

APPENDIX K
AQUATIC HABITAT MODEL

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1.0 Aquatic Habitat Model

1.1 Background

In order to evaluate the relative performance of the alternatives, the Aquatic Resources Team employed several contractors to formulate and construct a dynamic habitat-flow relationship capable of quantifying and modeling riverine habitat. Broadly defined, this approach combines the physical characteristics of a river, habitat use criteria for a given species, and hydrology data (in this case, URGWOM output) under a Geographic Information System (GIS) framework and calculates an explicit two-dimensional area of suitable aquatic habitat. The process of formalizing the Aquatic Habitat Model had four principal steps:

- 1) *Conceptual Approach* (Miller Ecological Consultants, Inc. and Science Applications International Corporation, 2000)
- 2) *GIS Model Report with Users Manual* (Miller Ecological Consultants, Inc., 2003)
- 3) *Pilot Hydraulic and Habitat Modeling Study* (Miller Ecological Consultants, Inc. and Mussetter Engineering, Inc., 2003)
- 4) Ecological Consultants, Inc., 2004)

Upon finalization of the alternatives and the subsequent completion of URGWOM output data, the Aquatic Habitat Model was used to produce a time series analysis of the 40-year hydrologic sequence in which daily flows were translated to a quantification of suitable habitat area for two representative study sites on the Rio Chama and six on the Rio Grande. These data were then used to evaluate the performance of the alternatives, for an array of indicator species, relative to the No Action.

The following are limited descriptions of the study sites as the length of above documents precludes their practical inclusion into this Review and EIS. In addition to Appendix K, more information on the study sites and results of the Aquatic Habitat Modeling effort can be found in Chapter IV. For more detailed information on the rationale, methods, and results of the Aquatic Habitat Model, any of the above referenced documents can be requested from the JLAs. When requesting these documents, please refer to the titles as stated in 1-4 above.

1.1.1 Study Site Descriptions

Seven sites that represent the geomorphologic variation within the Middle Rio Grande and the Rio Chama downstream of Abiquiu Reservoir were initially selected for analysis based on field reconnaissance and other available information (**Table K-1.1, Figure K-1.1**). Subsequent to the initial selection, additional funding was obtained and a second site was added on the Rio Chama because of the significant variation in geomorphic characteristics between Abiquiu Reservoir and the mouth at the confluence with the Rio Grande. The criteria that were used to evaluate and select the sites included the following:

- Geomorphic representativeness of the reach, including the planform bed material and other morphological characteristics of the channel.
- The length of the reach that could reasonably be surveyed, with the goal of defining study reaches that were at least seven times longer than the average channel width. The target reach length is likely to encompass the geomorphologic variation in channel characteristics, including meso- and macro-scale features such as pools, riffles, subaerial (braid bars) and subaqueous (linguoid/lobate bars), all of which are in-channel features that are associated with in-channel aquatic habitat.
- Access to the site based on property ownership, as well as physical access for a boat to support intermediate-level flow measurements.

- Proximity to a gaging station to provide a means of accurately estimating the discharge at the sites during the surveys, and for quantifying the long-term flow characteristics in the analysis phase of the work.

Table K-1.1 Summary of Sites Selected for the Hydraulic and Habitat Modeling Study

<i>Study Site</i>	<i>Description*</i>
Pena Blanca	Rio Grande at Pena Blanca (RM 227.5)
Bernalillo	Rio Grande at Bernalillo (RM 203.6)
Central	Rio Grande at Central Avenue Bridge (RM 183.2)
Bernardo	Rio Grande downstream of US 60 Bridge near Bernardo (RM 130.4)
Bosque del Apache	Rio Grande just downstream of north boundary of Bosque del Apache National Wildlife Refuge (RM 84.1)
San Marcial	Rio Grande below the San Marcial Railroad Bridge (RM 68.5)
Upper Rio Chama	Rio Chama about 3 miles downstream of Abiquiu Dam
Lower Rio Chama	Rio Chama just upstream of new Highway 285 Bridge

*River Miles along the Rio Grande represent the approximate mid-point of the modeled reach and are based on the 1997 U.S. Bureau of Reclamation River Atlas.

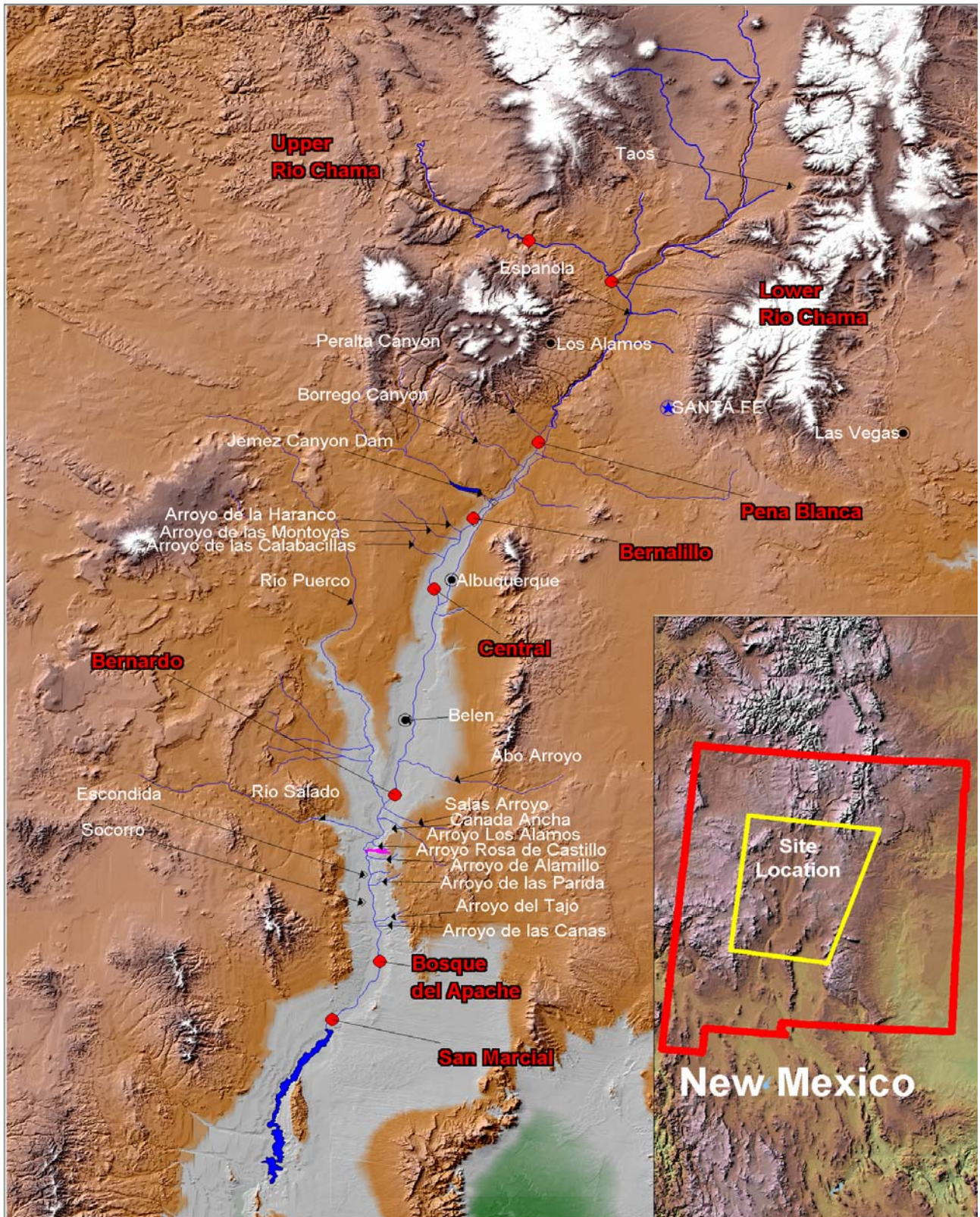


Figure K-1.1 Map of the Middle Rio Grande Showing Locations of the Study Sites Selected for the Hydraulic and Habitat Modeling Study.

1.2 *Rio Grande at Pena Blanca (Pena Blanca)*

The Pena Blanca study site is located at approximately River Mile (RM) 227.5 between the southern boundary of the Cochiti Pueblo Reservation and the northern boundary of the Santo Domingo Pueblo Reservation. The site is about 0.6 miles long, the active channel width is about 150 feet, and the average gradient is about 10 feet per mile. This reach of the Rio Grande is characterized by split flows around vegetated bars and islands, and it has relatively coarse, gravel- and cobble-sized bed material due, in part, to winnowing of fines as a result of reduced upstream sediment supply since Cochiti Dam was constructed in 1973. Based on Bureau of Reclamation range line bed material samples in the vicinity of the site, the median (D_{50}) size of the bed material is about 19 mm, and the D_{84} is about 58 mm. Some sediment is still supplied to the reach by Peralta Canyon Arroyo located about 2 miles upstream of the site. Analysis of the effects of Cochiti Dam on the downstream morphology of the channel indicates that the bed of the channel at the study site has probably degraded by about 2 feet since the dam was closed (Lagasse, 1980; Leon, 1998; Mussetter Engineering, Inc. (MEI), 2002), but it is unlikely that further degradation will occur because the bed has armored. The study site includes split flow around a large island with several smaller splits that occur at low flows. Single-channel segments are located both upstream and downstream of the split-flow reach. A number of low elevations, formerly (pre-Cochiti) active gravel braid bars are located through the site and these are heavily vegetated with willows and Russian olive trees. The pre-incision floodplain is densely vegetated with primarily tamarisk and Russian olive trees, but there are also some large cottonwoods. The site is bounded to the east by the levee on the west side of the Cochiti East Side Riverside Drain, and to the west by an informal levee that is located along the west bank of the river.

1.3 *Rio Grande at Bernalillo (Bernalillo)*

The Bernalillo study site is located at approximately RM 204 just downstream of NM Highway 550 at Bernalillo. The site is about 1,800 feet long, the active channel width is about 500 feet and the average gradient is about 2.5 feet per mile. This reach of the Rio Grande is characterized by a braided high flow planform, with a number of relatively high-elevation vegetated bars present in the channel. Under low flow conditions the reach has a single channel with low sinuosity. The reach has degraded since the sediment supply to the reach was reduced by construction of Jemez Reservoir in 1954 and Cochiti Reservoir in 1973. Between 1973 and 1998 the mean elevation of the bed of the river decreased by 2 feet (Bauer, 2000; MEI, 2002), and degradation may be on-going. Associated with the channel degradation has been coarsening of the bed material. In 1970 the D_{50} of the bed material was about 0.3 mm, but by 1998 it had coarsened to about 8 mm (MEI, 2002). Currently, the riffles within the reach are composed of gravels, but no recent gradation analyses are available for the reach. It is likely, however, that the bed of the river will further coarsen with time. The reach is confined on the east side of the river by the levee that is located on the west side of the Bernalillo Riverside Drain. Jetty jacks are present along the left bank of the river and on the floodplain between the river bank and the levee. The west side of the reach is bounded by the pre-incision floodplain, the bank of which is actively being eroded by the river. Urbanization of the floodplain will probably result in armoring of the bank. The pre-incision floodplain on both sides of the river is heavily vegetated with a mixture of tamarisk, Russian olive, elm and cottonwoods.

1.4 *Rio Grande at Central Avenue Bridge (Central)*

The Central study site is located just downstream of the Central Avenue Bridge in Albuquerque at about RM 183. The site is about 2,700 feet long, the active channel width is about 500 feet and the average gradient is about 2.6 feet per mile. This reach of the Rio Grande is characterized by a slightly sinuous meandering planform caused by the stabilization of bank-attached bars with native and introduced

vegetation species, and the presence of Kelner Jack fields. The study site includes a split-flow segment around a vegetated (willows and Russian olive) mid-channel bar that provides a range of channel sizes within the site. All of the channel segments contained subaerially exposed sandy braid bars, and subaqueous, migrating linguoid bars, the spacing of which, scale to the width of the individual active channels. Analysis of the U.S. Geological Survey (USGS) discharge rating curves for the Albuquerque gage located at the Central Avenue Bridge indicates that there has been about 2 feet of downward shift in the rating curves between 1974 and 2001 (MEI, 2002). This suggests that there has been about 2 feet of bed lowering in the reach since the upstream dams were emplaced. The amount of degradation is corroborated by review of the Bureau of Reclamation range lines in this location that show about 2 foot of reduction of mean bed elevation between 1973 and 1998 (MEI, 2002), but these data indicate that there has been bed stability since 1998. The bed material in the reach is primarily sand sized, but there are local concentrations of gravels on the riverbed. Analysis of bed material gradations at the gage from 1968 to 2001 indicates that the D_{50} of the bed material has coarsened slightly over time from about 0.3 mm to 0.5 mm, but the D_{84} values have remained consistently at about 10 mm (MEI, 2002). The river is bounded to the east by the levee located on the west side of the Albuquerque Riverside Drain, and to the west by the levee that is located on the east side of the Atrisco Riverside Drain. Kelner jacks are located on the floodplain surface on both sides of the river, and both sides of the floodplain are heavily vegetated with tamarisk, Russian olive, elm, willows and cottonwoods.

1.5 *Rio Grande Downstream of US 60 Bridge near Bernardo (Bernardo)*

The Bernardo study site is located just downstream from the U.S. Highway 60 Bridge near Bernardo at about RM 130. The study site is about 2,500 feet long, and has an average channel width of about 600 feet. This width is about 40 percent wider than the average width of the Rio Grande in the approximately 13-mile reach between the mouths of the Canada Ancha Arroyo, located about 4.2 miles downstream from the Highway 60 Bridge, and Belen (MEI, 2002). The reach is characterized by a wide, braided, sand-bed channel with numerous vegetated and non-vegetated mid-channel bars, sandy braid bars, and migrating subaqueous linguoid bars. The average gradient of the Rio Grande in this reach is about 4.7 feet per mile. Analysis of Bureau of Reclamation range lines surveys between 1962 and 1998 indicates that there has been about 2 feet of bed lowering in this reach of the river (Bauer, 2000). The degradation was most probably due to channelization of the river, and may also be related to the increased flows that have occurred in the reach as a result of importation of San Juan-Chama water to the basin as well as increased wastewater discharges from the City of Albuquerque (MEI, 2002). The sandy bed material at the site is mobile over essentially the entire range of flows that occur in the reach, and bedforms ranging from ripples to remnant dunes are evident under low-flow conditions. The D_{50} of the bed material is about 0.2 mm, and this has not changed since 1968 (MEI, 2002). Hydraulic variability through the site is created by flow deflection around the micro- and meso-scale bedforms, local scour holes and plunge pools that develop on the downstream side of the linguoid bars and at locations where flow impinges on the relatively erosion-resistant banks. Jetty-jacks line the channel along both sides of the river, resulting in well-defined, erosion-resistant banklines that are vegetated with a mixture of primarily salt cedar and Russian olive. The channel is bounded on the east side by the levee that is located on the west side of the San Juan Riverside Drain and on the west side by the levee that is located on the east side of the San Francisco Riverside Drain. The floodplain on each side of the river is densely vegetated with a mixture of tamarisk, Russian Olive and cottonwoods.

1.6 *Rio Grande just Downstream of North Boundary of Bosque del Apache National Wildlife Refuge (Bosque del Apache)*

The Bosque del Apache study site is located just downstream of the north boundary of the Bosque del Apache National Wildlife Refuge at about RM 84. The site is about 2,500 feet long, the average channel width is about 700 feet, and the average gradient is about 3.3 feet per mile. This site is located in a relatively straight reach of the Rio Grande that is characterized by the presence of alternate bars with a wavelength of about 4,000 feet. The alternate bars create low-flow sinuosity in a reach of the river where it is braided at higher flows. The alternate bar, which is attached to the right (west) bank of the river, extends for the entire length of the site. At the time of the site surveys, the bar was composed of two main surfaces: (1) a subaerially exposed sand bar devoid of vegetation, and (2) a predominantly willow-dominated vegetated sand bar at a somewhat higher elevation. A pre-existing secondary channel between the west margin of the alternate bar and the primarily cottonwood dominated vegetated floodplain extends for most of the length of the site, and was being used at the time of the survey to convey pumped flows from the Low Flow Conveyance Channel (LFCC) to the river. The floodplain along the east (left) bank of the river is primarily vegetated with tamarisk and Russian olives whose roots provide root reinforcement to the sandy floodplain sediments, thereby, limiting the erosion potential. Under low-flow conditions, subaqueous linguoid bars whose spacing scaled to the width of the active channel were present throughout the site. Bed and bar sediments are composed primarily of medium-fine sands, but thick clay-dominated drapes were present on many of the bar surfaces. Some fine gravel was observed in the bed and bar sediments as well, and was probably derived from the east-side tributaries located upstream of the Highway 380 bridge. The D_{50} of the bed material is about 0.3 mm. The site is bounded to the east by an abandoned historic levee and to the west by the levee on the east side of the LFCC.

1.7 *Rio Grande below the San Marcial Railroad Bridge (San Marcial)*

The San Marcial study site is located just downstream of the San Marcial Railroad Bridge at about RM 69. The site is about 2,700 feet long, the average channel width is about 250 feet and the average gradient is about 2.0 feet per mile. This reach of the Rio Grande is characterized by active channel aggradation as a result of base-level control exerted by Elephant Butte Reservoir. Comparative surveys indicate that the bed of the river has aggraded about 24 feet in this reach since 1885 (Smith et al., 2001). The river channel within this reach is entirely man-made and is relatively narrow, and is somewhat further constricted by the BNSF railroad bridge. Numerous sandy braid bars and subaqueous, migrating linguoid bars are present within the channel. The D_{50} of the bed material is about 0.2 mm (MEI, 2002). The hydraulic capacity of the BNSF railroad bridge, located immediately upstream of the reach, is about 3,800 cfs (Smith et al., 2001), and this limits the magnitude of the controlled flow releases from upstream. Higher peak flows derived primarily from summer thunderstorm flows in the Rio Puerco and Rio Salado drainages may exceed the bridge capacity. The east side of the site is bounded by Mesa del Contradero, a Cenozoic-age volcanic-capped mesa. The west side of the site is bounded by the levee on the east side of the LFCC. The floodplain on the west side of the river is very heavily vegetated.

1.8 *Rio Chama Downstream of Abiquiu Dam (Upper Rio Chama)*

The Upper Rio Chama at this site, which is located about 3 miles downstream of Abiquiu Dam, is canyon bound and has very coarse bed material composed primarily of cobbles and boulders. The coarse nature of the bed material may be in part due to the elimination of bed material sediment supply from upstream by the dam. The site is about 2,500 feet long, the active channel width in the single channel portion of the reach is about 250 feet and the average gradient is about 14 feet per mile. The modeled reach includes a large vegetated mid-channel bar that owes its existence to a downstream constriction formed by

horizontally-opposed tributary alluvial fans. A low elevation bench-like surface is present around the margins of the mid-channel bar and on the banks of the river, and this probably represents the morphological adjustment of the river to closure of the dam in 1963. Coarse material delivered by the downstream tributaries helps to maintain the constriction that is the downstream hydraulic control for the large mid-channel bar. Two vegetated secondary bars are present in the right channel. A right bank tributary located upstream of the modeled reach provides sediment to the reach, which otherwise has a low sediment supply because of the presence upstream of Abiquiu Dam. The planform of the river just upstream of the modeled reach is controlled by bedrock outcrop. Bedrock outcrop (Triassic-age Chinle Formation) crops out in the right bank of the river near the downstream end of the reach, but the remainder of the right bank is comprised of a gravel-capped strath terrace. Bedrock outcrop and the margin of the left bank alluvial fan bound the river on the east side of the reach. This site was chosen by the COE to represent brown trout fishery habitat in the reach of the river below the dam.

1.9 *Rio Chama Upstream of new Highway 285 Bridge (Lower Rio Chama)*

The Lower Rio Chama Site is located about 2,000 feet upstream of the Highway 285 Bridge near Chamita and was added to the study to represent conditions in the lower portion of the Rio Chama that are very different to the canyon-bound reach represented by the upper study site. The study site is about 2,500 feet long, and it has an average channel width of about 200 feet and an average gradient of about 6.5 feet per mile. The modeled reach is relatively straight and uniform. The left bank of the river in the modeled reach is composed primarily of sediments deposited on the alluvial fan of Rio Ojo Caliente, a left bank tributary whose present confluence with the Rio Chama is located about 2000 feet upstream of the modeled reach. The fan surface is primarily vegetated with cottonwoods. The right bank of the river is composed of Rio Chama sediments that have been stabilized in the post-dam era by primarily non-native vegetation species and jetty jacks. A levee has been constructed on the historic floodplain and has cutoff a former channel of the river that was located to the south of its present position. The bed of the river at this site is composed primarily of gravels and cobbles. Sands that are delivered from the numerous tributary arroyos that drain the Santa Fe Formation, that forms the basin fill upstream of the reach, are transported over the gravels and cobbles when discharges in the river are less than critical for mobilization of the bed material. A low elevation berm that is vegetated with willows and small Russian olives has formed along both banks of the river in response to flood flow control by Abiquiu Dam. A right bank un-named tributary arroyo forms a fan about 600 feet upstream of the highway bridge that extends out into the channel of the Rio Chama. Small boulders and cobbles derived from the fan form a coarse-grained riffle at the confluence and this provides a stable baselevel for the upstream channel of the Rio Chama.

1.9.1 Field Data Collection

Field data were collected by MEI and Bohannon Huston Inc. (BHI) at each of the study sites to obtain the data necessary to develop and verify the 2-D hydraulic models. The data collection program included a topographic survey of the channel and overbanks, paired depth and velocity measurements that were geo-referenced to each site survey, and general descriptive information about each site. Water-surface elevations were also collected as part of the topographic survey for use in validating the modeled water-surface elevations. Data were collected during two site visits at each site to obtain data for use in model calibration at different flow levels. **Table K-1.2** summarizes the dates of the surveys and the discharges and number of depth and velocity measurements made during each site visit. Average discharges provided in **Table K-1.2** are based on flow measurements conducted during the survey, or available data from the nearest USGS stream gage. Where both flow measurements and data from a nearby stream gage were available, the decision on which data to use was based on judgment as to the accuracy of the flow

measurements, the closeness of the gage to the site, the presence of diversions or tributaries between the gage and the site, and published remarks as to the accuracy of the flow records at the gage.

The topographic surveys were conducted using a survey-grade Global Positioning System (GPS) and total station theodolite, with the surveys tied to the state-plane coordinate system (New Mexico Central Zone, North American Datum of 1983 (NAD83) for the horizontal datum. At sites where preliminary work was performed by others before BHI's involvement in the project, the National Geodetic Vertical Datum of 1929 (NGVD29) was used for the vertical datum along with local control points. At sites where BHI established the local control, the North American Vertical Datum of 1988 (NAVD 88) was used for the vertical datum. This included the two sites on the Rio Chama as well as the Central Ave. site on the Rio Grande. BHI used the field survey data, in conjunction with aerial photography of each site that was flown prior to the field surveys, to create a 1-foot contour interval topographic map of each study site.

Table K-1.2 Summary of Site Surveys

Study Site	First Site Visit			Second Site Visit		
	Survey Dates	Average Discharge (cfs)	Number of Depth-Velocity Pairs	Survey Dates	Average Discharge (cfs)	Number of Depth-Velocity Pairs
Pena Blanca	Feb 9-10, 2002	544 ¹	121	Oct 3, 2002	295 ¹	44
Bernalillo	Jan 28-29, 2002	514 ^m	93	Oct 2, 2002	247 ^m	39
Central Avenue	Jan 30-31, 2002	462 ^m	179	Sep. 30-Oct. 1, 2002	197 ^m	80
Bernardo	Feb 1-2, 2002	605 ²	108	Apr 26, 2002	7 ²	0
Bosque del Apache	Feb 3-4, 2002	454 ^m	95	Apr 24-25, 2002	76 ^m	178
San Marcial	Feb 5-6, 2002	477 ³	149	Apr 22-23, 2002	46 ³	97
Upper Rio Chama	Feb 7-8, 2002	18 ^m	135	Oct 8-9, 2002	220 ^m	85
Lower Rio Chama	Jul 11-12, 2002	916 ⁴	186	Dec 10, 2002	73 ⁴	119

^mMeasured flow at the site

¹Average flow at the Rio Grande below Cochiti Dam stream gage

²Average flow at the Rio Grande Floodway near Bernardo stream gage

³Average flow at the Rio Grande Floodway at San Marcial stream gage

⁴Average flow at the Rio Chama near Chamita stream gage

Notes:

1. All sites were surveyed in US survey feet.
2. All sites were surveyed in Modified State Plane Coordinates, Central Zone.
3. All sites were surveyed in North American Datum 1983, North America Vertical Datum 1988, except Bosque del Apache and San Marcial.
4. Bosque del Apache and San Marcial were surveyed in North American Datum 1927 and North America Vertical Datum 1988.

1.9.2 Limitations of the Aquatic Habitat Model

The Aquatic Habitat Model was formulated to evaluate riverine habitat and does not address impacts within reservoirs. Moreover, the Aquatic Habitat Model is functionally limited to quantitatively evaluating alternative impacts in the areas defined by the study sites only; however, again, these regions were selected to be representative of larger reaches. Viewed in this way, the habitat behavior of the larger reaches can be expected to follow the general trend of the associated study site (*i.e.* a gain or lose aquatic habitat) but direct extrapolation or proportional scaling of study site gains or losses cannot be attempted with the available data. In addition, the model is limited to evaluating habitat within the active channel and cannot address overbank (floodplain) areas.

An additional limitation of the Aquatic Habitat Model concerns the limited availability of calibration flows. Again, the Aquatic Habitat Model ultimately depends upon a measured relationship between species-specific habitat preferences (a bi-variate correlation of both depth *and* velocity) and the physical characteristics and hydraulic behavior of the river at differential flows. The model applies the habitat use preferences to the physical behavior of the river and calculates the two-dimensional extent (in ft.²) of useable habitat for a given input flow, with respect to depth *and* velocity, and tabulates a time series dataset of habitat extent. As such, the hydraulic modeling portion (RMA2, Version 4.35) of the larger Aquatic Habitat Model requires a calibration that measures depth and velocity at a range of flows. Table **XX** below shows the survey dates, average discharge, and number of depth/velocity paired measurements that were taken during field data collection. All RMA2 calibration took place in 2002; a drought of record year. As a result, the high-flow calibration datasets tend to be lower than average flows and therefore limit the ability to fully understand the hydraulic behavior of the river and study sites at higher flows. Thus, confidence in the habitat predictions of the Aquatic Habitat Model should be considered somewhat bounded by the upper limits of the calibration flows shown in **Table XX**, and confidence in any predictions beyond these upper limits is limited. Nonetheless, the Aquatic Habitat Model is generally considered robust as the frequency of exceeding the upper calibration flows are low with respect to the 40-year sequence ($n = 14,610$ = daily average flow of modeled URGWOM hydrology – used as Aquatic Habitat Model input data in alternative evaluation).

Thus, the interpretive limitations of the Aquatic Habitat Model can be summarized as follows:

- 1) Aquatic Habitat Model results and conclusions are valid for riverine habitat only,
- 2) The model only evaluates habitat for the active channel and, by construction, cannot address potential floodplain habitat during overbank events,
- 3) Extrapolation of results to larger river reaches was not attempted and habitat quantification is valid for the study sites only – however, study sites were chosen to be generally representative of larger reaches,
- 4) Lack of high-flow calibration of the RMA2 hydraulic model limits the confidence of subsequent habitat predictions.

All of these inherent limitations should be considered data gaps and subject for refinement and/or improvement when future actions are proposed and further defined. Subsequent to the formulation and use of the Aquatic Habitat Model in this Review and EIS, significant methodological improvements have occurred and should be strongly considered in future analyses.

1.9.3 Selected Results of the Aquatic Habitat Model

The following are selected results of the Aquatic Habitat Model. Included here, is an example of the results derived from the Aquatic Habitat and Hydraulic Model for the Rio Grande at Central Avenue

Bridge (Central) study site for Rio Grande Silvery Minnow (RGSM) adult. Again, for a complete account of all sites, species, and life stages the Aquatic Habitat Model addressed, the *Final Aquatic Habitat and Hydraulic Modeling Study for the Upper Rio Grande Water Operations Model* (Bohannon Houston, Inc., Mussetter Engineering, Inc., and Miller Ecological Consultants, Inc., 2004) should be requested and referenced (also noted in the *Background* Section above). This report, and additional Aquatic Habitat Model documentation and data, are available by request from the JLAs.

Topographic survey data was used to produce one-foot contour maps of all study sites (Central is shown in **Figure 1-2** below). These data were used, in combination with the paired depth/velocity measurements, RMA2 hydraulic modeling, and species-specific habitat use data to ultimately derive a two-dimensional, spatially explicit GIS surface that quantifies the weighted aquatic habitat (in terms of suitability) with respect to calibration flows. This GIS based habitat-flow polynomial relationship (**Figure 1-3**) is then used to calculate a time-series dataset of habitat values for the flows output from the 40-year URGWOM planning sequence for all alternatives (**Figure 1-4**).



Figure K-1.2 One-Foot Contour Map of the Central Study Site

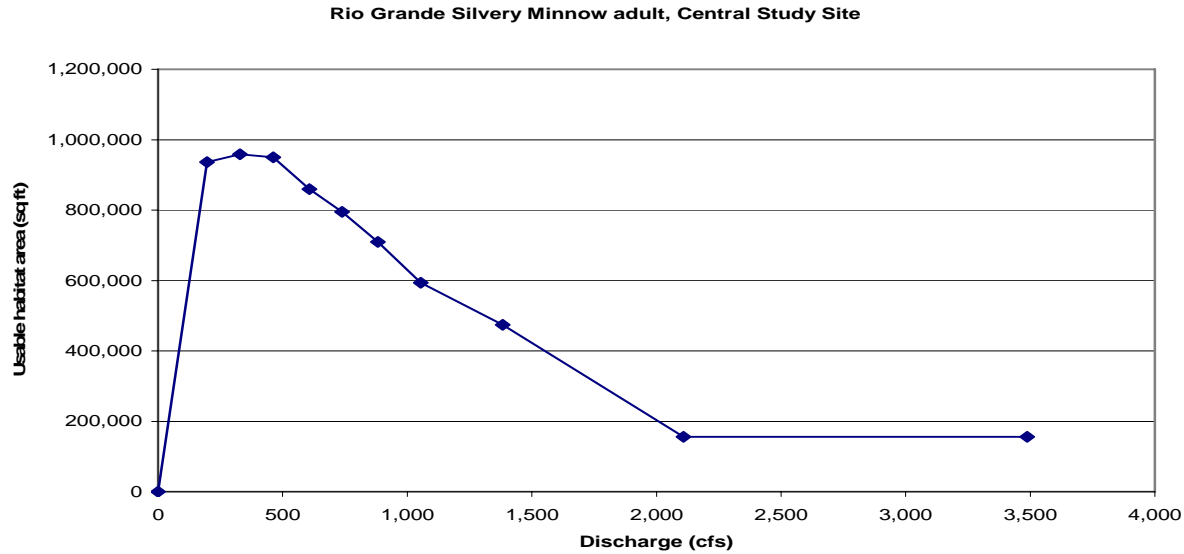


Figure K-1.3 Habitat-Flow Relationship of the RGSM at Central Study Site

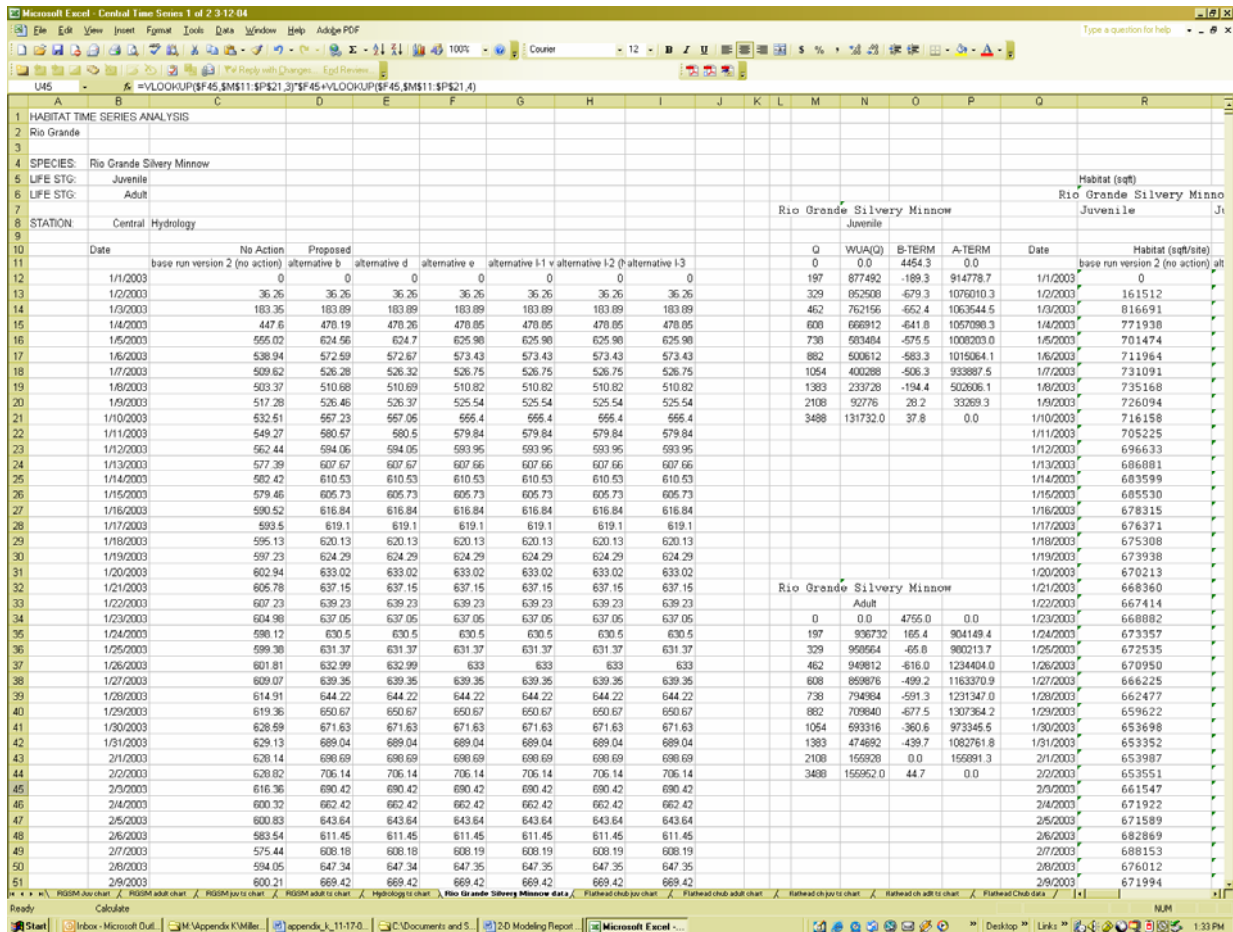


Figure K-1.4 Habitat Time-Series Analysis – Central Study Site, RGSM

1.9.4 Tabulated Results of all Study Sites, Species, and Life Stages

The following are tabulated results for the time-series analyses for all sites, species, and life stages. Modeling analyses did not have sufficient habitat use criteria for River Carpsucker, adult. Values indicate the mean habitat (ft.²) for the 40-year planning sequence, difference from No Action alternative, and percent change from No Action alternative. Note negative values indicate a loss of habitat.

1.9.4.1 Rio Grande at Pena Blanca Study Site

Rio Grande Silvery Minnow

Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	233,325.1	221,988.8	225,209.2	224,177.6	231,941.7	226,197.1	224,364.7
Difference Gained or Lost from No Action (ft ²)	0.0	-11,336.2	-8,115.9	-9,147.5	-1,383.3	-7,127.9	-8,960.3
Percent Change from No Action (%)	0.0	-4.9	-3.5	-3.9	-0.6	-3.1	-3.8

Rio Grande Silvery Minnow

Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	306,259.1	292,993.1	296,894.6	295,631.9	304,691.4	297,996.7	295,779.7
Difference Gained or Lost from No Action (ft ²)	0.0	-13,266.0	-9,364.6	-10,627.2	-1,567.8	-8,262.4	-10,479.5
Percent Change from No Action (%)	0.0	-4.3	-3.1	-3.5	-0.5	-2.7	-3.4

Flathead Chub
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	90,763.1	85,555.3	86,869.9	86,469.3	90,153.9	87,661.3	86,606.3
Difference Gained or Lost from No Action (ft²)	0.0	-5,207.8	-3,893.2	-4,293.8	-609.2	-3,101.7	-4,156.8
Percent Change from No Action (%)	0.0	-5.7	-4.3	-4.7	-0.7	-3.4	-4.6

Flathead Chub
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	192,563.8	185,508.0	187,544.9	186,940.3	192,276.9	189,442.0	186,981.4
Difference Gained or Lost from No Action (ft²)	0.0	-7,055.8	-5,018.8	-5,623.5	-286.8	-3,121.8	-5,582.4
Percent Change from No Action (%)	0.0	-3.7	-2.6	-2.9	-0.1	-1.6	-2.9

Longnose Dace
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	56,880.3	53,840.2	54,604.5	54,377.3	56,737.1	55,394.1	54,434.9
Difference Gained or Lost from No Action (ft²)	0.0	-3,040.0	-2,275.8	-2,503.0	-143.2	-1,486.2	-2,445.4
Percent Change from No Action (%)	0.0	-5.3	-4.0	-4.4	-0.3	-2.6	-4.3

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	280,455.4	275,509.2	277,493.5	276,815.5	280,582.1	278,659.4	276,591.2
Difference Gained or Lost from No Action (ft ²)	0.0	-4,946.1	-2,961.9	-3,639.9	126.7	-1,795.9	-3,864.2
Percent Change from No Action (%)	0.0	-1.8	-1.1	-1.3	0.0	-0.6	-1.4

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	82,107.2	78,075.6	79,047.8	78,738.5	81,523.4	79,564.3	78,859.6
Difference Gained or Lost from No Action (ft ²)	0.0	-4,031.5	-3,059.4	-3,368.7	-583.8	-2,542.9	-3,247.5
Percent Change from No Action (%)	0.0	-4.9	-3.7	-4.1	-0.7	-3.1	-4.0

Channel Catfish
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	172,970.0	164,288.6	166,610.6	165,894.0	171,797.7	167,452.8	166,085.7
Difference Gained or Lost from No Action (ft ²)	0.0	-8,681.4	-6,359.4	-7,076.0	-1,172.3	-5,517.2	-6,884.3
Percent Change from No Action (%)	0.0	-5.0	-3.7	-4.1	-0.7	-3.2	-4.0

Channel Catfish
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	634,215.1	617,946.2	622,977.6	621,286.2	633,202.1	625,577.7	621,153.2
Difference Gained or Lost from No Action (ft²)	0.0	-16,268.9	-11,237.5	-12,928.9	-1,013.0	-8,637.4	-13,061.9
Percent Change from No Action (%)	0.0	-2.6	-1.8	-2.0	-0.2	-1.4	-2.1

Rio Grande at Bernalillo Study Site –

Rio Grande Silvery Minnow
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	96,469.1	100,733.2	99,594.0	99,744.3	95,998.5	97,464.3	99,754.9
Difference Gained or Lost from No Action (ft²)	0.0	4,264.1	3,124.9	3,275.2	-470.6	995.3	3,285.8
Percent Change from No Action (%)	0.0	4.4	3.2	3.4	-0.5	1.0	3.4

Rio Grande Silvery Minnow
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	127,887.4	130,374.4	129,905.7	129,823.0	127,033.4	127,774.5	129,884.0
Difference Gained or Lost from No Action (ft²)	0.0	2,487.0	2,018.3	1,935.6	-854.0	-112.9	1,996.6
Percent Change from No Action (%)	0.0	1.9	1.6	1.5	-0.7	-0.1	1.6

Flathead Chub
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	46,101.0	52,859.0	50,844.4	51,337.7	46,168.0	48,916.7	51,232.0
Difference Gained or Lost from No Action (ft²)	0.0	6,758.0	4,743.5	5,236.7	67.0	2,815.7	5,131.0
Percent Change from No Action (%)	0.0	14.7	10.3	11.4	0.1	6.1	11.1

Flathead Chub
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	77,368.4	80,729.8	79,955.0	80,083.0	77,226.4	78,945.7	79,991.0
Difference Gained or Lost from No Action (ft²)	0.0	3,361.4	2,586.6	2,714.6	-142.0	1,577.3	2,622.6
Percent Change from No Action (%)	0.0	4.3	3.3	3.5	-0.2	2.0	3.4

Longnose Dace
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	28,206.6	30,853.2	29,851.0	30,074.3	28,193.0	28,619.2	30,026.3
Difference Gained or Lost from No Action (ft²)	0.0	2,646.6	1,644.4	1,867.7	-13.6	412.6	1,819.7
Percent Change from No Action (%)	0.0	9.4	5.8	6.6	0.0	1.5	6.5

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	99,377.3	95,442.1	96,838.9	96,316.0	98,685.1	96,880.2	96,334.3
Difference Gained or Lost from No Action (ft²)	0.0	-3,935.2	-2,538.4	-3,061.2	-692.2	-2,497.1	-3,043.0
Percent Change from No Action (%)	0.0	-4.0	-2.6	-3.1	-0.7	-2.5	-3.1

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	41,947.5	47,617.1	45,984.6	46,386.4	41,990.4	44,440.9	46,296.3
Difference Gained or Lost from No Action (ft²)	0.0	5,669.6	4,037.0	4,438.8	42.9	2,493.3	4,348.8
Percent Change from No Action (%)	0.0	13.5	9.6	10.6	0.1	5.9	10.4

Channel Catfish

Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	72,554.6	76,284.9	74,873.5	75,100.5	72,199.8	72,370.7	75,118.8
Difference Gained or Lost from No Action (ft²)	0.0	3,730.3	2,318.9	2,546.0	-354.7	-183.8	2,564.2
Percent Change from No Action (%)	0.0	5.1	3.2	3.5	-0.5	-0.3	3.5

Channel Catfish

Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	254,589.8	251,668.7	252,806.9	252,182.6	253,310.6	251,221.8	252,111.5
Difference Gained or Lost from No Action (ft²)	0.0	-2,921.1	-1,782.9	-2,407.1	-1,279.2	-3,367.9	-2,478.3
Percent Change from No Action (%)	0.0	-1.1	-0.7	-0.9	-0.5	-1.3	-1.0

1.9.4.2 Rio Grande at Central Avenue Bridge Study Site

Rio Grande Silvery Minnow
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	527,121.1	506,084.9	513,585.9	510,543.2	523,396.0	514,096.8	510,322.1
Difference Gained or Lost from No Action (ft ²)	0.0	-21,036.2	-13,535.2	-16,577.8	-3,725.0	-13,024.3	-16,799.0
Percent Change from No Action (%)	0.0	-4.0	-2.6	-3.1	-0.7	-2.5	-3.2

Rio Grande Silvery Minnow
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	670,380.1	648,777.2	657,102.5	653,871.0	666,727.1	658,818.9	653,253.3
Difference Gained or Lost from No Action (ft ²)	0.0	-21,602.9	-13,277.7	-16,509.1	-3,653.1	-11,561.2	-17,126.8
Percent Change from No Action (%)	0.0	-3.2	-2.0	-2.5	-0.5	-1.7	-2.6

Flathead Chub
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	264,950.4	254,667.9	258,566.7	256,777.1	262,462.6	257,984.3	256,937.4
Difference Gained or Lost from No Action (ft²)	0.0	-10,282.5	-6,383.7	-8,173.3	-2,487.8	-6,966.1	-8,013.0
Percent Change from No Action (%)	0.0	-3.9	-2.4	-3.1	-0.9	-2.6	-3.0

Flathead Chub
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	284,589.4	274,061.5	278,013.8	276,330.2	281,798.9	277,247.4	276,352.8
Difference Gained or Lost from No Action (ft²)	0.0	-10,527.8	-6,575.5	-8,259.2	-2,790.5	-7,341.9	-8,236.6
Percent Change from No Action (%)	0.0	-3.7	-2.3	-2.9	-1.0	-2.6	-2.9

Longnose Dace
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	104,723.9	101,743.3	102,797.1	102,152.9	104,270.0	102,841.4	102,264.7
Difference Gained or Lost from No Action (ft²)	0.0	-2,980.6	-1,926.8	-2,571.0	-453.9	-1,882.5	-2,459.2
Percent Change from No Action (%)	0.0	-2.8	-1.8	-2.5	-0.4	-1.8	-2.3

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	163,690.9	157,248.6	159,238.1	158,642.2	163,550.3	160,297.3	158,275.9
Difference Gained or Lost from No Action (ft²)	0.0	-6,442.2	-4,452.8	-5,048.6	-140.5	-3,393.6	-5,415.0
Percent Change from No Action (%)	0.0	-3.9	-2.7	-3.1	-0.1	-2.1	-3.3

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	235,795.9	227,824.7	230,864.9	229,440.7	233,635.9	230,432.9	229,528.6
Difference Gained or Lost from No Action (ft²)	0.0	-7,971.3	-4,931.1	-6,355.2	-2,160.1	-5,363.1	-6,267.3
Percent Change from No Action (%)	0.0	-3.4	-2.1	-2.7	-0.9	-2.3	-2.7

Channel Catfish
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	478,576.2	461,388.5	468,245.9	465,336.4	474,254.1	467,453.6	465,303.7
Difference Gained or Lost from No Action (ft²)	0.0	-17,187.7	-10,330.3	-13,239.8	-4,322.1	-11,122.6	-13,272.4
Percent Change from No Action (%)	0.0	-3.6	-2.2	-2.8	-0.9	-2.3	-2.8

Channel Catfish
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	998,606.4	998,028.5	999,024.7	997,795.3	997,850.5	998,947.6	996,200.1
Difference Gained or Lost from No Action (ft²)	0.0	-577.9	418.3	-811.1	-755.8	341.2	-2,406.3
Percent Change from No Action (%)	0.0	-0.1	0.0	-0.1	-0.1	0.0	-0.2

1.9.4.3 Rio Grande Downstream of US 60 Bridge near Bernardo Study Site

Rio Grande Silvery Minnow

Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	342,267.0	338,800.6	337,577.7	338,477.7	338,847.1	335,048.7	337,494.5
Difference Gained or Lost from No Action (ft²)	0.0	-3,466.3	-4,689.3	-3,789.2	-3,419.9	-7,218.2	-4,772.5
Percent Change from No Action (%)	0.0	-1.0	-1.4	-1.1	-1.0	-2.1	-1.4

Rio Grande Silvery Minnow

Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	144,349.2	160,600.4	153,510.3	155,814.8	146,241.1	151,764.2	155,357.3
Difference Gained or Lost from No Action (ft²)	0.0	16,251.2	9,161.0	11,465.6	1,891.9	7,414.9	11,008.1
Percent Change from No Action (%)	0.0	11.3	6.3	7.9	1.3	5.1	7.6

Flathead Chub
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	127,044.2	130,717.6	128,700.6	129,502.0	126,030.1	127,097.5	129,130.9
Difference Gained or Lost from No Action (ft²)	0.0	3,673.5	1,656.4	2,457.8	-1,014.1	53.3	2,086.8
Percent Change from No Action (%)	0.0	2.9	1.3	1.9	-0.8	0.0	1.6

Flathead Chub
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	698,816.9	709,889.3	701,192.0	704,471.3	698,889.9	701,793.4	702,285.1
Difference Gained or Lost from No Action (ft²)	0.0	11,072.4	2,375.1	5,654.4	73.0	2,976.5	3,468.2
Percent Change from No Action (%)	0.0	1.6	0.3	0.8	0.0	0.4	0.5

Longnose Dace
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	55,186.3	56,810.0	55,799.4	56,185.4	55,182.6	55,673.7	55,989.4
Difference Gained or Lost from No Action (ft²)	0.0	1,623.6	613.1	999.1	-3.7	487.3	803.1
Percent Change from No Action (%)	0.0	2.9	1.1	1.8	0.0	0.9	1.5

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	300,525.6	293,367.0	292,871.0	293,284.4	299,985.7	295,225.2	292,370.2
Difference Gained or Lost from No Action (ft²)	0.0	-7,158.6	-7,654.6	-7,241.2	-539.9	-5,300.3	-8,155.4
Percent Change from No Action (%)	0.0	-2.4	-2.5	-2.4	-0.2	-1.8	-2.7

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	322,772.1	322,532.1	320,735.1	321,738.9	319,833.7	318,255.7	320,811.3
Difference Gained or Lost from No Action (ft²)	0.0	-240.0	-2,037.0	-1,033.2	-2,938.4	-4,516.4	-1,960.8
Percent Change from No Action (%)	0.0	-0.1	-0.6	-0.3	-0.9	-1.4	-0.6

Channel Catfish
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	250,963.8	251,727.5	249,951.2	250,855.3	248,330.7	247,379.9	250,166.1
Difference Gained or Lost from No Action (ft²)	0.0	763.7	-1,012.6	-108.4	-2,633.1	-3,583.9	-797.7
Percent Change from No Action (%)	0.0	0.3	-0.4	0.0	-1.0	-1.4	-0.3

Channel Catfish
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	721,625.5	735,096.0	725,688.2	729,208.8	721,873.2	725,417.0	727,069.5
Difference Gained or Lost from No Action (ft²)	0.0	13,470.5	4,062.7	7,583.4	247.8	3,791.5	5,444.1
Percent Change from No Action (%)	0.0	1.9	0.6	1.1	0.0	0.5	0.8

1.9.4.4 Rio Grande just Downstream of North Boundary of Bosque del Apache National Wildlife Refuge Study Site

**Rio Grande Silvery Minnow
Juvenile**

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	364,526.9	250,278.5	251,144.1	251,578.9	307,365.2	275,018.8	250,954.1
Difference Gained or Lost from No Action (ft²)	0.0	-114,248.5	-113,382.8	-112,948.1	-57,161.8	-89,508.2	-113,572.9
Percent Change from No Action (%)	0.0	-31.3	-31.1	-31.0	-15.7	-24.6	-31.2

**Rio Grande Silvery Minnow
Adult**

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	440,221.9	304,595.3	305,494.5	306,051.9	375,386.1	335,219.0	305,267.4
Difference Gained or Lost from No Action (ft²)	0.0	-135,626.6	-134,727.5	-134,170.0	-64,835.8	-105,002.9	-134,954.5
Percent Change from No Action (%)	0.0	-30.8	-30.6	-30.5	-14.7	-23.9	-30.7

Flathead Chub

Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	233,007.3	139,822.4	140,633.6	140,887.4	186,722.2	159,373.0	140,580.0
Difference Gained or Lost from No Action (ft²)	0.0	-93,184.8	-92,373.7	-92,119.9	-46,285.1	-73,634.2	-92,427.3
Percent Change from No Action (%)	0.0	-40.0	-39.6	-39.5	-19.9	-31.6	-39.7

Flathead Chub

Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	286,909.2	154,882.0	156,158.1	156,356.2	224,680.3	184,047.1	156,049.9
Difference Gained or Lost from No Action (ft²)	0.0	-132,027.1	-130,751.0	-130,553.0	-62,228.8	-102,862.1	-130,859.2
Percent Change from No Action (%)	0.0	-46.0	-45.6	-45.5	-21.7	-35.9	-45.6

Longnose Dace

Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	101,067.7	40,355.4	40,857.5	40,990.7	73,637.4	53,168.2	40,937.0
Difference Gained or Lost from No Action (ft²)	0.0	-60,712.4	-60,210.2	-60,077.0	-27,430.4	-47,899.5	-60,130.7
Percent Change from No Action (%)	0.0	-60.1	-59.6	-59.4	-27.1	-47.4	-59.5

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	200,863.7	85,096.6	86,603.4	86,488.1	146,689.2	112,477.7	86,327.9
Difference Gained or Lost from No Action (ft²)	0.0	-115,767.0	-114,260.3	-114,375.6	-54,174.4	-88,386.0	-114,535.7
Percent Change from No Action (%)	0.0	-57.6	-56.9	-56.9	-27.0	-44.0	-57.0

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	216,021.8	133,155.8	133,727.0	134,024.5	176,482.5	150,557.4	133,725.6
Difference Gained or Lost from No Action (ft²)	0.0	-82,866.0	-82,294.7	-81,997.3	-39,539.3	-65,464.4	-82,296.2
Percent Change from No Action (%)	0.0	-38.4	-38.1	-38.0	-18.3	-30.3	-38.1

Channel Catfish
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	323,608.9	231,388.2	231,923.9	232,388.3	278,043.3	251,103.4	231,799.4
Difference Gained or Lost from No Action (ft²)	0.0	-92,220.8	-91,685.0	-91,220.6	-45,565.6	-72,505.6	-91,809.5
Percent Change from No Action (%)	0.0	-28.5	-28.3	-28.2	-14.1	-22.4	-28.4

Channel Catfish
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	672,004.2	364,374.5	367,511.1	367,835.2	531,637.3	436,265.2	367,008.2
Difference Gained or Lost from No Action (ft²)	0.0	-307,629.8	-304,493.2	-304,169.0	-140,366.9	-235,739.0	-304,996.0
Percent Change from No Action (%)	0.0	-45.8	-45.3	-45.3	-20.9	-35.1	-45.4

1.9.4.5 Rio Grande Below the San Marcial Railroad Bridge Study Site

Rio Grande Silvery Minnow

Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	86,507.9	109,878.5	108,372.1	108,974.2	99,399.4	102,121.9	108,614.1
Difference Gained or Lost from No Action (ft²)	0.0	23,370.6	21,864.2	22,466.3	12,891.5	15,614.0	22,106.2
Percent Change from No Action (%)	0.0	27.0	25.3	26.0	14.9	18.0	25.6

Rio Grande Silvery Minnow

Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	120,951.6	148,541.5	146,257.5	147,153.8	135,048.0	137,932.9	146,627.3
Difference Gained or Lost from No Action (ft²)	0.0	27,589.9	25,305.9	26,202.2	14,096.4	16,981.3	25,675.7
Percent Change from No Action (%)	0.0	22.8	20.9	21.7	11.7	14.0	21.2

Flathead Chub
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	46,877.3	59,155.6	58,421.7	58,724.7	53,249.6	54,918.0	58,533.9
Difference Gained or Lost from No Action (ft²)	0.0	12,278.3	11,544.4	11,847.4	6,372.3	8,040.7	11,656.6
Percent Change from No Action (%)	0.0	26.2	24.6	25.3	13.6	17.2	24.9

Flathead Chub
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	68,259.3	76,691.3	75,423.5	75,919.7	73,679.9	72,004.3	75,657.9
Difference Gained or Lost from No Action (ft²)	0.0	8,432.0	7,164.3	7,660.4	5,420.6	3,745.1	7,398.7
Percent Change from No Action (%)	0.0	12.4	10.5	11.2	7.9	5.5	10.8

Longnose Dace
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	14,645.7	17,055.1	16,593.7	16,736.2	16,708.0	15,052.3	16,670.6
Difference Gained or Lost from No Action (ft²)	0.0	2,409.4	1,947.9	2,090.5	2,062.3	406.5	2,024.8
Percent Change from No Action (%)	0.0	16.5	13.3	14.3	14.1	2.8	13.8

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	43,410.3	32,191.5	30,997.1	31,445.1	40,112.1	31,294.8	31,322.9
Difference Gained or Lost from No Action (ft²)	0.0	-11,218.8	-12,413.2	-11,965.2	-3,298.2	-12,115.5	-12,087.4
Percent Change from No Action (%)	0.0	-25.8	-28.6	-27.6	-7.6	-27.9	-27.8

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	52,760.5	68,014.6	67,306.4	67,608.9	59,893.4	63,449.3	67,376.7
Difference Gained or Lost from No Action (ft²)	0.0	15,254.1	14,545.9	14,848.4	7,132.8	10,688.8	14,616.2
Percent Change from No Action (%)	0.0	28.9	27.6	28.1	13.5	20.3	27.7

Channel Catfish
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	93,906.3	123,037.5	121,412.5	122,054.5	107,473.8	113,264.9	121,627.6
Difference Gained or Lost from No Action (ft²)	0.0	29,131.2	27,506.2	28,148.2	13,567.5	19,358.6	27,721.3
Percent Change from No Action (%)	0.0	31.0	29.3	30.0	14.4	20.6	29.5

Channel Catfish
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	280,477.5	242,802.0	238,269.6	240,243.5	261,909.3	237,799.8	239,292.1
Difference Gained or Lost from No Action (ft²)	0.0	-37,675.4	-42,207.8	-40,233.9	-18,568.2	-42,677.7	-41,185.4
Percent Change from No Action (%)	0.0	-13.4	-15.0	-14.3	-6.6	-15.2	-14.7

1.9.4.6 Rio Chama Downstream of Abiquiu Dam –

Brown Trout
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	328,748.7	325,101.8	327,012.4	326,051.5	331,059.4	329,050.7	325,808.2
Difference Gained or Lost from No Action (ft ²)	0.0	-3,646.9	-1,736.4	-2,697.2	2,310.7	302.0	-2,940.5
Percent Change from No Action (%)	0.0	-1.1	-0.5	-0.8	0.7	0.1	-0.9

Brown Trout
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	264,620.4	261,850.6	262,981.8	262,276.1	266,358.5	264,949.6	262,002.2
Difference Gained or Lost from No Action (ft ²)	0.0	-2,769.8	-1,638.6	-2,344.3	1,738.2	329.2	-2,618.2
Percent Change from No Action (%)	0.0	-1.0	-0.6	-0.9	0.7	0.1	-1.0

Flathead Chub
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	26,639.9	27,271.4	28,136.3	27,928.0	27,176.3	27,568.0	28,022.7
Difference Gained or Lost from No Action (ft²)	0.0	631.5	1,496.3	1,288.1	536.4	928.0	1,382.7
Percent Change from No Action (%)	0.0	2.4	5.6	4.8	2.0	3.5	5.1

Flathead Chub
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	59,929.6	60,250.5	62,314.2	61,776.6	60,762.1	61,817.3	61,885.3
Difference Gained or Lost from No Action (ft²)	0.0	320.9	2,384.6	1,847.0	832.5	1,887.7	1,955.7
Percent Change from No Action (%)	0.0	0.5	4.0	3.1	1.4	3.1	3.2

Longnose Dace
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	13,944.8	14,329.9	14,863.4	14,742.5	14,237.6	14,541.9	14,808.1
Difference Gained or Lost from No Action (ft²)	0.0	385.2	918.6	797.8	292.8	597.2	863.3
Percent Change from No Action (%)	0.0	2.8	6.6	5.7	2.1	4.3	6.2

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	100,795.8	101,936.6	105,672.1	104,780.9	102,347.7	104,981.4	104,854.3
Difference Gained or Lost from No Action (ft²)	0.0	1,140.9	4,876.4	3,985.2	1,551.9	4,185.7	4,058.5
Percent Change from No Action (%)	0.0	1.1	4.8	4.0	1.5	4.2	4.0

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	32,906.4	32,611.7	32,600.5	32,550.9	33,281.4	32,250.5	32,576.0
Difference Gained or Lost from No Action (ft²)	0.0	-294.7	-305.9	-355.5	375.0	-655.9	-330.4
Percent Change from No Action (%)	0.0	-0.9	-0.9	-1.1	1.1	-2.0	-1.0

Channel Catfish
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	65,643.1	65,588.3	68,015.0	67,464.3	65,952.0	67,286.9	67,572.8
Difference Gained or Lost from No Action (ft²)	0.0	-54.8	2,371.9	1,821.2	309.0	1,643.9	1,929.7
Percent Change from No Action (%)	0.0	-0.1	3.6	2.8	0.5	2.5	2.9

Channel Catfish
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	186,239.6	186,800.4	192,444.9	191,011.1	188,172.7	191,940.5	191,084.0
Difference Gained or Lost from No Action (ft²)	0.0	560.8	6,205.3	4,771.4	1,933.0	5,700.8	4,844.4
Percent Change from No Action (%)	0.0	0.3	3.3	2.6	1.0	3.1	2.6

1.9.4.7 Rio Chama Upstream of New Highway 285 Bridge

Rio Grande Silvery Minnow

Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	44,592.8	41,176.4	43,113.2	42,715.3	43,294.2	42,758.1	42,838.8
Difference Gained or Lost from No Action (ft ²)	0.0	-3,416.3	-1,479.6	-1,877.5	-1,298.6	-1,834.7	-1,753.9
Percent Change from No Action (%)	0.0	-7.7	-3.3	-4.2	-2.9	-4.1	-3.9

Rio Grande Silvery Minnow

Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft ²)	65,460.3	60,865.0	63,295.4	62,865.3	63,750.1	62,692.5	62,978.4
Difference Gained or Lost from No Action (ft ²)	0.0	-4,595.3	-2,164.9	-2,595.0	-1,710.2	-2,767.8	-2,481.9
Percent Change from No Action (%)	0.0	-7.0	-3.3	-4.0	-2.6	-4.2	-3.8

Flathead Chub
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	18,573.2	17,540.5	18,283.9	18,048.3	18,148.7	17,979.7	18,158.8
Difference Gained or Lost from No Action (ft²)	0.0	-1,032.7	-289.2	-524.8	-424.4	-593.5	-414.4
Percent Change from No Action (%)	0.0	-5.6	-1.6	-2.8	-2.3	-3.2	-2.2

Flathead Chub
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	53,494.1	51,023.4	52,567.6	52,180.8	52,778.9	51,962.9	52,284.8
Difference Gained or Lost from No Action (ft²)	0.0	-2,470.8	-926.6	-1,313.3	-715.2	-1,531.2	-1,209.4
Percent Change from No Action (%)	0.0	-4.6	-1.7	-2.5	-1.3	-2.9	-2.3

Longnose Dace
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	12,240.2	11,770.5	12,090.0	11,971.3	12,135.7	11,956.2	12,009.5
Difference Gained or Lost from No Action (ft²)	0.0	-469.6	-150.2	-268.8	-104.4	-284.0	-230.6
Percent Change from No Action (%)	0.0	-3.8	-1.2	-2.2	-0.9	-2.3	-1.9

Longnose Dace
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	88,080.1	84,548.0	86,510.8	86,080.6	87,566.9	86,065.7	86,067.3
Difference Gained or Lost from No Action (ft²)	0.0	-3,532.1	-1,569.3	-1,999.5	-513.2	-2,014.4	-2,012.8
Percent Change from No Action (%)	0.0	-4.0	-1.8	-2.3	-0.6	-2.3	-2.3

River Carpsucker
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	14,092.2	13,506.0	13,971.5	13,817.7	13,807.7	13,659.5	13,909.5
Difference Gained or Lost from No Action (ft²)	0.0	-586.2	-120.7	-274.5	-284.5	-432.7	-182.7
Percent Change from No Action (%)	0.0	-4.2	-0.9	-1.9	-2.0	-3.1	-1.3

Channel Catfish
Juvenile

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	33,962.2	31,906.3	33,130.3	32,865.5	33,021.1	32,780.8	32,987.4
Difference Gained or Lost from No Action (ft²)	0.0	-2,055.9	-831.9	-1,096.7	-941.1	-1,181.4	-974.9
Percent Change from No Action (%)	0.0	-6.1	-2.4	-3.2	-2.8	-3.5	-2.9

Channel Catfish
Adult

	<i>No Action</i>	<i>Alternative B-3</i>	<i>Alternative D-3</i>	<i>Alternative E-3</i>	<i>Alternative I-1</i>	<i>Alternative I-2</i>	<i>Alternative I-3</i>
Mean Habitat (ft²)	164,817.6	160,909.3	161,755.2	161,607.8	164,468.5	160,199.3	161,644.8
Difference Gained or Lost from No Action (ft²)	0.0	-3,908.3	-3,062.4	-3,209.8	-349.1	-4,618.3	-3,172.8
Percent Change from No Action (%)	0.0	-2.4	-1.9	-1.9	-0.2	-2.8	-1.9

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