safety of operations among the different alternatives. Prolonged durations (more than 1 month) at channel capacity were deemed undesirable due to ancillary effects on levees, diversion structures, and agricultural lands. Alternatives D-3, E-3, I-3, and I-2 offered improvements compared to the No Action Alternative in duration at channel capacity. **Figures 4-3 and 4-4** show days at channel capacity below Abiquiu and Cochiti dams, respectively. Alternatives B-3 and I-1 performed similar to No Action, with extended durations at channel capacity below Abiquiu Dam occurring in 17 of 40 years. Channel capacities below Abiquiu Dam were exceeded in only 4 years out of 40 for Alternatives B-3 and I-1. Days at channel capacity below Cochiti all showed improvements among Alternatives D-3, I-1, and I-2 as compared to No Action for channel capacities of 7,000 cfs. Alternatives B-3 and E-3 had zero days at their proposed channel capacities of 8,500 and 10,000 cfs, respectively (See Appendix I).

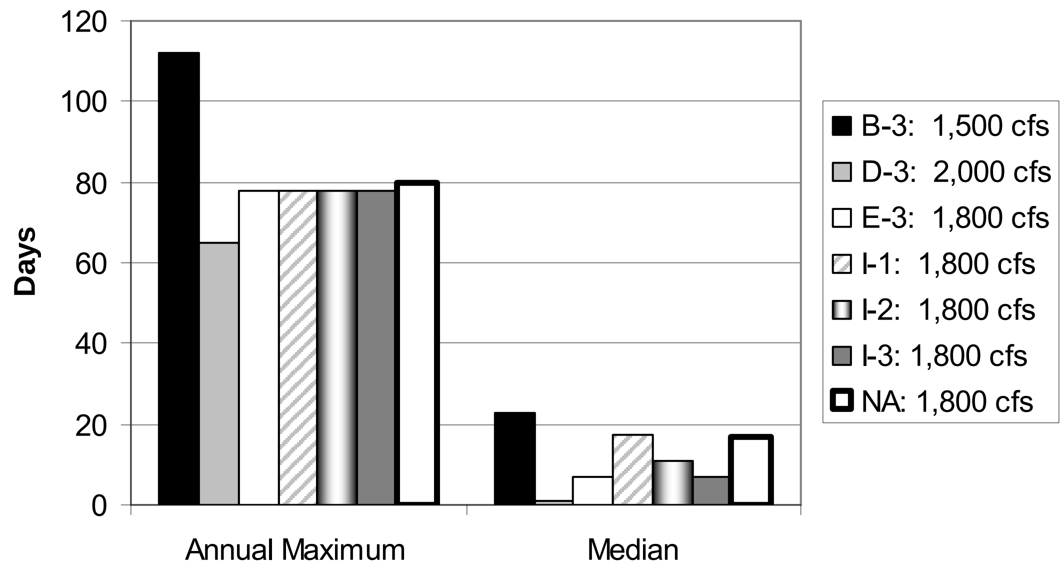


Figure 4-3. Days at Channel Capacity below Abiquiu Dam over 40-Year Planning Period

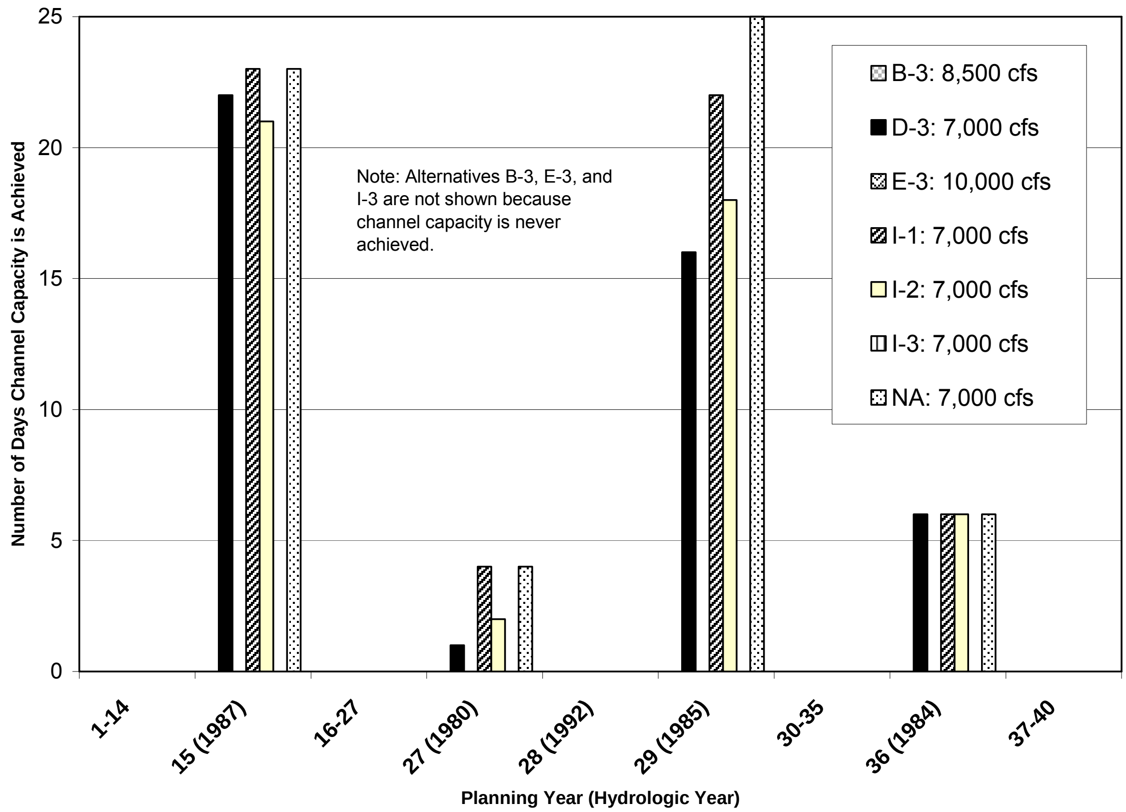


Figure 4-4. Days at Channel Capacity below Cochiti Dam over 40-Year Planning Period

In the Southern Section, flood control protocols for Elephant Butte Reservoir were invoked only when reservoir storage exceeded 2 million AF. This condition occurred only 9 days of the 40-year planning period, thus impacts from changes in water operations for the Southern Section relating to implementation of flood control protocols were not significant.

Heron Reservoir firm yield was used to evaluate water storage for contracted water deliveries. Firm yield is the amount of water that can be provided by a basin and reservoir system with reasonable certainty each year. As shown on **Figure 4-5**, all alternatives retained for detailed analysis were able to support the firm yield of 96,200 acre-feet per year (AFY). Annual median storage at Heron Reservoir is more than 240,000 AFY across the 40-year planning period. The 15th percentile daily storage values under all alternatives approximate the firm yield and occur across alternatives during the dryer years when reservoir levels are drawn down due to downstream demand. The 15th percentile daily storage under Alternatives B-3 and D-3 is slightly below the San Juan-Chama Project firm yield of 96,200 AFY.

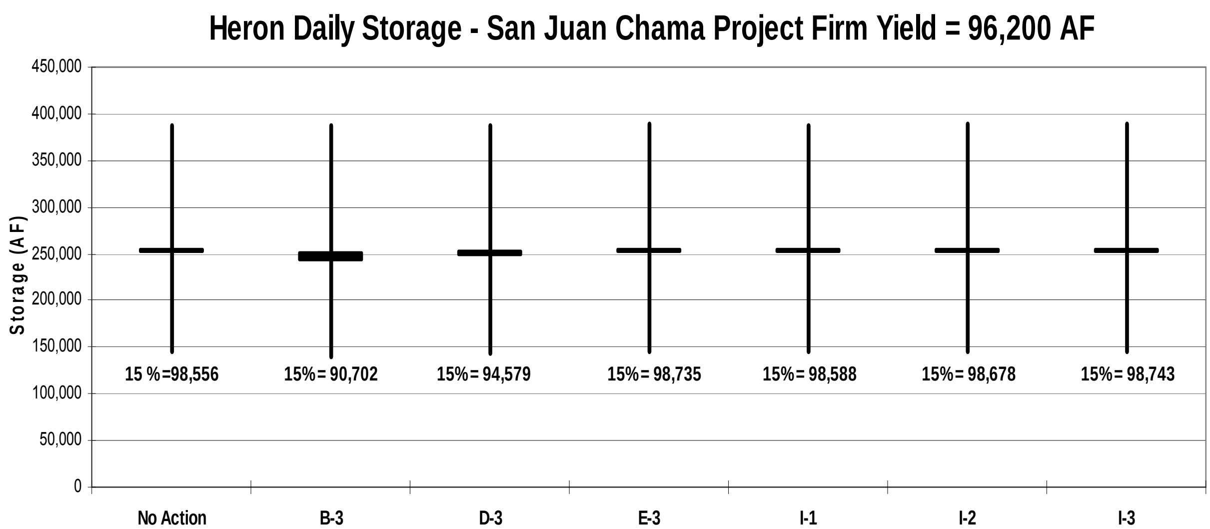


Figure 4-5. Heron Reservoir Storage by Alternative

Compact deliveries were further used to distinguish alternatives, as they differ in their ability to meet New Mexico's Compact obligations. This ability is impacted by both the upstream storage and release pattern of native conservation water and the efficient delivery of water through the San Acacia Section. As shown on **Figure 4-6**, alternatives that maximize storage and possess the largest diversion capacities in the LFCC are the alternatives that maximize Compact deliveries and provide a more favorable credit status. While all alternatives provide a positive credit status at the end of the 40-year planning period, Alternatives I-1 and I-2 do not perform as well as the other alternatives.

While all alternatives offer improvements to New Mexico Compact credit status, Alternatives I-1 and I-2 do not meet threshold criteria for Compact deliveries due to lesser capacities of the LFCC and higher delivery losses incurred in the San Acacia section. Alternatives I-1 and I-2 also experienced extended accrued debit periods for Compact deliveries to Texas of 11 and 6 consecutive years, respectively. Under the No Action Alternative there were 13 consecutive years where New Mexico was in accrued debit status All other alternatives limited the accrued debit period to 4 years under the hydrologic sequence and release assumptions used in the modeling scenarios.

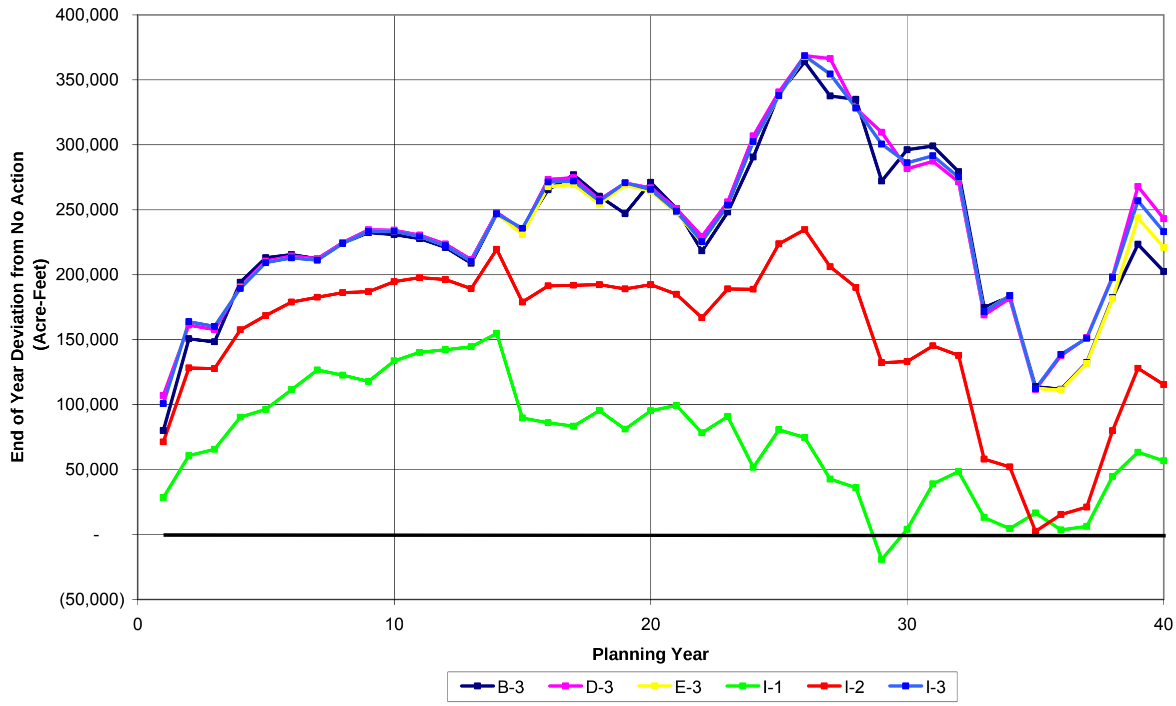


Figure 4-6. New Mexico Credit/Debit Status Compared to No Action

A summary of hydrologic performance regarding threshold criteria is provided in **Table 4-2**. Alternatives I-1, I-2, and No Action do not meet threshold performance criteria for Compact deliveries. However, these alternatives will be carried through in the detailed analysis in order to identify the range of impacts and evaluate mitigation needs as per the request of the National Environmental Policy Act (NEPA) Interdisciplinary (ID) team.

Table 4-2. Summary of Threshold Criteria Evaluation by Alternative

Parameter	Measure	Units	No Action (LFCC at 0 cfs)	B-3	D-3	E-3	I-1	I-2	I-3
THRESHOLD CRITERIA									
Safety of Dams	Set by URGWOM Planning Model Rules	NA	Met	Met	Met	Met	Met	Met	Met
Total Days at Channel Capacity	Below Abiquiu Dam (38 years out of 40)	Days/year	26	30	13	17	27	22	17
	Years where >30 days at channel capacity below Abiquiu	Years	17	17	7	9	17	11	9
	Below Cochiti Dam (4 years out of 40)	Days/year	15	0	11	0	14	12	0
Firm Yield – Heron Reservoir	15th Percentile Annual Storage (Target 96,200 AF)	AF	98,556	90,702	94,579	98,735	98,588	98,678	98,743
Compact Deliveries	Median New Mexico Compact Credit Status	AF	48,725	272,065	296,788	290,319	125,356	208,579	295,569

Notes: *Range of flows under No Action at LFCC Diversions of: 0, 500, 1,000, and 2,000 cfs.
** Range of flows under No Action LFCC Diversions not evaluated – comparisons reflect action of LFCC, not difference between alternatives at same level of NO Action diversion.

4.4.1.2 General Conclusions

Alternatives I-3, E-3, D-3, and B-3, listed in order of preference, offer the best performance for maximizing both native Rio Grande conservation storage in Abiquiu Reservoir and LFCC diversion relative to the three threshold criteria under the assumed release pattern: safe operations; ability to meet water deliveries; and ability to meet Compact and Treaty obligations. Despite exercising maximum potential to store and divert water, actual hydrologic inflow conditions limit storage and diversion during dry years. In many years, Rio Grande Compact restrictions further limit storage until downstream obligations are met. The alternatives maximizing conservation storage offer significant advantages in accommodating multiple uses, especially if year-to-year carryover is negotiated for stored water. The multi-year carryover offers the potential to provide a stored water reserve that can be tapped for multiple benefits during later dry years. By offering more options for water storage and management control, water releases could be used to maximize flood peaks and minimize periods of intermittency. However, the impact of carryover storage and different release patterns of the conservation pool on the threshold criteria was not evaluated in this EIS.

The I-2, I-1, and No Action Alternatives offer fewer opportunities for storage that reduce operating flexibility in managing water for multiple benefits, including deliveries to meet New Mexico Compact obligations.

Geomorphologic impacts were evaluated along the Rio Chama and Central and San Acacia Sections. Sediment volume decreases for all action alternatives as compared to the No Action Alternative. However, the computed change in bed elevation for the action alternatives is nearly identical to that of the No Action Alternative. Aggradation/degradation changes were insignificant as they were predicted to be on the order of hundredths of feet. Below San Acacia, impacts are related to diversions to the LFCC. Greatest diversions to the LFCC result in increased aggradation due to lesser river flows and less erosive energy along the banks.

4.4.1.3 Impact Indicators

The following indicators were used to evaluate hydrologic and geomorphologic impacts:

Hydrologic Impacts	Geomorphologic Impacts
Reservoir storage	Sediment Volume
Reservoir elevation change	Aggradation/Degradation Trends
Days at channel capacity	Erosion – Bank Energy Index
LFCC usage relative to available flow	
Water delivered for Compact compliance	
Peak discharge	
Availability of winter flows	

4.4.1.4 Methods of Analysis

Water operations and hydrologic impacts were evaluated using the URGWOM planning model. The URGWOM planning model includes the RiverWare surface water model as modified by inputs from the MODFLOW/MODBRANCH surface water/groundwater model developed for the San Acacia Section. Model documentation is provided in Appendix J. The URGWOM planning model simulates the hydrologic response to a change in reservoir operation, channel capacity, or water diversion based on defined physical characteristics of the system. Key assumptions concerning the physical system model included the following: 1) use of a single 40-year inflow hydrograph sequence of historical years; 2) initial use of 2001 reservoir storage conditions; 3) computed losses associated with seepage, evaporation, and transpiration from riparian vegetation along a given reach; 4) using an average year for the link to MODFLOW/MODBRANCH results in the San Acacia Section.

The policy impacts of operating within reservoir-authorizing legislation, Compact and Treaty obligations, imported and native water management, and other operating policy is a source of uncertainty. Rigid triggers for water operations management include limits on upper and lower reservoir storage that correspond to safe operating limits; seasonal flow requirements; Compact restrictions on storage in dry years; and other rules. Diversions by irrigators, municipalities, and other water users were assumed to continue per historic patterns and do not take population growth or year-to-year variability in irrigation demand into account (see Appendix I.).

The URGWOM planning model was calibrated and sensitivity runs were performed to improve model performance relative to historic conditions documented by actual data. However, uncertainties do exist. Model results are provided at specific locations along the river that typically coincide with United States Geological Survey (USGS) stream gages. These gages have a calibration accuracy of about 5 percent. The model was used to compare alternative operations and evaluate resulting differences. However, the resulting flows are only available for key locations along the river and cannot be easily extrapolated to other locations.

The methods used to estimate geomorphic changes in the river are described in Appendix H, and include estimating changes in sediment volume, predicting aggradation/degradation, and evaluating erosion energy by using a bank erosion index.

Thresholds for Significance

Typically, deviations greater than 10 percent from No Action were examined for cause and identified as a potentially significant impact. However, flow records at key model gages were considered accurate within 5 percent, as this is the standard of calibration used by the USGS for actual gage data. Thus, changes in flow within 5 percent of No Action were not deemed significant.

4.4.1.5 Discussion of Results

Hydrology

To understand the impacts of changes in water operations, it is easiest to trace the flow from the upper Rio Grande watershed and progressively move down each river section (**Figure 4-7**). Flows along the Rio Chama are shown by the graphs on the left and flows on the Rio Grande are depicted by graphs along the right margin. These flows are in part dictated by the 40-year synthetic inflow hydrograph shown on Figure 2-1 in Chapter 2. No operational changes were proposed for facilities located in the Northern Section, thus typical monthly flows at Lobatos characterize main stem Rio Grande flows delivered from Colorado to New Mexico. Peak flows are shown by the patterned bar measured against the left-hand scale. The $75^{th}/50^{th}/25^{th}$ percentile and average flows are shown against the right-hand scale. A percentile is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. The 50^{th} percentile flow is the median, where half the flow records are above and half the flow records are below the median. The 75^{th} percentile is above normal or in the high range of flows. The 25^{th} percentile is below normal or in the low range. In the upper Rio Grande basin, the average monthly flow is typically higher than the median due to the large variability in the higher daily flows. Monthly flows delivered from Colorado to New Mexico at the Lobatos gage had a monthly peak flow near 5,000 cfs, with a median daily flow of 288 cfs. All of the proposed changes to water storage occur along the Rio Chama—specifically modifications to Heron Reservoir waiver dates and various degrees of native Rio Grande conservation storage in Abiquiu Reservoir. Increases and decreases above the current channel capacity below Abiquiu were also considered.

Rio Chama tributary inflow is approximately one third of the total flow passing Otowi gage. Discussion of changes along the Rio Chama requires discussion of both flows and changes in reservoir storage. Changes in reservoir storage are shown on **Figure 4-8**. This figure shows the 75th/50th/25th percentiles and the average storage for each reservoir. Together with flow data reported on Figure 4-7, the effects of operational changes on flows and reservoirs can be evaluated.

Heron Reservoir Waivers: The greatest proposed change in water operations occurs at Heron Reservoir. Potential changes in San Juan-Chama Project water waiver dates include extending possible carryover of water in Heron Reservoir from April to August or September. Changing waiver dates allows water to be held back longer in the reservoir, without that water being lost to the contractor and reverting back to project storage (see Figure 4-5). With the exception of decreased minimum storage under Alternative B-3, there were no significant impacts on 75th, 50th, and 25th percentiles in Heron Reservoir storage—maximum and minimum reservoir elevations are constrained by the model to account for operational safety (see Figure 4-5). Significant impacts are defined as greater than 10 percent changes in storage from No Action.

Figure 4-8 shows impacts to Heron Reservoir pool elevation under alternatives with August and September waivers exercised during dry years when upstream storage is restricted by Article VII of the Rio Grande Compact. Extended waiver dates show that a greater volume of San Juan-Chama water is transferred to El Vado Reservoir during the extended dry period. Additional transfers to El Vado Reservoir result in less water reverting to project storage during dry years. The total volume of water transferred is on the order of 6,000 to 7,000 AF over the entire 40-year period; however, these transfers occur during a dry decade when reservoir storage is already critically low.

Changes attributed to extending waiver dates include the ability to store more water in El Vado as indicated by significantly greater median reservoir storage under Alternatives B-3 and D-3 with September and August waiver dates, respectively. Alternatives E-3 and I-3 show smaller increases in El Vado storage suggesting that downstream native conservation storage in Abiquiu Reservoir may also result in increased ability to store water in El Vado. Daily flows below El Vado are decreased under Alternatives B-3 and E-3 suggesting that September waiver dates cause some shaving of flows along the Rio Chama. Average and median flows were essentially unaffected by extended waiver dates.

Average annual El Vado Reservoir elevation fluctuations are shown on Figure 4-8. The fluctuations in El Vado elevations are primarily related to the sequence of wet and dry years comprising the 40-year hydrologic sequence, rather than significant changes related to water operations. This is because all alternatives, including No Action, initiate storage in El Vado in a similar fashion starting near the same point each spring. However, during periods when Article VII storage restrictions are quickly lifted then enacted (model years 2037 through 2039), noticeable departures from the No Action Alternative are observed. Alternatives B-3 and E-3, with September waiver dates at Heron Reservoir, show the greatest annual elevation departures: about 10 to 20 feet higher than those expected under No Action.

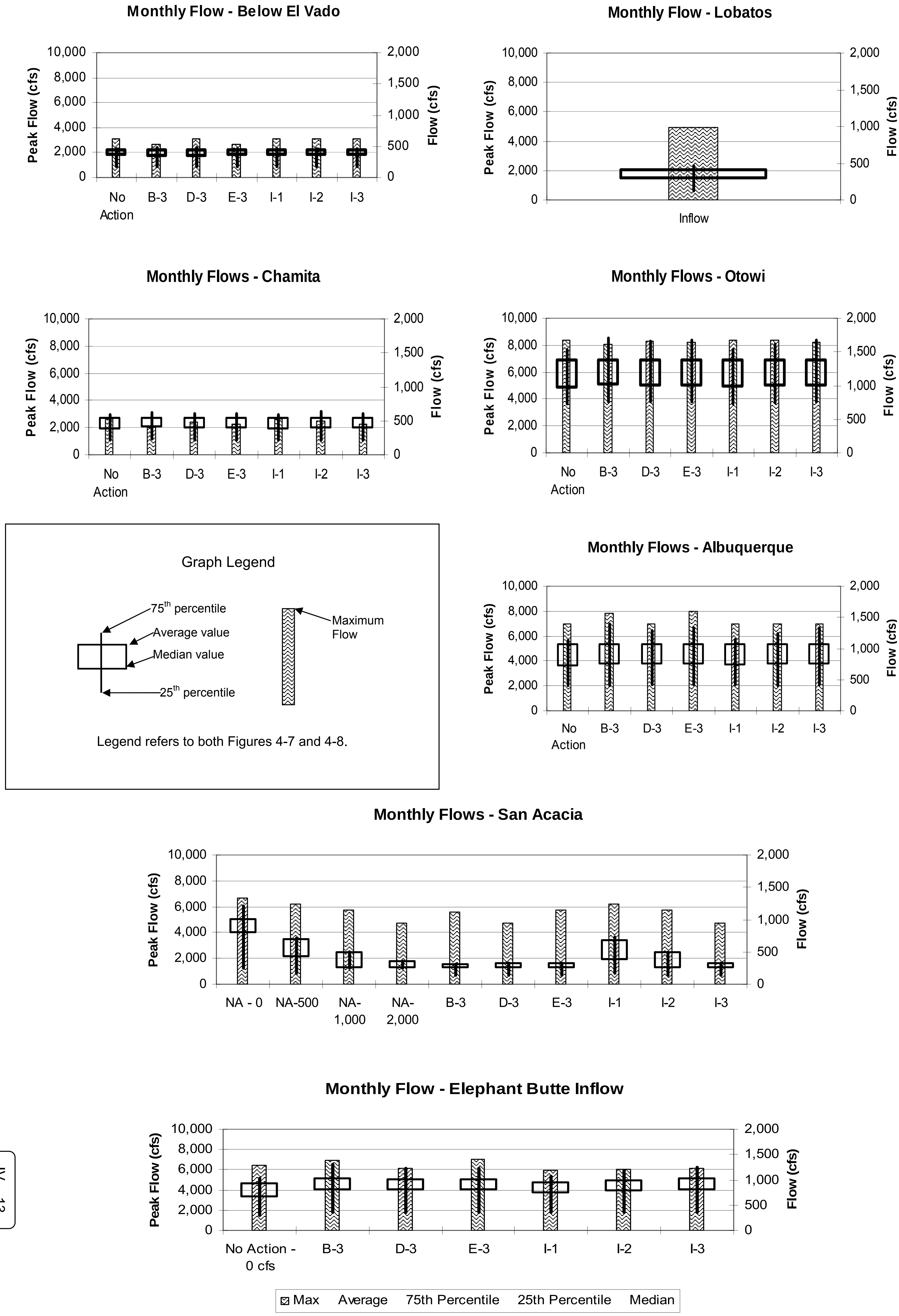


Figure 4-7. Flows at Gages along the Rio Chama and Rio Grande

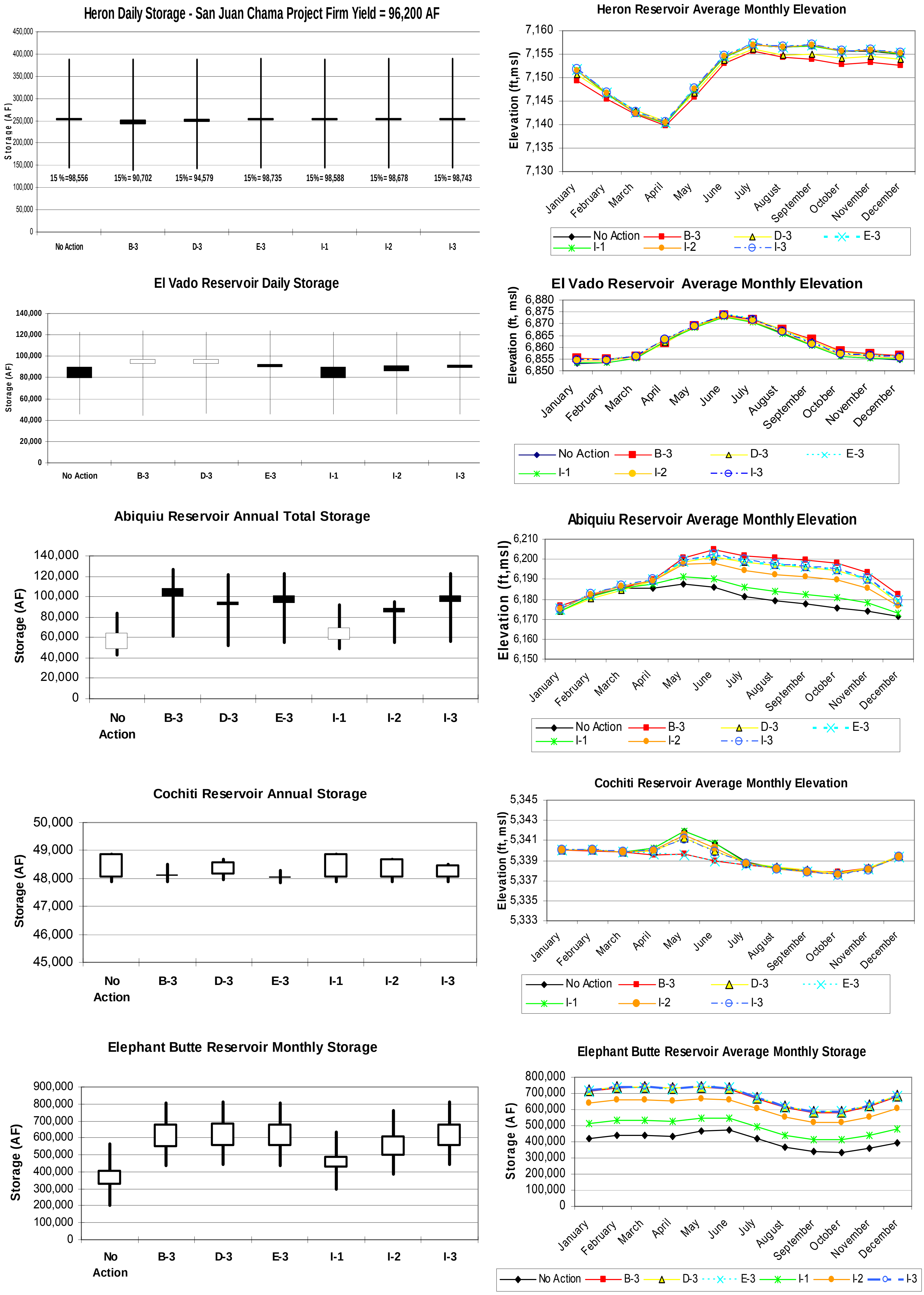


Figure 4-8. Reservoir Storage and Annual Elevation Fluctuations

Abiquiu Native Conservation Water Storage: Maximum storage observed in Abiquiu Reservoir is typically less than the maximums available under the 180,000 AF for all alternatives except B-3. With the lower channel capacity below Abiquiu Dam, Alternative B-3 has a higher duration of flow retention behind Abiquiu Dam resulting in higher total storage and native conservation water storage. Alternatives E-3, I-3, and D-3 are also favorable in providing conservation storage opportunities with mean storage near 100,000 AF. Alternatives I-2 and I-1 store about 84,000 and 62,000 AFY, but are constrained in maximum native water storage capacity to 75,000 and 25,000 AF, respectively. The No Action Alternative demonstrates water typically stored for flood control purposes only, ranging from about 45,000 to 62,000 AFY.

Water stored under the No Action Alternative is subject to Compact restrictions in its use and release (P.L. 86-645), unless specific annual deviations are obtained. The No Action Alternative has no provision for native conservation water storage. Frequency analysis of conservation storage in Abiquiu Reservoir was conducted over the 40-year planning period for the action alternatives (**Figure 4-9**). Results indicate that the opportunity to store conservation water in Abiquiu Reservoir could occur in about 20 of 40 years. Under Alternatives B-3, D-3, E-3, and I-3, the opportunity to store at least 100,000 AF in a given year could occur about 35 percent of the time.

Native conservation storage was identified as water that could possibly be stored and used later in the year. Storage was allowed to occur in the model when specific criteria were met (see Abiquiu Reservoir Native Storage descriptions in Sections 2.4.3 and 2.4.4). The specifics regarding the release, year-to-year carryover, and other use of this water remain to be defined by specific agreements for storage in Abiquiu Reservoir. Storage at Abiquiu Reservoir and changes in downstream channel capacity result in small impacts on daily and percentile flow distributions at the Chamita gage. In developing impact analyses for other resources, resource teams made different assumptions about how much of the native water stored in Abiquiu would be available and how it would be released.

Storage at Abiquiu Reservoir and changes in downstream channel capacity result in small impacts on daily and percentile flow distributions at the Chamita gage. The alternatives storing the least water, No Action, I-1, and I-2 have the higher daily flows, but the 75th/50th/25th percentile flows are similar among all alternatives. Increases in native conservation storage in Abiquiu result in a slight reduction in daily flows at the Chamita gage. As most storage impacts occur along the Rio Chama, frequency analysis of the Rio Chama flow at Chamita for all action alternatives (**Figure 4-10**) indicated that there would be a 10 to 20 percent reduction from the No Action Alternative for flow with a recurrence interval of 1.25 years. A recurrence interval is the probability that a flow event with the same intensity will be equaled or surpassed in the next year – for example, a 100-year recurrence interval indicates a 1 in 100 chance such an event would occur in the next year. The flow with a 10-year recurrence interval would be similar to those under No Action for all action alternatives except Alternative B-3, which would show a reduction of 15 percent. As Rio Chama inflows represent one-third of the flows at Otowi, changes at Otowi were typically less than the 5 percent variability expected from gage error alone, with the exception of slightly higher 75th percentile flows under all alternatives except I-1 due to the release pattern used in the analysis.

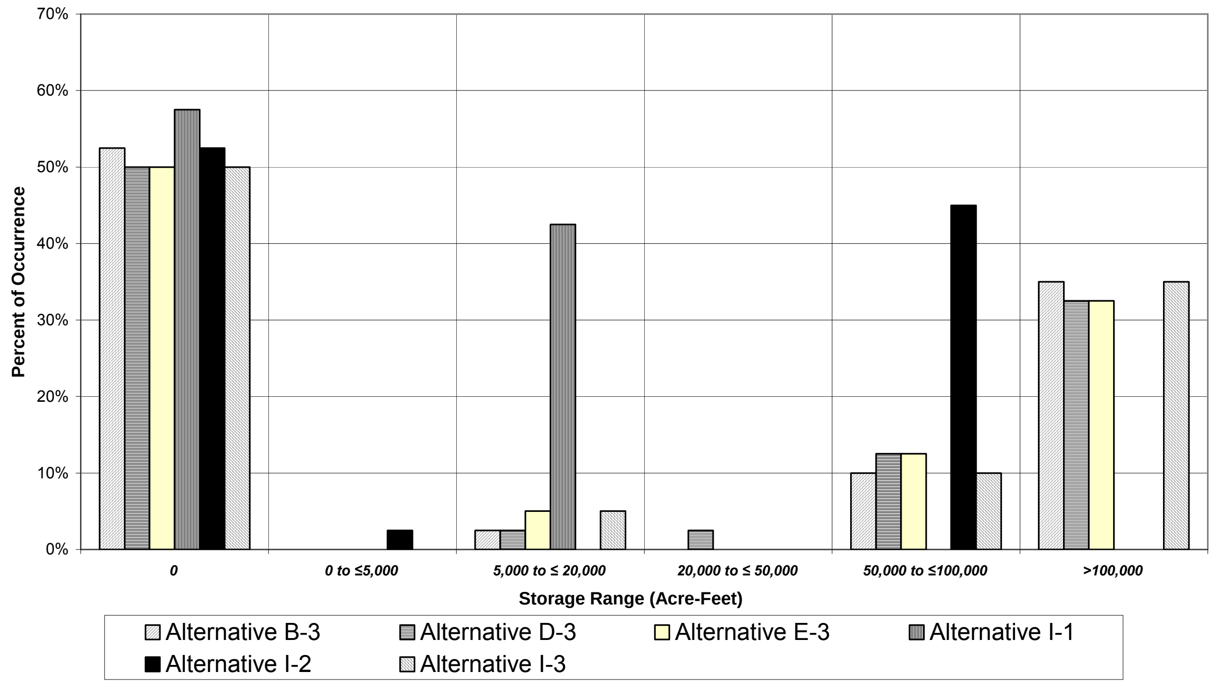


Figure 4-9. Percent of Occurrence of Conservation Storage in Abiquiu Reservoir

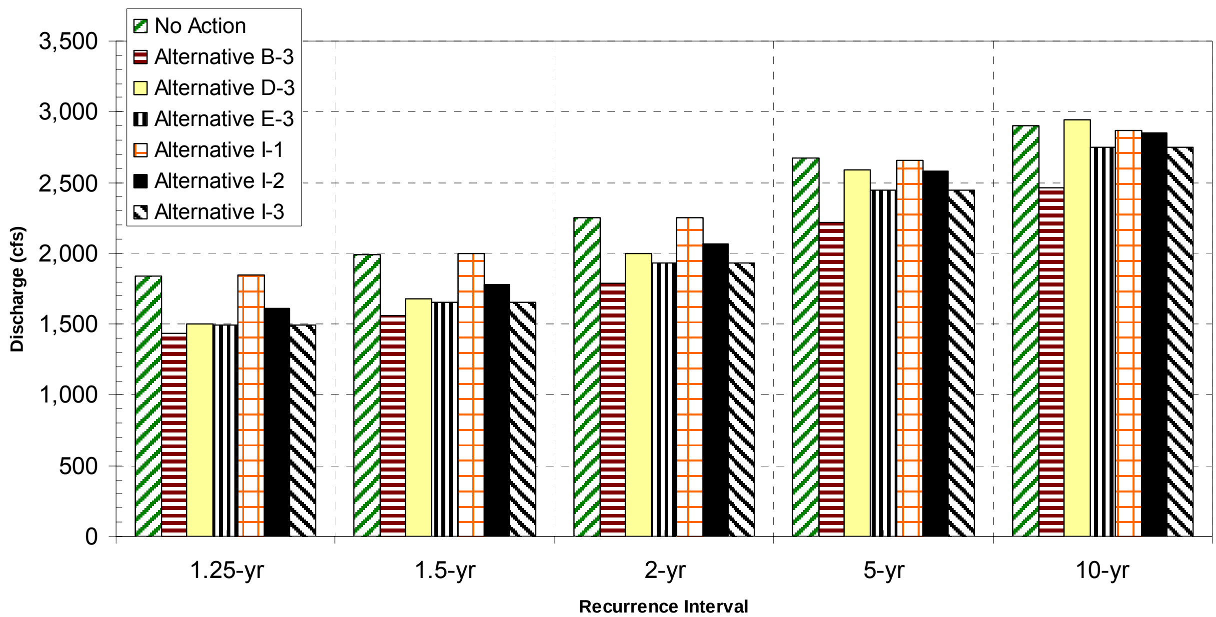


Figure 4-10. Frequency Analysis Summary of the Rio Chama at Chamita Gage under Each Alternative

Changes in geomorphology in the Rio Chama were evaluated, and there was no significant difference in sediment volume, aggradation/degradation trends, or bank energy indices among any of the alternatives in this section (See Appendix H).

Mainstem Rio Grande at Otowi: The impact of proposed operational changes along the Rio Chama into the Rio Grande mainstem is examined by behaviors in monthly flows at Otowi gage as shown on Figure 4-7. Significant (greater than 10 percent) impacts to flows were observed as increased 75th percentile flows under Alternatives B-3, D-3, E-3, I-3, and I-2. Presumably, higher levels of native conservation storage and the release of that water during November and December of each year result in the higher flows observed. Median flows increased under Alternatives B-3 and I-3. No other significant changes to monthly peak or lower flows at Otowi gage were observed for any of the alternatives.

Albuquerque Gage: Monthly peak flows for Alternatives B-3 and E-3 approach 8,000 cfs due to higher channel capacities below Cochiti Dam. Alternatives B-3, D-3, E-3, I-3, and I-2 all had increased 75th percentile flows passing the Albuquerque gage, presumably related to the release of native conservation storage in Abiquiu. No other significant changes in flow were observed at the Albuquerque gage for any of the alternatives.

LFCC Diversions and Flow at San Acacia Gage: Flow analysis in the San Acacia Section first needs to consider the impacts under No Action resulting from varying levels of diversion into the LFCC. Daily flows vary by 2,000 cfs, which is equal to the maximum diversion allowed under No Action. All diversions to the LFCC were modeled assuming a minimum of 250 cfs would be left in the river channel, with no diversion allowed to the LFCC when river flows at San Acacia are less than 250 cfs. For example, if the flow at San Acacia is 1,250 cfs and the LFCC capacity is 500 cfs, 500 cfs would be diverted to the LFCC and 750 cfs would remain in the river channel. If flow at San Acacia is less than 250 cfs, there would be no diversions to the LFCC. Hydrology controls the maximum levels of diversions, demonstrated by the fact that the full 2,000 cfs LFCC capacity is used only 4 percent of the time and 75 percent capacity (1,500 cfs) is used only 14 percent of the time. While 100 percent of the annual river flow could potentially be diverted, only 49 percent of the flow is conveyed even with the maximum 2,000 cfs LFCC capacity due to the 250 cfs bypass assumption. **Figure 4-11** shows average annual diversions to the LFCC over the 40-year period. The data were limited only to the I alternatives because they represent the range of LFCC capacity applied in the model.

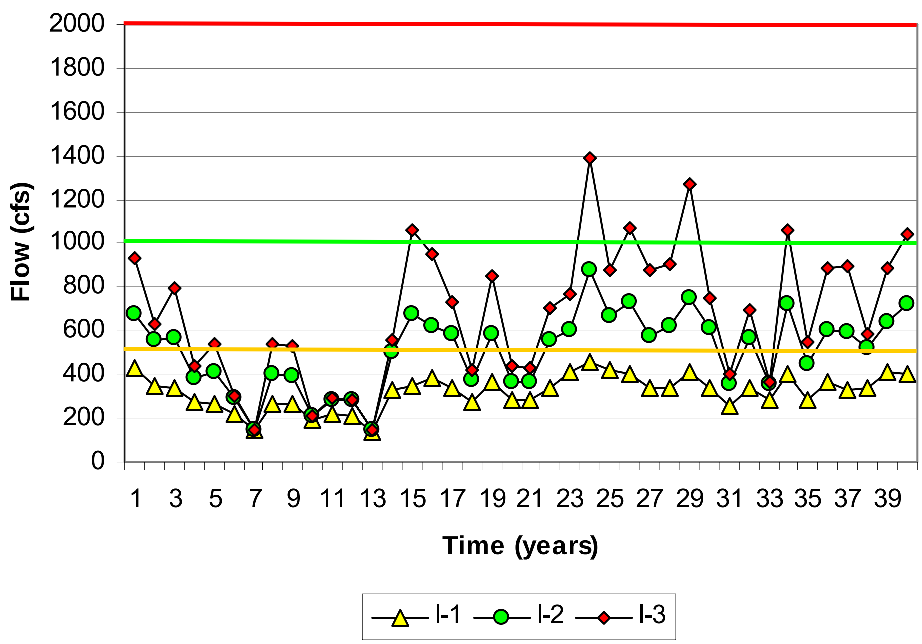


Figure 4-11. Average Annual LFCC Diversions

At the San Acacia gage (Figure 4-7), proportional decreases occur across the 75th/50th/25th percentile flows, depending on the level of LFCC diversion. Changes among alternatives were compared to the corresponding level of diversion under No Action. For example, changes under Alternative I-1 were compared to No Action at 500 cfs; changes in Alternative I-2 were compared to No Action at 1,000 cfs;

and changes in Alternatives B-3, D-3, E-3, and I-3 were compared to No Action at 2,000 cfs. Flows predicted for No Action with zero diversion provides the highest river flows in the San Acacia Section.

Changes in flow at the San Acacia gage attributed to alternative water operations occur as follows:

- Maximum daily flows increased for Alternatives B-3 and E-3 due to higher channel capacities allowed below Cochiti Dam under these alternatives
- Alternative I-2 shows significantly higher 75^{th} percentile flows compared to No Action at 1,000 cfs diversion, as a result of Abiquiu conservation storage releases
- Alternative I-1 has slightly lower 50^{th} percentile flows than No Action at 500 cfs diversion
- Most alternatives show lower 25^{th} percentile flows than No Action due to diversions into the LFCC

Elephant Butte Inflow: Inflow to Elephant Butte Reservoir was used as a surrogate gage to evaluate flows into the Southern Section (Figure 4-7). Highest daily flows were recorded under Alternatives B-3 and E-3; lowest daily flows were observed under Alternatives I-1 and I-2. Alternatives D-3 and I-3 maintained higher flows than No Action in all flow categories (75^{th}/50^{th}/25^{th} percentiles). Alternatives I-1 and I-2 had reduced daily flows when compared to No Action, but showed some improvements in flows in the middle and lower flow categories. Alternatives B-3, D-3, E-3, and I-3 all showed 10 percent improvements in average monthly flows over the 40-year period. Alternatives I-1 and I-2 had 3 percent and 7 percent improvements in average monthly flows as compared to No Action with zero diversions to the LFCC.

Flows in the Southern Section were not explicitly evaluated as flood operations in Elephant Butte and Caballo Reservoirs were not triggered by any of the alternatives during the 40-year analysis period.

Geomorphology

The geomorphologic impacts for the No Action Alternative in the Central Section would remain degradational, although continued coarsening of the bed material would likely limit the amount of bed lowering that occurs. Although degradation has historically occurred from the confluence of the Jemez River to Bernalillo, this subreach would be close to equilibrium, due primarily to the increased sediment input from the Jemez River with the October 2001 elimination of the sediment pool in Jemez River (MEI 2002). From Bernalillo to San Acacia would be slightly aggradational under this alternative. From San Acacia to the north boundary of Bosque del Apache National Wildlife Refuge (NWR), the channel would continue to be degradational, and the magnitude of the sediment imbalance would actually increase compared to recent historic conditions. From Bosque del Apache NWR to San Marcial would continue to aggrade with the late-1990s bed topography, but the drop of pool elevations in Elephant Butte Reservoir and construction of the Elephant Butte Pilot Channel are likely to result in a degradational trend in this reach, at least until the Elephant Butte pool level increases back to its historic higher levels.

The only potentially significant changes in geomorphic indicators occurred between San Acacia and San Marcial (**Figure 4-12**) and were associated with the magnitude of diversion to the LFCC. Diversion to the LFCC decreased sediment transport, decreased river channel flow volume, and decreased erosive energy resulting in changes in aggradation/degradation when compared to No Action with zero diversions to the LFCC. It should be noted that active diversions to the LFCC under No Action were not explicitly evaluated. Thus, much of the change attributed to action alternatives is likely the result of implementing diversions to the LFCC. The following value judgments were applied to sediment/erosion information provided for this DEIS: 1. Aggradation was favored for the Central Section; Degradation was favored in the San Acacia Section 2. A stable bank energy index was desired for the Central and San Acacia Sections; a decreased bank energy index was desired for the Rio Chama Section.

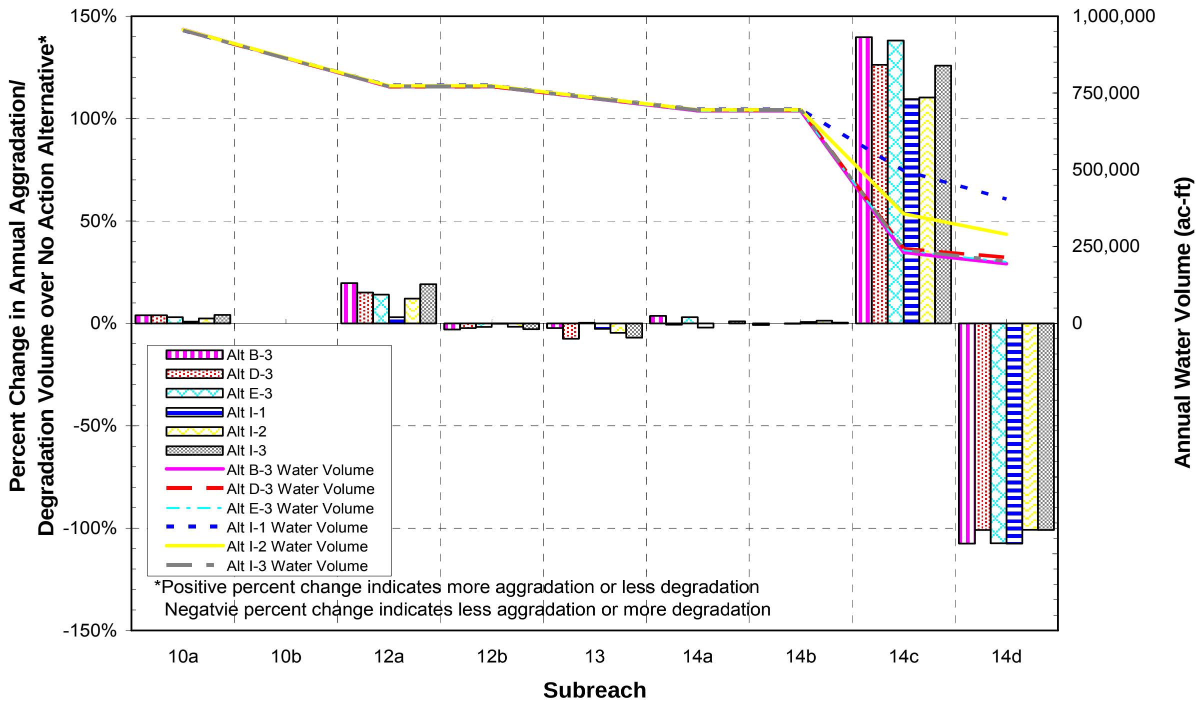


Figure 4-12. Changes in Aggradation/Degradation and Flow Volume

Geomorphologic changes between alternatives were not significant. Except for the river channel below the San Acacia Diversion Dam, the computed change in bed elevation for the action alternatives would be nearly identical to the No Action Alternative. Very slight changes in the San Acacia Section river channel elevation were observed from the diversion dam to river mile 78. Aggradation in this reach ranged between 0.01 and 0.03 feet per year for the action alternatives. Below river mile 78, the computed lowering in bed elevation was 0.01 feet per year or less under all action alternatives. These minor changes in bed elevation should be viewed only in a relative sense because the changes would not occur uniformly in time or space through the reach, nor would they continue indefinitely as the channel geometry, gradient, and bed material adjust toward a state of equilibrium with the upstream supply. Changes below San Acacia were associated with the amount of diversion to the LFCC. Additional information regarding geomorphic analysis is provided in Appendix H.

Sources of Uncertainty and Data Gaps

Most of the sources of uncertainty in the analysis of flow, storage, and geomorphology are related to availability of and confidence in gage, elevation, and other input data. Due to the 40-year planning horizon, computer modeling resources were constrained in their ability to perform multiple model runs. Thus, the particular 40-year inflow sequence may limit the degree of changes observed – especially when considering possible reservoir filling and emptying sequences. For example, the use of 2001 reservoir conditions coupled with the 40-year inflow sequence meant that the Elephant Butte/Caballo Reservoir flood control protocols were not invoked and impacts to the Southern Section were not considered. Due to the propagation of error along the river system, there is at least 10 percent uncertainty in model results increasing with downstream distance from Albuquerque.

Sensitivity analyses for the range of LFCC diversions under the No Action Alternative were performed as an adjunct to the primary alternative scenarios. In some cases, direct comparisons for the varying LFCC diversions under each alternative in the San Acacia section were not possible and qualitative estimates of impact substitute for quantitative analyses.

4.4.1.6 Summary/Comparison by Alternative

River flow and water movement throughout the Rio Chama and upper Rio Grande is constrained by the management of water in existing facilities under existing authorities and physical channel capacities. Differences between alternatives are subtle and may often be masked by gage error. Changes in operations typically have the greatest impacts to the river sections immediately in or downstream of the proposed change.

Along the Rio Chama, changes in storage using waivers at Heron Dam and storage of native conservation water in Abiquiu result in slight variations in daily and monthly flows. Alternatives B-3 and E-3 offer the greatest opportunity to store native Rio Grande water in Abiquiu Reservoir. Alternatives I-3 and E-3 offer slightly lesser advantages in native conservation storage. Alternatives I-2 and I-1 are constrained in their abilities to store water and offer intermediate storage up to the capacities of 75,000 and 25,000 AFY. Under the No Action Alternative, conservation water would not be stored. Currently, under specific circumstances and upon State of New Mexico request, native water can be stored and carried over only after obtaining expensive and cumbersome emergency deviations and permits.

No changes in operations are proposed on the Rio Grande above the confluence with the Rio Chama. Below the confluence, there are no significant changes to daily flows at Otowi under any of the alternatives; and all alternatives except I-1 show improvements in 75th percentile flows. Alternatives B-3 and I-3 also show improved median flows.

On the main stem of the Rio Grande near Albuquerque, Alternatives B-3 and E-3 (with increased channel capacity below Cochiti) show improved maximum and 75th percentile flows. Alternatives D-3 and I-3 also show greater 75th percentile flows, presumably due to releases in upstream storage. There were no significant changes in median or low flows among the other alternatives.

Flows in the San Acacia Section are influenced primarily by diversion to the LFCC and to a lesser extent by changes in channel capacity below Cochiti. Under the No Action Alternative when hydrology permits, river flows are maintained up to 250 cfs prior to diversion into the LFCC. The 2,000 cfs operation has the potential to divert over 100 percent of the river flow at San Acacia. Under the action alternatives with a 250 cfs bypass assumed in URGWOM, only 49 percent of the total flow is actually diverted by the model. By comparison, the 1,000 cfs flow diverts 47 percent and the 500 cfs flow diverts 37 percent of the total river flow. Flows projected for the San Acacia gage for the No Action Alternative under various diversions to the LFCC show proportional decreases in river flows at the daily flow and 75th percentiles. Median and low flows converge quickly with diversion. The full 2,000 cfs capacity is used only 4 percent of the time; the 1,000 cfs capacity is used only 13 percent of the time; and the 500 cfs capacity is used 34 percent of the time over the 40-year period. See Appendix H for additional detail.

All alternatives result in higher median and average inflows to Elephant Butte Reservoir, as compared to No Action. Alternatives B-3 and E-3 provide the highest daily and 75th percentile flows. Alternatives I-1 and I-2 show reductions in daily flows when compared to No Action, but sustain higher mean and median flows over the 40-year period. Overall, Alternatives B-3 and E-3 deliver the most water to Elephant Butte Reservoir due to increased channel capacities below Cochiti Dam. The next highest ranked alternatives for managing water operations are Alternatives D-3 and I-3, offering comparable median and average flows as compared to B-3 and E-3. Alternatives I-2 and I-1 transmit lesser amounts of water, with No Action delivering the least water to Elephant Butte Reservoir.

Impacts to flows below Elephant Butte Reservoir were not considered as flood control protocols were not invoked during the 40-year planning period.

Geomorphologic impacts were considered insignificant as none of the changes exceeded a 10 percent departure from No Action. Sediment volumes, aggradation/degradation changes, and changes in bank energy indices were all similar to No Action, suggesting that changes in sediment volume and water flow among alternatives were not of sufficient magnitude to induce substantial changes in channel morphology.

Water flow in the upper Rio Grande basin is tightly constrained within the limits of current authorities and regulations. Performance measures for water operations flexibility and sediment management are summarized in **Table 4-3**.

The rank order of preference among alternatives after evaluating hydrologic and geomorphologic impacts is as follows: I-3, E-3, B-3, I-2, I-1, No Action, and D-3.

4.4.1.7 Mitigation Measures

Impacts for hydrologic effects requiring possible mitigation could include the occasional need for higher channel-forming flows and release of upstream storage for the benefit of New Mexico Compact deliveries and endangered species. Alternatives providing upstream storage of native conservation water allow the best potential for mitigating impacts to other resources. Geomorphologic characteristics were not significantly impacted by proposed changes in water operations, thus no mitigation measures were proposed.

Table 4-3. Operating Flexibility Performance Measures and Results

Parameter	Measure	Units	No Action LFCC-0 cfs	B-3	D-3	E-3	I-1	I-2	I-3
OPERATIONAL FLEXIBILITY									
Conservation Storage in Abiquiu	July 1 Median Storage (20 of 40 years)	AF	0	129,400	115,600	116,800	19,130	73,300	118,800
	# of Years Storage Occurs	Years	0	19	20	20	17	19	20
Maximizes Peak Discharge	75th percentile Chamita Gage	cfs	585	616	601	607	640	589	607
	75th percentile Otowi Gage	cfs	1,533	1,704	1,654	1,671	1,529	1,611	1,674
	75th percentile Albuquerque Gage	cfs	1,134	1,389	1,289	1,331	1,150	1,246	1,331
	75th percentile San Acacia Gage*	cfs	1,210; 710; 250; 250	250	250	250	724	414	250
Maximizes Sediment Transport	Total Sediment Volume	AF	993	753	765	759	869	814	760
Supports Winter Flows (Dec-Feb)	Chamita Gage – median winter flow	cfs	214	234	220	224	221	218	222
	Otowi Gage – median winter flow	cfs	830	894	845	847	840	855	847
	Albuquerque Gage – median winter flow	cfs	799	847	823	826	813	820	826
	San Acacia Gage – median winter flow*	cfs	979; 488; 250; 250	250	250	250	491	250	250
Stable Reservoir Levels	Heron – 75%/25% Elevation Fluctuation	Ft	54	56	55	54	54	54	54
	El Vado – 75%/25% Elevation Fluctuation	Ft	42	44	42	43	43	43	43
	Abiquiu – 75%/25% Elevation Fluctuation	Ft	21	31	30	30	18	25	30
	Cochiti – 75%/25% Elevation Fluctuation	Ft	1.8	1.7	1.7	1.8	1.8	1.8	1.9
	Elephant Butte – 75%/25% Storage Fluctuation	AF	310,028	324,540	321,735	321,193	338,395	342,669	320,581
	Caballo – 75%/25% Storage Fluctuation	AF	8,405	7,437	7,564	7,565	8,081	7,751	7,559
Supports Recreation – Summer Rafting	April 1 – Sept 30, Chamita Gage >500 cfs	Days	132	122	122	119	126	122	119
SEDIMENT MANAGEMENT									
Sediment Volume	Sediment Supply – Central	AF	409	401	401	402	407	403	399
	Sediment Supply – San Acacia**	AF	584	352	365	357	462	412	361
Aggradation/ Degradation Trends positive = aggradation	Ag/Deg Volume – Central	AF	23	27	26	26	23	25	26
	Ag/Deg Volume – San Acacia**	AF	42	38	36	37	26	30	36
Bank Energy Index positive = increased erosion negative = decreased erosion	Rio Chama	Percent	0	2.17	2.58	-0.23	-0.23	-0.55	-0.21
	Central	Percent	0	-1.28	-0.95	-1.06	-0.12	-0.56	-1.23
	San Acacia – North	Percent	0	0.24	0.22	0.1	0.22	0.31	0.21
	San Acacia – South**	Percent	0	-58.1	-56.4	-57.4	-26.6	-42.8	-56.6

Notes: * Range of flows under No Action at LFCC Diversions of: 0, 500, 1,000, and 2,000 cfs.
** Range of flows under No Action LFCC Diversions not evaluated – comparisons reflect action of LFCC, not difference between alternatives at same level of No Action diversion.

4.4.2 Biological Resources

4.4.2.1 Aquatic Habitat

Issues

Both riverine and reservoir aquatic impacts were evaluated in the analysis of alternatives. Alternatives that alter the magnitude, variability, and duration of flow were assumed to have the potential to change the availability of suitable riverine fish habitat, the timing and magnitude of spawning peaks, and the timing and degree of potential intermittencies. Alternatives that change upstream storage and affect reservoir elevations were assumed to have potential impacts on littoral (shoreline) habitat, reservoir exchange rates, and reservoir fish habitat.

The Rio Grande silvery minnow (RGSM) is the only threatened and endangered species identified in the riverine habitat. Impacts to RGSM habitat are briefly evaluated here and are discussed in greater detail in Section 4.4.2.3.

General Conclusions

Possible changes in reservoir storage included modifying waiver dates in Heron Reservoir and increasing the amount of native conservation storage in Abiquiu Reservoir.

Heron Waivers: Changes in waiver dates have the potential to modify spring and summer reservoir storage; however, analysis for Heron Reservoir was limited to an evaluation of water elevation stability and exchange rates. Statistical analysis of Heron Reservoir daily storage did not reveal any significant changes among the alternatives. Alternatives B-3 and D-3 appeared to support lower exchange rates with possible impacts to reservoir fisheries. Alternatives I-3, I-1, I-2, and I-3 did not show significant changes.

Native Conservation Storage in Abiquiu Reservoir: Changes in storage affect reservoir elevation, rates of water exchange, and littoral habitat availability. Alternatives B-3, D-3, E-3, and I-3 maximize storage, with median reservoir storage typically greater than 90,000 AF. However, these alternatives experience lower rates of water exchange than other alternatives, with possible negative impacts to reservoir fisheries. Littoral habitat availability is increased under Alternatives I-3 and D-3, counterbalancing lower exchange rates. Alternatives with lesser storage, I-1 and I-2, provided increased littoral habitat, but low exchange rates. Downstream impacts to fisheries in Cochiti Lake showed dampened responses. Median storage in Cochiti is not affected by the alternatives; however, changes in Cochiti storage are maximized when there is less storage available in Abiquiu. Thus, Alternatives I-1 and I-2 have the potential for higher reservoir elevations than other alternatives. Also, alternatives with increased channel capacities below Cochiti (B-3 and D-3) offer the most stable reservoir levels as flood waters can be evacuated more quickly with higher channel capacities. There were no significant changes in reservoir exchange rates among alternatives. Changes in storage and channel capacity also modified river flows in some segments of the river. The greatest magnitude of change to flow occurs along the Rio Chama, where all changes in storage occur, than in the Central and San Acacia Sections, where changes in channel capacity and diversion to the LFCC affect flows.

Fish habitat was generally not significantly affected (less than 2 percent) until the San Acacia Section. Progressive diversion to the LFCC resulted in loss of fish habitat. Diversion to the LFCC at 1,500 cfs resulted in the greatest impacts, with habitat losses ranging from 19 (RGSM) to 49 percent (longnose dace). Alternatives were compared to the No Action Alternative with the corresponding level of diversion to the LFCC. Alternatives B-3, D-3, E-3, and I-3, had 6 to 27 percent habitat area losses observed when compared to No Action diverting up to 2,000 cfs to the LFCC. No major changes in fish habitat over comparable No Action Alternative diversions to the LFCC were observed under Alternatives I-1 and I-2 in comparison to No Action at 500 and 1,000 cfs diversion, respectively.

Impact Indicators

Both riverine and reservoir impacts were assessed in the evaluation of alternatives. Indicators are identified below.

Riverine	Reservoir
Fish habitat area	Reservoir elevation stability
Duration of overbank flooding	Littoral habitat area
Area of overbank flooding	Water exchange rate
Average low flow days	
Average peak flow magnitude and duration	
Low flow augmentation capability	

Methods of Analysis

Riverine impacts were evaluated by considering periods of high and low flows, periods of intermittent flows, area and duration of overbank flooding, and suitable aquatic fish habitat. The potential for supplementing flows using native conservation storage was also assessed. Flows were evaluated at key gages based on URGWOM modeling. The area and duration of overbank flooding was estimated based on analysis of FLO-2D outputs for each alternative. Estimates of fish habitat area by indicator species and life stage were obtained as output from the aquatic habitat model. Indicator species selected for fish habitat analyses included the RGSM, longnose dace, flathead chub, carpsucker, and channel catfish. Appendix L provides information concerning ecosystem resource analyses. Additional information concerning the FLO-2D and aquatic habitat models is provided in Appendices J and K.

Impacts to reservoir habitats were analyzed considering the net reservoir elevation rate of change, the area of littoral habitat available, and the reservoir exchange rate. Habitat stability (measured by rate of change in reservoir elevation), is important in spring months to promote successful reproduction of fish species that spawn in submerged vegetation in the shoreline habitats. Values closest to zero represent reservoir stability. The amount of shoreline habitat measures the availability of spawning, nursery, and foraging habitat crucial to the reproduction of reservoir fish species. Littoral habitat data were available only for Abiquiu Reservoir. For other reservoirs, shoreline habitat availability was estimated using the three-dimensional shape of each reservoir and reservoir elevation changes predicted under each alternative. The number of days available in ten-foot elevation increments was then calculated. High values of littoral habitat are the most desirable. The reservoir exchange rate considers the turnover of water in each reservoir as a measure of fishery productivity and is calculated by dividing the reservoir volume by the average annual discharge. Low exchange rates are generally associated with higher productivity and better fisheries support.

Thresholds for Significance

Propagation of error and uncertainty is expected with the use of modeling tools that build upon data received from river gages and elevation measures. Starting with an initial 5 percent gage error, using a series of models including the URGWOM planning model, spatial analysis of flow and habitat using RMA-2 and the Aquatic Habitat Model, the starting point for identifying significant changes is expected to be at least 10 percent deviation from No Action.

Discussion of Results

The No Action Alternative with zero diversions to the LFCC would offer the highest potential for preserving aquatic habitats in the system. The No Action Alternative would best preserve riverine fish diversity, receiving maximum scores on all parameters with the exception of brown trout habitat, where the alternative ranks third overall. With zero diversions to the LFCC, the No Action Alternative would best preserve hydrology supporting aquatic habitats in the San Acacia Section, with slightly lesser performance in the Rio Chama and Central Sections due to reduced overbank flooding acres and durations. The No Action Alternative would provide mid-ranked reservoir stability and reservoir exchange rates, ranking fourth among alternatives for the reservoir parameters evaluated. With zero diversions to the LFCC, it ranks third overall among the alternatives evaluated for riverine and reservoir aquatic resources.

All alternatives were compared to the No Action Alternative. No significant changes in usable fish habitat were identified in the Rio Chama and Central Sections (±2 percent). Detailed analysis can be found in Appendix L.

The RGSM is extirpated from Rio Chama. Alternative B-3 would result in a reduction of habitat in the Rio Chama Section for all other species. Brown trout habitat would be reduced under Alternatives B-3, D-3, E-3, and I-3; would not change under Alternative I-2; and would increase slightly under Alternative I-1. Habitat for longnose dace, flathead chub, carpsucker, and channel catfish would increase under all alternatives except Alternative B-3. The projected changes in riverine habitat parameters, including RGSM habitat area, are shown in **Table 4-4**.

Table 4-4. RGSM and Riverine Habitat Change by Alternative

Alternative	RGSM Habitat Area (sq. feet)	Duration of Overbank Flooding (avg. days/year)	Area of Overbank Flooding (acres)	Average Number of Days of 0 cfs	Average Number of Days <100 cfs	Average High Flow Magnitude (cfs)	Average High Flow Duration (days/year)
RIO CHAMA SECTION							
No Action	55,030	2	477,530	0	9	2,900	54
B-3	51,020	29	137,600	0	9	2,520	53
D-3	53,200	28	489,700	0	10	2,740	47
E-3	52,790	26	323,750	0	9	2,670	49
I-1	53,520	28	331,840	0	9	1,920	53
I-2	52,730	31	396,600	0	9	2,790	48
I-3	52,910	37	477,530	0	10	2,670	49
CENTRAL SECTION							
No Action	1,224,030	15	1,545,900	15	33	3,970	48
B-3	1,200,200	11	2,731,600	15	32	3,850	44
D-3	1,206,700	13	1,663,300	16	33	3,770	44
E-3	1,204,040	9	2,938,000	16	33	4,010	42
I-1	1,217,400	12	1,424,500	16	33	4,050	47
I-2	1,204,600	13	1,598,500	16	33	3,870	45
I-3	1,203,100	16	1,800,900	16	33	3,700	46
SAN ACACIA SECTION							
No Action – 0 cfs	511,470	33	8,789,800	0	99	3,580	39
No Action – 500 cfs	460,500	—	7,119,700	69	214	3,205	34
No Action – 1,000 cfs	422,700	—	5,361,760	69	214	2,710	29
No Action – 1,500 cfs	412,570	—	—	69	—	—	—
No Action – 2,000 cfs	434,970	—	2,461,140	69	214	2,400	26
B-3	406,650	10	2,679,000	—	108	2,010	26
D-3	405,630	11	2,375,500	—	110	1,920	29
E-3	406,900	8	2,606,200	—	109	2,150	26
I-1	458,600	16	4,386,800	—	106	2,710	34
I-2	425,150	27	7,952,100	—	109	2,700	29
I-3	405,730	29	8,251,500	—	110	1,860	28

Note: — indicates No Data available

Table 4-5 summarizes the effects on aquatic habitats in the San Acacia Section under each action alternative, compared to the No Action Alternative. Available aquatic habitat for the indicator fish species is maximized under zero diversions to the LFCC. Habitat decreases with 1,000 to 1,500 cfs diversions to the LFCC, while improvements are observed with diversions of 2,000 cfs. The longnose dace has the greatest reductions in habitat with diversion to the LFCC. **Figure 4-13** shows the impact of diversion to the LFCC on longnose dace at several life stages. A significant decrease in adult and juvenile habitats for longnose dace is observed at the Bosque del Apache National Wildlife Refuge (NWR) site.

Table 4-5. Significant Change in Usable Fish Habitat in the San Acacia Section

Action Alternative	Change of Habitat Compared to the No Action Alternative with Comparable Diversion to the LFCC			
	RGSM	Longnose Dace	Chub/ Carpsucker	Channel Catfish
B-3	-6%	-27%	-10%	-10%
D-3	-7%	-22%	-10%	-10%
E-3	-6%	-21%	-10%	-10%
I-1	0%	0%	0%	0%
I-2	+1%	+5%	+1%	+2%
I-3	-7%	-21%	-10%	-10%

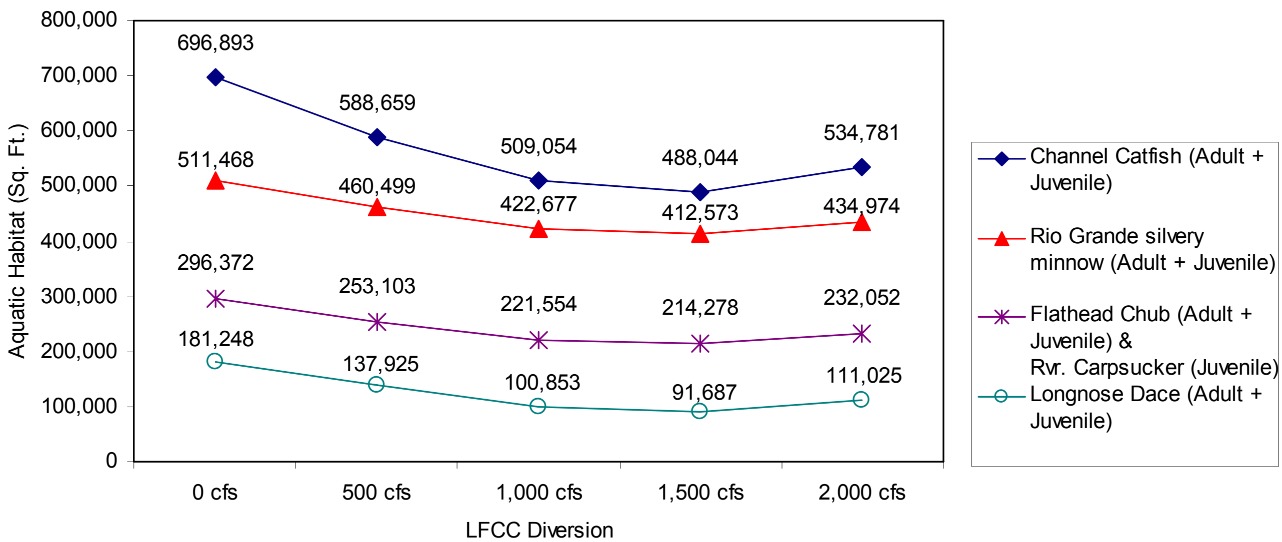


Figure 4-13. Aquatic Habitat Impacts with LFCC Diversions under No Action

One of the drawbacks to the No Action Alternative is that it would not provide any upstream storage for water that might be used to augment flows for ecosystem needs. When stored water was available, emergency exceptions were made in the past on a case-by-case basis to accommodate endangered species needs in times of drought without considering system-wide implications. However, the process depends on identifying water rights holders in possession of sufficient water in storage and a willingness to relinquish that water, typically using a short-term lease. But these emergency exceptions and deviations are difficult to negotiate, are time-consuming and expensive to implement, and provide limited options for long-term ecosystem management to improve the status of all species.

The ability to provide low flow augmentation was also considered in the analysis of alternatives (**Figure 4-14**). Figure 4-14 depicts the number of days of water available to offset days of low flow in two Sections. Supplemental flows could help mitigate the effects of zero and low flow days on riverine habitat and fish communities. Alternatives D-3, E-3, and I-3 could mitigate low flow days in the Central Section, but stored volumes of water are approximately 10 days short to provide sufficient water to augment low flows in the San Acacia Section. Alternative I-2 would augment low flows in the Central Section, but would be 48 days short in the San Acacia Section. Alternative I-1 is short on water for 16 days in the Central Section and 100 days in the San Acacia Section. Only Alternative B-3 provided sufficient water to offset the number of predicted days less than 100 cfs at both Central and San Acacia sections. No water is available for augmentation under the No Action Alternative, except by emergency deviations.

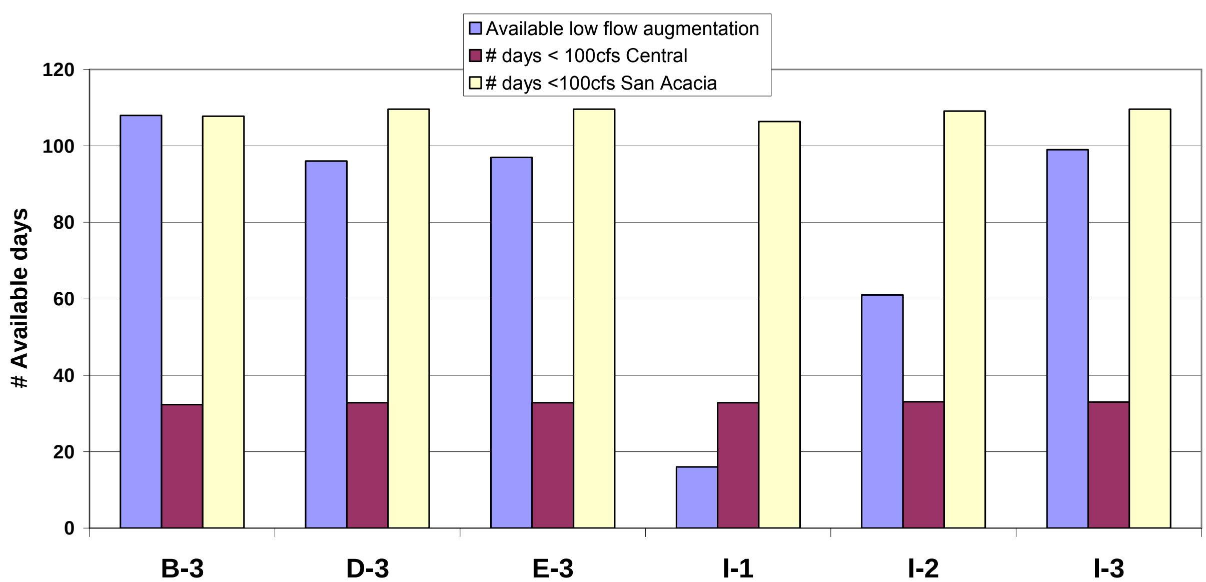


Figure 4-14. Low Flow Augmentation by Alternative

Reservoir fisheries impact analyses for Heron and Abiquiu Reservoirs, and Cochiti Lake are summarized in **Table 4-6**. At Heron Reservoir, elevation rates of change are most stable with the lowest exchange rates observed under Alternatives B-3 and D-3 and No Action. Littoral habitat availability in Abiquiu Reservoir improves under all action alternatives, while exchange rates suffer slightly. At Cochiti Lake, reservoir stability improves under all action alternatives except I-1; exchange rates are less favorable under Alternatives I-1, I-2, and I-3. In summary, Alternatives B-3, D-3, and E-3 offer similar reservoir conditions as compared to No Action. Action Alternatives I-1, I-2, and I-3 are slightly less favorable than No Action in reservoir fisheries support, primarily due to increases in reservoir exchange rates at Abiquiu Reservoir and Cochiti Lake.

Table 4-6. Summary of Reservoir Fisheries Impacts by Alternative

Parameter	Units	Desired Condition	No Action	B-3	D-3	E-3	I-1	I-2	I-3	Comments
HERON RESERVOIR										
Net Reservoir Elevation Range of Change	ft/week	Zero	-0.001	-0.001	-0.001	-0.012	-0.009	-0.011	-0.012	B-3 and D-3 are most favorable
Area of Littoral Habitat	Acre-days	Maximum	NA	NA	NA	NA	NA	NA	NA	No data available
Reservoir Exchange Rate	AFY	Minimum	0.796	0.779	0.788	0.798	0.796	0.798	0.798	No significant change
ABIQUIU RESERVOIR										
Net Reservoir Elevation Range of Change	ft/week	Zero	0.029	0.228	0.342	0.326	0.086	0.262	0.337	No Action is most favorable
Area of Littoral Habitat	Acre-days	Maximum	42,840	42,840	54,612	48,756	54,612	48,756	48,756	D-3 and I-1 are most favorable
Reservoir Exchange Rate	AFY	Minimum	0.017	0.019	0.019	0.019	0.272	0.274	0.275	I-1, I-2, and I-3 are least favorable
COCHITI LAKE										
Net Reservoir Elevation Range of Change	ft/week	Zero	0.13	0	0.081	-0.008	0.145	0.098	0.084	B-3 is most favorable
Area of Littoral Habitat	Acre-days	Maximum	NA	NA	NA	NA	NA	NA	NA	No data available
Reservoir Exchange Rate	AFY	Minimum	0.007	0.007	0.007	0.007	0.117	0.117	0.117	I-1, I-2, and I-3 are least favorable

Sources of Uncertainty and Data Gaps

Sources of uncertainty and data gaps in the analysis of riverine and reservoir habitat include propagation of gage and URGWOM modeling error, understanding of desirable fish habitat conditions, model spatial sensitivity and further propagation of error across the Aquatic Habitat and FLO-2D models. The combined potential effects suggest that changes predicted by modeling would be significant if there is a greater than 10 percent departure from conditions predicted under No Action.

Summary/Comparison by Alternative: Aquatic Riverine and Reservoir Habitats

There were no significant changes in riverine fish habitat in the Rio Chama and Central Sections. The RGSM is considered extirpated in the Rio Chama Section and changes in habitat were less than 2 percent (about ½ acre) from No Action for the Central Section. However, any loss of habitat for the RGSM in the Rio Grande should be avoided because it could contribute to its extirpation in other areas of the river and confound future recovery efforts.

Significant changes in fish habitat were observed in the San Acacia Section and are, for the most part, related to diversions to the LFCC. The performance of each alternative in the San Acacia Section is referenced against the appropriate level of LFCC diversion under the No Action Alternative. Under Alternatives I-1 and I-2, small increases (1 to 5 percent, respectively, were observed) in fish habitat for all species in the San Acacia Section. Habitat losses in the San Acacia Section would be significant for all species under Alternatives B-3, D-3, E-3, and I-3. A 6 to 7 percent reduction in total RGSM habitat (about 0.67 acres) is projected under Alternatives B-3, D-3, E-3, and I-3. Longnose dace habitat would be reduced by over 20 percent, while chub/carpsucker and catfish habitat would be reduced by almost 10 percent. Habitat losses for all species may be highest in the San Acacia Section due to many factors, including diversion to the LFCC, higher channel velocities for alternatives with increased channel capacities in the Central Section, and native conservation storage in upstream reservoirs.

Alternatives B-3, D-3, and E-3 provided reservoir fisheries support similar to that observed under No Action. Alternatives I-1, I-2, and I-3 had slight decreases in reservoir fisheries support compared to No Action, primarily related to lower reservoir exchange rates coupled with changing reservoir elevations.

Overall, aquatic habitats were best supported by the No Action Alternative, with zero diversions to the LFCC. Riverine fish habitat area in the San Acacia Section was negatively affected under No Action by LFCC diversions of 1,000 and 1,500 cfs. The aquatic habitat ranking order of the action alternatives is as follows: I-2, I-1, I-3, D-3, B-3, and E-3. However, there is only a three percentage point difference in overall weighted resource performance measures among the action alternatives other than No Action. **Figure 4-15** provides a general summary of alternative performance relative to aquatic habitat criteria. This figure does not take into account the weighted importance of the endangered RGSM over other aquatic resources such as riverine sportfishing. See Appendix P for more detail.

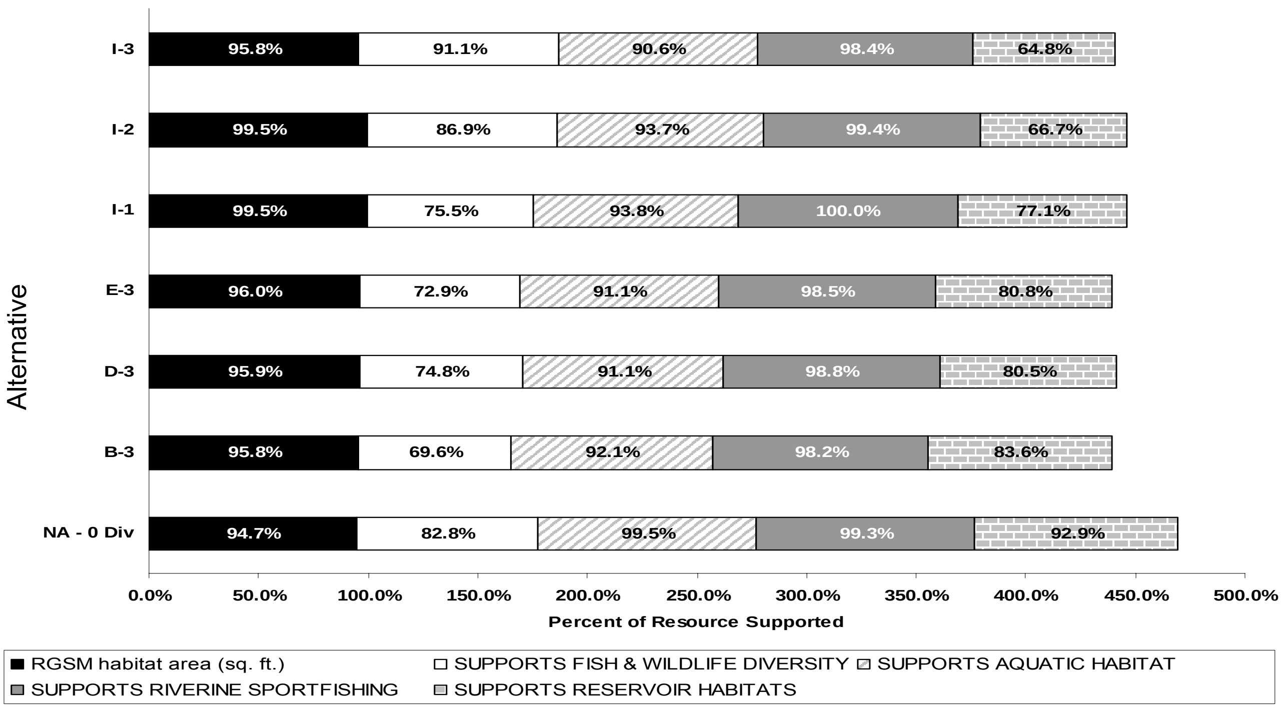


Figure 4-15. Aquatic Habitat Resources Supported by Alternative

Mitigation Measures

Mitigation measures for alternatives with projected loss of critical habitat would include support of habitat restoration activities in the sections affected. Alternatively, the specific use of stored native conservation water with carryover storage agreements could be negotiated to allow for water flows that foster the development of additional habitat in years where low peak flows and/or periods of intermittency would not adequately support species.

Figure 4-16 illustrates potential aquatic habitat gains predicted when conservation storage flows are released to meet specific flow targets (100 or 200 cfs) at the Central and San Acacia gages. Thus, some of the potential habitat lost under active diversion to the LFCC could be mitigated by releases of conservation storage water, resulting in additional aquatic habitat.

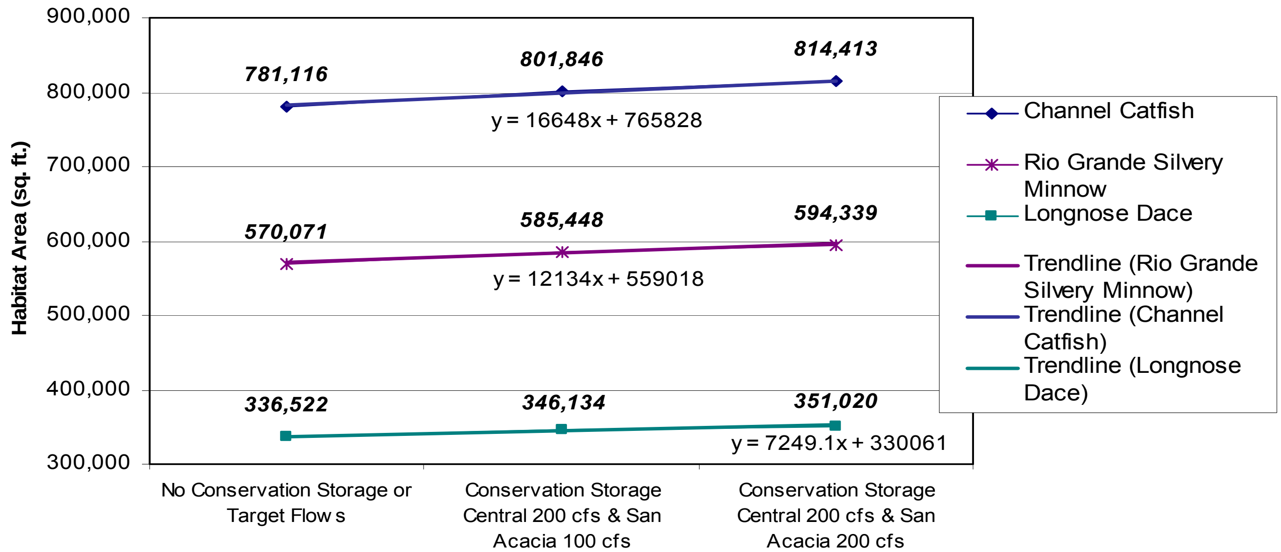


Figure 4-16. Fish Habitat Area Gained Using Native Conservation Storage Water to Meet Flow Targets

Figure 4-17 is a rose diagram depicting the potential to use the Abiquiu native conservation storage available under Alternative B-3. The figure shows the effects of using an annual storage allotment to supplement flows (either 40,000 or 75,000 AF) combined with a year-to-year carryover provision. The year-to-year carryover provisions evaluated allowing either 25 or 50 percent of the conservation water remaining at the end of the calendar year to be held in the reservoir for use the following season. In each case (4 options), it was assumed that the full target allotment was used in a given year and that the appropriate fraction of carryover water was left in storage for the following year, subject to storage limits of the reservoir, flood control requirements, and higher priority needs for San Juan-Chama Project water storage. Negotiation of carryover storage provisions allows the capability to meet flow targets in several successive years, thereby offering a possible buffer during short-term droughts. This is best illustrated by examining water availability from years 17 to 20 and years 37 through 40. The lower amount of reserved water storage combined with the ability to carryover 50 percent of the unused portion (Alternative B-3, option C in Figure 4-18) provides the greatest opportunities to buffer a dry period of several years. While most of the options in the following rose diagram have the same amounts of native water stored in each year, evidenced by the years when the lines overlay each other, option C (green line) is shown to have a few more years at higher storage levels, encompassing a larger area in the diagram.

Using less than the projected stored water provides slightly more water for carryover to the next year. It is not only the ability to seasonally store water, but the negotiation of carryover provisions for this stored water that allows optimal flexibility to meet ecosystem needs.

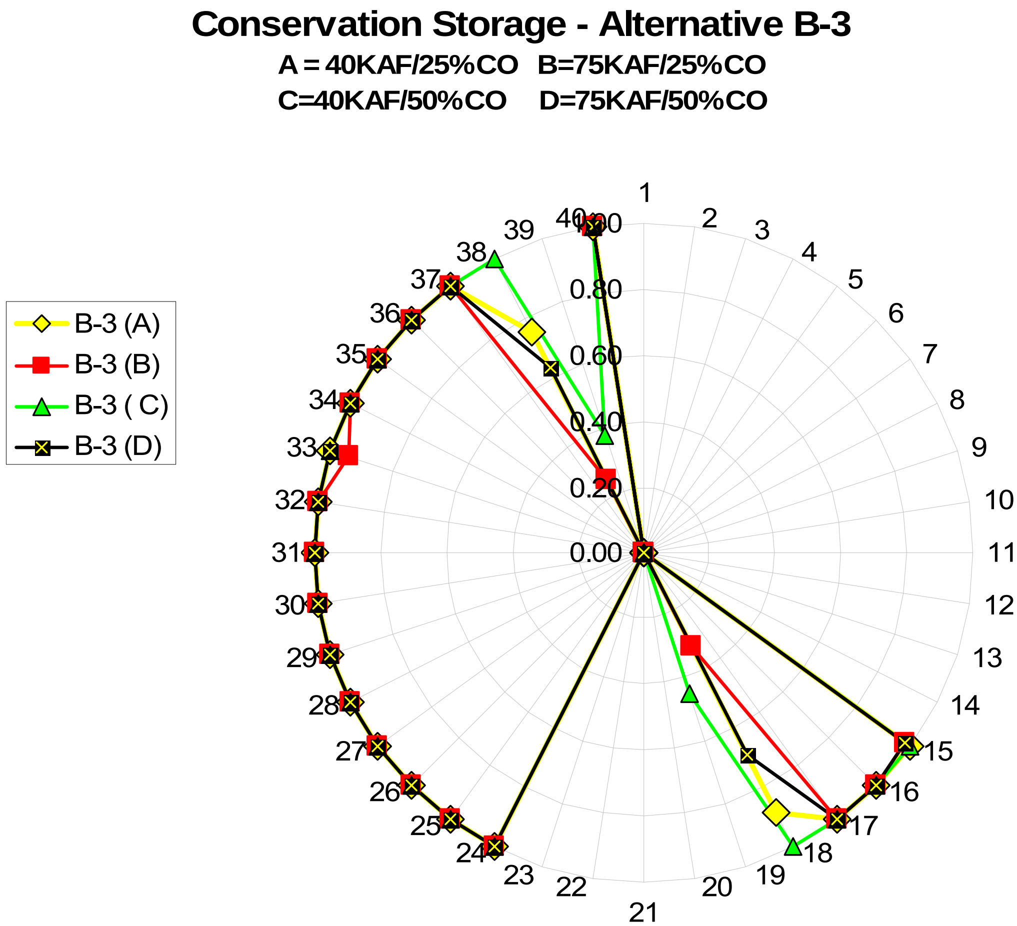


Figure 4-17. Using Native Conservation Storage to Meet Flow Targets

4.4.2.2 Riparian Habitat

Issues

Riparian habitats include the soils, vegetation, and associated wildlife that border waterways, including the open sand bars along the main river channels. Healthy riparian zones include a diversity of plants and structural types, as well as a variety of native and non-native species. Impacts on riparian habitat related to changes in water operations are generally indirect and long-term. Periodic overbank flooding is needed to maintain the health of established native plant communities; to scour away existing vegetation and create new seedbeds for the regeneration of young vegetation; and reduce susceptibility to fire, infestation of non-native species, and disease. The timing, duration, and magnitude of peak flood flows are also critical to maintaining desired habitats and wildlife diversity. High hydrologic variability often correlates to habitat and species diversity.

Physiography and geomorphology also play a role in shaping riparian habitats by constraining bed mobility and opportunities for overbank flooding. For example, the Rio Chama Section is characterized by a steep canyon with a sharp gradient and narrow floodplain. This section has high structural diversity characterized by predominantly native vegetation of mixed age and species. The primary issue for riparian resources in the Rio Chama Section is the effect of holding back spring runoff in order to accumulate stored native water in Abiquiu Reservoir.

In contrast, the Central Section is a warm-water reach with a riparian vegetation corridor known as the “bosque” supporting a mixture of non-native and native species. Levees and irrigation further constrain the corridor and structural diversity is low. The primary issue to riparian health in the Central Section is the lack of overbank flooding and the resulting decrease in native riparian species that depend on regular overbank flooding.

The San Acacia Section is relatively unconstrained by levees, with the LFCC comprising a western boundary. This mobile sand bed river has historically been subject to aggradation in the San Acacia Section. It is dominated by saltcedar, mixed native and non-native vegetation, and contains relatively large areas of young to intermediate-aged riparian forests with high biological value. The primary issue for riparian resources in the San Acacia Section is the effect of proposed diversion of flow to the Low Flow Conveyance Channel. The analysis examines four possible operations at the LFCC to determine the relative impact of different diversion levels on riparian resources.

Riparian resources are best supported by alternatives that provide increased opportunities for overbank flooding that sustain and regenerate desirable habitat. Opportunities for overbank flooding are available either by the operational constraints on releases combined with natural spring runoff, or by augmentation of spring runoff using conservation storage.

General Conclusions

The San Acacia Section contains the greatest acreage of riparian habitat. However, habitat improvements are also possible in the Central and Rio Chama Sections. Thus, care was used in the analysis to weigh riparian impacts by section, rather than by total acres of impact. Higher channel capacities and lesser diversions to the LFCC offer higher river flow potentials, while intermediate diversions to the LFCC increased the level of groundwater support to wetland areas. Based on the analyses of impact indicators, Alternatives I-1, I-2, and No Action (with LFCC diversions up to 1,000 cfs) best support riparian resources. Of the remaining alternatives with 2,000 cfs diversions to the LFCC, the order of preference in riparian resources supported is as follows: E-3, D-3, I-3, and B-3.

Impact Indicators

Changes in water operations have the potential to affect riparian resources, but such impacts are typically indirect and long-term. Potential beneficial and adverse impacts to riparian resources were evaluated using the quantitative measures listed below. Additional details on the derivation and use of these impact indicators is provided in Appendix L.

- Acre-days of spring overbank flooding
- Percentile of inundation
- Frequency of overbank flooding
- High flow variability
- Mean annual maximum acres of overbank flooding
- Conservation storage capability
- Average annual acre-days of flooding by vegetation type
- Flow augmentation

Methods of Analysis

The primary tools for estimating biological effects included the URGWOM planning model, Hink and Ohmart vegetation classification and mapping (1982 data and adapted methods applied in 2002-2003), and FLO-2D models generated for the Rio Grande and Rio Chama (Appendix J). The combined modeling and mapping efforts provided information for analysis, typically assuming that the operational maximum allowed under each alternative would be exercised. That is, if conservation storage was allowed up to 180,000 AF, then storage would be maximized when available. Similarly, if flows at San Acacia permit diversion to the LFCC, then diversion would be performed up to the allowed capacity of the LFCC. In many cases, hydrology and Compact constraints limit the ability to store and/or divert water, not the physical maxima available in the facilities.

The FLO-2D model of overbank inundation is most precise and accurate in the Rio Chama and Central sections. It is less reliable in predicting inundation in the San Acacia Section due to streambed instability. FLO-2D modeling was supplemented by Reclamation’s use of the Hydrologic Engineering Centers River Analysis System (HEC-RAS) model for flows below the San Marcial gage to evaluate the portion of the San Acacia Section between the south boundary of Bosque del Apache NWR and the power lines at the full pool of Elephant Butte Reservoir. HEC-RAS data were merged with FLO-2D data and analyzed using Geographic Information System (GIS) to evaluate the effects of flooding greater than 0.5 foot.

Thresholds for Significance

As stated for other resources, minimum gage error in this system is 5 percent; propagation of error increases with successive layers of modeling and analysis. Thus, a minimum change of 10 percent was assumed to be the threshold for significant change, with the exception of analyses for threatened and endangered species, which are addressed in a separate section.

Discussion of Results of Analysis

Table 4-7 shows a comparison of the effects of the alternatives, by river section, on riparian habitat performance measures. Under the No Action Alternative, operations would continue largely unchanged, but with improved inter-agency coordination for flood control and delivery of water downstream. With no diversion into the LFCC, current operations would provide the best overall support for riparian resources compared with all the action alternatives based on the relative performance of riparian impact indicators. Current operations demonstrated support for existing wetlands, natural management areas, riparian fauna, and threatened and endangered species. However, despite overall support of riparian resources, adverse impacts would occur under the No Action Alternative, varying in degree by river section.

In the Rio Chama Section, Alternatives D-3 and I-1 perform significantly better than No Action for mean annual acre-days of flooding, but do not show significant differences for other riparian performance measures. Alternative B-3 shows a significant adverse impact in mean annual maximum acres flooded in the Rio Chama Section, but provides the greatest conservation storage and peak flow variability. Overall, the analysis indicates that storage of native water at Abiquiu Reservoir does not necessarily lead to significant adverse effects for the Rio Chama Section. Beneficial impacts to riparian vegetation would occur in the Central Section under Alternatives B-3 and E-3, both with higher channel capacities proposed below Cochiti Dam. The remaining alternatives (D-3, I-1, I-2, and I-3) perform similarly to the No Action Alternative.

Table 4-7. Effects of Alternatives on Riparian Habitat Performance Measures

Performance Measure	Units	No Action				B-3	D-3	E-3	I-1	I-2	I-3
RIO CHAMA											
Mean Annual Maximum Acres Flooded	Acres	147				69	134	108	147	125	108
Mean Annual Acre-Days of Flooding *	Acre-days	1,137				1,070	2,643	2,006	3,004	2,450	2,073
Frequency of Spring Flooding	Per-cent	93%				85%	85%	88%	93%	90%	88%
Days greater than 75th percentile flows	Days	1,830				1,513	1,470	1,499	1,782	1,625	1,499
Peak Flow Variability – Coefficient of Variation (CV)	CV	23				32	36	34	23	28	35
Mean July 1 Conservation Storage – Abiquiu Reservoir (AF)	AF	0				53,574	50,375	51,341	8,141	32,328	51,557
Peak Flow Augmentation Capability (rank)	Rank	7				1	4	2	6	5	3
CENTRAL SECTION											
Mean Annual Maximum Acres Flooded	Acres	260				463	280	496	303	268	241
Mean Annual Acre-Days of Flooding *	Acre-days	7,646				8,429	7,606	8,733	8,255	7,424	6,886
Frequency of Spring Flooding	Per-cent	50%				48%	48%	40%	48%	50%	48%
Days greater than 75th percentile flows	Days	1,830				1,570	1,559	1,567	1,802	1,676	1,578
Peak Flow Variability – Coefficient of Variation (CV)	CV	47				57	51	58	48	49	51
SAN ACACIA SECTION *(LFCC Diversion in cfs)*		***0***	***0-500***	***0-1,000***	***0-2,000***	***0-2,000***	***0-2,000***	***0-2,000***	***0-500***	***0-1,000***	***0-2,000***
Mean Annual Maximum Acres Flooded	Acres	5,357	4,778	3,535	1,755	1,294	1,233	1,285	2,601	2,464	1,645
Mean Annual Acre-Days of Flooding *	Acre-days	132,065	—	—	—	47,056	48,756	46,859	111,901	91,773	60,994
Frequency of Spring Flooding	Per-cent	100%	—	—	—	90%	90%	90%	95%	90%	90%
Days greater than 75th percentile flows	Days	1,830	1,830	1,830	1,830	2,074	2,166	2,166	1,830	1,891	2,166
Peak Flow Variability – Coefficient of Variation (CV)	CV	46	—	—	—	94.1	84.8	95.1	53.4	65	85.6

* Developed to provide a relative comparison of alternatives and over estimates the area and duration of flooding. The acre-days of flooding do not represent absolute values of average years.

In the San Acacia Section, the action alternatives and the No Action Alternative test the potential effects of four different levels of diversion to the LFCC. Each of the alternatives specifies a range of LFCC diversions up to a maximum flow. The ranges of LFCC diversions represented were as follows: 0 diversions only; diversions of 0-500 cfs; 0-1,000 cfs; and 0-2,000 cfs. In the San Acacia Section, there were only limited data available for the spatial duration and extent of overbank flooding since FLO-2D models were only conducted for two of the possible maximum diversion options: 0 cfs diversions and 2000 cfs diversions. Therefore only maximum acres of overbank flooding, frequency of overbank flooding, days greater than 75th flow percentile, and coefficient of variation for peak flows were available as indicators for comparing effects of all the alternatives on riparian resources in the San Acacia Section. The results in Table 4-7 show that significant adverse impacts would occur to riparian resources in the San Acacia Section from implementation of any of the action alternatives when diversions to the LFCC were modeled at 1,000 and 2,000 cfs. Significant adverse impacts are indicated for acres of inundation and mean annual acre-days of flooding. Significant adverse impacts were found for all indicators except the coefficient of variation and days with greater than 75th percentile flows, both of which improved for alternatives B-3, D-3, E-3, and I-3.

Without diversions to the LFCC, the No Action Alternative would provide the greatest amount of overbank flooding to the San Acacia Section, including wetland areas as measured in acre-days. Should the LFCC become operational, Reclamation could potentially divert up to 2,000 cfs, if in compliance with all pertinent Biological Opinions. Implementation of diversions of 1000 cfs or higher diversions would result in a reduction of overbank flooding regardless of the alternative, as shown in **Figure 4-18**. It is anticipated that long-term adverse effects would occur to riparian resources as a result of reduced levels of inundation when diversion to the LFCC occurs. However, higher peak flow variability in the San Acacia Section would be accommodated under Alternatives B-3, D-3, E-3, and I-3 as well as more days with greater than 75th percentile flows, both beneficial impacts for riparian habitats.As shown on Figure 4-18, progressive diversions to the LFCC under No Action result in decreases in the maximum, median, mean, and minimum wetted floodplain acres. Results suggest that Alternatives E-3 and I-3 provide higher levels of riparian support than No Action at 2,000 cfs. Alternatives B-3 and D-3 provide slightly reduced maximum acreages, medians, and means when compared to No Action at 2,000 cfs. Similarly, Alternatives I-1 and I-2 perform better with higher peak, median, and mean wetted floodplain area than the No Action Alternative with 500 and 1,000 cfs diversions, respectively.

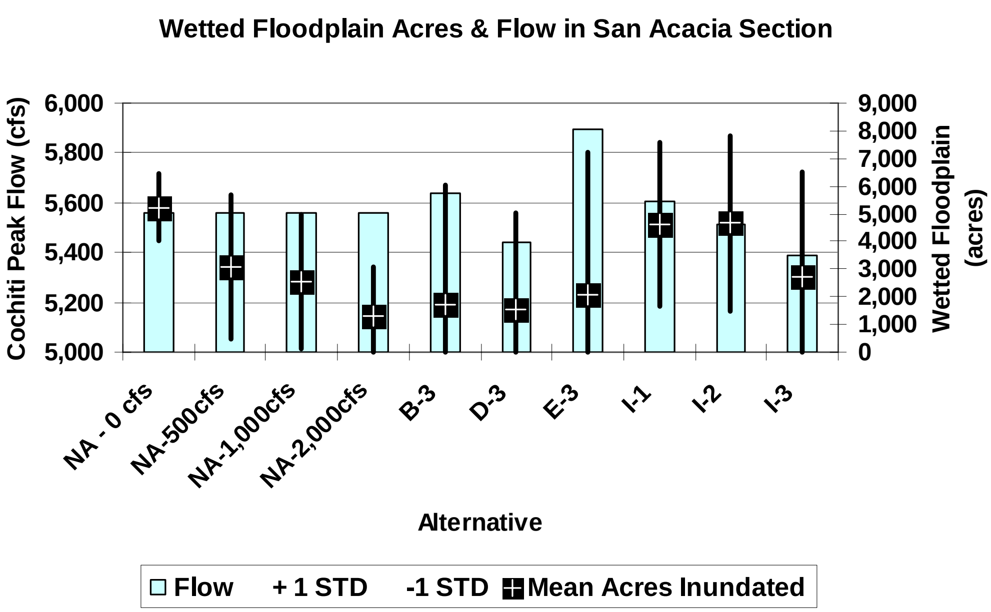


Figure 4-18. San Acacia Section Inundation vs. LFCC Diversion under No Action

Support for native vegetation was also evaluated by considering the average annual acre-days of inundation for Hink and Ohmart vegetation classification Types 1, 2, 3, and 5; and for Fish and Wildlife Service (FWS) Resource Category Types 2 and 3 (See Chapter 3, Section 3.3.1.2 for definition of types.) The degree to which alternatives may negatively impact riparian corridors by providing unwanted support to invasive species was also evaluated. **Figure 4-19** summarizes alternative performance relative to total days of inundation in desirable native vegetation types. The acre-days of inundation ranged from 92 (No Action) to 2142 (I-1) in the Rio Chama; from 8,730 (I-3) to 11,125 (E-3) in the Central Section, and from 72,340 (B-3) to 188,060 (No Action-0 cfs to LFCC). Overall, the rank order of alternatives for native vegetation community support is as follows: I-1, I-2, D-3, E-3, No Action, I-3, and B-3.

Figure 4-19 provides a comparison of two riparian performance measures in the San Acacia Section that would be affected by diversions to the LFCC. Adverse biological effects of any alternative would be proportional to the amount of diversion to the LFCC actually implemented in the proposed project. The effect of a decrease in overbank flooding from diversion of up to 500 cfs would probably not have a significant effect on riparian resources, but might require monitoring of endangered species habitats to assure that this level of diversion does not have an adverse effect. With diversions capped at 1,000 cfs, both the frequency and amount of overbank flooding would be adversely affected. With diversions of up to 2,000 cfs, the frequency of flooding would decrease by 5 percent, resulting in significant adverse impacts to resources.

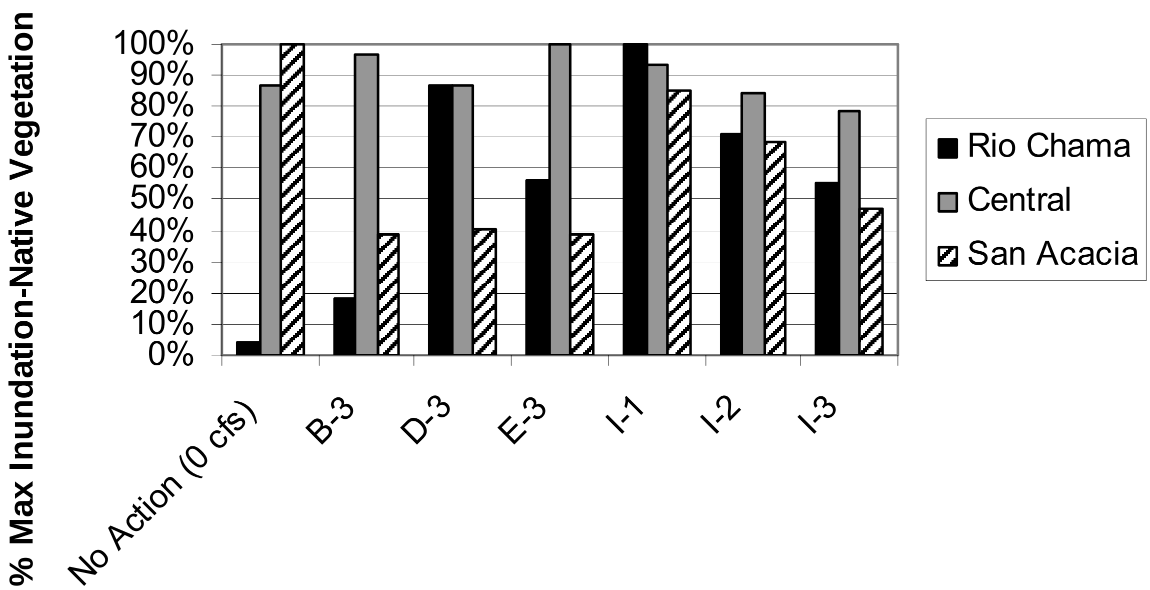


Figure 4-19. Percent of Maximum Possible Inundation of Native Vegetation Communities by River Section and Alternative

Sources of Uncertainty and Data Gaps

The primary tools used in the riparian analysis included vegetation inventory and classification maps, results from the URGWOM planning model, FLO-2D model, and aquatic habitat models. The quality and limitations of each dataset depend on modeled data and uncertainties in input data, including gage error and hydrologic inputs. Full alternative impact modeling was performed only for No Action at zero diversions to the LFCC in order to provide a baseline comparison. This is especially of interest in the San Acacia Section, because diversion to the LFCC is one of the primary causes of impact in this section. Where analyses offered a means to discriminate between No Action at a specified diversion to the LFCC and an alternative with the same diversion to the LFCC, more direct comparisons were provided.

The FLO-2D model is most precise and accurate for the Rio Chama and Central Sections, but is less reliable in the San Acacia Section due to streambed instability. Model output was developed to provide a relative comparison of alternatives and over estimates the area and duration of flooding. The HEC-RAS model was used to predict inundation south of Bosque del Apache NWR to the power lines at the full pool of Elephant Butte Reservoir. Using GIS and database analysis, these predictions were added to FLO-2D predictions above San Marcial to predict inundation for the San Acacia Section.

Summary/Comparison by Alternative: Riparian Habitat Analysis

The effect of diversions of 1,000 and 2,000 cfs to the LFCC would likely produce significant adverse impacts to riparian resources in the San Acacia Section, including riparian habitats and fauna, natural management areas, wetlands, and threatened and endangered species such as nesting southwestern willow flycatcher (SWFL) populations.

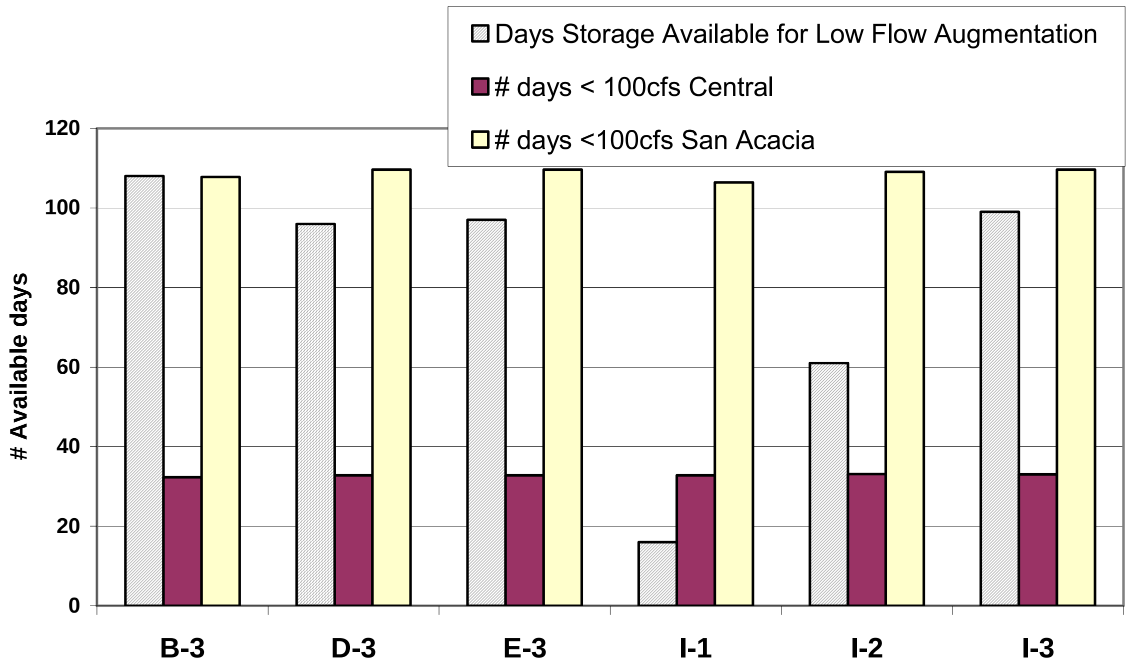
The degree of support for various types of vegetation provided by the alternatives, in comparison to No Action, is summarized in **Table 4-8**. It is important to note that for the San Acacia Section, all comparisons were initially performed against No Action with zero diversion to the LFCC. Consequently, the magnitude of habitat loss is roughly correlated to the level of diversion to the LFCC. Alternatives with 2,000 cfs LFCC diversions (B-3, D-3, E-3, and I-3) have the largest projected habitat losses, with lesser impacts associated with 500 and 1,000 cfs diversions (I-1 and I-2, respectively). Subsequent evaluations for habitat changes comparing equivalent diversions to the LFCC yield overall increases in riparian habitat for Alternatives E-3, I-1, I-2, and I-3, and no significant changes for Alternatives B-3 and D-3.

Table 4-8. Change in Riparian Habitat Support Relative to No Action

	B-3	D-3	E-3	I-1	I-2	I-3
Rio Chama Section						
Supports Hink & Ohmart Vegetation Types 1 & 2	**156%**	**1,180%**	**780%**	**1,460%**	**1,020%**	**780%**
Supports Hink & Ohmart Vegetation Types 3 & 5	**366%**	**2,011%**	**1,235%**	**2,122%**	**1,604%**	**1,228%**
Supports FWS Type 2	**339%**	**1,861%**	**1,206%**	**2,072%**	**1,564%**	**1,197%**
Supports FWS Type 3	**267%**	**2,117%**	**1,267%**	**2,167%**	**1,650%**	**1,258%**
Central Section						
Supports Hink & Ohmart Vegetation Types 1 & 2	9%	-1%	**12%**	8%	-3%	**-10%**
Supports Hink & Ohmart Vegetation Types 3 & 5	**13%**	1%	**17%**	7%	-4%	-9%
Supports FWS Type 2	**13%**	0%	**17%**	8%	-3%	**-10%**
Supports FWS Type 3	8%	0%	**12%**	7%	-2%	-9%
San Acacia Section						
Supports Hink & Ohmart Vegetation Types 1 & 2	**-80%**	**-79%**	**-79%**	**-18%**	**-28%**	**-62%**
Supports Hink & Ohmart Vegetation Types 3 & 5	**-64%**	**-61%**	**-62%**	**-15%**	**-31%**	**-53%**
Supports FWS Type 2	**-56%**	**-55%**	**-56%**	**-14%**	**-33%**	**-52%**
Supports FWS Type 3	**-74%**	**-71%**	**-75%**	**-16%**	**-25%**	**-55%**
Change in Riparian Habitat Support Relative to Equivalent No Action Diversion to LFCC	**3%**	**-3%**	**15%**	**16%**	**24%**	**36%**

Notes: Negative values represent loss of habitat.
= Beneficial impacts
= Adverse impacts

Figure 4-20 represents the potential number of days available for low flow augmentation in the Central and San Acacia Sections. It was assumed that 50 percent of the conservation storage in Abiquiu Reservoir was available for low flow augmentation. No Action alternative is unable to augment low flow days due to lack of conservation storage. All other alternatives are able to augment all low flow days in the Central Section that result from hydrologic variability. Only Alternative B-3, however, provides adequate storage to augment all low flow days in the San Acacia Section. I-1 and I-2 have the least capability for low flow augmentation due to limited storage of native water at Abiquiu Reservoir. Alternatives D-3, E-3 and I-3 could mitigate low flow days for the Central Section but would require approximately 10 additional days for the San Acacia Section.



Note: Averaged over the 40-year planning period. Augmentation flow is defined as an additional 150 cfs release from Abiquiu to the particular low flow event.

Figure 4-20. Average Annual Days of Conservation Storage Available in Abiquiu Reservoir for Low Flow Augmentation in Central and San Acacia Sections by Alternative

Evaluation of the impacts of varying levels of LFCC diversion on groundwater elevation and acres of wetlands used URGWOM and MODBRANCH in conjunction with GIS. **Figure 4-21** shows monthly changes in groundwater elevation for LFCC diversions at 0, 1,000, and 2,000 cfs. Diversion to the LFCC supports wetland habitats immediately adjacent to the LFCC, with lesser support east of the river, especially if all river flow is diverted to the LFCC. **Figure 4-22** shows the spatial shift in wetlands supported by LFCC diversions at 0, 1,000 and 2,000 cfs on wetland areas from Bosque del Apache NWR south to Fort Craig above Elephant Butte Reservoir. Diversions at 1,000 cfs and a 250 cfs bypass increased wetland habitat supported by almost 2.0 acres above the 14.5 acres supported by No Action with 0 cfs diverted to the LFCC. Diversions at 2,000 cfs with no bypass to the river decreased wetland habitat supported by about 1.4 acres as compared to No Action.

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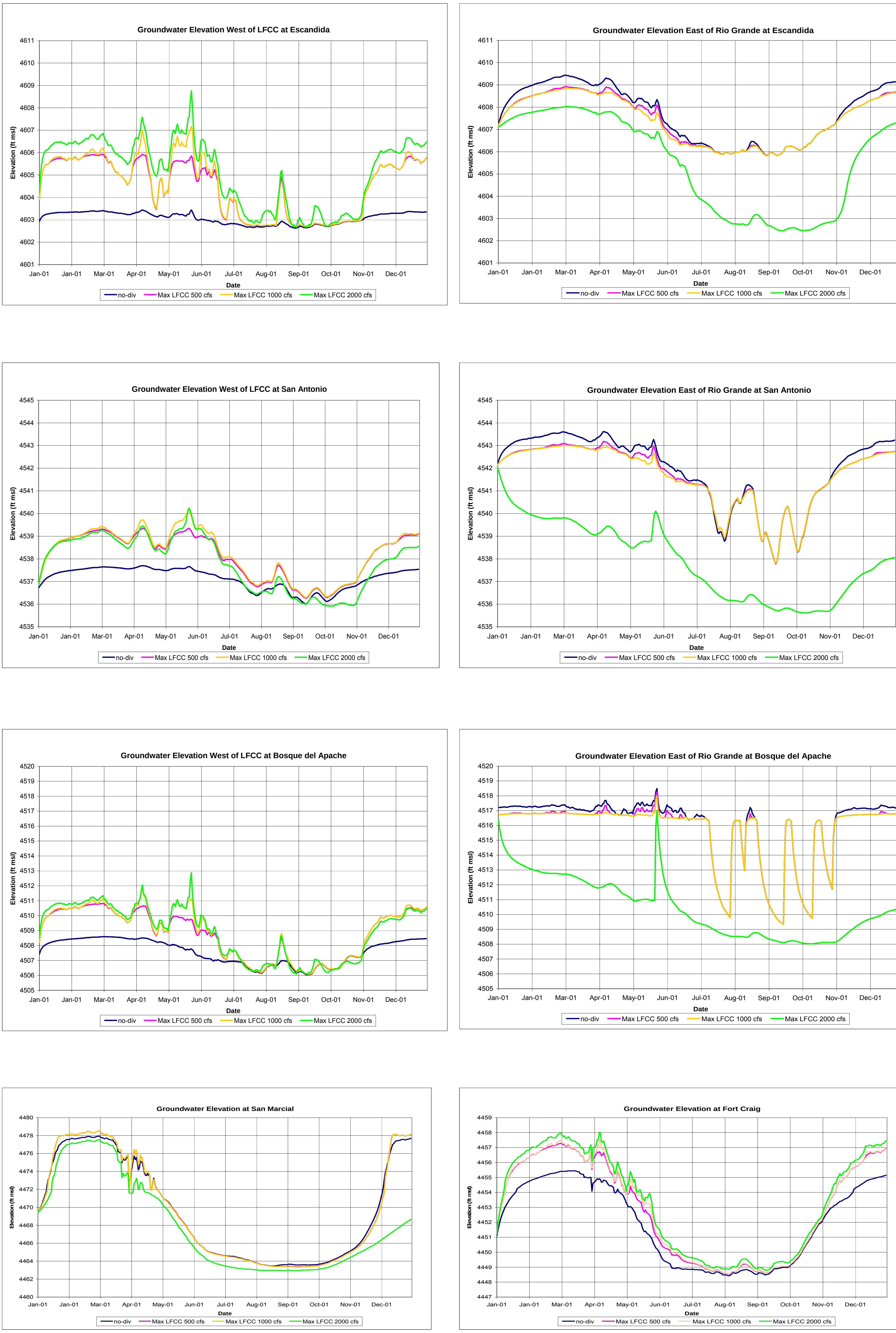


Figure 4-21. San Acacia Section: Changes in Water Table Elevation with Increasing LFCC Diversion

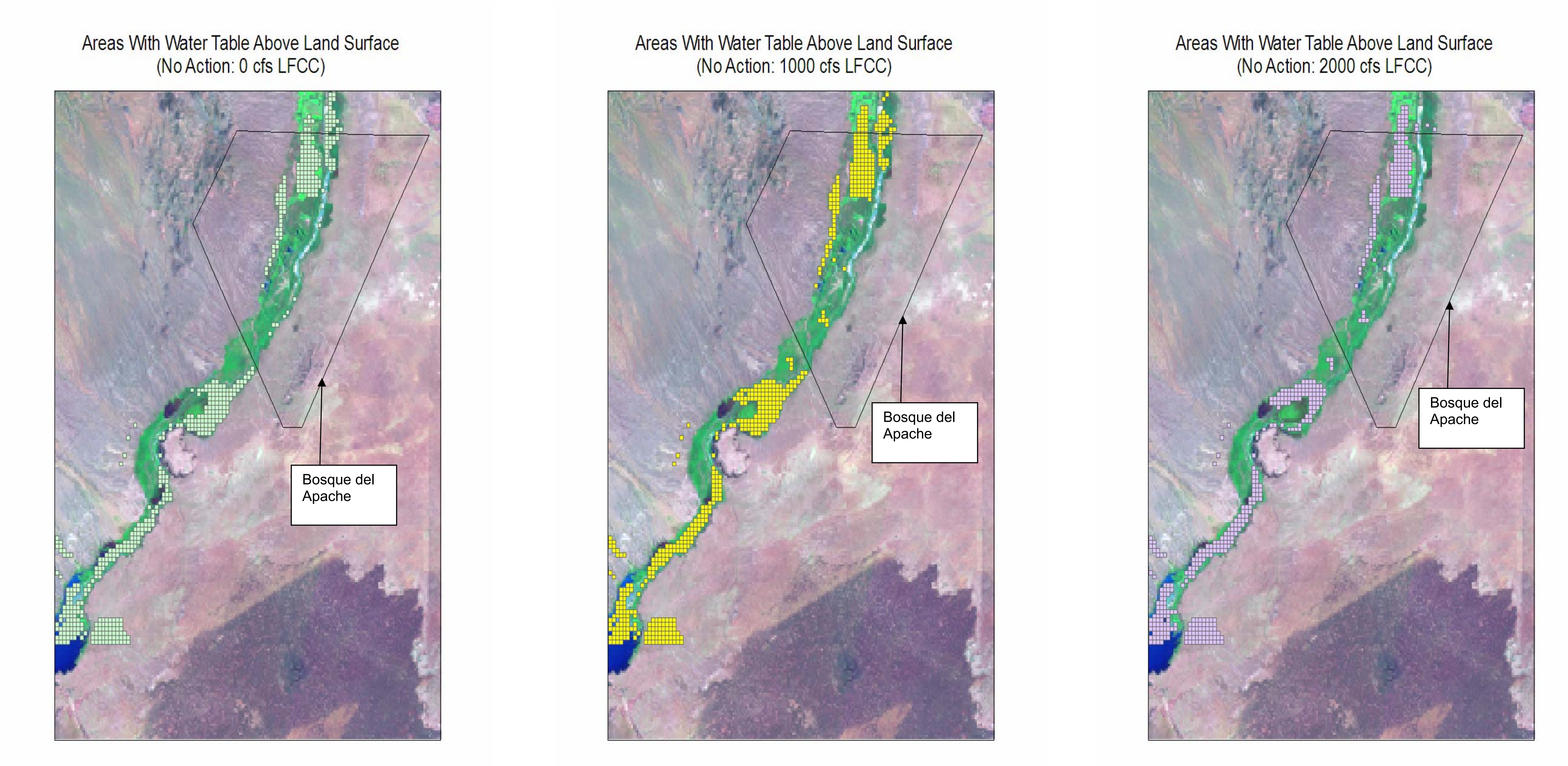


Figure 4-22. San Acacia Section: Locations Where Water Table Elevation Exceeds Land Surface Elevation

Compared to the No Action Alternative, modeled with zero diversions to the LFCC, riparian benefits were generally not evident under the action alternatives. Alternative I-1 would result in the fewest adverse impacts across the three sections of the river summarized in **Table 4-9**.

Table 4-9. Overall Impacts to Riparian Resources by River Section and Alternative

Alternative	Rio Chama Section	Central Section	San Acacia Section
No Action: LFCC = 0 cfs	No effect	No effect	Continued benefits
No Action: LFCC = 500 cfs	No effect	No effect	No effect
No Action: LFCC = 1,000 cfs	No effect	No effect	Slight adverse impact
No Action: LFCC = 2,000 cfs	No effect	No effect	Significant adverse impact
Alternative B-3	No effect	Slight beneficial impacts	Significant adverse impact compared to No Action at 2,000 cfs (except low-flow augmentation)
Alternative D-3	Slight adverse impact	No effect	Significant adverse impact compared to No Action at 2,000 cfs
Alternative E-3	No effect	Significant beneficial impact	Significant adverse impact compared to No Action at 2,000 cfs
Alternative I-1	No effect	No effect	Significant adverse impact compared to No Action at 500 cfs
Alternative I-2	No effect	No effect	Slight adverse impact compared to No Action at 1,000 cfs
Alternative I-3	No effect	No effect	Slight adverse impact compared to No Action at 2,000 cfs

Note: *No effect* means there is no significant impact to riparian resources.

The distribution of ecosystem benefits by river section is shown on **Figure 4-23**. Alternatives I-1 and I-2 perform better at equalizing riparian resource benefits across the Rio Chama, Central, and San Acacia sections. The remaining alternatives perform better in one or two sections, at the expense of the third. Riparian habitat in the San Acacia Section is typically most affected by the level of LFCC diversion.

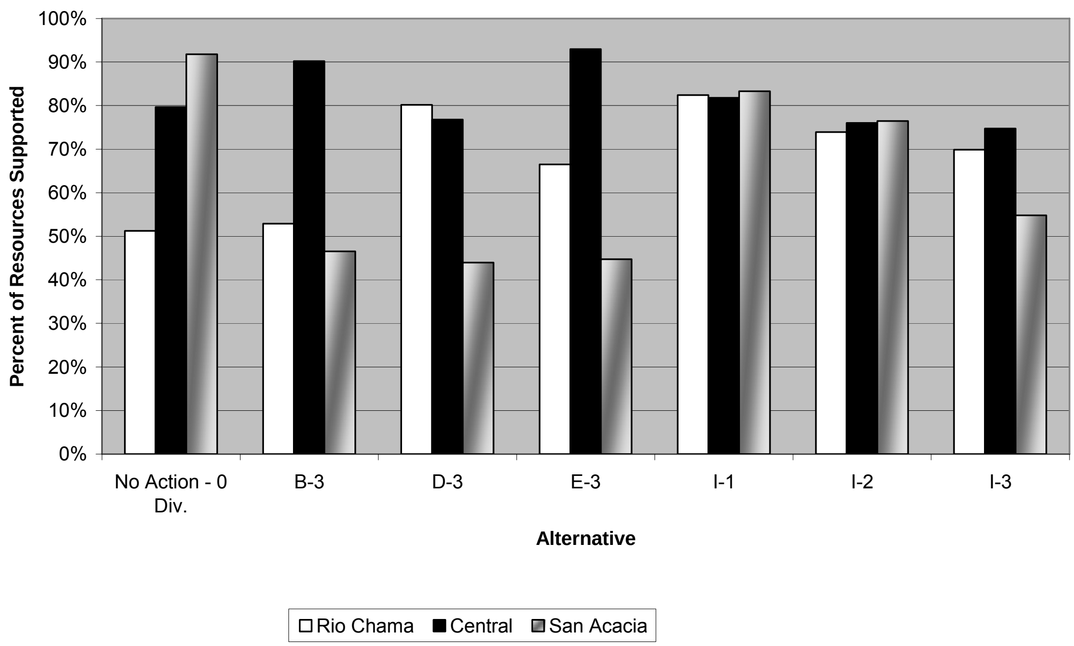


Figure 4-23. Riparian Resources Supported by River Section and Alternative

Support for riparian habitats, including threatened and endangered species, is summarized in **Figure 4-24**. Alternative I-1 offers significant improvement over No Action with zero diversions to the LFCC. Alternative I-2 offers slightly improved conditions for riparian resources. No Action with zero diversions to the LFCC is only slightly better than the alternatives allowing a full 2,000 cfs diversion: Alternatives E-3, I-3, D-3, and B-3. The overall difference in weighted resource performance measures between the No Action and the remaining alternatives is less than 5 percent.

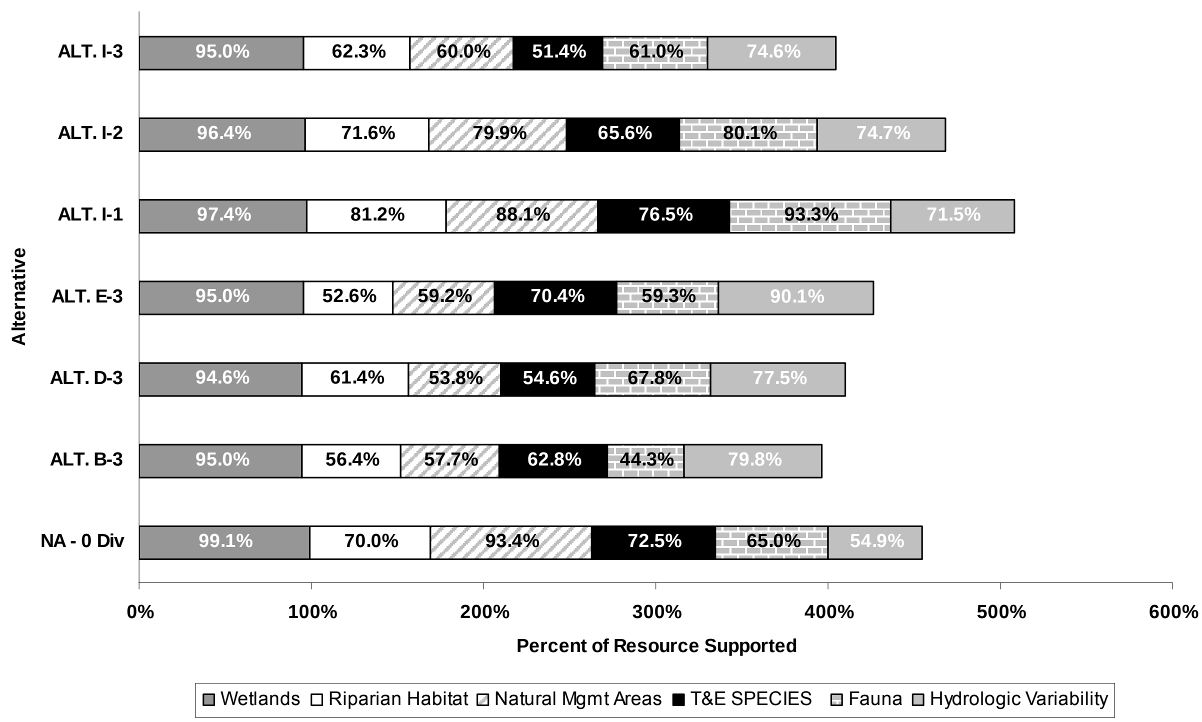


Figure 4-24. Riparian Resources Support by Alternative

Mitigation Measures

Mitigation needs for riparian resources include periodic overbank flooding to support the regeneration of native riparian vegetation, which provides high habitat diversity for wildlife. Hink and Ohmart Type 3 vegetation supports the greatest biodiversity, followed by Types 1 and 5. During extended dry periods, the use of conservation water to promote overbank flooding needed to maintain and sustain these habitats is advocated. **Figure 4-25** shows the correlation between peak flow and riparian acres flooded, by reach. Reaches 10, 12, and 13 are in the Central Section and Reach 14 is the San Acacia Section.

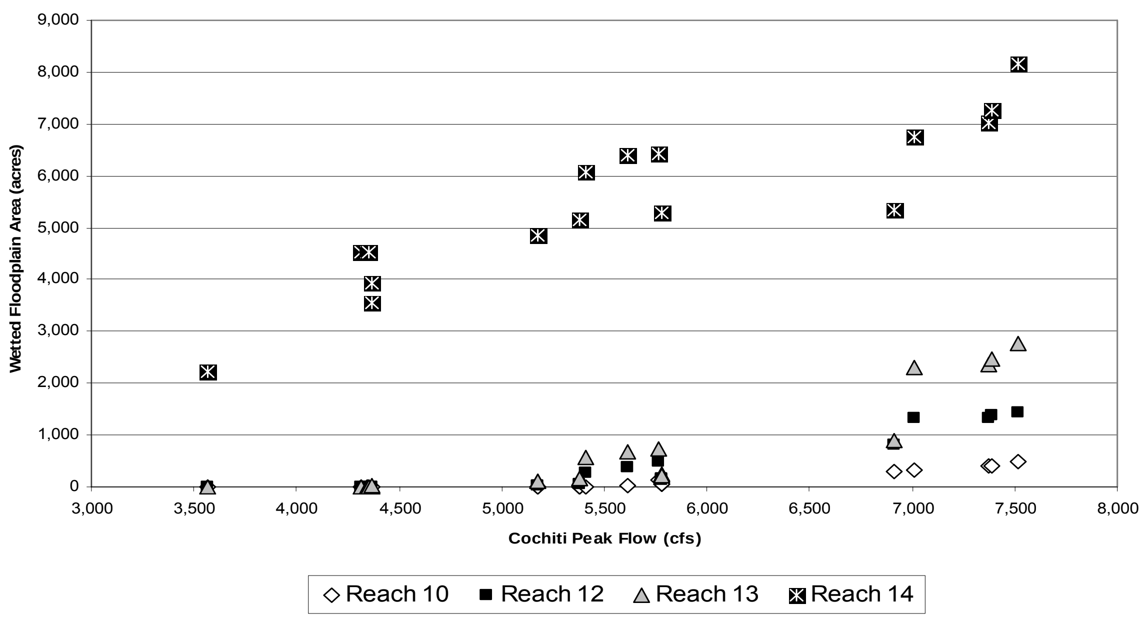


Figure 4-25. Wetted Floodplain Area Versus Peak Flows below Cochiti

The following is a list of mitigation measures to be considered for the benefit of both riparian and aquatic environments beyond the March 2003 Biological Opinion.

- Operate the LFCC in order to preserve ecosystem function and benefits from higher flows along the main river channel.
- Release conservation storage to maintain desired target flows, to reduce intermittency, and to minimize low flow days.
- Release conservation storage to increase spring peak flows in order to promote RGSM spawning and increase overbank flooding.
- Secure carryover storage agreements for conservation water that could be held over to support future ecosystem needs.
- Moderate abrupt changes to flow that could potentially strand fish and decrease support for cottonwood regeneration by ramping down reservoir release rates to slow the rate of decline.
- Monitor populations and impact indicators in order to implement adaptive management.

4.4.2.3 Threatened and Endangered Species

Issues

Of the five federally-listed threatened and endangered species identified in Chapter 3, the RGSM, the SWFL, and bald eagle were considered in the impact analysis. The interior least tern and brown pelican are only occasional migrants and were not considered further. Impacts to the New Mexico meadow jumping mouse, a state-listed threatened species, were also evaluated.

The RGSM, once abundant in the Rio Grande, is now extirpated, except in the Central and San Acacia Sections. The impact analysis also considered whether suitable habitat may be present in the Rio Chama Section. Critical habitat elements required to sustain the RGSM include favorable stream morphology and sufficient flowing water that provides food and cover for all life stages. Water quantity provides continuous flows that enable fish movement, limits predation by birds and aquatic predators, and provides sufficient habitat area to limit the spread of disease-causing pathogens. Water quantity also relates to water quality in that it prevents water stagnation and the undesirable increases in temperature and decreases in dissolved oxygen.

The SWFL is a riparian obligate that nests in thickets associated with streams and wetlands. Willow, buttonbush, box elder, Russian olive, and saltcedar are among the desirable species. Breeding territories are typically located in dense vegetation within 164 feet (50 meters) of open water. Territories tend to occur in clusters, within approximately 10 miles of each other. SWFL return to established nesting sites annually. The SWFL Recovery Plan (FWS 2002a) outlines the desired recovery goals, and Table 3-7 outlines the recovery goal territories by river section. Alternatives will be evaluated based on overall support to suitable SWFL habitat and by progress towards recovery goals.

The bald eagle is a threatened species that winters along the Rio Grande from November through March. It prefers to roost in large trees near water, typically where large cottonwoods occur at the river's edge or in large snags near reservoirs. Prey includes fish, waterfowl, and small mammals. The impact analysis will consider effects on availability of roost sites and impacts to prey bases.

The New Mexico meadow jumping mouse is a New Mexico Department of Game and Fish (NMDGF) threatened species. The meadow mouse requires dense vegetation found in marshes, moist meadows, and riparian habitats. It is also occasionally found in constructed habitats including irrigation drains and canals. The meadow jumping mouse has been reported in the Northern, Rio Chama, Central, and San Acacia Sections, with key wetland habitats identified in Espanola, Rio Cebolla, Isleta Marsh, and Bosque del Apache NWR. Wetland and wet meadow support are the key factors used to assess impacts to this state-listed species.

General Conclusions

Impacts to the various threatened and endangered species vary, and are discussed by each species as follows. In general, Alternatives I-1, I-2, E-3, and D-3 provided the best support when comparing across all species evaluated.

Evaluation of impact to the RGSM included an analysis of suitable habitat at various life stages using the aquatic habitat model, augmentation of river flow with supplemental water, and threshold water velocity during overbank flooding conditions. The RGSM is best supported across the Rio Chama, Central, and San Acacia sections with potentially suitable habitat as follows: I-1, I-2, E-3, D-3, I-3, B-3, and No Action. If habitat improvements in the Rio Chama are excluded because the RGSM is considered extirpated in this section of the river, the top two alternatives remain I-1 and I-2, with the rank order for the remaining alternatives changing as follows: No Action, D-3, E-3, I-3, and B-3.

Alternatives B-3 and D-3 provide for benefits to RGSM by having the greatest potential to augment periods of river drying or low flows using supplemental water from upstream reservoirs. These alternatives also have the potential benefit to RGSM in having fewer periods of high velocity flows that can flush eggs and larvae downstream.

Opportunities exist among the action alternatives to potentially improve the range of SWFL by increasing the availability of suitable habitat in the Rio Chama and Central Sections. Support for suitable SWFL habitat in the San Acacia Section is related to the magnitude of diversion to the LFCC. All action alternatives support territory goals identified in the SWFL Recovery Plan (FWS 2002a). However, increasing diversion to the LFCC reduces support for riparian habitat adjacent to the river in the San Acacia Section, with a 57 percent reduction in flooded acres observed when comparing 0 cfs to a 2,000 cfs diversion to the LFCC. However, all action alternatives, with the exception of D-3, offer potential improvements in wetted floodplain acres as compared to the No Action Alternative at similar levels of diversion. Alternative rank in order of preference for supporting SWFL habitat in the Rio Chama, Central, and San Acacia Sections in accordance with Recovery Plan goals is as follows: E-3, I-1, I-2, B-3, D-3, I-3, and No Action.

The bald eagle is not expected to be significantly affected by any of the alternatives. Changes in elevation at Abiquiu Reservoir increase due to the addition of native conservation storage and this offers potential enhancements in supporting the prey base. Changes in average monthly water elevation at Heron Reservoir and Cochiti Lake were not significantly different between alternatives. Effects of elevation changes in Elephant Butte and Caballo Reservoirs were not considered because this EIS considered changes only to flood control operations and not water supply.

Alternatives I-2, I-1, and No Action with LFCC diversions up to 1,000 cfs best support the wet meadow, marsh, and wetland areas frequented by the New Mexico meadow jumping mouse. Of the remaining alternatives with 2,000 cfs diversions to the LFCC, alternatives with higher channel capacities below Cochiti (E-3 and D-3) offer better support than I-3 or B-3.

Impact Indicators

Impact indicators were selected based on considerations for specific species habitat and life-stage needs.

Rio Grande Silvery Minnow—Changes in square feet of RGSM habitat were ranked by alternative considering the duration of overbank flooding, the average number of days of zero cfs flow, the average number of low flow days (less than 100 cfs), the average peak flow magnitude, and the average peak flow duration. The threshold velocity for hatching and retention of RGSM eggs in the Central and San Acacia Sections was calculated to be 1.85 feet per second. Velocities in excess of this threshold result in increased egg and larval mortality as they drift into Elephant Butte Reservoir. It is assumed that there is no recruitment of RGSM eggs or larvae in the reservoir. Reservoir habitats are not suitable for RGSM and were not evaluated further.

Southwestern Willow Flycatcher—Suitable SWFL habitat within reasonable proximity to open water was evaluated using indicators determined from the FLO-2D model including: the 40-year frequency of inundation, mean and maximum durations of dry years, mean annual acre-days of inundation, and maximum annual acre-days of inundation. More value was assigned to inundation of suitable habitat within 10 miles of currently occupied habitat due to the increased probability of SWFL expansion into areas adjacent to existing territories.

Bald Eagle—Nesting bald eagles are documented only in a few locations in New Mexico, none of which are in the planning area. Bald eagles are winter residents and most closely associated with reservoirs along the Rio Chama and Rio Grande. Impacts to bald eagles were qualitatively evaluated considering potential water operations impacts on perch/roost structures and foraging habitat.

New Mexico Meadow Jumping Mouse—Impacts to the meadow jumping mouse were evaluated considering the average annual acre-days of flooding by vegetation type to assess the hydrological support for preferred habitat. GIS overlays of vegetation mapping and FLO-2D data were used to quantitatively assess differences between alternatives. It was assumed that the baseline condition would be to maintain existing meadow jumping mouse habitat.

Methods of Analysis

Three federally-listed and one state-listed species were considered in the impact analysis, based on their known occurrence in areas most likely to be affected by changes in water operations. Quantitative analysis was based on data predicting flow-based changes in suitable habitat. Qualitative analysis was used where specific data were not available.

The RGSM impact analysis considered the URGWOM flow data, FLO-2D predictions of inundation, and the aquatic habitat modeling results for each alternative, in order to provide quantitative predictions of changes in suitable habitat.

The SWFL impact analysis used GIS overlays of vegetation mapping with inundation predicted by FLO-2D and SWFL occupied habitat patches (1999-2004). The FLO-2D model evaluated SWFL habitat quality using surrogate measures such as: 40-year frequency of inundation, mean and maximum durations of dry years, mean annual acre-days of inundation, and maximum annual acre-days of inundation. Based on prior SWFL habitat use along the middle Rio Grande and habitat requirements provided in the Recovery Plan (FWS 2002a), the most suitable SWFL breeding habitat was identified using Hink and Ohmart vegetation types. Occupied SWFL breeding sites within suitable vegetation types that are within 164 feet (50 meters) of surface water were overlain with FLO-2D inundation results to evaluate suitable habitat within 10-miles of occupied sites as well as at distances greater than 10 miles from occupied sites.

Qualitative analysis of changes in reservoir elevation in supporting perch/roost sites and foraging habitat for the bald eagle was used to evaluate impacts to this species.

Wet meadow habitat support was used to assess impacts to the New Mexico meadow jumping mouse. This analysis used GIS overlays of the inundated vegetation types to predict changes in wet meadow habitat support.

Thresholds for Significance

The significance of adverse impacts could only be determined through assessment of species status and the intensity of measurable impacts. For example, endangered species within designated critical habitat are considered to have the most sensitive context wherein even minor adverse impacts would be considered significant.

Discussion of Results of Analysis

Rio Grande Silvery Minnow—The status of the RGSM is expected to remain unchanged under the No Action Alternative, with no diversions to the LFCC. This alternative would provide fewer overbank flooding durations in the Rio Chama Section—which is beyond the current range of the species. This alternative would support habitat in the Central Section, but would provide only about half (52 percent) of the potential acres of overbank flooding supported by other alternatives. The No Action Alternative, assuming zero diversions to the LFCC, would benefit species habitat in the San Acacia Section; however, if full 2,000 cfs diversions to the LFCC were implemented, adverse impacts could be anticipated. Baseline habitat conditions under the No Action Alternative are shown in **Table 4-10**.

Table 4-10. Minnow Habitat Area by Life Stage and Section

Section	No Action (acres)	
	Juvenile	Adult
Rio Chama	<1	<1
Central	22	27
San Acacia	9	11

The lack of upstream storage limits the ability to find supplemental water, to augment high flows, and to avoid periods of intermittent flow. Within the past few years, upstream storage was used to supplement flows under emergency conditions in response to drought, requiring deviations in operations to be approved on a case-by-case basis with species-specific NEPA compliance.

The No Action Alternative would offer the least flexibility in storing upstream native Rio Grande water to support ecological needs. As modeled, it would offer a view of the maximum riverine hydrology available without supplemental water inputs. However, improvements for this listed species would likely require additional water storage that would be better supported by other alternatives. The greatest potential adverse effect would be entrainment of RGSM during diversions to the LFCC.

Limited data are available regarding the entrainment of RGSM eggs in the LFCC. Currently there are ongoing projects funded by Reclamation examining entrainment in the LFCC during peak spawning season. Previous studies by Smith (1999) found evidence of RGSM eggs in the LFCC, but were unable to identify a significant difference between the numbers of eggs entering the LFCC and the number of eggs exiting through the LFCC temporary outfall. Increased water velocity beyond 1.85 feet per second threshold would transport RGSM eggs and larvae into Elephant Butte Reservoir before they can develop swimming ability. The No Action Alternative has the greatest potential to exceed this threshold. Recent reports suggest that many viable RGSM eggs and larvae which survive do not travel far downstream (Reclamation 2004a).

Although RGSM has been extirpated from the Rio Chama Section, both juvenile and adult spring habitat area would improve under all action alternatives, as shown in **Table 4-11**. However, on an annual basis, RGSM general habitat area would decrease for all action alternatives. In the Central Section, there would be no significant difference for all habitat areas and life stages. In the San Acacia Section, there would be decreases in RGSM habitat ranging from 4 to 20 percent, primarily dependent on the degree of diversion to the LFCC. Spring habitat losses could potentially be mitigated using conservation storage.

Table 4-11. Riverine Habitat for Adult and Juvenile RGSM by Alternative

Alternative	Percent Change Relative to the No Action Alternative at 0 cfs Diversion to the LFCC								
	Rio Chama Section			Central Section			San Acacia Section		
	RGSM Juvenile Habitat Spring	RGSM Adult Habitat Spring	RGSM General Habitat Annual	RGSM Juvenile Habitat Spring	RGSM Adult Habitat Spring	RGSM General Habitat Annual	RGSM Juvenile Habitat Spring	RGSM Adult Habitat Spring	RGSM General Habitat Annual
B-3	2	4	-7	1	-2	-2	-15	-16	-20
D-3	5	6	-3	1	-1	-1	-16	-16	-20
E-3	5	6	-4	1	-1	-2	-15	-16	-20
I-1	<1	<1	-3	<-1	<-1	<-1	-4	-4	-9
I-2	2	2	-4	<1	-1	-2	-9	-9	-16
I-3	5	6	-4	<1	-1	-2	-16	-16	-20

Notes: "General" includes juvenile and adult populations. Negative values represent loss of habitat.
= Beneficial impacts
= Adverse impacts

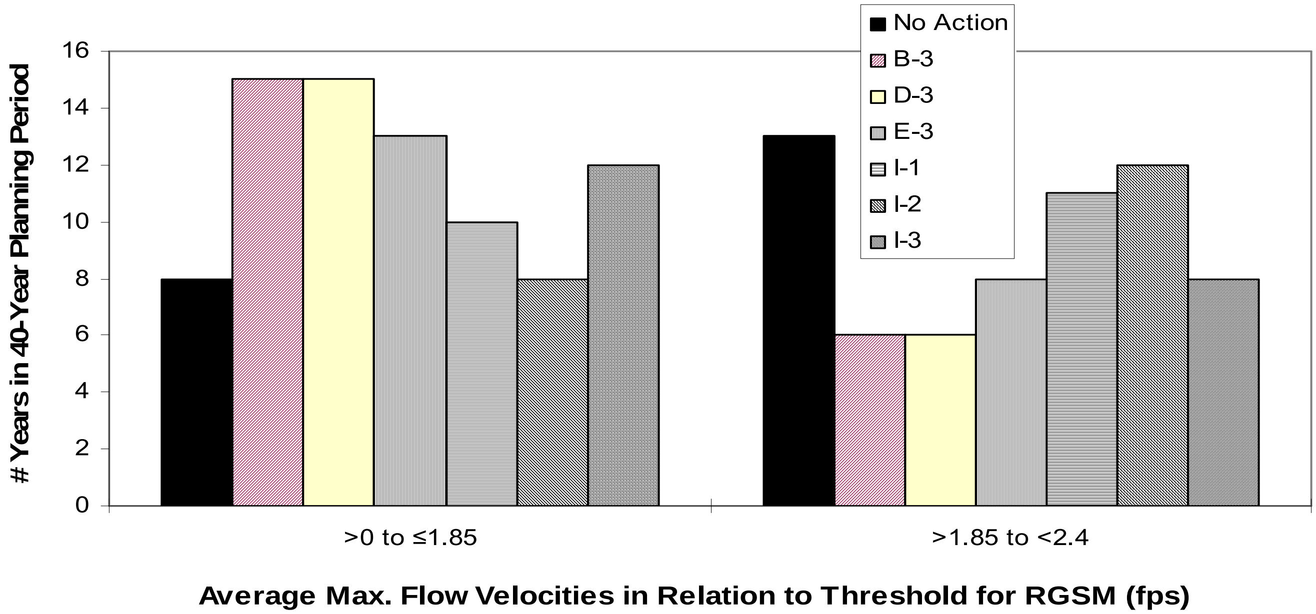
More detailed examination of the impacts of LFCC diversion on RGSM habitat was performed to better differentiate between effects of LFCC diversion and effects of change in other water operations. **Table 4-12** shows a detail of sensitivity analyses performed for varying levels of LFCC on RGSM habitat by life stage for the San Acacia Section. Total RGSM habitat area for the alternatives is provided for comparison. RGSM habitat under varying diversions to the LFCC ranges from 9.5 to 11.7 acres. Alternatives I-1 and I-2 provide RGSM habitat within 0.1 acres of the corresponding LFCC diversion under No Action. Alternatives B-3, D-3, E-3, and I-3 all result in 0.7 acre reductions in RGSM habitat when compared to No Action at the comparable 2,000 cfs LFCC diversions. Thus, reductions in RGSM habitat are approximately 7 percent in the San Acacia Section, with the remaining 7 to 15 percent reductions shown on Table 4-12 above attributed to the 2,000 cfs LFCC diversion.

Table 4-12. RGSM Riverine Habitat by Life Stage – San Acacia Section Detail

RGSM Habitat by Life Stage	Aquatic Habitat Model Site	Habitat Area (ft^2)										
		NA-0 cfs	NA-500 cfs	I-1	NA-1,000 cfs	I-2	NA-1,500 cfs	NA-2,000 cfs	B-3	D-3	E-3	I-3
Juvenile	Bosque del Apache NWR	364,851	306,171	307,365	271,748	275,019	261,397	284,466	250,279	251,144	251,579	250,954
	San Marcial	90,939	102,381	99,399	103,528	102,122	105,074	102,238	109,879	108,372	108,974	108,614
	TOTAL	455,790	408,552	406,765	375,276	377,141	366,471	386,704	360,157	359,516	360,553	359,568
	Acres	10.5	9.4	9.3	8.6	8.7	8.4	8.9	8.3	8.3	8.3	8.3
Adult	Bosque del Apache NWR	440,529	374,406	375,386	331,638	335,219	318,132	345,658	304,595	305,495	306,052	305,267
	San Marcial	126,617	138,040	135,048	138,440	137,933	140,542	137,586	148,542	146,258	147,154	146,627
	TOTAL	567,146	512,446	510,434	470,078	473,152	458,674	483,244	453,137	451,752	453,206	451,895
	Acres	13.0	11.8	11.7	10.8	10.9	10.5	11.1	10.4	10.4	10.4	10.4
Total Acres RGSM Habitat	Bosque del Apache NWR	18.5	15.6	15.7	13.9	14.0	13.3	14.5	12.7	12.8	12.8	12.8
	San Marcial	5.0	5.5	5.4	5.6	5.5	5.6	5.5	5.9	5.8	5.9	5.9
	Total Acres RGSM Habitat	**23.5**	**21.1**	**21.1**	**19.4**	**19.5**	**18.9**	**20.0**	**18.6**	**18.6**	**18.7**	**18.7**
Percent RGSM Habitat at Model Sites	Bosque del Apache NWR (40.2 acres)	46%	39%	39%	34%	35%	33%	36%	32%	32%	32%	32%
	San Marcial (15.5 acres)	32%	36%	35%	36%	36%	36%	36%	38%	38%	38%	38%

The No Action Alternative has the greatest potential for adverse impacts to RGSM eggs and larvae due to flushing flows during overbank flood events (**Figure 4-26**). Alternatives B-3 and D-3 provide the greatest number of days of low velocities and the fewest number of days of threshold-exceeding velocities.

Figure 4-26. Frequency of Threshold Velocity Exceedance During Years of Overbank Flooding in



the Rio Grande from Angostura Diversion Dam to Elephant Butte Reservoir

Southwestern Willow Flycatcher—The effects of the No Action Alternative on the endangered SWFL are not uniform in the planning area, as shown in **Tables 4-13** and **4-14**. In the Rio Chama and Central Sections, the No Action Alternative may not provide sufficient frequency or extent of overbank inundation to meet recovery goals identified in the SWFL Recovery Plan (FWS 2002a). However, continued benefits to SWFL habitat would be anticipated in the San Acacia Section under the No Action if no diversions to the LFCC were implemented during the 40-year period.

No Action with 0 cfs diversions to the LFCC would provide the best support to occupied SWFL sites and suitable habitat in the San Acacia Section, which has the greatest number of occupied sites and largest acreage of suitable habitat within 10 miles of occupied sites. By contrast, the No Action Alternative would provide less support to the Rio Chama and Central Sections. Suitable habitat within 10 miles of occupied sites in the Rio Chama Section would receive inundation during 67 percent of the years, with an annual average of 0.7 acre-days of inundation. Suitable habitat less than 10 miles from occupied territories in the Central Section would receive an annual average of 530 acre-days of flooding during 16 percent of the years. Overall, this alternative would provide the least support to suitable habitat of any of the alternatives in the Rio Chama Section.

The overall average performance of the No Action Alternative with zero diversions to the LFCC would be beneficial to the species, given the large areas of habitat supported in the San Acacia Section. It would provide the flows necessary to maintain and expand the population in the Middle Rio Grande SWFL Recovery Unit. However, this alternative would not assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and establishing and supporting suitable habitat in the Upper Rio Grande Unit.

Impacts of different levels of diversion into the LFCC would have an increasing adverse effect to flycatcher territories along the Rio Grande, but there would be some beneficial effects to territories located at the existing LFCC outfall. The total area of floodplain inundation averaged over the 40-year planning period would decrease by 16 percent with 500 cfs diversions, 34 percent with 1,000 cfs diversions, and 67 percent with 2,000 cfs diversions, as shown in Figure 4-19.

Bald Eagle—Impacts to bald eagle habitat include decreasing available roost sites (tall snags) near suitable open water foraging areas, reducing the aquatic habitat supporting the eagle's prey base, or increasing the distance from suitable roosting habitat to open water feeding areas. All action alternatives increase average monthly reservoir elevations when compared to No Action. None of the action alternatives are expected to result in adverse effects to bald eagles at the key reservoirs, as increased water storage is anticipated under all scenarios when compared to No Action. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

Table 4-13. Impacts of SWFL Habitat Inundation

			Section					
					San Acacia			
					LFCC Diversion			
Measure	**SWFL Habitat Class**	**Alternative**	**Rio Chama**	**Central**	**0 cfs**	**500 cfs**	**1,000 cfs**	**2,000 cfs**
Average Inundated Acres		No Action			3,788	3,236	2,680	1,615
						85%	71%	43%
Mean Annual Days Inundation - Occupied Sites	Occupied Sites	No Action	No Territories	10	462			
		B-3	No Territories	37				100
		D-3	No Territories	10				116
		E-3	No Territories	39				102
		I-1	No Territories	11		391		
		I-2	No Territories	10			383	
		I-3	No Territories	9				200
Mean Annual Acre-Days Inundation - Suitable Habitat	Suitable Habitat <10 miles from Core Areas	No Action	11	888	20,374			
		B-3	72	1,010				8,789
		D-3	200	903				9,177
		E-3	141	1,063				8,842
		I-1	238	950		17,615		
		I-2	179	872			13,552	
		I-3	140	817				9,621
Mean Annual Acre-Days Inundation - Suitable Habitat	Suitable Habitat >10 miles from Core Areas	No Action	21	584	3,476			
		B-3	21	618				584
		D-3	219	582				648
		E-3	109	645				572
		I-1	174	625		2,861		
		I-2	138	564			2,654	
		I-3	108	527				1,392

Measure	SWFL Habitat Class	Alternative	Section					
			Rio Chama	Central	San Acacia			
					LFCC Diversion			
					0 cfs	500 cfs	1,000 cfs	2,000 cfs
Mean Annual Acres Inundated	Suitable Habitat <10 miles from Core Areas	No Action	14	33	345			
		B-3	6	57				224
		D-3	12	36				221
		E-3	9	63				224
		I-1	14	37		322		
		I-2	11	34			308	
		I-3	9	30				237
Mean Annual Acres Inundated	Suitable Habitat >10 miles from Core Areas	No Action	5	22	106			
		B-3	1	35				29
		D-3	10	23				25
		E-3	4	40				27
		I-1	5	25		99		
		I-2	5	23			95	
		I-3	4	20				50

Table 4-14. Frequency of Inundation and Duration of Dry Years—SWFL Habitat

Measure	SWFL Habitat Class	Alternative	Section					
			Rio Chama	Central	San Acacia			
					LFCC Diversion			
					0 cfs	500 cfs	1,000 cfs	2,000 cfs
40-year Frequency of Inundation (percent)	Occupied Sites	NA	No Territories	17	53			
		B-3	No Territories	25				40
		D-3	No Territories	20				43
		E-3	No Territories	23				38
		I-1	No Territories	20		53		
		I-2	No Territories	20			50	
		I-3	No Territories	18				48
40-year Frequency of Inundation (percent)	Suitable Habitat <10 miles from Core Areas	NA	90	50	100			
		B-3		48				90
		D-3		48				90
		E-3						90
		I-1	90	53		95		
		I-2	85	50			90	
		I-3		48				90

Measure	SWFL Habitat Class	Alternative	Section					
					San Acacia			
					LFCC Diversion			
			Rio Chama	Central	0 cfs	500 cfs	1,000 cfs	2,000 cfs
40-year Frequency of Inundation (percent)	Suitable Habitat >10 miles from Core Areas	NA	90	50	53			
		B-3	85	48				30
		D-3	85	48				30
		E-3	88					25
		I-1	93	53		53		
		I-2	90	50			50	
		I-3	88	48				35
Maximum Duration - Dry Years	Occupied Sites	NA	No Territories	11	5			
		B-3	No Territories	12				6
		D-3	No Territories	12				6
		E-3	No Territories	**7**				12
		I-1	No Territories	12		6		
		I-2	No Territories	12			6	
		I-3	No Territories	11				5
Maximum Duration - Dry Years	Suitable Habitat <10 miles from Core Areas	NA	1	5	0			
		B-3		5				1
		D-3		5				1
		E-3	1	5				1
		I-1	1	5		1		
		I-2	1	5			1	
		I-3		5				1
Maximum Duration - Dry Years	Suitable Habitat >10 miles from Core Areas	NA	1	5	5			
		B-3	1	5				11
		D-3	1	5				11
		E-3	1	6				11
		I-1	1	5		5		
		I-2	1	5			5	
		I-3	1	5				11

New Mexico Meadow Jumping Mouse—Impacts to meadow jumping mouse populations are limited to available wet meadow habitat. **Table 4-15** indicates the amount of habitat supported in each section for each alternative. This analysis provides a baseline comparison for the San Acacia Section, as the full range of diversions to the LFCC under No Action was not explicitly evaluated. This table also considered only surface water inundation and not groundwater support for wet meadow habitats. Considering impacts to wetland areas, LFCC diversions near 1,000 cfs supported the maximum wetland habitat areas in the San Acacia Section. Therefore, based on increased wetland habitat support from higher groundwater elevations, it is reasonable to consider that Alternatives I-1 and I-2 may provide the most wet meadow habitat support.

Table 4-15. Acre-Days of Wet Meadow Inundation

Alternative	Acre-Days Wet Meadow Inundation — Section: Rio Chama	Central	San Acacia	Sum	% Max	Rank
No Action (0 cfs diversion to LFCC)	3	7.3	8.6	18.9	100%	1
B-3	NA	7.3	0.0	7.3	39%	7
D-3	NA	8.4	0.3	8.7	46%	4
E-3	NA	7.0	5.7	12.7	67%	2
I-1	NA	7.4	4.7	12.1	64%	3
I-2	NA	6.8	1.0	7.8	41%	5
I-3	NA	6.8	1.0	7.8	41%	5

Sources of Uncertainty and Data Gaps

Model predictions in the San Acacia Section offer less certainty due to limitations in modeling and highly dynamic and unstable river and riparian environments. Thus, a 10 percent threshold of significance is considered the absolute minimum in this section, with the exception of impacts affecting endangered species in designated critical habitats.

SWFL-occupied habitat within the pool of Elephant Butte Reservoir was not considered in this analysis. Changes in water operations were associated with flood control operations only, not changes in water supply at this Reservoir.

Summary/Comparison by Alternative: Threatened and Endangered Species

Rio Grande Silvery Minnow

The greatest abundance of RGSM habitat occurs in the Central and San Acacia Sections. Potentially suitable habitat was also identified for the Rio Chama Section. Overall, RGSM habitat is best supported by No Action at 0 cfs diversions to the LFCC. All alternatives are either neutral or offer slight improvements to RGSM habitat in the Rio Chama and Central Sections. In the San Acacia Section, RGSM habitat is most directly influenced by diversions to the LFCC. Alternatives I-1 (up to 500 cfs to the LFCC) and I-2 (up to 1,000 cfs to the LFCC) had the smallest impact on RGSM habitat. LFCC diversions up to 1,500 cfs cause the greatest loss of habitat, with slight gains observed once diversions increase to 2,000 cfs. However, slight gains in habitat are observed under action alternatives when compared to equivalent LFCC diversions at No Action at the San Marcial site. Under the same comparisons, slight RGSM habitat losses are observed at the Bosque del Apache NWR site. Of alternatives allowing up to 2,000 cfs diversions to the LFCC, the order of preference in support of RGSM habitat is as follows: E-3, B-3, I-3, and D-3.

The No Action Alternative has the greatest potential for adverse impacts to RGSM eggs and larvae due to flushing flows during overbank flood events (Figure 4-26). Alternatives B-3 and D-3 provide the greatest number of days of low velocities and the fewest number of days of threshold-exceeding velocities. Alternative B-3 has the greatest potential to provide benefits to RGSM by augmenting low flows provided by supplemental water from upstream reservoirs.

Southwestern Willow Flycatcher

Known active SWFL territories have historically been concentrated in the San Acacia Section with lesser occurrences in the other river sections. The SWFL Recovery Plan (FWS 2002a) has established recovery goals for a number of territories and suitable habitat acreage. The suitability of habitat is determined by vegetation, composition, structure, and proximity to surface water.

The SWFL Recovery Plan (FWS 2002a) sets a minimum goal of 250 territories for the Rio Grande Recovery Unit needed to warrant reclassification of this subspecies from endangered to threatened. **Table 4-16** shows a comparison of habitat acres by river section compared to Recovery Plan goals (FWS 2002a). Only the Central and San Acacia Sections currently exceed Recovery Plan goals. SWFL territories in the Northern Section appear to meet recovery goals, but the acres of suitable habitat were not mapped in support of this evaluation. The Rio Chama Section is currently below recovery goals in number of SWFL territories and acres of suitable habitat. SWFL territories in the Southern Section were not mapped, so the status of this section with respect to Recovery Plan goals is not known.

Table 4-16. Habitat acres Versus Recovery Plan Goals Per Section for Each Alternative

Habitat Parameter/Alternative	Northern Section		Rio Chama Section	Central Section	San Acacia Section	Southern Section
	River Reaches					
	1, 2	3, 4, 5, 6	7, 8, 9	10, 11, 12, 13	14	15, 16
Known Active SWFL Territories	40-65	12	1	10	149	6
Rio Grande SWFL Recovery Management Unit	San Luis Valley	Upper Rio Grande Unit		Middle Rio Grande Unit		Lower Rio Grande
Recovery Goal Territories	50	75		100		25
Recommended Acres Suitable SWFL Habitat to Meet Recovery Goal	271	407		543		136
Suitable SWFL Habitat in Acres (% mapped)	Not Mapped	172 (5% Reach 4 only)	137 (5% Reach 7 only)	942 (5%)	1374 (7%)	Not Mapped
Acres Suitable Habitat Supported by Alternative[1]						
No Action	Not Mapped		1	18	1,567	Not Mapped
B-3			<1	36	901	
D-3			1	21	797	
E-3			1	39	980	
I-1			1	20	1,570	
I-2			1	19	1,303	
I-3			1	17	810	

Note: [1] Mean annual acres of inundated, suitable habitat less than 10 miles from core areas
Source: Moore and Ahlers 2003; Moore and Ahlers 2004; Stone 2003

All action alternatives would support SWFL Recovery Plan goals in the Central and San Acacia Sections. None of the alternatives are projected to provide adequate acreage of suitable habitat in the Rio Chama Section. There is insufficient data to assess the progress towards recovery goals in the Northern and Southern Sections.

Bald Eagle

The bald eagle is only a winter visitor to reservoirs in the planning area. Bald eagle impact analysis was based on qualitative evaluation of reservoir elevation changes affecting roosting, foraging, and prey base.

None of the alternatives are projected to have a significant impact on bald eagle populations in the planning area.

New Mexico Meadow Jumping Mouse

New Mexico meadow jumping mouse habitat in the Rio Chama Section is improved under all alternatives. The meadow jumping mouse habitat in the Central Section is best supported by Alternatives I-1, E-3, and B-3. Wet meadow habitats supported by surface flows in the San Acacia Section were influenced by alternatives with the least diversion to the LFCC (No Action, I-1 and I-2). Qualitative considerations including groundwater elevation analysis suggests that maximal wetland areas are best supported by LFCC diversions between 500 and 1,000 cfs, also favoring the No Action, I-1, and I-2 Alternatives.

Mitigation Measures

Potential mitigation measures for riverine habitat were identified in Section 4.4.2.1. Mitigation measures needed to support overall aquatic habitat would also benefit the RGSM. Additional mitigation measures for RGSM support include the construction of additional in-stream or off-stream habitat to offset potential losses incurred under the Preferred Alternative, continued support for the captive breeding and release programs, and continued rescue and recovery efforts during prolonged channel drying in times of drought.

Mitigation of the adverse effects of the No Action Alternative with 0 cfs diversion to the LFCC on the SWFL is the subject of a 2003 Section 7 consultation with the FWS entitled, "Final Programmatic Biological Opinion on the Effects of Actions Associated with the Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Action on the Middle Rio Grande, New Mexico through February 28, 2013."

The effects of fluctuating reservoir levels at Elephant Butte on the SWFL and their habitat in the flood pool are being addressed separately between Reclamation and the FWS.

No mitigation measures are proposed for the bald eagle.

Mitigation measures for the New Mexico meadow jumping mouse should evaluate support for wetland areas. If an alternative favoring 2,000 cfs diversion to the LFCC is implemented, the change in wetland habitat should be evaluated and, if an adverse impact is observed, increased year-to-year overbank flooding together with targeted supplemental pumping may be needed to provide wet meadow habitat support.

4.4.3 Water Quality

4.4.3.1 Issues

The natural variability of surface water quality within the upper Rio Grande can be attributed to a variety of watershed characteristics and hydrologic processes. These processes include the dynamic balance between the chemical composition of surface water, including tributary inflow and groundwater interaction, precipitation, surrounding geology, nutrient uptake, erosive capability of the channel and surrounding land, and evapotranspiration.

Water quality is further impacted by dams and reservoir operation. Reservoir operations affect water quality by altering water chemistry, natural flow variation, and the transport of sediments, nutrients, and contaminants. Within the Rio Grande watershed, these impacts occur in three primary ways. (1) Reservoirs regulate the downstream flow of sediments, nutrients, and contaminants contributed by groundwater, tributaries, and overland flow sources. Diminished water velocity in reservoirs causes nutrients and suspended sediments to settle, thus decreasing the natural nutrients and sediments in the system. (2) Reservoirs and dams create a unique physical and chemical environment that affects nutrient cycling within the reservoirs, and ultimately may impact riverine environments upstream and downstream of the reservoir. (3) Reservoirs commonly alter the natural temperature regime downstream. Water released from the depths of a reservoir may produce cooler surface temperatures downstream, altering natural conditions that species have become adapted to. Conversely, water released from higher levels in a reservoir may increase surface temperature downstream.

The effects of reservoirs on water quality dissipate as flows continue downstream. With distance from the reservoir, the impacts of tributaries, overland flow, atmospheric conditions, adjacent land use, and surrounding geology on local water quality increase. For example, as water travels downstream after being released from a reservoir, temperature and dissolved oxygen, as well as other constituents, quickly equilibrate with ambient atmospheric conditions. The specific manner in which these changes occur depends on air temperature, storm or snowmelt runoff, land use, and other factors such as turbulence within a river reach.

4.4.3.2 General Conclusions

There is little difference in the projected impacts on water quality among the action alternatives, except for the No Action Alternative, which ranks last. The only potential impact identified for water quality was reduced dissolved oxygen at Elephant Butte and Caballo Reservoirs, which occurred in all alternatives.

4.4.3.3 Impact Indicators

Impact indicators used to assess water quality include: dissolved oxygen (DO), temperature, TDS/conductivity, and the ability to use conservation storage to modify water quality identified as adaptive flexibility. These indicators were selected based on data availability, data quality, availability of numeric standards, and ability to be influenced by changes in reservoir operations. Additional details on the derivation and use of these impact indicators is provided in Appendix M.

4.4.3.4 Methods of Analysis

Water quality resource indicators were identified by evaluating specific water quality constituents most likely to be affected by reservoir operations and the availability of sufficient quality data for analyses. Two reservoirs and 18 USGS gages were selected for detailed water quality analysis. Water temperature, dissolved oxygen, total dissolved solids (TDS)/conductivity, and pH datasets were used for modeling.

The impact of changes in water operations were evaluated by using URGWOM model discharges at the various gages in a series of linear regression models developed to predict water quality changes as a result of dependent and independent variables. Applicable state, tribal, and Compact standards were reviewed for each of the five river sections. Boundaries of these reaches were set when a change in water quality regulations or land governance occurred, or when waters entered or left a reservoir. Regression modeling was then used to predict water quality changes based on URGWOM model discharges at the various gages under each alternative. The result was a prediction of the daily values of water temperature, dissolved oxygen, and total dissolved solids at selected locations in the four analysis reaches. The number of predicted values that exceeded the appropriate water quality standards were counted and used to develop the weighted values in Table 4-17.

Thresholds for Significance

The regression equations were developed for a significance level of 0.05; therefore, at least a 5 percent level of error is expected when coupled with the use of URGWOM discharge data at a similar level of error. In general, changes greater than 10 percent were viewed as potentially significant.

4.4.3.5 Discussion of Results of Analysis and Summary/Comparison of Alternatives

Table 4-17 summarizes the values based on water quality monitoring data. A value of 100 percent indicates the best condition; lesser values indicate an unfavorable impact. As modeled, the No Action has the largest adverse impact, especially for temperature along the Rio Chama and the Southern Section reservoirs—Elephant Butte and Caballo. TDS/conductivity is adversely affected in the San Acacia Section. Dissolved oxygen is relatively unchanged except in the reach below Elephant Butte Reservoir where dissolved oxygen would be adversely affected under all action alternatives. Alternative B-3 provides the best performance with respect to water quality, with slight impacts to temperature and dissolved oxygen in the Central and Southern sections. Alternatives D-3, E-3, I-1, and I-3 all perform similarly, with the largest changes anticipated for dissolved oxygen in Elephant Butte and Caballo Reservoirs. Alternative I-2 performs similarly to the No Action Alternative and ranks sixth of seven alternatives.

Table 4-17. Water Quality Summary

	Section					
Water Quality Parameter	**Rio Chama**	**Central**	**San Acacia**	**Southern (Elephant Butte & Caballo only)**	**Total Weighted Score***	**Water Quality Rank**
No Action						
Dissolved Oxygen	100%	99%	100%	100%		
Temperature	64%	100%	100%	28%	88%	7
TDS/Conductivity	100%	100%	53%	100%		
Alternative B-3						
Dissolved Oxygen	100%	89%	100%	74%		
Temperature	100%	99%	100%	99%	96%	1
TDS/Conductivity	100%	100%	100%	100%		
Alternative D-3						
Dissolved Oxygen	100%	94%	100%	74%		
Temperature	89%	99%	100%	100%	94%	4
TDS/Conductivity	100%	100%	94%	100%		
Alternative E-3						
Dissolved Oxygen	100%	99%	100%	74%		
Temperature	89%	99%	100%	99%	94%	3
TDS/Conductivity	100%	100%	94%	100%		
Alternative I-1						
Dissolved Oxygen	100%	99%	100%	74%		
Temperature	89%	99%	100%	99%	91%	6
TDS/Conductivity	100%	100%	94%	100%		
Alternative I-2						
Dissolved Oxygen	100%	99%	100%	77%		
Temperature	79%	100%	100%	94%	93%	5
TDS/Conductivity	100%	100%	94%	100%		
Alternative I-3						
Dissolved Oxygen	100%	99%	100%	74%		
Temperature	89%	99%	100%	100%	94%	2
TDS/Conductivity	100%	100%	94%	100%		

Total weighted score was calculated by summing the percentage of time that modeled water quality met the appropriate standards over the 60-year period of the model. Percentages were standardized by dividing the each percentage by the highest percentage. The water quality team then applied a weighting score to each standardized value depending on the quality of the data used in the model and the confidence the team had in the modeled values. These weighted values were summed across reaches and constituents to arrive at the weighted value for each alternative.

Figure 4-27 shows the departure from the No Action Alternative, with negative values indicating that the No Action Alternative would perform better than the action alternatives listed. Only constituents and sections where differences were identified are included in the graph. The most significant negative departures occurred for dissolved oxygen at Elephant Butte and Caballo Reservoirs.

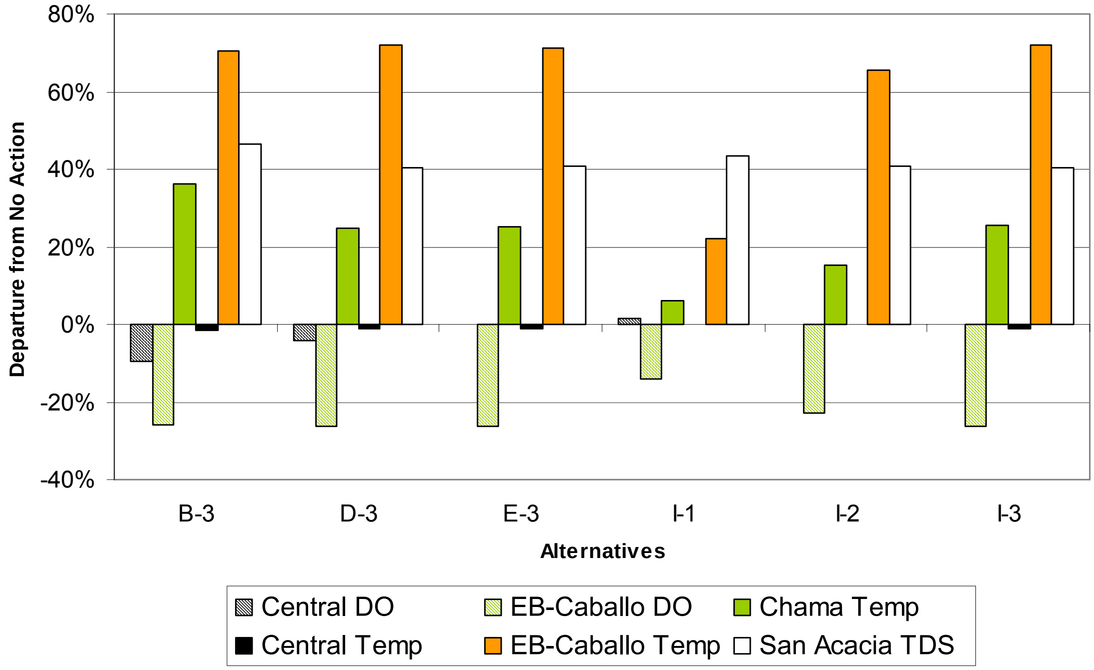


Figure 4-27. Comparison of Water Quality Parameters to No Action

Sources of Uncertainty and Data Gaps

The current water quality analysis is based on limited data collected by various agencies at selected gage locations in the four analysis reaches. Because of the lack of data in some locations, the models were developed with few values with which models could be calibrated. This mostly occurred for the total dissolved solids models. For these models, there is some level of uncertainty in the results of the models and the results of these models were weighted lower than those with greater certainty. Additional data gaps occurred in the reservoirs where water quality data was limited and of questionable quality.

4.4.3.6 Mitigation Measures

Significant impacts to dissolved oxygen in Elephant Butte and Caballo Reservoirs occurred with all alternatives. Proposed mitigation measures for water quality provide more oxygenated waters to the reservoir. Mitigation could be accomplished by increasing seasonal discharges of better oxygenated water to the reservoir. This would most easily be accomplished by alternatives providing the most opportunity for upstream native conservation storage and by coordination with other ecosystem mitigation opportunities and Compact water delivery requirements.

4.4.4 Indian Trust Assets and Cultural Resources

4.4.4.1 Issues

Native Americans use the Rio Grande for traditional and cultural purposes. All Pueblos and Tribes are committed to preserving the river and riparian ecosystem; many are implementing habitat restoration projects. Formal government-to-government consultation and informal meetings have identified a variety of concerns related to Indian Trust Assets including water flows, water quality, protection of lands and structures, cultural resources, and support for riparian and riverine habitats.

Cultural resources in the planning area include archaeological sites, historic and prehistoric buildings, potential cultural landscapes, and traditional cultural properties. They are of concern based on various laws including the National Historic Preservation Act, the Archaeological Protection Act, and the Native American Graves Protection and Repatriation Act.

4.4.4.2 General Conclusions

The identification of preferences by individual Pueblos and Tribes is pending. Pueblos and Tribes have been informed about the project through formal government-to-government consultation, coordination meetings with governments from the Eight Northern Pueblos Council, the Ten Southern Pueblos Council, and the Middle Rio Grande Pueblo Water Coalition. Review of impacts specific to Pueblo and Tribal lands is underway.

The preferences regarding Indian Trust Assets (ITAs) reflected in this Draft EIS reflect the opinions provided by cooperating agencies, including the Bureau of Indian Affairs. Alternatives D-3, I-1, I-2, and I-3 were all considered to provide improvements to ITAs including preserving unique and sensitive sites, avoiding impacts to traditional cultural properties, and preserving acequias and other irrigation structures. Alternatives B-3 and E-3, together with the No Action Alternative were considered fair with respect to impacts to ITAs.

The area of potential effect was limited to the Rio Chama, Central, and San Acacia Sections. Cultural resources in the Northern and Southern Sections were not affected by proposed changes in operations. Impacts to the San Acacia Section were the greatest, with 55 to 90 percent of sites affected by the alternatives. Alternatives B-3, I-3, D-3, E-3, and I-2 showed improvements over No Action. Alternative I-1 exacerbated cultural resources impacts.

4.4.4.3 Impact Indicators

Current impact indicators are limited to those identified in discussions with the Bureau of Indian Affairs and ID NEPA team participants from various tribes. Impacts to ecosystem and water quality resources were considered in earlier analyses. Impact indicators in the assessment of ITAs included: preservation of unique and sensitive sites; minimizing impact to traditional cultural properties; preserving acequias and other structures.

Similar impact indicators were used in the evaluation of alternative performance concerning cultural resources preservation. The impact indicators included: number of sites potentially impacted, average duration of inundation over the 40-year period, the degree of channel erosion, and the character of sites affected. This included consideration for the preservation of unique and sensitive sites and preserving acequias and other structures.

4.4.4.4 Methods of Analysis

Impacts to ITAs and cultural resources were analyzed by similar methods. Based on preliminary evaluation of projected inundation, the area of impact was limited to the Rio Chama, Central, and San Acacia Sections. The number of known sites were identified by reach in each river section. URGWOM and FLO-2D model data were used to identify areas of flooding, inundation, and erosion. The number of sites affected by the degree and duration of inundation was identified for each reach. An analysis of variance was performed to identify significant differences between alternatives. Qualitative assessment was also performed to identify whether certain types of sites were unduly impacted.

Thresholds for Significance

Qualitative analyses were the only analyses performed for ITAs in this EIS. Confidence intervals of 5 to 10 percent should be used in interpreting results from cultural resources analysis. No significant differences were observed between alternatives, the range of impacted sites was 383 to 465 among all alternatives, the number of days inundated ranged from 2 to 7 among all alternatives.

4.4.4.5 Discussion of Results of Analysis

ITAs were evaluated in a qualitative manner based on information provided by the Bureau of Indian Affairs. The No Action Alternative and Alternatives B-3 and E-3 were considered fair in preserving unique and sensitive sites, avoiding impacts to traditional cultural properties, and preserving acequias and other irrigation structures. The remaining action alternatives (D-3, I-1, I-2, and I-3) provided improvements to ITAs over the No Action Alternative.

For cultural resources under all action alternatives, the San Acacia Section would have the greatest impacts, with 55 (Alternative E-3) to 90 percent (Alternative I-1) of sites impacted by projected inundation. **Table 4-18** identifies the results of alternative analysis based on projected impacts to cultural resources in all river sections.

Table 4-18. Weighting of Alternatives Based on Impacts to Cultural Resources

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Performance Measure							
Total Sites Inundated	418.0	436.0	383.0	465.0	406.0	406.0	387.0
Percent of Sites Inundated	78.0	81.0	69.0	92.0	73.0	73.0	67.0
Percent of Inundated Sites Eligible for Registry	25.0	20.0	84.0	84.0	24.0	24.0	24.0
Frequency of Inundation over 40-Year Period (years)	1.3	0.6	0.6	0.6	1.3	1.1	0.7
Annual Duration of Inundation (days)	7.0	2.0	2.0	2.0	7.0	4.0	4.0
RANK	**7**	**1**	**2**	**4**	**6**	**5**	**3**

Figure 4-28 depicts the estimated number of sites that would be inundated by river section under each alternative.

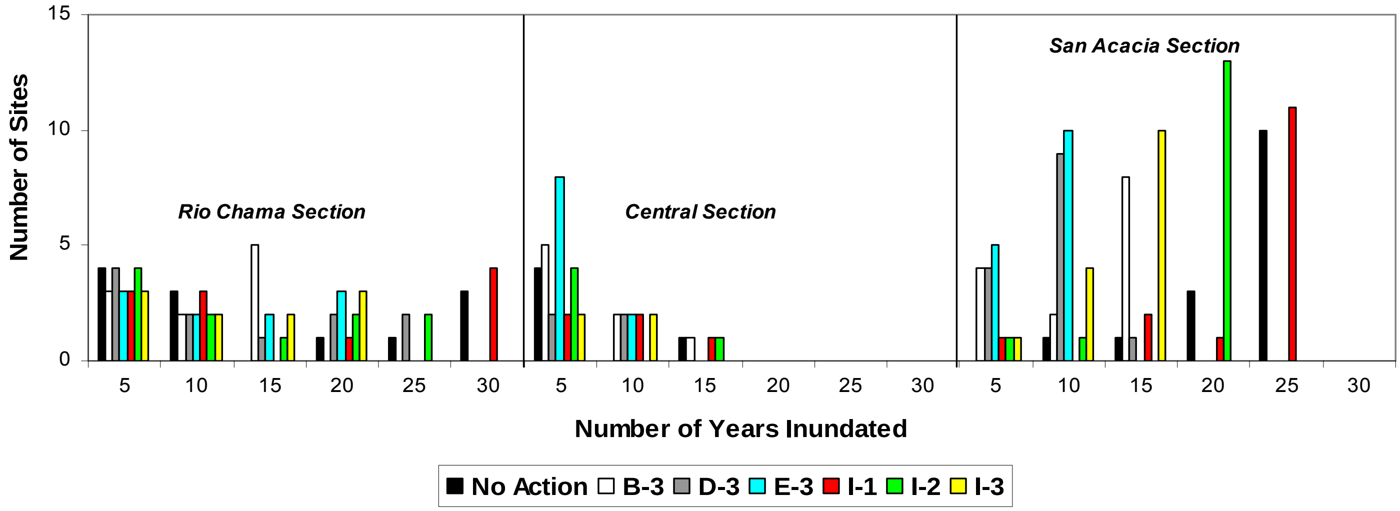


Figure 4-28. Cultural Resources Site Inundation

Sources of Uncertainty and Data Gaps

The propagation of uncertainty and the lack of archaeological surveys in certain river sections are limitations in the analysis of cultural resources. It is estimated that errors of 5 to 10 percent can be expected on analyses founded on URGWOM and other models.

4.4.4.6 Summary/Comparison by Alternative

The No Action Alternative and Alternatives B-3 and E-3 were considered fair in preserving unique and sensitive sites, avoiding impacts to traditional cultural properties, and preserving acequias and other irrigation structures. The remaining action alternatives (D-3, I-1, I-2, and I-3) provided improvements to these indicators that were used to determine impacts to ITAs. This analysis may be refined through government-to-government consultations.

Listed in descending order of preservation of cultural resources, Alternatives B-3, D-3, I-3, E-3, I-2, and I-1 had beneficial effects as compared to the No Action Alternative. While favorable in many respects, Alternatives B-3 and E-3 were projected to have seasonal adverse impacts due to higher channel capacities below Cochiti Dam, primarily related to the preservation of unique and sensitive sites.

4.4.4.7 Mitigation Measures

For *all* the alternatives, site inundation rates are greatest in the San Acacia Section. Between 55 percent (Alternative E) to 90 percent (Alternative I-3) of sites are inundated by all alternatives. The Rio Chama and Central Sections also show elevated inundation rates depending on specific alternatives, albeit at rates considerably lower than for the San Acacia Section.

Therefore, it is anticipated that mitigation measures should focus on preventing overbank flooding in the San Acacia Section. The precise nature of such measures can be determined in consultation with various lead agencies. Measures designed to prevent overbank flooding should also be implemented below Abiquiu Dam to the confluence of the Rio Grande in the Rio Chama Section and below Isleta Diversion Dam in the Central Section.

Alternatively, in the event that overbank flooding should emerge as a desired goal of changes in water operations (e.g., for restoration of riparian habitat), mitigation measures might include the construction of barriers. These may take the form of cofferdams or other structures that would prevent or limit overbank flooding of cultural resources.

Finally, if overbank flooding *is* desirable and barriers *cannot* be constructed, it is recommended that archaeological excavations be conducted at those sites where flooding is likely. This mitigation program could be phased so that sites in the greatest danger of flooding would be excavated first, followed–in order–by excavations at sites that are progressively less subject to overbank flooding.

4.4.5 Agriculture, Land Use, and Recreation

4.4.5.1 Agriculture

Issues

Agricultural activity in the Upper Rio Grande basin would continue, subject to the existing plans and regulations for water operations and expected water deliveries to irrigators. It is assumed that current crop types, acreage, cropping patterns and trends would continue.

Impacts to delivery of water to irrigators and growers and impacts to acequia diversion structures are assessed under each alternative. Inundation is another key criteria evaluated because crops could be damaged or destroyed by flooding, depending on the timing and duration of the flood event. Diversion structures can also be overtopped, typically requiring maintenance and repair after high flow events.

General Conclusions

The potential to impact agricultural activities was identified within a 5-kilometer buffer on either side of the Rio Chama and Rio Grande. Changes in water operations have the potential to affect agricultural lands in the Rio Chama, Central, and San Acacia Sections. The Northern Section is not affected by proposed operational changes. The Southern Section did not invoke flood control operations that would result in any impacts from proposed operational changes.

Based on the impact analyses performed, Alternative B-3 is the most favorable for agricultural uses, with the greatest benefits observed in the Rio Chama Section due to decreased channel capacities below Abiquiu. Alternatives I-3, E-3, D-3, and I-2 provide improved support for agriculture when compared to No Action. Alternative I-1 provides less support for agriculture, especially along the Rio Chama due to increases in the acres and duration of inundation, the number of overtopping events. All alternatives provide the same level of support for irrigation water deliveries in the Central and San Acacia Sections.

Impact Indicators

The review for agricultural resources evaluates whether operational actions could change conditions needed to support the type, extent, and quantity of agriculture currently practiced within the Upper Rio Grande Basin. This analysis is primarily concerned with identifying distinguishable differences between the alternatives for key issues that directly affect agriculture in the Basin. These include:

- Impacts to delivery of water to irrigators and growers (Central and San Acacia sections)
- Impacts to acequia diversion structures (Rio Chama section)
- Loss of viable agricultural land and crops through inundation
- Loss of or reduced productivity of agricultural lands due to saturated soil conditions (Rio Chama)

Detailed information on impact indicators and analysis is provided in Appendix N.

Methods of Analysis

The analysis relies on summarized outputs from URGWOM and FLO-2D to make broad comparisons using the following measurable criteria:

- Average seasonal shortfall in meeting irrigator water requests; number of years with shortfalls; number of days with shortfalls
- Number of days when diversion elevation are exceeded by river elevation
- Extent and duration of inundated agricultural land (Reaches 7, 8, 9, 12, 13, 14)
- Frequency of prolonged "bankfull" flows (Reach 7)

Thresholds for Significance

The estimates for agricultural impacts rely on the URGWOM and FLO-2D data and are therefore subject to the same 5 to 10 percent level of error in the evaluation of results for significant changes.

Discussion of Results of Analysis

Table 4-19 shows alternative performance for agricultural impact indicators along the Rio Chama, Central, and San Acacia Sections. Alternative B-3, with a reduced channel capacity below Abiquiu Dam, decreases inundation and diversion overtopping events, while maintaining the same level of support for irrigation season deliveries in the Central and San Acacia Sections. These provide quantitative measures for the impact indicators listed above. All other alternatives, except I-1, provide more days of adverse conditions than the No Action Alternative for agricultural measures.

Table 4-19. Agricultural Impacts by Alternative

	Rio Chama				Central & San Acacia Sections
Alternative	Total Acres Inundated over 40-year Period	Duration of Inundation (acre-days)*	Number of Events Where Diversions Overtopped	Extended Bankfull Events >1,500 cfs for >7 days	Average Irrigation Season Shortfall (%)
No Action	692	1,736	219	33	32
B-3	126	4,970	174	0	32
D-3	673	32,847	199	20	32
E-3	507	24,016	210	19	32
I-1	694	39,123	225	32	32
I-2	592	30,643	214	27	32
I-3	488	23,903	210	19	32

* Developed to provide a relative comparison of alternatives. The acre-days of flooding do not represent absolute values of average years.

Over the 40-year planning period there would be no significant difference in the average annual seasonal shortfall in deliveries to irrigators in the Central Section compared to the No Action Alternative. Agricultural lands in the Central and San Acacia Sections were not projected to be inundated at any time during the planning period, in part due to the protection assumed by the levees.

Table 4-20 indicates that over the 40-year planning period there would be no significant difference in the average annual seasonal shortfall in deliveries to irrigators in the Central and San Acacia Sections compared to the No Action Alternative. There would be no real difference in the percentage of delivery days where shortfalls are estimated over the 40-year planning period.

Table 4-20. Average Annual Seasonal Shortfall to Irrigators in the Central Section over 40 Years

Alternative	Average Irrigation Season Shortfall (%)	40-Year Average Annual Seasonal Shortfall (acre-feet)			
		Cochiti Diversion	Angostura Diversion	Isleta Diversion	San Acacia Diversion
No Action	32	0.2	8	62	16
B-3	32	0.1	8	62	16
D-3	32	0.2	8	63	16
E-3	32	0.2	8	62	16
I-1	32	0.2	8	62	16
I-2	32	0.2	8	63	16
I-3	32	0.2	8	63	16

Source: Derived from URGWOM Planning Model Runs

Sources of Uncertainty and Data Gaps

The agricultural land use analysis did not include evaluation of impacts to Pueblo and Tribal lands. The review is limited to operations that may affect less than 30 percent of the agricultural land in the Upper Rio Grande basin – about 53,000 acres along the Rio Chama, Central and San Acacia Sections. Other sections and reaches that are outside the influence of operations within the authority of this review and decision are not further evaluated, including the Northern Section, Reach 5 in the Rio Chama Section, Reach 11 in the Central Section, and the Southern Section. Several existing agreements ensure water needs for irrigators along the Rio Chama are met; therefore, issues in this section revolve around performance of the diversion structures, soil saturation, and inundation. In the Central Section, the demand schedule for irrigators below Cochiti was assumed to be the same as current demands over the next 40-years.

Delivery of irrigation water to tribes and pueblos is provided as one of the non-discretionary operational criteria and therefore would not vary between alternatives. The impact of drought on deliveries to tribes is beyond the scope of this evaluation. The difference in impacts between the alternatives from inundation of agricultural lands on pueblos may be similar to the effects reported for all inundation. Based on this, inundation of agricultural lands on pueblos may be slightly less extensive under the No Action.

Summary/Comparison by Alternative

Based on impact analyses, Alternative B-3 is the most favorable for agricultural uses, with the greatest benefits observed in the Rio Chama section. All other alternatives perform slightly worse for agricultural support in the Rio Chama than No Action. All alternatives provide the same level of support for irrigation water deliveries in the Central and San Acacia Sections.

Mitigation Measures

No mitigation measures are currently proposed for projected impacts to agricultural lands.

4.4.5.2 Land Use

Issues

Much of the land in the project area is undeveloped. However, other land uses in the area include residential, commercial, industrial, transportation, communications and utilities, agricultural, institutional, and recreational. Primary concerns that could affect land use include:

- Maintaining reliable water delivery for agricultural, municipal and industrial purposes
- Public safety and flood control
- Damage to property and productive uses from inundation
- Impacts of flooding on specially managed areas and recreational opportunities

General Conclusions

All action alternatives perform better than No Action in promoting desirable land uses for agriculture, recreation, and minimizing property damage.

Impact Indicators

The issues above were considered within three overall indicators for assessing desirable land uses:

- Degree to which an alternative promotes recreational use
- Degree to which an alternative preserves suitable conditions for agriculture
- Degree to which damage to property or loss of productive uses is minimized

Methods of Analysis

The indicators listed above were derived from the impact analyses specific to the three land use criteria considered: recreation, agriculture, and flood damages.

Thresholds for Significance

At least a 10 percent change was required to identify a significant impact, based on the sources of error and uncertainty in the underlying gage data, URGWOM and FLO-2D models, and GIS database.

Discussion of Results of Analysis

Overall, periodic inundation immediately along the river would not alter land use patterns that have evolved in response to periodic flood events and controls on development in floodplains. Occasional inundation would occur within the historic floodplain over the 40-year planning period, as verified by the FLO-2D model. These inundated areas are either undeveloped, or used for agriculture, grazing, and dispersed recreation.

With no diversion into the LFCC under the No Action Alternative, the San Acacia Section would experience the highest amount of inundation (about 2.8 million acre-days over 40 years). However, none of the projected inundation would occur on agricultural land, and only one residential structure encroaching on the floodplain is projected to be at risk.

Coordination between county planning and permitting officers is intended to limit encroachment into floodplains and flood easements in order to protect public safety and preserve flexibility for water operators. Similarly, management and control of private development in flood easements, particularly around Abiquiu Reservoir, would prevent encroachment and enhance flexibility for water operations to meet multiple objectives.

Sources of Uncertainty and Data Gaps

Land use impacts were identified for non-Tribal lands in the planning area. Tribal land impacts were evaluated in consideration of Indian Trust Assets.

- The analysis is limited to the Rio Chama Section (Reaches 6, 7, 8, 9), the Central Section (Reaches 10, 12, and13), and the San Acacia Section. The Northern and Southern Sections are not influenced by operations under the authority or review of this effort. Operations for flood control (below Elephant Butte reservoir) did not vary between alternatives.
- Operations will not cause changes in overall land status and ownership.
- All levees function adequately and areas protected by levees will not be inundated.

Summary/Comparison by Alternative

Table 4-21 summarizes overall performance on the three impact indicators identified above. All action alternatives perform better than No Action in supporting the varied land uses in the basin. Alternative I-3 provides the highest score for maintaining desirable land uses, while Alternative B-3 best supports agriculture. Alternative E-3 is similar to I-3 in support of recreational uses, and Alternative D-3 is similar to I-3 in minimizing flood damages.

Table 4-21. Desirable Land Use Performance in Rio Chama, Central, San Acacia Sections

Indicator	No Action	Alt B-3	Alt D-3	Alt E-3	Alt I-1	Alt I-2	Alt I-3
Minimizes flood damages	6.6	9.0	9.8	8.6	7.4	8.8	9.8
Promotes Recreational Uses	5.3	5.6	5.9	6.0	5.0	5.5	6.0
Promotes Agricultural Uses	7.7	8.3	6.6	7.9	7.6	7.7	7.9
Total score	19.6	22.9	22.3	22.5	20.0	22.0	23.7

Mitigation Measures

Current practices exercised under varying agency authorities are already in place and it is anticipated that no mitigation measures are needed for land use impacts as a result of these action alternatives.

4.4.5.3 Recreation

Issues

Reservoir recreation is affected by proposed changes in the various water operations alternatives. Current operations reflect the challenges from recent drought-induced low lake levels. Measures have already been implemented at key recreation sites to add new boat ramps and improve boat access as lake levels change. Facility managers consider the “safe boating capacity” of the lake or reservoir in terms of surface area per boat. At Elephant Butte, where recreation is by far the greatest of any reservoir in the planning area, the possible number of boats at the reservoir is limited by the number of mooring slots and tie-up points for boats. Based on average reservoir water levels (and surface areas) and maximum boat numbers, the ratio of acres per boat is well above generally accepted safe boating standards (BLM 1999). While this is not currently an issue, setting standards at each reservoir based on the type of boating allowed and the experience desired would be a beneficial safeguard for maintaining safe and high quality boating opportunities.

River-based recreation takes place at key locations where facilities have been developed and in areas where the public has access, primarily to publicly-owned land. Most facilities are beyond the zone of inundation, but some trails, picnic areas, and campsites along the river may be subject to occasional flooding. Like reservoir use, visitation to developed recreation sites is heavily influenced by a variety of factors including proximity to urban areas, availability of recreational alternatives, access to river-side facilities and put-in locations, vandalism and sense of safety for visitors, weather, and restrictions such as forest closures.

Through informal agreements, water operators currently time the release of water to meet desired flows of 1,000 cfs on weekends during the rafting season, as rafting activities require certain minimal flows. However, factors that have no relation to water operations have a significant effect on rafting. For example, during some years, rafting operations ceased when access to put-ins on public land were restricted due to fire hazard conditions. However, specific releases to support rafting were not explicitly modeled for the evaluation of alternatives.

Fishing on the Rio Chama and Rio Grande depends on suitable conditions for high quality fisheries, and for flows that are conducive to safe fishing, particularly for in-stream anglers. Other pressures, such as overcrowding at favorite fishing spots, could impinge on the quality of the experience over time. In general, fish stocking practices by the NMDGF would continue to maintain a reasonable supply of fish for recreational purposes. The relative frequency of days with flows that are suitable for fishing at selected popular fishing locations is an important criterion used for evaluating fishery quality.

Conflicts can occur between recreational uses along the same river reach. For example, minimum flows for rafting on the Rio Chama below El Vado and Abiquiu Dams are 500 cfs during the April 1 through September 15 rafting season. Whereas anglers require flows conducive to safe fishing—for example, below Abiquiu, suitability is determined by flows in the range of 50 to 300 cfs between May 1 and October 1. One of the goals of this EIS is to minimize conflicts and provide better opportunities for the varied users in the river system.

General Conclusions

River- and reservoir-based recreation would be affected by changes in water operations in the Upper Rio Grande basin. However with respect to recreation, all the action plans would result in improved conditions in comparison to No Action, with Alternative B-3 offering the largest potential overall gains in access. Alternatives B-3 and D-3 offer the most opportunity to satisfy the needs of recreational users with conflicting requirements (i.e., anglers vs. rafters).

Impact Indicators

Impact indicators for reservoir recreation were based on days of access provided by suitable lake elevations. Impact indicators for rafting considered the number of days less than the 500 cfs desired minimum flows on the Rio Chama below El Vado and Abiquiu Reservoirs. Angling suitability was evaluated based on the number of days with suitable fishing flows at selected fishing spots along the Rio Chama below El Vado and Abiquiu Reservoirs.

Methods of Analysis

Because of the variability of water-based recreation, the analysis focuses on qualitative effects rather than on estimating changes in visitation or use. Criteria selected are representative and generally only apply to some reaches or facilities. These measures are comparative indicators to assess the degree to which the alternatives may promote suitable conditions for recreation. URGWOM model data were used to obtain reservoir elevations and flows at key gages along the Rio Chama to support this analysis.

Thresholds for Significance

As with other resources using data from gages, models, and the GIS database, at least a 10 percent change from No Action was considered as signifying a potentially significant impact.

Discussion of Results of Analysis

Table 4-22 summarizes the number of days over the 40-year planning period when water levels would be unsuitable for access to facilities based on indicator levels provided by reservoir personnel and other sources (Casados 2001; Dunlap 2001; Corps 2001c, d; Kirkpatrick 2001). Current management of facilities under the No Action Alternative would be less beneficial than under the other alternatives. Current operations and visitation reflect the challenges from recent lower lake levels. For example, at Elephant Butte Reservoir, the most visited lake in the planning area, new boat ramps have been added to provide access for boats as lake levels change. This evaluation does not take into account these new facilities.

Table 4-22. Percent of Days with Impaired Access for Water-Based Activities at Reservoirs

Alternative	Days When Lake Elevation Impairs Access (%)			
	Heron Lake	Abiquiu	Cochiti	Elephant Butte
No Action	29	88	1	12
B-3	31	65	<1	0
D-3	29	70	<1	0
E-3	29	69	<1	0
I-1	29	86	<1	6
I-2	29	78	<1	<1
I-3	29	69	<1	0

Notes: Critical (unsuitable) elevations:
Heron Lake—less than 7,136 feet (Casados 2001)
Abiquiu Reservoir—less than 6,202 feet (Dunlap 2001)
Cochiti Lake—less than 5,317 feet or greater than 5,370 feet (Corps 2001d)
Elephant Butte—less than 4,400 feet (Kirkpatrick 2001)
Source: Derived from URGWOM (40-year planning period, daily reservoir elevations)

Table 4-23 shows that under the No Action Alternative, flows would fall below 500 cfs—the preferred minimum level on the Rio Chama between El Vado and Abiquiu—on 48 percent of the days during the rafting season over the 40-year planning period. Rafting would benefit from formalized agreements to the extent that this does not conflict with meeting other priorities or contract obligations. It should be noted that during some years, rafting operations have ceased when access to put-ins on public land were restricted due to fire hazard conditions.

Table 4-23. Suitability[1] for Rafting on Rio Chama between El Vado and Abiquiu Reservoirs

Alternative	Days <500 cfs over 40-years[2, 3] (Number)	Suitable Rafting Days (%)
No Action	3,435	48
B-3	3,344	49
D-3	3,356	49
E-3	3,444	47
I-1	3,428	48
I-2	3,433	48
I-3	3,444	47

Notes: 1. Unsuitable rafting conditions indicated when flow rate is less than 500 cfs.
2. Based on rafting season from April 1 through September 15.
3. Estimated for gage below El Vado
Source: Derived from URGWOM Planning Model (40-year planning period, daily flows)

Table 4-24 shows the relative frequency of days with flows that are suitable for fishing at selected popular fishing locations. There is little difference between alternatives on conditions along the Rio Chama below El Vado. The Rio Chama below Abiquiu Dam has the most variation with the No Action Alternative being the least favorable.

Table 4-24. Suitability for Anglers at Selected Locations on Rio Chama

Alternative	Days with Suitable Fishing Flows over 40-year Planning Period (%)	
	Rio Chama Section below El Vado Dam[1]	Rio Chama Section below Abiquiu Dam[2]
No Action	71	21
B-3	71	38
D-3	72	38
E-3	70	38
I-1	69	26
I-2	69	33
I-3	70	38

Notes: 1. Suitability >190 cfs and <830 cfs at gage below El Vado between May 1 and October 1.
2. Suitability >50 cfs and <300 cfs at gage below Abiquiu between May 1 and October 1.
Source: Derived from URGWOM Planning Model runs

Sources of Uncertainty and Data Gaps

Analysis of recreation resources was affected by relatively coarse datasets or lack of detailed information that required broad, mostly qualitative analyses. Data were provided in inconsistent formats from one river section to another, making comparisons difficult. For this reason, data quality was mostly rated fair, indicating the need for more uniform data collection of recreational uses of reservoirs and rivers along the Rio Chama and Rio Grande corridors to improve future analyses.

Summary/Comparison by Alternative

Reservoir-based recreation is best-supported by Alternative B-3. All alternatives result in some impaired recreational access at Heron Lake and Abiquiu Reservoirs – largely a function of hydrology. However, improvements over No Action are realized with increased conservation storage in Abiquiu Reservoir. While Alternative B-3 shows slightly less access at Heron Lake, access to Abiquiu Reservoir is improved. Recreational access to Cochiti is not affected by any of the alternatives. Recreational access to Elephant Butte would be significantly impacted only under No Action (12 percent), while Alternative I-1 would potentially reduce access 6 percent of the time. Overall, No Action provided the least support for reservoir recreation, while Alternatives B-3, E-3, and I-3 were the three top-ranked alternatives for this resource.

River recreation is a primary activity along the Rio Chama Section, and is only incidental in the Central and San Acacia Sections. River recreation in the Northern and Southern Sections was not subject to impacts from changes in water operations. Rafting suitability along the Rio Chama between El Vado and Abiquiu is best supported by Alternatives B-3, D-3, and I-1. Angling activities along the Rio Chama are best supported by Alternatives D-3, B-3, E-3, and I-3. Thus, for riverine recreation, Alternatives B-3 and D-3 offer opportunities to best satisfy multiple users with conflicting requirements.

Overall, recreation along the upper Rio Grande is better supported by all action alternatives when compared to No Action. Alternative B-3 best supports all forms of river and reservoir recreation. Alternatives D-3, E-3, and I-3 rank in the top tier, with Alternatives I-2, and I-1 offering lesser support for recreational activities.

Mitigation Measures

Mitigation measures already employed by recreation facility managers at the reservoirs and lakes include the extension of boat ramps to accommodate access during times of low lake levels, and promotion of alternative shore-line activities when lake surface areas are low. It is expected that similar measures would be implemented by these same recreation facility managers as hydrologic conditions and reservoir storage change. Projected conditions are presented to the public annually in April, in conjunction with preparation of the Corps' Annual Operating Plan.

Rafting would benefit from formalized agreements to the extent that this does not conflict with meeting other priorities or contract obligations. It should be noted that, during some years, rafting operations have ceased when access to put-ins on public land were restricted due to fire hazard conditions.

Stocking fish would continue in the future and partially offset any adverse impacts on reproduction of native fish. No significant changes to sport fishing at reservoirs would result. Therefore, recreational reservoir fishing would follow the same patterns and trends that have been experienced in the past

4.4.6 Flood Control

4.4.6.1 Issues

There have been no property damages sustained or anticipated from direct releases by the flood control facilities under consideration by this EIS. However, residual flood damages from unregulated drainages could occur depending on flows. Evaluation of alternatives, therefore, focuses on changes in residual flood damages associated with the proposed operation changes. The affected environment includes the current flood control structures and benefits, as well as the areas that remain threatened by floods.

Total flood control benefits from Corps projects along the Rio Grande and its tributaries since their inception through 2002 have totaled over $1 billion (Corps 2003). In addition, significant damages from river sedimentation are also prevented. Other projects along the Rio Grande have prevented significant flood damages as well. These include Elephant Butte/Caballo, El Vado, the U.S. Section, International Water Boundary Commission levees on the Rio Grande, and numerous dams constructed by the Natural Resources Conservation Service.

Operational changes proposed under the action alternatives have the ability to affect only the Rio Chama, Central, and San Acacia Sections. While the Northern Section has sustained damages from flows along the Rio Grande Mainstem, no changes are proposed, thus impacts resulting from water operations were not evaluated. Similarly, flood control operations at Elephant Butte and Caballo Reservoirs were not triggered during the 40-year planning period, thus no impact analysis was performed in the Southern Section.

4.4.6.2 General Conclusions

With respect to flood control, all action alternatives offer improvements over No Action. Alternatives B-3, D-3, E-3, and I-3 offer the most protection, with varying degrees of improvement along the Rio Chama. Alternatives B-3 and E-3 project additional flooding potential near Belen due to the higher channel capacities below Cochiti, where Alternatives D-3 and I-3 offer greatest reduction in flooding of the San Acacia Section. Alternatives I-1 and I-2 offer lesser levels of improvement, as they reduce the amount of conservation water impounded upstream in Abiquiu Reservoir.

4.4.6.3 Impact Indicators

URGWOM daily stream gage flow projections were retrieved to estimate flooding at locations near damage centers identified above for the No Action and action alternatives. Each damage center has a flow-damage relationship, and has a maximum flow that can pass without creating property damage, called the “start of damages”. Each day over the analysis time frame that a stream gage flow was equal to or greater than the start of damages flow for a given damage center was identified for each alternative. Alternatives that create more days over the project life where flows exceed the start of damages can be said to be increasing damages, and would be less desirable than those with equal or fewer total days where flooding exceeds the start of damages. In the following tables, this measurement was termed “Days Flooded.”

Another measure of alternative impacts is an estimate of the dollar damages over the project life cycle, generated by interpolating the flows for each day to the flow-damage relationships available, and then generating a grand total over the project life cycle. No estimates of growth within the floodplain are available, and the flow-damage relationships used are current as of their stated price level. No discounting of future benefits was performed to bring the price levels across damage centers in line, and the damages represent nominal damages, in thousands of dollars, at the price level indicated on the flow damage relationship for that damage center.

4.4.6.4 Methods of Analysis

The hydro-economic model used to develop expected annual damages is based on discharge-frequency, stage-frequency, and stage-damage curves used to develop a damage-discharge curve. Stage-percent damage curves express dollar damages resulting from varying depths of water based on a percentage of the value of structure and contents.

Each surveyed property was assigned to a category (e.g., commercial, residential, public, outbuilding, transportation facilities, utilities, and vehicles) with as many subcategories as necessary. Details of ground and first floor elevations were also noted. The depth-damage relationship for each category was expressed as a cumulative percentage of value for each foot of inundation. The depth-damage relationships were derived from historical data obtained from insurance companies, a commercial content survey, the Flood Insurance Administration, and Corps data and experience. Note that the 2001 residential curves developed by the Institute of Water Resources (IWR) were used; thus, the residential content damages are a direct relationship to structure value.

A survey of structures within the floodplain was conducted to evaluate the flood threat to each damage center. Property categories surveyed include residential, commercial, public buildings, vehicles, transportation facilities, utilities, and outbuildings (e.g., sheds and detached garages). Depreciated, replacement residential structure values were computed using local experts such as realtors, appraisers, and builders. The properties were then compared to actual sales data in the area and field inspected for consistency and first floor elevations.

Content values were estimated from several sources. Residential content values were fixed at 50 percent of the structure value. Generally, property insurers estimate content values at greater than 55 percent of structure value. Commercial and public content values were estimated primarily from surveys of similar establishments and interviews.

Vehicle estimates were determined using in-house data and published surveys. It is assumed that all business-related vehicles would have been evacuated from the floodplain. Therefore, the vehicles that would remain in the floodplain would be associated with residential structures and apartments. Census data or locally available information was used to determine the per capita vehicles per household. It was assumed that one of these vehicles per household was driven out of the floodplain. The remaining vehicles will be distributed among the residential structures located within the 0.2 percent chance exceedance floodplain.

Potential flood effects occur at all the locations listed below. In addition, there are several areas along the Rio Grande that have not experienced flooding recently, but as a result of the deterioration of a nonengineered levee or other facilities, are prone to flooding under certain flow conditions. These areas include Española, from Bernalillo to Belen, and from San Acacia to Elephant Butte. All of these areas are currently being analyzed in studies by the Corps.

For purposes of currently available flood control analysis the Rio Grande and Tributary floodplains are broken down into several reaches:

- The upper reach is comprised of the Rio Grande as it flows through Colorado, primarily centered upon Del Norte, Monte Vista, and Alamosa
- The next reach is comprised the area from Pilar, New Mexico through Española
- The third reach is the Chama Valley from Abiquiu to the Rio Grande
- The fourth reach is from Bernalillo to Belen
- The fifth reach is from San Acacia to Elephant Butte
- The sixth reach is in Hudspeth County to the east of El Paso. Other areas that do not currently have flood control analysis have the potential for damages. These include the area from Elephant Butte through El Paso, several points on the river north of Bernalillo, Mexico, and the area east of Fort Quitman

Information regarding damages to Mexico is currently not available. Most damages in this reach are not readily converted into a damage-flow curve, because many occur from a rise in groundwater rather than direct overflow.

Thresholds for Significance

As discussed for other resources, a minimum change of 10 percent from No Action was considered to be the threshold of significance for identifying significant changes in performance between alternatives. This threshold considers the propagation of errors associated with input data, modeling, and spatial analyses.

4.4.6.5 Discussion of Results of Analysis

A summary of days of flooding and projected damages by alternative is provided in **Table 4-25**.

Table 4-25. Flooding and Projected Residual Damages by Alternative

	Rio Chama Section				Central Section				San Acacia Section	
	Below Abiquiu to Confluence		Confluence to Española		Corrales		Belen		San Acacia	
Alter-native	Days Flooded (Days)	Damages ($)	Days Flooded (Days)	Damages ($)	Days Flooded (Days)	Damages (Dollars)	Days Flooded (Days)	Damages ($)	Days Flooded (Days)	Damages ($)
No Action	1000	$5,000	300	$200,000	120	$3,100	0	$0	200	$4,300,000
B-3	340	$1,300	260	$152,000	88	$6,500	46	$36,000	56	$1,054,000
D-3	710	$4,100	280	$175,000	100	$7,000	0	$0	6	$5,400
E-3	610	$2,800	270	$160,000	100	$8,200	52	$53,000	64	$1,462,000
I-1	987	$4,800	301	$200,100	120	$800	0	$0	188	$3,228,000
I-2	770	$3,600	280	$183,000	100	$700	0	$0	140	$1,400,000
I-3	620	$2,800	270	$166,000	100	$650	0	$0	6	$53,000

Under the No Action Alternative, flood control reservoirs—Abiquiu and Cochiti—would reduce flood peaks and continue to provide flood control benefits to downstream areas. Periodic flooding and damages from unregulated drainages would continue to occur over the 40-year planning period. No Action has the highest number of days flooded and highest total dollars in damage projected over the 40-year planning period. With the lower channel capacity below Abiquiu, Alternative B-3 provides the best overall performance and largest improvements in the Chama Section. However, with the higher channel capacities below Cochiti, both Alternatives B-3 and E-3 increase the potential for flood damages in the Central Section near Belen. Due to the levee system near Albuquerque, no flood damages were observed under any alternative. Alternatives D-3 and I-3 provide similar reductions in flooding, with the greatest changes observed in the San Acacia Section. Alternatives I-1 and I-2 perform only slightly better than No Action.

Sources of Uncertainty and Data Gaps

Corps hydraulic engineers developed floodplains and event stages for specific frequency flood events, as well as the single occurrence damages associated with each event. Some of these studies predate new GIS-related tools so data other than the flow-damage relationship is unavailable. Note that some growth may have occurred since the initial study, and further growth is expected, such that the damages associated with specific frequency events will be higher than indicated.

Future development would change potential damages from any flood event. While future population estimates in the planning area are important, the quantity of that development that occurs within the floodplain is the relevant aspect and is a rough estimate at best. Note that any future development that occurs should follow Federal Emergency Management Agency (FEMA) requirements and be elevated to the 100-year flood event.

It should also be noted that the analysis for No Action was performed under zero diversions to the LFCC, potentially impacting the evaluation of flooding potential in the San Acacia Section. Under diversions to the LFCC, it is expected that No Action would perform similarly to I-1 for 500 cfs diversions, I-2 for 1,000 cfs diversions, and I-3 for 2,000 cfs diversions.

4.4.6.6 Summary/Comparison by Alternative

Figures 4-29 to 4-31 summarize the change from No Action under each alternative by the three affected river sections, Rio Chama, Central, and San Acacia. All action alternatives offer improvements in flood control over the No Action condition. Detailed information by reach is provided in Appendix P.

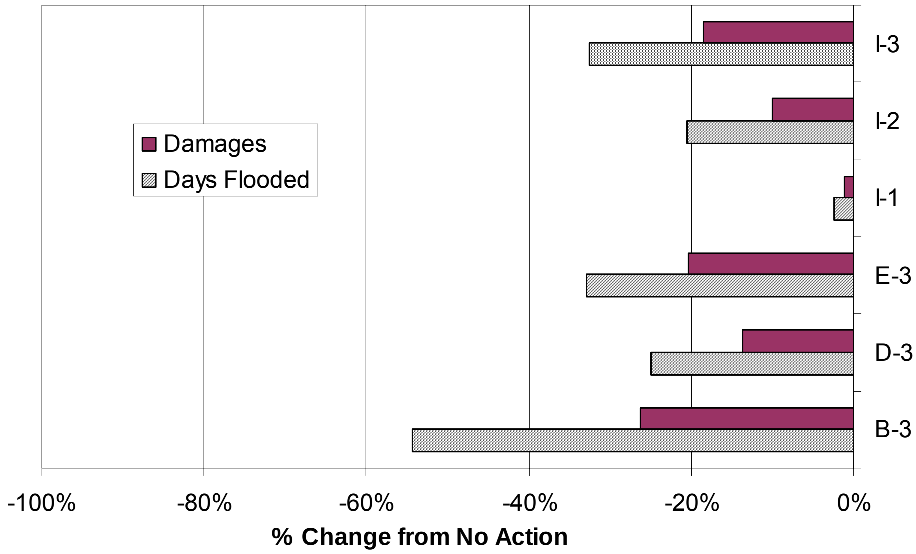


Figure 4-29 Days Flooded and Projected Damages in Rio Chama Section

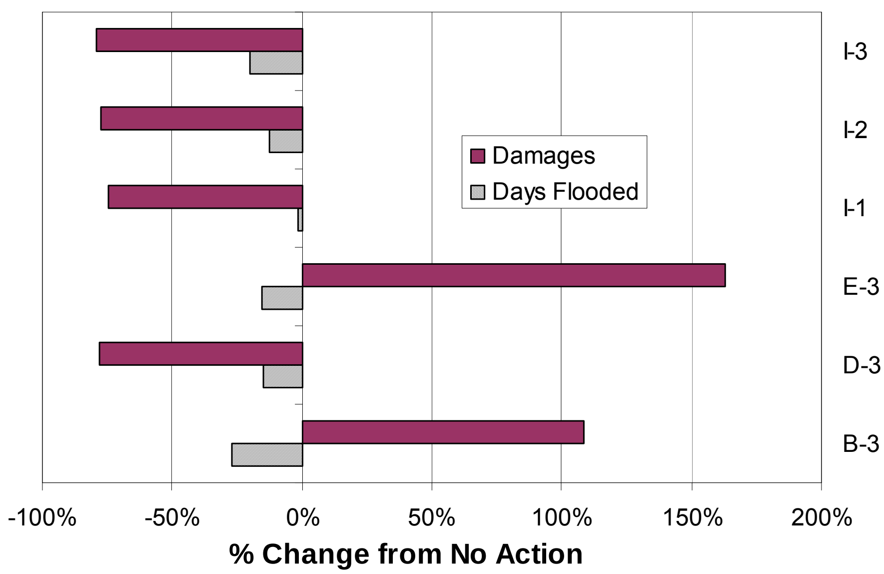


Figure 4-30. Days Flooded and Projected Damages in Central Section

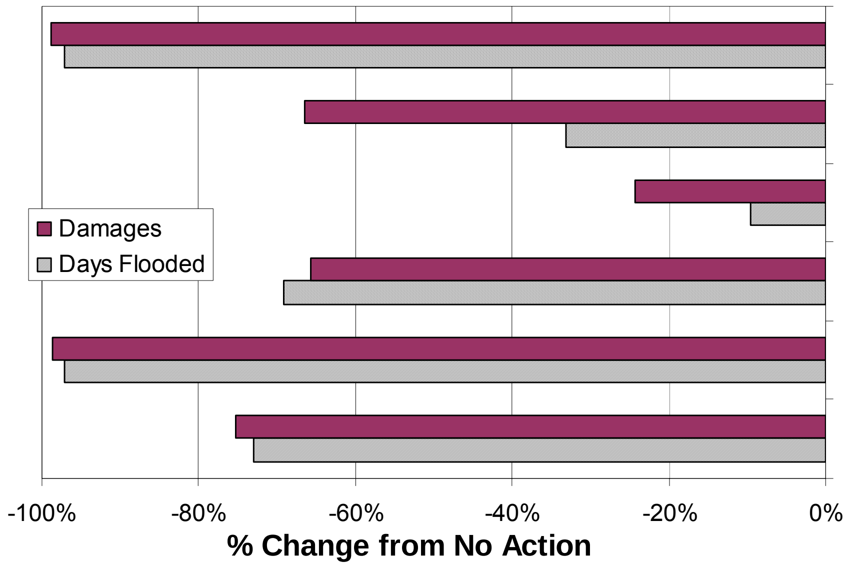


Figure 4-31. Days Flooded and Projected Damages in San Acacia Section

4.4.6.7 Mitigation Measures

No mitigation measures are proposed at this time for any damages related to flooding, as all alternatives show improvement over No Action.

4.4.7 Hydropower

4.4.7.1 Issues

Hydropower production is impacted by storage regulation and water allocation among the various reservoirs in the Rio Grande Basin. Hydropower production facilities include El Vado, Abiquiu, and Elephant Butte Reservoirs. The first two facilities are located on the Rio Chama, while Elephant Butte Reservoir is located in the Southern Section of the Rio Grande near the city of Truth or Consequences. Changes in operation will affect the total power generation at these plants.

4.4.7.2 General Conclusions

All alternatives produce additional output at Abiquiu and Elephant Butte Reservoirs as compared to No Action. However, all alternatives also marginally decrease energy production at El Vado Reservoir, but the additional output at Abiquiu and Elephant Butte Reservoirs more than make up for this loss.

Alternatives I-3, E-3, and D-3 result in an almost $3.0 million projected increase in hydropower revenues over No Action. Alternatives I-2, I-1, and B-3 provide the second tier in performance, with incremental increases ranging from $1.4 to $2.7 million over the No Action Alternative.

4.4.7.3 Impact Indicators

There are two components to hydropower benefits. The first, the capacity benefit, is associated with investment costs that would be displaced by the additional hydro generation. The capacity benefits are based on the dependable capacity of the hydro plant and a unit capacity value based on the fixed costs of the most likely thermal alternative. A significant impact would be a material increase or decrease in the capacity benefit.

The second component is the energy benefit. This measures the displaced variable costs and is the cost of energy that would be produced from other generation sources if the hydropower is not available;

specifically, the cost of generation from the area power plants that would most likely provide the replacement generation (or would be displaced by additional hydro generation). These energy costs are primarily fuel costs, along with some variable operations and maintenance and transmission costs. Energy benefits are computed as the product of the average annual energy and unit energy value which represents the average cost of replacement generation. A significant impact would be a substantial increase or decrease in the energy benefits provided by an alternative considered.

4.4.7.4 Methods of Analysis

Hydropower values on the dams are computed differently. The El Vado and Abiquiu plants are used primarily to displace thermal energy and are not considered to have dependable capacity. Hence, there will not be any gain or loss in capacity benefits at these projects as a result of changes in reservoir operation. The value of energy from these plants can be estimated by examining outside generation resources available to this system and how they will be used to meet loads during 1991 and subsequent years. Outside generation resources include Public Service Company of New Mexico’s San Juan coal-fired steam plant; Basin Electric’s Laramie River coal-fired steam plant in Wyoming; Department of Energy – Los Alamos Utilities gas-fired steam capacity; and Western Area Power Administration (Western) excess capacity.

At Elephant Butte, power generation is no longer marketed directly to individual utilities. It is marketed instead as a part of a system which also includes Reclamation’s Colorado River projects. Since Western contracts power with Plains Electric and other users for delivery of a portion of the combined system output, the individual utilities would not be directly impacted by changes in the output of Elephant Butte. Western would be the entity feeling these impacts. They would have to purchase replacement power to make up any shortfalls or market for any excess. The value of any hydropower losses could vary, depending upon what type of operational change is proposed at Elephant Butte. The value of energy might change if operational adjustments require that the daily generating pattern be shifted to more of a base load or to more of a peaking operation than is presently followed.

Elephant Butte has value as a plant providing dependable capacity. This is a measure of its ability to carry peak load and is used to determine how much thermal generating capacity would be required in the power system if the hydro capacity were not available. The dependable capacity accounts for the periodic unavailability of part of the hydro plant’s generating capacity due to the variability of hydrologic factors such as streamflow and reservoir elevation. For a hydro project in a thermal-based power system such as the Arizona-New Mexico system, dependable capacity would normally be computed as the average capacity available in the peak demand months. An alternative method would be to base dependable capacity on the capacity available for some specified percentage of the time during the peak demand months. The latter method is used by Western in estimating the marketable capacity of the hydro projects in their system. Elephant Butte contributes 27 megawatts of marketable capacity to the Western system, and marketable capacity will be used in this case as a measure of dependable capacity. Western bases marketable capacity on the capacity that is available 90 percent of the time during the peak demand months (which in this system are December and January in the winter and July and August in the summer). Some of the proposed reservoir operation plans could result in lower average pool elevations during these periods and hence a loss in dependable capacity. As an interim energy value for the 1991 study, subsequent to discussions with a Western representative and local utilities, market prices were used for the next 5 to 10 years (28.83 mills/kilowatt hours). After that period, Western customers would likely purchase replacement power from a new power plant (51.5 kilowatt hours) much of the time. An average of market price and the cost of new combined cycle plant is 40.2 mills/kilowatt hours.

The kilowatts estimated for each operating plan will be multiplied by the value of a hydropower kilowatt. The difference between plans will be measured on the basis of a $5^{5/8}$ percent interest level, current prices, and standard discounting procedures.

Thresholds for Significance

As discussed for other resources, a minimum change of 10 percent from No Action was considered to be the threshold of significance for identifying significant changes in performance between alternatives. This threshold considers the propagation of errors associated with input data, modeling, and spatial analyses.

4.4.7.5 Discussion of Results of Analysis

Hydroelectric power generation at Abiquiu and El Vado Reservoirs would continue as "run-of-the-river" power generation facilities generating power when releases are made. Under the No Action Alternative, there would be no change in hydropower generation. Elephant Butte Dam would continue to provide dependable power over the planning period, as projected by the Western Area Power Authority.

All action alternatives have the potential to increase hydroelectric power generation. **Table 4-26** provides a summary of the marginal output increases above the baseline power production projected for No Action.

Table 4-26. Marginal Increases in Hydropower by Alternative

Alter-native	Facility						Total Hydropower Benefit	Hydropower Rank
	Abiquiu		El Vado		Elephant Butte			
	Total Marginal Output		Total Marginal Output		Total Marginal Output			
	Megawatts	Dollars	Megawatts	Dollars	Megawatts	Dollars		
No Action	Baseline	$0	Baseline	$0	Baseline	$0	$0	7
B-3	15,260	$445,950	-640	($18,690)	34,750	$1,007,850	$1,435,110	6
D-3	67,600	$1,958,740	-490	($14,390)	34,900	$1,012,100	$2,956,450	3
E-3	68,820	$1,994,400	-380	($10,960)	34,700	$1,006,130	$2,989,570	2
I-1	63,310	$1,833,100	-160	($4,600)	11,440	$324,830	$2,153,330	5
I-2	67,270	$1,948,950	-230	($6,690)	27,490	$794,980	$2,737,240	4
I-3	68,880	$1,996,200	-270	($7,880)	34,920	$1,012,590	$3,000,910	1

Each action alternative would slightly decrease energy production at El Vado Reservoir as compared to the No Action Alternative, but the additional power output at Abiquiu and Elephant Butte Reservoirs would compensate for this loss at El Vado. On an annual basis, losses at El Vado Reservoir would be small, and there would be little impact to the reservoir hydroelectric output at El Vado from implementing any of the alternatives.

Sources of Uncertainty and Data Gaps

Information was used from the 1991 study for the existing condition analysis as related to each alternative. Future development in this context includes both demand within the region and the resulting impact upon prices.

4.4.7.6 Summary/Comparison by Alternative

In general, each alternative would produce additional output at Abiquiu and Elephant Butte Reservoirs and would be differentiated by the amount of additional output produced at each reservoir. Each alternative would have the effect of lowering energy production at El Vado Reservoir, but the additional output at Abiquiu and Elephant Butte Reservoirs would more than make up for this loss. There would be a significant, positive impact even when considering the adverse effects of lower power output at El Vado Reservoir. On an annual basis, El Vado's losses would be approximately $300 to $1,000, which falls within measurement tolerances.

Alternatives I-3, E-3, and D-3 result in the highest power revenues. Alternatives I-2, I-1, and B-3 provide the second tier in performance, with No Action providing the least hydropower production.

The bulk of excess hydropower generation revenue is realized at Abiquiu and Elephant Butte Reservoirs. Hydropower benefits from Abiquiu hydropower production is distributed directly to the City of Los Alamos. Elephant Butte is marketed as part of a system which also includes Reclamation's Colorado River projects. Since Western contracts the power with Plains Electric and other users for delivery of a portion of the combined system output, the individual utilities would not be directly impacted by changes in the output of Elephant Butte. Western would be in the position of marketing excess power produced.

4.4.7.7 Mitigation Measures

No mitigation measures are proposed for impacts to hydropower production associated with implementation of any of the proposed alternatives.

4.4.8 Economics

4.4.8.1 Issues

Recreation has a significant impact on the regional economy – reservoir recreational spending alone may exceed $100 million annually. River recreation usage is not as well defined. Agriculture is also important to the area economy with market values for agricultural products exceeding $550 million annually. Agriculture, recreation, and tourism are aspects of the economy that are potentially related to proposed changes in water operations.

4.4.8.2 General Conclusions

Changes in water operations have the potential to impact regional and local economy by affecting agricultural lands, river and reservoir recreation, and tourism. Agriculture would be affected by proposed changes primarily in the Rio Chama below Abiquiu, with the greatest concerns associated with land inundation and overtopping of diversion structures. Water deliveries in the Central and San Acacia Sections had no significant differences between alternatives and the high degree of channelization and the levee system provide protections for agricultural land inundation. Agricultural economic impacts were not significant and were not evaluated in detail.

Increases in reservoir recreation above No Action were identified for all alternatives. Alternatives B-3, D-3, I-2, and E-3 all provided greater than $7 million increased reservoir recreation benefit. Alternatives I-1 and I-3 provided increases of $5.8 and $2.6 million, respectively. Alternatives B-3 and D-3 provided benefit at Heron, El Vado, Abiquiu, and Elephant Butte Reservoirs, whereas Alternative I-3 provided increased recreation at only Abiquiu and Elephant Butte.

4.4.8.3 Impact Indicators

Changes in visitation/tourism and economic benefit derived from reservoir recreation were used to evaluate potential impacts to local economies adjacent to water storage facilities.

4.4.8.4 Methods of Analysis

Visitation modeling results can be used to estimate the impacts of different alternatives on reservoir recreation activities. The common variable across alternatives is reservoir elevation. Holding all other variables constant at their current level, the URGWOM modeling results for reservoir elevation for each alternative can be input into the visitation model. This provides an estimate of the impact on visitation of changes in reservoir elevation associated with each alternative. All of the changes in visitation are compared to the No Action Alternative. Results are not presented for Jemez Canyon Reservoir because there was not enough variation in reservoir elevation to have any significant impact on visitation.

These visitation impacts can be translated into economic benefits if the benefit per visit is known. A net benefit value of $20 per visit was used to value the benefits of reservoir recreation. This value is based on the results for fishing and wildlife viewing activities for New Mexico published in *Net Economic Values for Wildlife-Related Recreation in 2001: Addendum to the 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* (FWS 2003d).

The 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation provides estimates of trip-related expenditures. Based on the survey results, trip-related expenditures are estimated to be $12 per trip.

Thresholds for Significance

The comparison performed evaluated marginal increases above baseline conditions provided by No Action. A 10 percent change was identified as potentially significant.

4.4.8.5 Discussion of Results of Analysis

Table 4-27 provides the results of the evaluation of reservoir recreation, as compared to No Action. All alternatives increased recreational opportunities at the four reservoirs evaluated. Alternatives B-3 and D-3 increased visitation at Heron, El Vado, Abiquiu, and Elephant Butte Reservoirs. Alternatives E-3, I-1, and I-2 provided increased recreation at El Vado, Abiquiu, and Elephant Butte Reservoirs. Alternative I-3 increased recreation only at Abiquiu and Elephant Butte Reservoirs.

Table 4-27. Marginal Increase in Reservoir Recreation above No Action

Alter-native	Facility								Total Added Economic Benefit	Reser-voir Recre-ation Rank
	Heron Reservoir		El Vado Reservoir		Abiquiu Reservoir		Elephant Butte Reservoir			
	Increase in Annual Recreation		Increase in Annual Recreation		Increase in Annual Recreation		Increase in Annual Recreation			
	Visitors	Dollars	Visitors	Dollars	Visitors	Dollars	Visitors	Dollars		
No Action	Baseline	$0	Baseline	$0	Baseline	$0	Baseline	$0	$0	7
B-3	10,250	$205,000	500	$10,000	53,000	$1,060,000	329,000	$6,580,000	$7,855,000	1
D-3	6,100	$122,000	500	$10,000	42,500	$850,000	333,300	$6,666,000	$7,648,000	2
E-3	0	$0	500	$10,000	45,050	$901,000	329,650	$6,593,000	$7,504,000	4
I-1	0	$0	150	$3,000	31,600	$632,000	257,900	$5,158,000	$5,793,000	5
I-2	0	$0	350	$7,000	45,400	$908,000	332,150	$6,643,000	$7,558,000	3
I-3	0	$0	0	$0	12,050	$241,000	117,450	$2,349,000	$2,590,000	6

4.4.8.6 Summary/Comparison by Alternative

The largest increase in visitation would occur at Elephant Butte Reservoir, with a potential beneficial impact of approximately 19 percent. All of the alternatives would have a positive impact or no impact on visitation compared to the No Action Alternative, assuming zero diversions to the LFCC under No Action.

4.4.8.7 Mitigation Measures

No mitigation measures are proposed for economic impacts, as all action alternatives offer potential improvements to recreation and tourism as compared to the No Action Alternative.

4.4.9 Environmental Justice

4.4.9.1 Issues

Environmental justice addresses the potential for disproportionate impacts on minority and/or low-income populations. According to the distribution of racial/ethnic populations in the planning area and a comparison of income and poverty rates to state averages, most counties in the planning area qualify for consideration of disproportionate impacts. In New Mexico, counties not considered for disproportionate impact analysis include: Bernalillo, Los Alamos, and Santa Fe counties comprising the northern portion of the Central Section. As water operations changes did not affect the Northern or Southern Sections, no detailed analysis was performed.

Retail trade from tourism and recreation accounts for the largest portion of sales and business receipts in the planning area. Agriculture is also an important economic mainstay for the non-urban areas of the planning region, especially in the Rio Chama and San Acacia Sections. Impacts to recreation, tourism, and agriculture were evaluated in the land use section. The environmental justice evaluation considers resource impacts by river section to evaluate whether alternatives provided disproportionate impacts on minority and/or low-income populations.

4.4.9.2 General Conclusions

Environmental justice concerns were evaluated by considering resources with potential adverse impacts. Riverine, reservoir, riparian, threatened and endangered species, and cultural resources were considered in the evaluation. The Rio Chama and San Acacia Sections had greater minority populations than the Central Section. Across all alternatives, the Central Section received the greatest potential benefit, while both the Rio Chama and San Acacia Sections incurred the greatest potential adverse impacts.

Alternatives B-3 and I-2 offered greater benefits than No Action for environmental justice concerns. However, Alternatives B-3 and I-3 provided beneficial improvements in resource conditions in two of three river sections evaluated. Alternative B-3 improved resource conditions in the Rio Chama and Central Sections. Alternative I-3 improved resource conditions in the Central and San Acacia Sections, but was ranked sixth due to the magnitude of adverse impacts observed. Other alternatives were typically beneficial or neutral in impacts on resources within the Central Section, with adverse impacts observed in both the Rio Chama and San Acacia Sections. Alternatives I-1 and I-3 offered the least difference in impact across all three river sections. No Action was considered neutral and was ranked third among the alternatives.

4.4.9.3 Impact Indicators

Resources with adverse impacts were selected for evaluation on the distribution of those impacts by river section. Impacts were considered for riverine, reservoir, riparian, threatened and endangered species, and cultural resources. All of the analyses for these resources identified impacts potentially requiring mitigation.

4.4.9.4 Methods of Analysis

Impacts of alternatives for each river section were compared to the No Action Alternative for each resource. Thus, the No Action Alternative is neutral with respect to environmental justice concerns. No changes were anticipated for the Northern and Southern Sections. Only the Rio Chama, Central, and San Acacia Sections were evaluated for environmental justice considerations. Some sections within various resources experienced adverse impacts when compared to the No Action Alternative.

Thresholds for Significance

Adverse impacts greater than 10 percent different from conditions expected under No Action for each resource were considered in this analysis. This threshold was selected to exclude sources of error associated with input data as well as potential propagation of error across the use of multiple models and analytical methods. However, for threatened and endangered species, the tolerance for significance when compared to No Action was raised to 5 percent due to the critical status of these species.

4.4.9.5 Discussion of Results of Analysis

The environmental justice evaluation is summarized in **Table 4-28**. No Action, as the baseline condition, was assumed neutral for all river sections. Alternatives were compared to No Action and identified as offering beneficial or adverse impacts for each resource evaluated. Rankings were based on numerical conversion of verbal ratings to scores: neutral = 0, beneficial = +1, slight loss = -0.5, and adverse = -1.

Table 4-28. Summary of Environmental Justice Evaluation

Section	Alternatives						
	No Action	**B-3**	**D-3**	**E-3**	**I-1**	**I-2**	**I-3**
Aquatic-Riverine Environment							
Rio Chama	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Central	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
San Acacia	Neutral	Adverse	Adverse	Adverse	Neutral	Neutral	Adverse
Aquatic-Reservoir Environment							
Rio Chama	Neutral	Beneficial	Mixed	Mixed	Adverse	Adverse	Adverse
Central	Neutral	Beneficial	Beneficial	Beneficial	Neutral	Beneficial	Beneficial
San Acacia	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Riparian Resources							
Rio Chama	Neutral	Beneficial	Adverse	Adverse	Adverse	Adverse	Adverse
Central	Neutral	Beneficial	Neutral	Neutral	Neutral	Neutral	Adverse
San Acacia	Neutral	Neutral	Slight Loss	Neutral	Neutral	Beneficial	Beneficial
Threatened & Endangered Species							
Rio Chama	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Central	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
San Acacia	Neutral	Slight Loss	Slight Loss	Slight Loss	Neutral	Beneficial	Slight Loss
Cultural Resources							
Rio Chama	Neutral	Beneficial	Adverse	Neutral	Neutral	Neutral	Neutral
Central	Neutral	Adverse	Neutral	Adverse	Neutral	Neutral	Neutral
San Acacia	Neutral	Adverse	Adverse	Adverse	Adverse	Adverse	Adverse
Rank	**3**	**1**	**7**	**5**	**4**	**2**	**6**

N/A = Not analyzed.

Sources of Uncertainty and Data Gaps

Environmental justice considerations are derived from the cumulative uncertainties and data gaps underlying the other individual resource analyses. Population distributions and incomes may change with time, thereby changing the socioeconomic profile of the planning area.

Potential adverse impacts to fisheries and recreation may be associated with all alternatives to some degree, but they are widespread and would not disproportionately affect low income or minority populations. Therefore, they do not represent a significant environmental justice concern.

Alternative I-1 has the least potential for environmental justice concerns, followed equally by Alternatives I-2, I-3, and D-3. Alternatives B-3 and E-3 would both result in adverse cultural resources impacts in sensitive areas.

4.4.9.6 Summary/Comparison by Alternative

Impacts of alternatives for each river section were compared to the No Action Alternative for each resource; results indicated that either positive or no change would be expected for the Northern and Southern Sections. River sections evaluated further for environmental justice considerations included the Rio Chama, Central, and San Acacia Sections. Five resource areas would experience adverse impacts in some sections, compared to No Action Alternative, including aquatic-riverine resources, aquatic-reservoir resources, threatened and endangered species, riparian resources, and cultural resources. The following discussion of the ranking of alternatives provides a comparison of the impacts of the alternatives.

4.4.9.7 Mitigation Measures

No mitigation measures are proposed regarding environmental justice considerations apart from the resource-specific mitigations recommended.

4.5 Identifying the Top-Ranked Alternative

4.5.1 Method

By applying the rankings derived from the criteria in the decision-support software, a top-ranked alternative was identified. This alternative is not the same as the environmentally preferable alternative, but was selected because it met the most criteria. No alternative was determined to be ideal for all resources, but this method of considering how well the alternatives met the threshold criteria in addition to those criteria determined to be important by the JLA and Steering Committee provided a tool to rank the alternatives for the decision makers.

Alternatives were evaluated using the performance measures and scored for maximum benefit. Where quantitative analysis was possible, if an alternative provided the maximum beneficial result, it received a score of 100 percent. Alternatives with lesser results received a score reflecting the percentage of the maximum resource benefit attainable. Where quantitative information was not available, qualitative scoring was performed using simple scales ranging from 1 to 10 and descriptors such as good, fair or poor. This information was input into the decision support software and the results are presented below.

4.5.2 Discussion

More detailed decision hierarchy reflecting sub-criteria and performance measures is shown on **Figure 4-33**. Appendix P provides additional details on the performance measures and development of alternative scores. The CD available with the EIS contains performance measure evaluations conducted by each resource team. **Table 4-29** displays the decision performance scores for alternative selection.

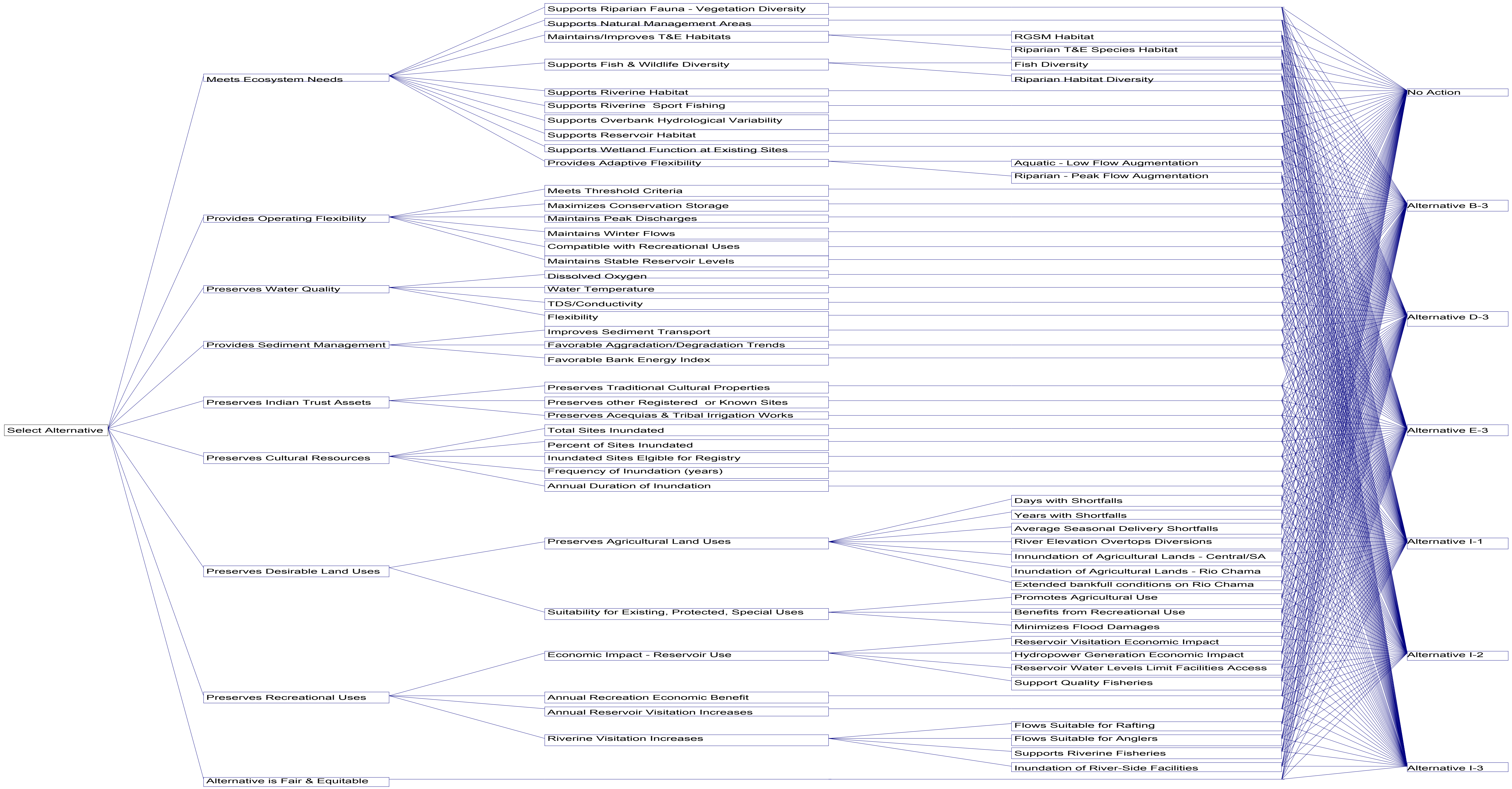


Figure 4-33. Detailed Decision Hierarchy

Table 4-29. Decision Performance Scores for Alternative Selection

						ALTERNATIVE SCORE						
Weights	Criteria	Weights	Performance Measure	Weights	Sub-Criteria	No Action	B-3	D-3	E-3	I-1	I-2	I-3
20	Meets Ecosystem Needs	14	Supports Riparian Habitats - Vegetation Diversity			63.6	44	65.4	57.8	89.3	76.9	58.3
		4	Supports Natural Management Areas			93.4	57.7	53.8	59.2	88.1	79.9	60
		8	Maintains/Improves T&E Habitats	43.5	RGSM Habitat	94.71	95.77	95.92	95.95	99.52	99.5	95.78
				56.5	Riparian T&E Species Habitat	70.1	59	53.6	66.4	77.7	70.1	53.5
		10	Supports Fish & Wildlife Diversity	78.5	Fish Diversity	82.76	69.59	74.85	72.94	75.52	86.91	91.12
				21.5	Riparian Habitat Diversity	76.7	57.4	70	62.2	87.1	75.2	63.5
		22	Supports Riverine Habitat			99.52	92.05	91.15	91.78	93.79	93.75	90.58
		2	Supports Riverine Sport Fishing			99.32	98.25	98.76	98.48	100	99.43	98.39
		16	Supports Overbank Hydrological Variability			55.4	78.2	76	88.6	76.1	74.6	74.1
		10	Supports Reservoir Habitat			92.91	83.55	80.52	80.81	77.12	66.69	64.83
		8	Supports Wetland Function at Existing Sites			99.1	95	94.6	95	97.4	96.4	95
		6	Provides Adaptive Flexibility	50	Aquatic - Low Flow Augmentation	48.1	100	94.2	94.7	55.8	77.4	95.7
				50	Riparian - High Flow Augmentation	16	96	89	97	30	66	91
17.78	Provides Operating Flexibility	37.5	Meets Threshold Criteria			50	83	89	94	58	72	95
		25	Maximizes Conservation Storage			0	98	95	95	50	76	96
		20	Maintains Peak Discharges			83	90	87	88	85	100	88
		10	Maintains Winter Flows			94	100	96	97	96	96	97
		5	Compatible with Recreational Uses			100	92	92	90	95	92	90
		2.5	Maintains Stable Reservoir Levels			90	98	96	97	88	93	98
15.56	Preserves Water Quality	34.57	Dissolved Oxygen			99.75	90.75	92	93.25	93.25	94	93.25
		41.47	Water Temperature			73	99.5	97	96.75	96.75	93.25	97
		23.04	TDS/Conductivity			88.25	100	98.5	98.5	98.5	98.5	98.5
		0.92	Flexibility			0	100	14.37	19.38	1.17	2.47	21.11
13.33	Provides Sediment Management	34	Improves Sediment Transport			100	76	77	76	87	82	77
		33	Favorable Aggradation/Degradation Trends			93	96	91	94	75	83	93
		33	Favorable Bank Energy Index			99	90	90	89	95	92	89
11.11	Preserves Indian Trust Assets	40	Preserves Traditional Cultural Properties			50	75	50	75	66.67	66.67	66.67
		30	Preserves other Registered or Known Sites			50	75	50	50	66.67	66.67	66.67
		30	Preserves Acequias & Tribal Irrigation Works			50	75	50	50	66.67	66.67	66.67
8.89	Preserves Cultural Resources	25	Total Sites Inundated			92	88	100	82	94	94	99
		20	Percent of Sites Inundated			86	83	97	73	92	92	100
		10	Inundated Sites Eligible for Registry			80	100	24	24	83	83	83
		20	Frequency of Inundation (years)			46	100	100	100	46	55	86
		25	Annual Duration of Inundation			29	100	100	100	29	50	50
6.67	Preserves Desirable Land Uses	50	Preserves Agricultural Land Uses	10	Days with Shortfalls	82.05	81.95	80.03	80.15	81.9	80.13	81.75
				10	Years with Shortfalls	49.38	50.63	49.08	50.63	50.63	49.08	49.08
				30	Average Seasonal Delivery Shortfalls	82.05	82	81.78	81.85	81.9	81.8	81.75
				10	River Elevation Overtops Diversions	57.9	66.5	61.7	59.6	56.7	58.8	59.6
				10	Inundation of Agricultural Lands - Central/SA	96.6	97.05	95.88	96.83	95.65	96.2	96.78
				10	Inundation of Agricultural Lands - Rio Chama	90.23	89.9	83.97	86.27	80.37	83.63	85.9
				20	Extended bankfull conditions on Rio Chama	78	100	86.7	87.3	78.7	87.3	78
		50	Suitability for Existing, Protected, Special Uses	40	Promotes Agricultural Use	7.7	8.3	6.6	7.9	7.6	7.7	7.9
				30	Benefits from Recreational Use	5.3	5.6	5.9	6	5	5.5	6
				30	Minimizes Flood Damages	4	15	100	11	6	12	86
4.44	Preserves Recreational Uses	40	Economic Impact - Reservoir Use	25	Reservoir Visitation Economic Impact	56	100	99	98	88	98	71
				25	Hydropower Generation Economic Impact	77	87	100	100	93	98	100
				45	Reservoir Water Levels Limit Facilities Access	51.98	54.48	59.7	60	46.73	53.78	60.05
				5	Support Quality Fisheries	59.7	52.8	51.2	50.9	100	94.3	92.2
		20	Annual Recreation Economic Benefit			56	100	99	98	88	98	71
		20	Annual Reservoir Visitation Increases			56	100	99	98	88	98	71
		20	Riverine Visitation Increases	53	Flows Suitable for Rafting	52	51	51	53	52	52	53
				32	Flows Suitable for Anglers	53.67	60.33	61.33	60.33	54.67	57.67	60.33
				11	Supports Riverine Fisheries	99.32	98.25	98.76	98.48	100	99.43	98.39
				4	Inundation of River-Side Facilities	100	100	98.33	100	95.67	99.17	100
2.22	Alternative is Fair & Equitable					3	1	7	5	4	2	6

4.5.3 Results of Alternatives Ranking

The performance and relative ranking of alternatives in accordance with resource team criteria and performance measures are documented in **Table 4-29**, in the CDP model file, and in the technical team information discussed in Appendix P. The decision hierarchy, performance measures, weights and alternative scores are summarized in the table. The scores reflected in Table 4-29 are normalized so that maximum resource benefits have a score of either 100 or 10, depending on the evaluation scale used. Alternatively, where qualitative analyses were performed, a simple ranking from one to seven was used—for example, in evaluating alternative fairness and equity. The final identification of a top-ranked alternative is based on the favorable weighted scores among all performance measures across all resources in combination with consideration of which alternative best meets JLA goals. Alternative rank by performance on the major selection criteria is shown on **Figure 4-34**. The range of alternative rankings is from 0.125 to 0.155, representing a 20 percent overall improvement for the top-ranked alternative as compared to no action. This outcome also reflects the constraints imposed by operating existing facilities under current authorities.

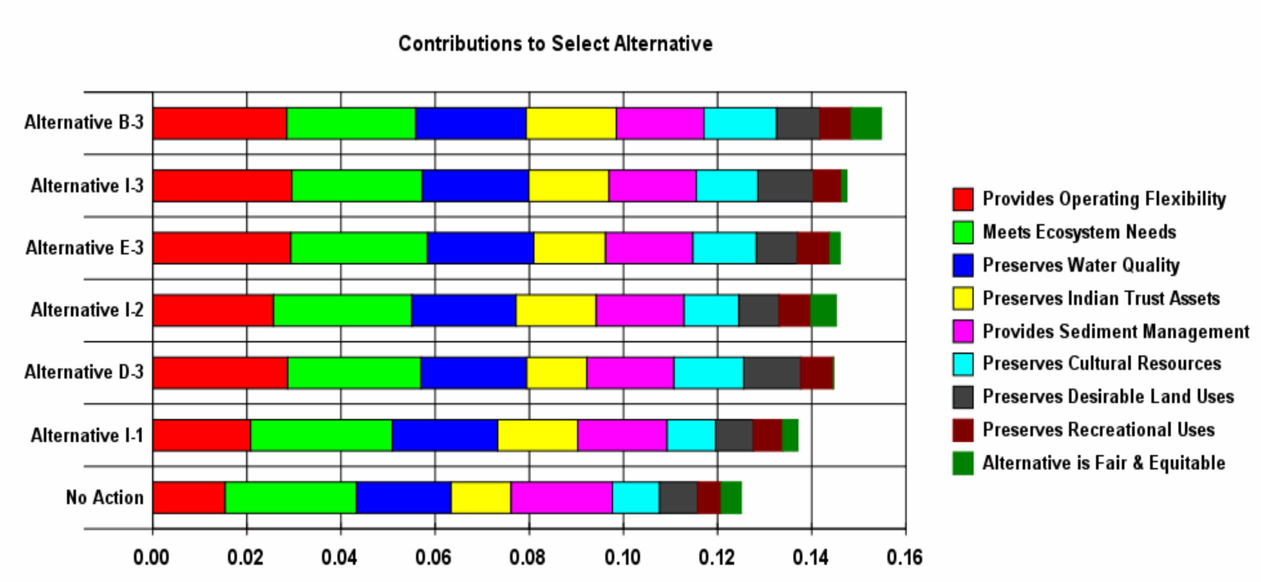


Figure 4-34. Final Ranking of Alternatives

Alternative E-3 is the JLA Preferred Alternative because it best satisfies the key goals of the EIS—to provide a plan for more efficient operation of federal reservoirs and facilities as an integrated system, to improve decision-making processes and interagency coordination, to support compliance with applicable laws and regulations, and to promote ecosystem sustainability. Alternative B-3 is the top-ranked alternative because it met the most criteria. Alternative E-3 was selected over B-3 as the Preferred Alternative in this Final EIS in response to public comments, internal comments from agency personnel, and to facilitate implementation of a single Preferred Alternative that enables all three lead agencies to best meet their respective water management responsibilities. A detailed comparison of alternative performance by criterion is shown on the radar diagram in **Figure 4-35,** with alternatives listed in order of preference in the legend. The best-performing alternative occupies the greatest area on the diagram. Better performance on a single criterion is indicated by line position at a greater distance from the centerpoint. A wide distribution across a single axis indicates a large degree of difference in alternative performance. The greatest variability in alternative performance occurs under operating flexibility, cultural resources, Indian trust assets, and land use support. Less variability between alternatives was observed for ecosystem needs, water quality, sediment management, and recreational uses.

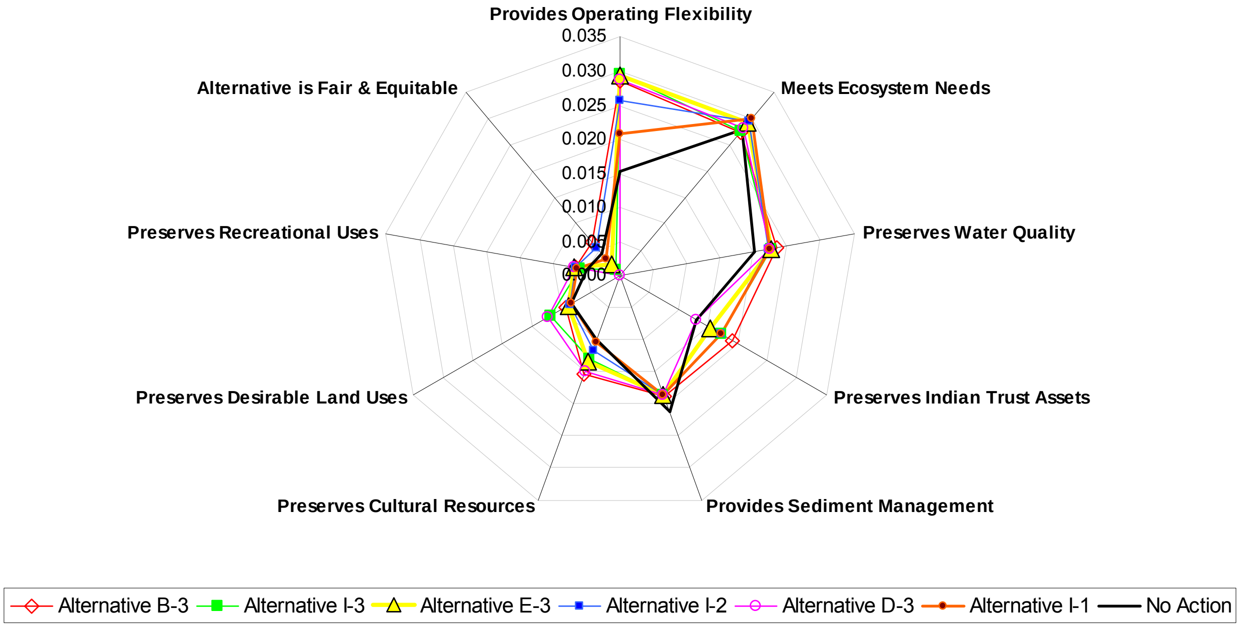


Figure 4-35. Radar Diagram of Alternatives

Alternative performance relative to the threshold criteria is shown on **Figure 4-36**. Alternatives I-2, I-1, and No Action do not satisfy minimum requirements for Compact deliveries and offer lesser degrees of flood control.

Alternative performance for operating flexibility is shown on **Figure 4-37**. Alternative I-3 is the top-ranked alternative from a water operations flexibility perspective. Alternatives I-2, I-1, and No Action did not meet minimum threshold criteria for selection based on their inability to satisfy interstate Compact deliveries. The top-ranked alternative, B-3, ranked fourth in operating flexibility. Alternative B-3 provides the greatest opportunity to maximize native conservation storage in Abiquiu Reservoir with decreased channel capacity below Abiquiu Dam and increased channel capacity below Cochiti Dam. LFCC diversions ranged from 0 to 2,000 cfs under Alternative B-3.

As shown on **Figure 4-38**, Alternatives I-1, I-2, and E-3 are the top three environmentally-preferable alternatives based on support for aquatic and riparian resources, including consideration for threatened and endangered species. The top ranked alternative, B-3, ranked last in ecosystem support, providing support for reservoir aquatic habitats, but lesser support for riverine and riparian habitat diversity. Of the alternatives evaluated that maximize native Rio Grande conservation water storage in Abiquiu Reservoir, Alternative E-3 ranked highest in ecosystem support.

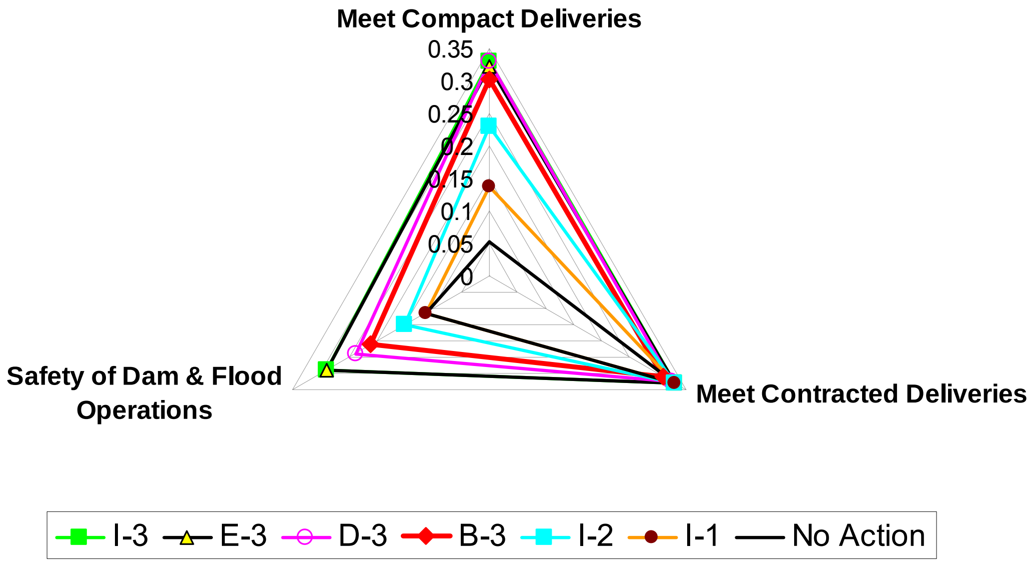


Figure 4-36. Threshold Criteria

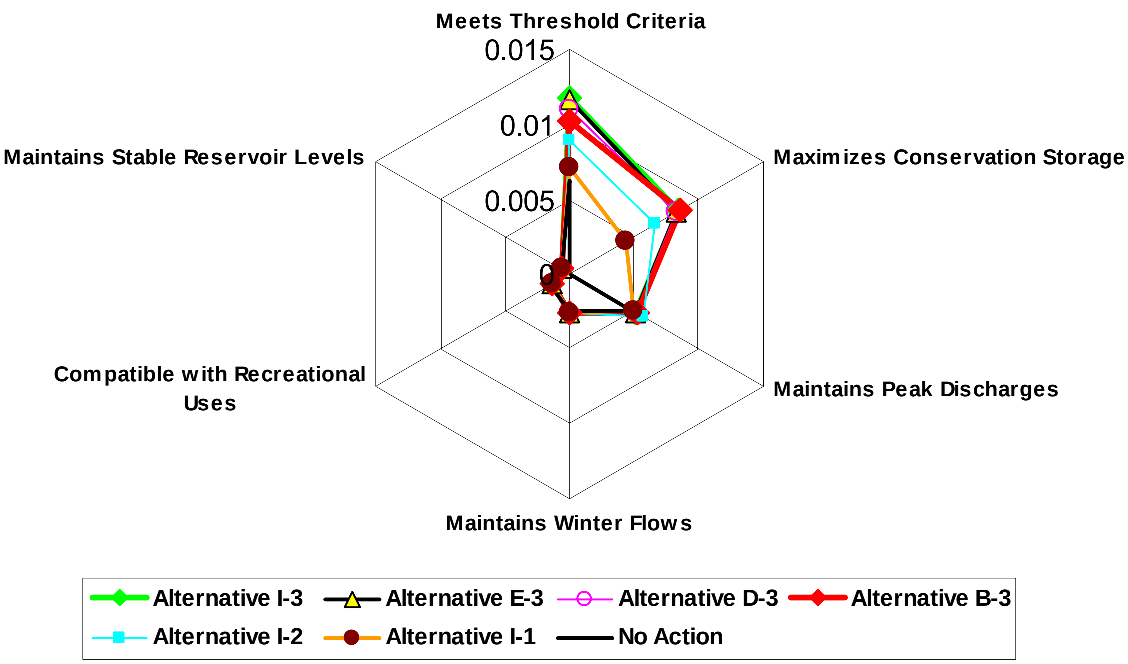


Figure 4-37. Operating Flexibility

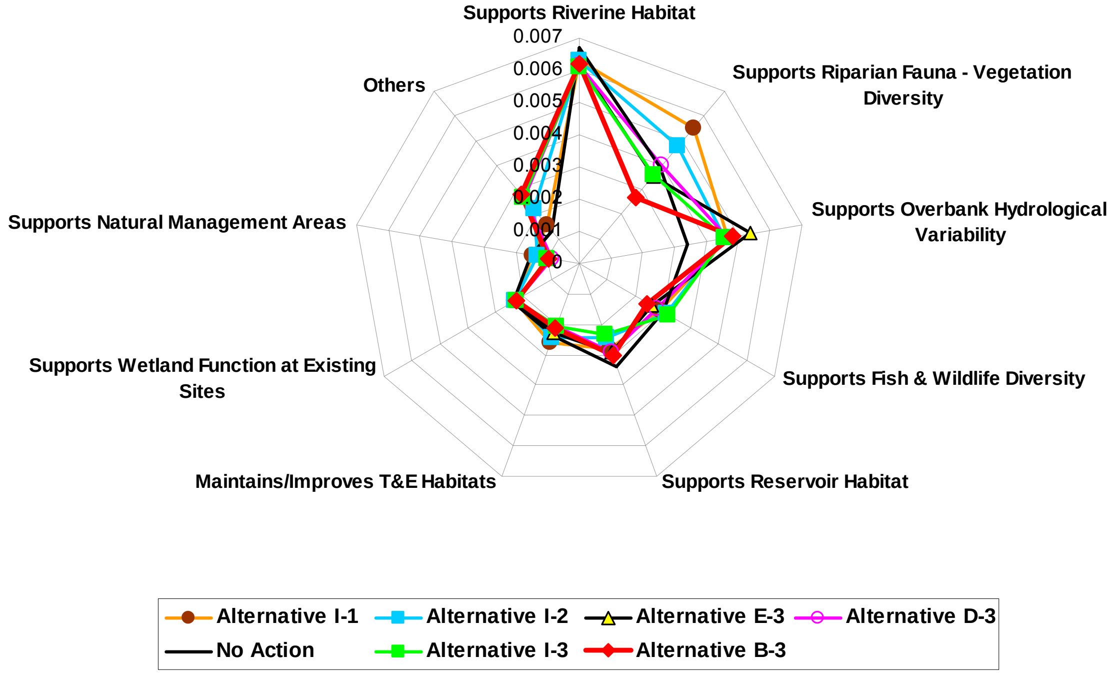


Figure 4-38. Ecosystem Support

4.6 Cumulative Impacts

Council of Environmental Quality regulations implementing NEPA define cumulative impacts as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of which agency (federal or non-federal) or person undertakes such actions" (40 CFR 1508.7).

As this EIS considers a 40-year planning period, there are numerous past, present, and reasonably foreseeable future actions in the planning area. This discussion of cumulative impacts focuses on actions that may have a continuing, additive, or significant relationship to water operations and resources that may be affected under the Preferred Alternative E-3. This analysis is qualitative and is based on information gathered by public scoping; consultation with cooperating agencies, tribal governments, other stakeholders in the planning area; and through conversations among JLA representatives and the ID NEPA Team.

The identified actions for cumulative effects assessment were considered for actions proposed for implementation within the next 5 to 10 years, with operational impacts assessed for the 40-year planning period. The geographical scope of the analysis includes the river corridor along the Rio Grande and Rio Chama, extending from the Closed Basin Project in Colorado to Fort Quitman, Texas. Past and present actions that affect water operations and the resources along the river corridor were taken into account in the analyses of direct and indirect effects by modeling the existing physical system, as described in Chapter 1, Section 1.6.1 and in each resource section of Chapter 4.

The evaluation of cumulative impacts, therefore, considers the reasonably foreseeable future projects that have the potential to affect water operations or the resources along the river corridor. Many projects are planned or underway in the project area that address resource problems; maintain or reconstruct existing structures; or study conditions to support future planning, adaptive management, and project needs.

Table 4-30 lists various major ongoing and reasonably foreseeable future projects, including planning and study efforts, in the planning area. All future projects or studies listed would only be implemented if funding were approved. This list is not all-inclusive, but can be used as a guide to evaluate future NEPA efforts in the basin, and provides a summary of the types of projects that are likely to occur that may affect water management in the planning area.

Table 4-30. Summary of Ongoing and Reasonably Foreseeable Future Projects or Actions

Project or Action (Lead Agency)	Description	Estimated Timing	Effects on Water Operations or Other Resources
1. Abiquiu Dam Oxygenator Project (Corps)	This project considers modifications to the hydroelectric plant that would improve water quality below Abiquiu Dam in conjunction with power generation for Los Alamos County.	Constructed in 2001	Dissolved oxygen concentrations were a concern in the Southern Section—Elephant Butte and Caballo Reservoirs. This project directly affects the Rio Chama Section, with lesser impacts downstream. Upstream improvements may also help downstream dissolved oxygen concentrations.
2. Los Alamos National Laboratory (LANL) Site-Wide EIS (Department of Energy)	This draft EIS evaluates many proposed changes at LANL. Those related to water resources include changes to the quality and quantity of water discharges into canyons that flow to the Rio Grande	2007–2012	Elimination of several permitted effluent outfalls discharging treated water from LANL would reduce the contribution of treated water and supplemental flows into canyons upstream of the Rio Grande.

Project or Action (Lead Agency)	Description	Estimated Timing	Effects on Water Operations or Other Resources
	and the construction of new facilities.		
3. Conservation Pool Assessment (Corps)	Assess options to develop a conservation pool to assist in meeting ESA requirements in the Middle Rio Grande.	Planned pending funding; duration indefinite	A Project Management Plan is in development with anticipated study to start quantifying water sources and needs; establish multiple storage scenarios; develop potential impacts for scenarios that include legal/institutional, tribal, environmental, cultural, geotechnical, engineering, real estate, etc.; and develop storage recommendations.
4. Cochiti Dam and Lake Environmental Baseline Study (Corps)	Proposed baseline studies are intended to characterize the interactions of Cochiti Dam and Lake with Tribal resources, including surface and subsurface hydrological analysis, water and sediment quality and wildlife bioaccumulation, as well as assessments of biological, cultural, and economic resources.	Ongoing; estimated completion date 2007	Provide a baseline against which the impacts of any future operational changes at Cochiti Dam and Lake may be evaluated. Intended to contribute to an evaluation of alternative water management strategies that include considerations for maintenance and restoration of endangered species as well as other reservoir management activities.
5. Jemez Canyon Dam and Reservoir EA (Corps)	This project considers long-term operation of Jemez Canyon Dam and Reservoir as a dry reservoir.	Court order; duration indefinite	Continuing the use of Jemez Canyon Reservoir as a dry reservoir. No change from current conditions, as modeled in the URGWOM Planning Model.
6. Albuquerque Levees (Corps)	This study is evaluating the overall condition of the levee system, its ability to function as designed, and to make recommendations for required future actions. The project study area includes the east and west side levee areas from the North Diversion Channel south to Isleta Pueblo within Reach 12.	Ongoing, with Final Report scheduled for completion in 2007.	Preliminary investigations conducted in 2005 indicate that the existing levees, constructed by the Corps of Engineers in the 1950s, may require extensive reconstruction. The levees were designed and constructed to convey 42,000 cfs.
7. Middle Rio Grande Project River Maintenance (Reclamation)	Reclamation maintains the river channel for the Middle Rio Grande Project from Velarde to Caballo Dam, NM with the goals of effective water conveyance; water conservation; reducing aggradation; and protecting riverside structures and facilities.	Ongoing; duration indefinite	River maintenance activities complement the actions considered under water operations alternatives including bank stabilization, channel realignment, bioengineering, and habitat enhancements, river training works, sediment removal, vegetation control, levee maintenance.

Project or Action (Lead Agency)	Description	Estimated Timing	Effects on Water Operations or Other Resources
8. Middle Rio Grande Endangered Species Collaborative Program (Multiple Agencies)	This multi-agency and public collaborative program authorizes the planning, evaluation, and funding of projects to improve habitat, conduct research, and obtain water to benefit federally listed species.	Ongoing; duration indefinite	Adaptive management activities anticipated as a result of implementing the Preferred Alternative should be coordinated through the Collaborative Program to ensure that water operations changes are contributing to recovery efforts for the species.
9. Water Operations Associated with 2003 Biological Opinion (Corps and Reclamation)	Implement the Reasonable and Prudent Alternative (RPA) and Reasonable and Prudent Measures associated with the Programmatic Biological Opinion (BO) of Reclamation's water and river maintenance operations, Corps' flood control operations, and related non-federal actions on the Middle Rio Grande.	3/2003–2/2013	All actions affecting habitat must be in compliance with the RPA and Reasonable and Prudent Measures of this BO to assist in the survival and recovery of the RGSM, SWFL, bald eagle, and interior least tern.
10. Various Federal, State, Local Entities, Non-Profit Organizations, and Universities	Numerous ecosystem and habitat restoration projects and research studies.	Ongoing	Restoration activities are intended to provide a beneficial effect on geomorphology, water quality, riparian and aquatic habitat. Research is intended to monitor the physical and chemical effects of human activities.
11. Rio Grande Integrated Management Plan (Corps and Reclamation)	Proposed development of a master plan for the Rio Grande	Planned pending funding; duration indefinite	Intended to help tie together the various activities on the Rio Grande in order to improve planning, coordination, and collaboration for stakeholders on the Rio Grande.
12. Belen Levee Project (Corps)	This project extends from Isleta Pueblo to Belen, NM along both banks of the Rio Grande. The existing spoil-bank levees would be rehabilitated to withstand higher and longer duration floods, accommodating the safe release of higher flows from upstream flood control reservoirs.	Planning stages; duration indefinite	Completion of this project is critical to the implementation of any alternative that calls for a channel capacity greater than 7,000 cfs in the Central Section.
13. San Acacia Diversion Dam Fish Passage and Related Projects EA (Reclamation)	EA for four proposed projects in the San Acacia Section, including installation of fish passage for RGSM at San Acacia Diversion Dam; installation of a siphon near Bernardo, NM; river maintenance upstream of the	2007–2010	Operation of the siphon and changes to the Diversion are likely to affect river flows in the vicinity, but the extent will depend on the options selected. The proposed projects are likely to affect habitat availability for RGSM.

Project or Action (Lead Agency)	Description	Estimated Timing	Effects on Water Operations or Other Resources
	Diversion; and maintenance of the Diversion riprap apron.		
14. Rio Grande Floodway Rehabilitation (Corps)	This project affects the east bank of the Rio Grande from the San Acacia Diversion Dam downstream to the San Marcial Railroad bridge. This project will rehabilitate the existing spoil-bank levee and relocate and increase the channel capacity below the railroad bridge.	Planning stages; duration indefinite.	Removes the restriction on channel capacity caused by the San Marcial railroad bridge, resulting in the ability to pass higher peak flows from upstream reservoirs. Completion of this project is critical to the implementation of any alternative that calls for a channel capacity greater than 7,000 cfs in the Central Section of the Rio Grande.
15. Rio Grande Realignment and LFCC Modifications (Reclamation)	This project proposes to realign the river channel and LFCC between San Acacia Diversion Dam and Elephant Butte Reservoir to improve water conveyance, enhance valley drainage, and improve sediment management.	Planning stages only; duration indefinite.	Possible operating impacts for a reconfigured LFCC range from 500 to 2,000 cfs diversion from the Rio Grande. This project has the potential to affect flows in the San Acacia Section. Changes due to physical realignment are not addressed but may occur.

There are many other public and private projects in the planning area that may modify surface water runoff and local inflows that are likely to affect the operation of specific facilities, especially for flood control. Where possible, operations of existing projects were considered during modeling and analysis. For example, City of Albuquerque Drinking Water Project diversions were considered in URGWOM modeling for all alternatives. In other cases, there was insufficient detail in future project operations and construction timelines to explicitly examine projects during quantitative analysis. Examples of projects that are known to be in the planning stages but either lack specific details or are likely to have minor local effects on Rio Grande system water operations include the following:

- Following the Cerro Grande Fire of 2000 in the vicinity of Los Alamos and Bandelier National Park, water control structures were installed to reduce surface water flows and minimize sediment delivery until the watersheds could be stabilized. In the near future, many of these structures are planned for removal, which will again change storm water flows into the Rio Grande.
- The Santa Fe National Forest is considering reducing its road network, resulting in long-term reductions in surface water runoff and sediment delivery from roads that outlet surface water into tributaries of the Rio Grande.
- The Buckman Water Diversion Project Draft EIS by BLM-Taos Field Office considers the impacts of diverting SJC water from the Rio Grande within Reach 9, for use by the City of Santa Fe.
- Population increases along the Rio Grande corridor and tributaries would increase the amount of impervious surfaces through construction of roads, buildings, and parking areas, resulting in increased local inflows to the Rio Grande. This is likely to alter flood control operations, especially

in wet years, so that they would be different than the water operations modeled for this Review and EIS.

Each resource considered in this EIS was reviewed to determine whether the impact of implementing the Preferred Alternative, in combination with other reasonably foreseeable future actions, could significantly affect water operations and the resource impacts described in the direct and indirect effects analyses in this chapter. The purpose of this evaluation is to provide an understanding of the incremental impact of the Preferred Alternative, which may have individually minor but collectively significant effects over a period of time.

4.6.1 Hydrology and Geomorphology

Projects in the region that have the potential to affect river flows and geomorphology include Projects 2, 3, 5, 7, 8, 9, 10, 13, 14, and 15 listed in Table 4-30. A qualitative evaluation of their impacts is summarized briefly as follows.

- Under the Preferred Alternative, the LANL Site-Wide EIS (Project 2) would result in minor reductions of surface water discharge in canyons that outlet into the Rio Grande. An associated impact would be a slight reduction of contaminants in the surface water flows in the canyons, some of which enters the shallow groundwater system or becomes trapped in Cochiti Lake sediments. Potential differences in flows would not significantly affect downstream channel capacities or water operations analyzed in this Review and EIS because they would be within the ranges already analyzed in Alternative E-3.
- Project 3, Conservation Pool Assessment, may eventually affect hydrology in the Rio Chama, Central, and San Acacia Sections, depending on what storage recommendations are implemented. However, it is anticipated that the recommendations would be within the existing authorities for water operations analyzed in this Review and EIS.
- Project 5 would not result in any change from the hydrology already analyzed in this Review and EIS because it continues the operation of Jemez Canyon Dam as it was included in the URGWOM Planning Model runs for each alternative.
- Project 7 involves maintenance of the Rio Grande channel for effective water conveyance and minimal bank erosion. This project maintains channel capacity from Velarde, New Mexico south to Caballo Reservoir and consequently affects the Northern, Rio Chama, Central, San Acacia, and Southern Sections. These routine maintenance activities are performed to maintain nominal channel capacity, and would only affect hydrology and geomorphology if they were not implemented.
- Projects 8, 9, and 10 include a wide variety of projects intended primarily to benefit federally listed species through restoration, maintenance, or improvement of riparian and aquatic habitat. The implementation of some of these projects is likely to affect hydrology or geomorphology. For example, destabilizing islands in the Central and San Acacia Sections would change flows and geomorphology in the river channel. Construction or restoration of wetlands may decrease local inflows by slowing surface water runoff before reaching the river channel. The specific impacts cannot be identified due to the broad range of projects planned and the unknown timing of implementation due to funding limitations.
- Project 13 is planned to address requirements of the 2003 Biological Opinion (BO) described in Table 4-30 as Project 10. While it is anticipated that flows and fishery habitats near the San Acacia Diversion Dam would be altered from the conditions evaluated in this Review and EIS, the effects are likely to be localized and within the range of the water operations evaluated under Alternative E-3.
- Implementation of Project 14 is necessary in order to carry out Alternative E-3 of this Review and EIS. The project involves removal of the San Marcial railroad bridge that currently limits channel

capacity above Elephant Butte Reservoir, as well as rehabilitation of the levees on the east bank of the Rio Grande between the San Acacia Diversion Dam and the railroad bridge. An assumption was made in the URGWOM Planning Model that the levees would be adequate and the bridge obstruction would be removed.

- Both the current zero diversion operation and potential future active diversions from the Rio Grande to the LFCC were evaluated in this Review and EIS in preparation for possible future changes in the physical realignment of the river including reconstruction of the LFCC (Project 15 in Table 4-30). It is anticipated that the LFCC will remain in zero diversion operations for the foreseeable future. Significant and costly physical changes to the LFCC would be required in order to implement the active diversions assumed in the URGWOM Planning Model runs for all action alternatives.

Other future projects that may affect hydrology and geomorphology include the Cerro Grande Fire recovery projects, Santa Fe National Forest road management decisions, and Buckman Water Diversion Project summarized above. However, the impacts are projected to be temporary or localized, having minor incremental effects that would be within the range of the water operations analyzed in this Review and EIS. Population increases may have significant future impacts on local inflows and downstream flooding due to increased impervious areas contributing high amounts of storm water runoff, but the locations and extent of these changes are impossible to predict.

Overall, the reasonably foreseeable future projects in the planning area may have locally significant or short-term impacts, but would not have significant long-term impacts on hydrology and geomorphology. The combined effects are not anticipated to exceed the range of water operations of federal facilities evaluated under the Preferred Alternative E-3.

4.6.2 Biological Resources

All of the projects listed in Table 4-30 that involve construction (Projects 2, 6, 7, 12, 13, 14, 15) have some potential for short-term effects on aquatic habitat, riparian resources, or threatened and endangered species by altering habitat or river flows, contributing sediment to the river, or causing other changes to water quality. Mitigation measures implemented during construction would minimize adverse impacts. A qualitative evaluation of project impacts that may affect biological resources is summarized briefly in the following list.

- Projects 1 and 2 are likely to improve aquatic habitat by improving water quality in the Rio Chama Section. Project 1 has been completed, but the majority of the water quality data for this Review and EIS was collected prior to project completion, so the benefits were not addressed in the analysis.
- Implementation of Projects 6, 7, 12, 13, and 14 is likely to result in localized, temporary adverse effects on aquatic habitat. However, impacts would be short-term, primarily during construction, and mitigation measures would be implemented to minimize potential adverse impacts from surface disturbance in and near the channel. Long-term impacts would be local and not likely to alter the impacts on biological resources analyzed in this Review and EIS, with the exception of Project 13, which is intended to improve aquatic habitat for the RGSM in the San Acacia Section.
- Implementation of Projects 8, 9, and 10 is intended to improve aquatic and riparian resources to benefit federally listed species. While the requirements of the BO were not expressly included in the URGWOM Planning Model runs for this Review and EIS, the improvements likely to result from implementation, in addition to completion of Project 12 (San Acacia Diversion Dam Fish Passage and Related Projects EA), may incrementally improve the effects of implementing Alternative E-3.
- Implementation of Project 15, river realignment and reconstruction of the LFCC, is likely to result in both short- and long-term impacts as a result of construction and operations. Construction impacts associated with river realignment and physical reconstruction are likely to be short-term, resulting from surface and channel disturbances, with adverse effects minimized by implementation of

mitigation measures. The effects of active operation of a reconstructed LFCC were evaluated in this Review and EIS. After including a 250 cfs bypass requirement in the URGWOM Planning Model to leave minimal flow in the Rio Grande, all alternatives considered active diversion from the Rio Grande to the LFCC ranging from 0 to 500, 1,000, or 2,000 cfs. Potentially adverse ecosystem impacts were observed in the San Acacia Section as a result of these active diversions. The future timeline for implementing the LFCC realignment is not clear due to funding uncertainties so the LFCC is expected to continue zero diversion operations for the foreseeable future.

The other future projects that may affect biological resources (Cerro Grande Fire recovery projects, Santa Fe National Forest road management decisions, Buckman Water Diversion Project) are projected to result in temporary or localized impacts.

Overall, reasonably foreseeable future projects are likely to have some locally significant, primarily beneficial, impacts on biological resources, some of which may offset the projected slight adverse impacts to biological resources under the Preferred Alternative (E-3), by improving wetlands and aquatic habitat.

4.6.3 Water Quality

Reasonably foreseeable future projects that change watershed characteristics and hydrologic processes may affect surface water quality by altering water chemistry, natural flow variation, and the transport of sediments, nutrients, and contaminants. The projects that have the potential to affect river flows are listed in Section 4.6.1 where it was concluded that the combined effects of future projects on changes to hydrology would not be significant and are within the range of alternatives evaluated under Alternative E-3. The only reasonably foreseeable future projects listed above that are likely to affect surface water quality are listed below.

- Abiquiu Dam Oxygenator Project (Project 1)—increase in dissolved oxygen below Abiquiu Dam
- LANL Site-Wide EIS action alternatives (Project 2)—reduction in discharge of contaminants to the canyons flowing to the Rio Grande
- Removal of water control structures installed after the Cerro Grande Fire—potential for immediate increase in sediment delivery and surface water runoff to the Rio Grande, followed by a tapering off as the watersheds stabilize
- Santa Fe National Forest road system reduction—reduction in sediment delivery from natural surfaced roads over the long term
- Increased concentrations of population at selected locations along the Rio Grande—increased pollutants in storm water runoff

The reasonably foreseeable future projects in the planning area listed in Section 4.6 above are more likely to result in minor incremental impacts on surface water quality than the implementation of Alternative E-3. Implementation of the Preferred Alternative E-3 would not significantly affect surface water quality.

4.6.4 Indian Trust Assets and Cultural Resources

Cumulative impacts on ITAs and cultural resources must consider the combined effects on unique and sensitive archaeological sites, traditional cultural properties, or acequias and other irrigation structures by implementation of reasonably foreseeable projects in combination with the Preferred Alternative E-3. The impacts to ITAs and cultural resources were determined to be minor, with little difference across alternatives, in the analysis presented in Section 4.4.4 of this Review and EIS. Because only minor effects on hydrology, inundation of riparian areas, and agriculture are anticipated under any of the reasonably foreseeable projects listed above, the cumulative impacts on ITAs and cultural resources would be insignificant overall.

4.6.5 Agriculture, Land Use, and Recreation

Potential changes in water delivery, surface water flows, reservoir levels, or land use may be considered significant if they were to result from the implementation of the Preferred Alternative E-3, in combination with the reasonably foreseeable projects listed in Section 4.6. Changes anticipated as a result of implementation of any of these projects, including Alternative E-3, may cause minor but insignificant impacts to acequia structures, land use, and recreational uses of rivers and reservoirs. Population increases are the most likely to result in land use changes, but the locations of the changes are difficult to predict at this time. No changes to irrigation water deliveries or agricultural land productivity would result from implementation of Alternative E-3.

4.6.6 Flood Control and Hydropower

The Preferred Alternative E-3 evaluated the full range of potential water operations and provides the greatest flexibility to accommodate flood control operations in the upper Rio Grande system. This alternative supports improved flood routing and flood control operations. Projects 7 and 15 could improve river channel conditions to better mitigate the impacts of high flood flows on adjacent lands. However, none of the reasonably foreseeable projects would alter the flood control operations, flood damages, or hydropower generation evaluated in this Review and EIS, so no significant cumulative impacts are projected.

4.6.7 Economics

Changes in visitation due to improved recreation opportunities were identified as the key parameter in evaluating economic impacts in this Review and EIS. None of the reasonably foreseeable projects listed in Section 4.6 would result in increased or decreased recreational opportunities. The analysis of the action alternatives in this Review and EIS project minor improvements in recreation opportunities and economics, with Alternative E-3, the Preferred Alternative, ranking in the middle of the action alternatives for effects on economics. Cumulative impacts from the Preferred Alternative, in combination with other reasonably foreseeable projects would be minimal.

4.6.8 Environmental Justice

Impacts related to environmental justice have been evaluated in this Review and EIS by focusing on the potential effects on biological resources and cultural resources. Under Alternative E-3, a slight adverse impact on environmental justice is projected, primarily due to the combination of slight adverse impacts to SWFL habitat and aquatic habitat in the San Acacia Section, and inundation of archaeological sites in the Central and San Acacia Sections. However, these impacts have been determined not to be significant when compared across all action alternatives in this Review and EIS. The reasonably foreseeable projects listed in Section 4.6 above are not anticipated to result in disproportionate impacts on minority or low-income populations in the planning area. No additional impacts to environmental justice issues are projected as a result of the combination of the Preferred Alternative and the other foreseeable projects, and those projected under the Preferred Alternative are likely to be insignificant.

4.6.9 Summary of Cumulative Impacts

In summary, implementation of the Preferred Alternative E-3, in combination with other past, present, and reasonably foreseeable future actions, would have insignificant direct or indirect effects on hydrology, geomorphology, biological resources, water quality, Indian Trust Assets, cultural resources, agriculture, land use, recreation, flood control, hydropower, economics, or environmental justice.

4.7 Short- and Long-Term Impacts

Section 102(2)(c)(iv) of NEPA and 40 Code of Federal Regulations (CFR) 11502.16 require comparison of the relationships between short-term uses of the human environment to the maintenance and enhancement of long-term productivity. None of the alternatives propose construction activity, thus there would be no construction-related short-term impacts. Action alternatives would result in operational changes in storage and release patterns from reservoirs and possibly contribute to land use changes in the basin. Long-term impacts would assist in conserving the RGSM, the SWFL, and better managing the limited water supply for the benefit of multiple users. Irreversible and irretrievable commitments are discussed in Section 4.8.1.

4.8 Unavoidable Adverse Impacts

Unavoidable adverse impacts are assumed to be long-term impacts to resources caused by implementation of an action alternative. Resources which can demonstrate notable adverse impacts include aquatic, riparian, water quality, and cultural resources. Specific mitigation measures are proposed for each of these resources to reduce the magnitude of impacts. With the exception of overbank flooding and attendant biological impacts in the San Acacia Section, impacts can be offset or mitigated to levels that would be better than under the No Action Alternative for each water operations alternative. However, seasonal restrictions on diversions to the LFCC could further improve the biological impacts in the San Acacia Section under all alternatives. However, restrictions would be deferred until specific actions are proposed by Reclamation, as physical limitations currently preclude active diversion to the LFCC. Primary impacts to water quality are related to dissolved oxygen in Elephant Butte and Caballo Reservoirs – direct and indirect measures can be used to increase flows and/or oxygenate waters. Impacts to cultural resources are associated with excessive flood flows in the San Acacia Section. Higher flood flows are desired to promote biological resources, but are also associated with potentially irreversible and irretrievable damages to known and unknown cultural resources sites. Thus, flood barriers such as coffer dams would be needed to reduce the impacts of higher flows. Diversions to the LFCC can also decrease the potential for damages associated with mainstem river flooding.

4.9 Irreversible or Irretrievable Commitments

Section 101 (2) (c)(v) of NEPA and 40 CFR 1502.16 require a discussion of irreversible and irretrievable commitment of resources. “Irreversible commitment of resources” is interpreted to mean those resources, once committed to the proposed alternative, would continue to be committed throughout the duration of operations; and that those resources used, consumed, destroyed, or degraded during operations under the proposed alternative could not be retrieved or replaced for the life of the operations or beyond.

Archaeological sites and Traditional Cultural Properties are the only resources potentially irreversibly and irretrievably affected by implementation of any of the alternatives, even with some of the proposed mitigation measures. For example, if the most appropriate mitigation measure were to excavate an archaeological site, this would permanently remove the site from its context.

Environmental commitments implemented for the selected alternative are intended to avoid, mitigate, or compensate for adverse impacts that would otherwise occur as a result of implementing the selected water operations alternative. In some cases, these commitments help ensure that activities are conducted in accordance with applicable laws and guidelines.

4.9.1 Environmental Commitments

Environmental commitments are actions that may be implemented upon the selection of any of the alternatives. These commitments are intended to avoid, mitigate, or compensate for adverse environmental impacts that would otherwise occur. Resources that may require additional environmental commitments are listed below.

- Threatened and Endangered Species Management
- Riparian Habitat
- Water Quality

- Cultural Resources

An adaptive management program would be implemented as specific federal actions are proposed and implemented. An adaptive management program provides guidance for monitoring EIS targets, compliance with current Biological Opinions, addressing changing conditions in the future management of water operations within established parameters, and providing a framework for ensuring that the selected alternative satisfies the purpose of and need for the proposed action.

4.10 Adaptive Management

4.10.1 Summary

Resource impacts were evaluated based on the quality of data available and current understanding of the system. However, as actions are implemented, further data are gathered, improvements in modeling and predicting system behavior occur, and agencies and stakeholders continue to cooperate and balance the ever-changing needs of natural ecosystems, a process for active and adaptive management is needed.

The question becomes, "*How do we adjust and integrate our program of operations in a manner that best serves the multiple and competing uses along this river system*?"

Adopting an adaptive management program is one approach that allows for science-based research and monitoring of responses to previous decisions. Monitoring information is analyzed and used to guide future decisions concerning human activities. Overarching management and ecosystem objectives remain fixed over time, and actions are adjusted to assure that future actions taken or modified promote sustainable positive impacts, to the degree possible and foreseeable. A general schematic of the adaptive management program is shown in **Figure 4-39.**

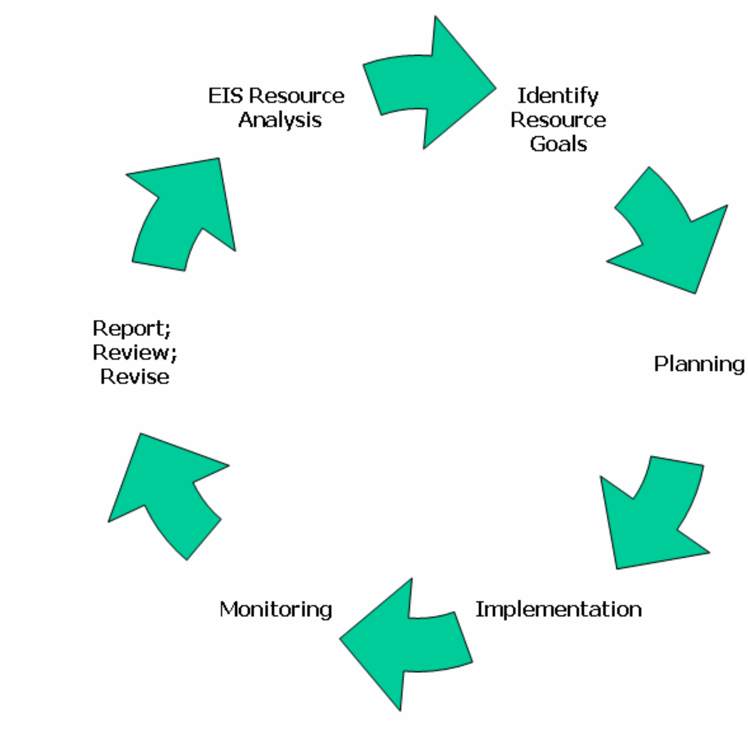


Figure 4-39. Overview of Adaptive Management Process

4.10.2 Goals and Objectives

In the upper Rio Grande basin, an adaptive management program would promote managing Federal facilities within an overall scientific-economic policy framework where decisions are based on data resulting from scientific inquiry and measured impacts. This decision framework can be considered as "continuing NEPA in action." Under adaptive management, proposed actions are implemented, a period of monitoring and research occurs, and modified actions are implemented based on analysis of data collected, with cycles of further measurement and adjustment continuing to reach and sustain management objectives. Water managers and stakeholders must first agree on acceptable or desirable conditions (management objectives) specific to the Rio Grande and then commit to developing and practicing the art of adjusting operations to sustain those conditions.

4.10.3 Process

Adaptive management activities in the Rio Grande system are underway. Multi-stakeholder collaborative efforts are ongoing in various portions of the basin, including the Middle Rio Grande ESA Collaborative Program and the Paso del Norte Watershed Council, and various regional water planning and watershed management groups.

Despite the actions of these agency and stakeholder groups, an overarching need exists for cooperative, adaptive management implementation across the entire study area encompassing the Federal facilities considered in this Review and EIS. A formal adaptive management program could be developed that extends from the Closed Basin Project and headwaters of the Rio Grande in Colorado to Fort Quitman, Texas with the charge of monitoring results of implementing the Preferred Alternative adopted by the JLAs and documented in individual agency Records of Decision. The adaptive management program could be administered through a formal, chartered organization representing the JLA, cooperating agencies, and stakeholders, that could transition into an advisory committee. The purpose of the adaptive management organization includes:

- Defining and recommending resource management objectives
- Conducting any additional research or studies to determine the impacts on various resources of the effects of operations conducted at Federal facilities along the Rio Grande
- Facilitating input and coordination of information among stakeholders
- Monitoring and reporting on regulatory compliance

4.10.4 Future Adaptive Management Activities

This EIS is a comprehensive planning document that supports a range of preferred water operations in the Upper Rio Grande Basin under the agencies' existing authorities. Detailed adaptive management plans would be developed as specific federal actions are proposed and implemented.

The baseline data, models, and analyses contained in this EIS will assist in the design and implementation of detailed adaptive management plans for future specific agency actions. Adaptive management and monitoring plans would need to be coordinated with other adaptive management activities being undertaken in the basin, such as those associated with the Rio Grande Compact Commission, Middle Rio Grande ESA Collaborative Program, the City of Albuquerque San Juan-Chama Drinking Water Project, and others.

The data quality database created as part of this EIS (Appendix P) identifies areas where data quality was limited or lacking. Adaptive management plans that are formulated should focus on areas where data gaps have been identified in order to validate, or correct, assumptions and conclusions that were made on the basis of limited data.

Sources of uncertainty and data gaps are summarized in the EIS and in Appendix P. Data gaps and sources of uncertainty for underlying models include:

- URGWOM Planning Model
    - Accuracy of flow predictions due to effects of groundwater/surface water interactions.
    - Effects of evapo-transpiration on flow predictions.
    - Improve predictions of how water moves through the system, i.e., improve determination of delivery schedules for differing water uses (e.g., recreation, irrigation).
- FLO-2D Model
    - Possible over-estimate of predicted overbank flow areas and durations due to limited gage data, size of grid elements, variable roughness and infiltration parameters, lack of model calibration for high flows, one-dimensional channel flows, and limited number of surveyed cross-sections in the Model.

Sources of uncertainty and data gaps for each resource area include:

- Hydrology and Geomorphology
    - Availability of and confidence in gage, elevation and other input data.
    - Limitations in the degree of changes observed due to the particular 40-year inflow sequence used.
    - Propagation of error moving downstream in the river system that resulted in at least 10 percent uncertainty in model results.
- Aquatic Habitat
    - Predicted changes to riverine and reservoir aquatic habitat are subject to propagation of gage and URGWOM modeling error, understanding of desirable fish habitat conditions, model spatial sensitivity, and further propagation of error across the Aquatic Habitat and FLO-2D models.
- Riparian Habitat
    - Quality and limitations of each dataset for the riparian analysis depend on modeled data and uncertainties in input data, including gage error and hydrologic inputs.
- Threatened and Endangered Species
    - Model predictions in the San Acacia Section offer less certainty than those offered for other sections due to limitations in modeling highly dynamic and unstable river and riparian environments. Conclusions regarding habitat and life-stage requirements for many of the species are based on current understanding and will continue to evolve.
- Water Quality
    - Flow-based differences in various water quality parameters need to be more thoroughly evaluated.
- Indian Trust Assets and Cultural Resources
    - The propagation of uncertainty and the lack of archaeological surveys in certain river sections.
- Agriculture, Land Use and Recreation
    - The agricultural land use analysis did not include evaluation of impacts to Pueblo and Tribal lands. The review is limited to operations that may affect about 53,000 acres of agricultural land along the Rio Chama, Central and San Acacia Sections, which represents less than 30 percent of the agricultural land in the Upper Rio Grande basin.

- Flood Control
  - New GIS-related tools have been developed since the source studies were done, so data other than the flow-damage relationship is unavailable. Some growth may have occurred since the initial study, and further growth is expected, such that the damages associated with specific frequency events will be higher than indicated. Future development would change potential damages from any flood event.
- Hydropower
  - Changes since the 1991 study will have to be quantified and applied to the existing condition analysis as well as each alternative. Future development in this context includes both demand within the region and the resulting impact upon prices.
- Environmental Justice
  - Population distributions and incomes may change with time, thereby changing the socioeconomic profile of the planning area.

Resource goals, mitigation measures, performance measures, and performance targets have also been evaluated throughout Chapter 4. A comprehensive adaptive management plan would also include monitoring beneficial and adverse impacts, and determining mitigation effectiveness, for each of the resource areas.

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