United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna Road NE
Albuquerque, New Mexico 87113
Phone: (505) 346-2525 Fax: (505) 346-2542

JAN -3 2012

Cons. No. 02ENNM00-2012-F-0005

Edward Paulsgrove, Regulatory Project Manager
Albuquerque District, Regulatory Division
U.S. Army Corps of Engineers
4101 Jefferson Plaza NE
Albuquerque, New Mexico 87109

Dear Mr. Paulsgrove:

This letter transmits the U.S. Fish and Wildlife Service's (Service) final biological opinion (BO) on the effects of the proposed action (Embayment Project) on the endangered Rio Grande silvery minnow, *Hybognathus amarus* (silvery minnow), and the endangered southwestern willow flycatcher, *Empidonax traillii extimus* (flycatcher). The U.S. Army Corps of Engineers, Albuquerque District (Corps), is evaluating the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) permit application (Action Number SPA-2010-00435-ABQ; Corps 2011) to discharge fill material, widen, regrade, and stabilize the westernmost portion of the North Diversion Channel from its outfall with the Rio Grande to the equipment crossing (Embayment Project; Figure 1). On November 9, 2011, the Corps provided AMAFCA's Biological Assessment (BA) (SWCA Environmental Consultants 2011) to the Service that evaluated the potential effects of the proposed Embayment Project action to species federally-listed under the Endangered Species Act of 1973 as amended (ESA; 16 U.S.C. 1531 et seq.).

The BA describes the proposed Embayment Project as having no effect on the designated critical habitat of the silvery minnow or the designated critical habitat flycatcher as these habitats were considered outside of the action area (SWCA Environmental Consultants 2011). This BO is based on information submitted in the public notice, the BA, and conversations and communications between the Corps, AMAFCA, the Pueblo of Sandia, and the Service; and other sources of information available to the Service. A complete administrative record of this consultation is on file at the Service's New Mexico Ecological Services Field Office at the above address.

During the proposed Embayment Project activities, we expect that there will be adverse effects to all silvery minnows that will be trapped in the Embayment during installation of the silt fences and coffer dams and that they will be stressed and some will die after being confined during the dewatering, and by water quality degradation as it is affected by construction and other activities. During discussions between AMAFCA, the Corps, the Pueblo of Sandia, and the Service, measures that employ the Service's New Mexico Fish and Wildlife Conservation Office rescue operations were recommended and are included in the proposed action to reduce the mortality of silvery minnows affected by Embayment Project dewatering and construction activities.

With reduction of mortalities of silvery minnows and the short duration of the Embayment Project, it is the Service's opinion that issuance by the Corps of a individual permit authorization (SPA-2010-00435-ABQ) under Section 404 of the Clean Water Act (33 U.S.C. 1251 *et seq.*) is not likely to jeopardize the continued existence of the endangered silvery minnow. Working with the Corps and AMAFCA, we have identified conservation measures that have been incorporated into the Embayment Project (BA, pages 1, and 26-28), and we have provided reasonable, and prudent measures as well as terms and conditions necessary to minimize the incidental take of silvery minnows associated with the proposed project action.

Southwestern Willow Flycatcher

The Corps has determined the proposed project "may affect, but is not likely to adversely affect," the flycatcher. We concur with this determination based on the rationale below.

The flycatcher is a migrant through the Middle Rio Grande, and may be present from April through August (Sogge et al. 2010). No flycatcher breeding habitat or occupied nest territories are known to exist along the mainstem of the Rio Grande near the outfall of the North Diversion Channel (Walker, H., New Mexico Department of Game and Fish, "Review of 2011 willow flycatcher survey and detection forms," email communication to D. Hill, dated October 28, 2011). Surveys for flycatchers have been conducted by the Pueblo of Sandia nearby. A limited number of migrating flycatchers have been detected, but no breeding pairs were detected (Service 2009b, 2010c). All proposed Embayment Project activities are scheduled to take place during January through April outside the flycatcher-nesting season (BA). Maintenance mowing of the vegetation along the Embayment is scheduled to occur biannually during September through February (BA); outside the flycatcher-nesting season. Suitable breeding habitat for flycatchers is not present. Marginal flycatcher habitat is present in the wetland and riparian vegetation on the southeast corner of the Embayment, but it is limited in depth and height and is frequently disturbed by humans. The Embayment Project does not occur in designated critical habitat. Thus, any effects to flycatchers are considered to be insignificant or discountable.

The remainder of this BO addresses the effects of the proposed action on silvery minnow.

BIOLOGICAL OPINION

I. DESCRIPTION OF THE PROPOSED ACTION

Precipitation falls onto the mountains and mesas, and areas east and south of the City of Albuquerque, and the runoff is collected by stormwater sewer systems and conveyed to the Rio Grande. The North Diversion Channel drains the largest basin in the stormwater sewer system, and is approximately 238 square kilometers (km^2) (92 square miles [mi^2]). The basin extends on the east side of the City, from the Pueblo of Sandia on the north, to Gibson Boulevard on the south, and from Interstate 25 on the west to the Sandia Mountain foothills on the east (SWCA 2004). The North Diversion Channel is lined with concrete in a trapezoidal shape, except for the Settling Basin and the Embayment where it is wide, unlined, earthen channel containing open water and a combination of upland, riparian, and wetland vegetation (SWCA 2004) (Figure 1). At the end of the North Diversion Channel is the Embayment (i.e., area between an earthen retaining feature called the Equipment Crossing and the Rio Grande to the west) (Figure 1).

The Corps is evaluating AMAFCA's permit application (Corps 2011) to discharge fill material (used to construct the coffer dams), and activities to widen, regrade, and stabilize the Embayment of the North Diversion Channel from its outfall with the Rio Grande to the equipment crossing (BA, Figure 1). All proposed Embayment Project construction activities are scheduled to take place during January through March, 2012 (BA, p.1). Currently, the Embayment maintains a perennial pool approximately 1,400 ft (423 m) long, with an average channel width of 140 ft (43 m) and depths extending down to 5 ft (1.5 m), and wetlands, which is approximately 4.67 acres (18,899 square meters (m^2)). The Embayment has an uneven, undulating channel bottom that seasonally impounds water that can become hypoxic (i.e., less 100 percent saturated with oxygen) and even anoxic (i.e., less than 2 milligrams per liter (mg/L)) due to poor circulation as well as high concentrations of oxygen demanding substances (Kelly and Romero 2003; Kelly et al.. 2006; Buhl 2005; DBS&A 2009; Service 2011c). A shallow sand bar has also developed at its outfall that also impedes return flow and circulation with the Rio Grande. Low DO concentrations have been associated with the Embayment water and are more severe during warm months (Service 2011c). Short duration, low DO concentrations have also been documented in the Rio Grande immediately downstream of the Embayment after stormwater pushes hypoxic Embayment water into the river (Van Horn 2008; DBS&A 2009; Service 2011c). The proposed Embayment Project is designed to smooth the channel bottom (i.e., regrade) to increase the hydraulic efficiency of the stormwater runoff to the Rio Grande, and allow greater circulation with the Rio Grande, as well as the atmosphere, in order to reduce the volume of low oxygen water that occurs there. In addition, the new design incorporates a shallow backwater habitat that may provide improved habitat conditions for fish and wildlife.

After construction, the Embayment would remain approximately 1,400 ft (423 m) in length, but have an approximate width of 260 ft (79 m), and a surface area (with wetlands) of approximately 8.5 acres (34,398 m^2), with maximum design depths ranging from 1 to 3 ft (0.3 to 0.9 m). According to the permit application (Corps 2011), a total of 30,980 cubic yards (23,686 cubic meters (m^3)) of earthwork will be conducted; including cut and fill activities, using traditional heavy equipment (e.g., loaders, backhoes, tractors, trucks) during the Embayment Project. The channel grade (approximately 0.25 percent) would be permanently stabilized by four interspaced rock-grade control structures. These structures would span the Embayment and be constructed sub-grade between 4 ft and 6 ft (1.2 to 1.8 m) deep with the elevation of the top of the structures level with the elevation the bottom of the Embayment. Each structure would require the permanent placement of up to 2,400 cubic yards (1,835 m^3) of locally obtained riprap, 50 percent of which would be 24 inches (in; 0.6 m) in diameter.

After installation of silt-control fences, two temporary coffer dams would be constructed across the Embayment outfall and across the Embayment at the Equipment Crossing prior to dewatering and construction activities. The silt fences would deflect the river's flow and significantly reduce the suspended sediment and turbidity effects associated with installation and erosion of the coffer dam. The coffer dam will be constructed using sediment and soils from the Embayment bottom and edges. The coffer dams will isolate the work area; one coffer dam will separate the Embayment from the Rio Grande, and the other coffer dam at the Equipment Crossing will prevent stormwater (and possibly water pumped from the Embayment) from the North Diversion Channel from entering the Embayment during construction activities. The applicant proposes using standard heavy construction equipment. Drawings attached to the Public Notice (Corps 2011) and the BA (SWCA Environmental Consultants 2011) provide additional details on elevations, revegetation plan, and the control structure placement.

After coffer dam construction, water from the Embayment will be mechanically pumped to the settling basin upstream of the Equipment Crossing in the North Diversion Channel where it will stand (and infiltrate into the ground or evaporate or it may be diverted into an irrigation ditch) until project activities conclude. Fine mesh, silt fence-screened water intakes will be installed around the pumps to prevent fish and other larger vertebrates from entering the hose intake and pump. Some water may remain in the Embayment as construction activities will occur at the control structures and coffer dams and will not occur across the entire bottom surface of the Embayment. Water pumping activities are anticipated to last no longer than one week (based on water volume and pump rates), and can be controlled to reflect the needs of the project as well as the needs of biologists to rescue silvery minnows or other animals that may become stranded in pools or at the edges of the receding pool of water remaining in the Embayment. During pumping and construction activities, daily observations of fish behavior or mortality will be made by onsite biologists and managers. As appropriate to the rescue of any stranded fish and wildlife species, the AMAFCA Embayment Project manager(s) and staff will coordinate with the Service's New Mexico Fish and Wildlife Conservation Office in conjunction with the Pueblo of Sandia to commence seining, netting, capture, and translocation of fish (and other aquatic organisms) to the Rio Grande during dewatering activities in order to minimize the mortalities of silvery minnows.

After construction, and after removal of the downstream coffer dam, AMAFCA proposes to revegetate the Embayment Project area according to the revegetation plan (BA, p. 29 to 38) in April. The goals of the revegetation plan are to 1) mitigate and augment herbaceous wetland vegetation in the channel; 2) plant grass and riparian shrubs to control erosion in the uplands; and, 3) and stabilize and maintain the hydraulic efficiency of the channel by planting riparian vegetation (*Salix spp.*) to stabilize the banks of the Embayment. Scheduled maintenance mowing (up to twice per year conducted outside the flycatcher nesting season) along the banks of the Embayment will reduce aboveground biomass and riparian habitat value. All plant materials have been selected to reduce introduction of invasive species. Some truck-watering will be conducted for assisting establishment of vegetation and reducing erosion and dust control, and will conducted so as not induce runoff into the Embayment or the Rio Grande.

After excavated sediment as well as coffer dams have been removed, the silt fences will be removed and water will again flow into and through the Embayment to the Rio Grande and revegetation with native plant species will be concluded. The regrading effort could provide a permanent, shallow pool (1-3 feet (ft; 0.3-0.9 meters (m)) deep) extending from the river's edge easterly toward the Equipment Crossing. According to the BA (p. 7), after the Embayment

Project regrading and stabilization will remain "[a] shallow pool [that] will circulate with river water and provide excellent nursery habitat for silvery minnow."

Conservation Measures included in the Proposed Action by AMAFCA

There are a number of conservation measures that have been offered by AMAFCA during the proposed project development that reduce adverse effects to silvery minnows (BA, p. 26-28) including:

1. Active daily observation of fish behavior during dewatering, and coordination of pumping efforts and fish rescue operations with the Service and Pueblo of Sandia staff;
2. Timing restrictions of activity only during winter. Silvery minnow eggs and larvae are not expected to be exposed to adverse effects in the Embayment during cold months;
3. Reducing or removing adverse water quality effects to the Rio Grande downstream;
4. Installation of protective, fine mesh screens around the pumps to prevent intake of silvery minnows;
5. Implementation of construction BMPs affecting equipment and operations (i.e., pollution prevention, spill response readiness, no herbicide use, reducing potential for dust abatement water quality impacts, clean riprap materials, reduced project footprint; see BA, pp. 1, 26-28);
6. Avoidance of existing wetland areas or disturbance of an island, and revegetation with native plant species;
7. Commitment to monitor the water quality parameters of water temperature and dissolved oxygen in the Embayment after regrading for up to 1.5 years, or more, and adaptive management to address any subsequent water temperature or low oxygen conditions considered detrimental to silvery minnows after construction activities cease; and,
8. Obtaining all applicable permits, certifications and authorizations prior to construction.

Consultation History

June 26-28, 2004. The United States Geological Survey (USGS) conducts toxicity testing of stormwater and sediment collected from the Embayment (Buhl 2005). During these toxicity tests, an extensive fish kill was observed in the Embayment (Lusk 2004). The low oxygen concentration in the Embayment water and stormwater collected was a major cause of the observed mortality of silvery minnows in the laboratory toxicity tests and of the native fish (Buhl 2005).

May 5, 2008. A Service-sponsored study conducted by UNM provides information that identifies low dissolved oxygen (DO) concentrations in the Rio Grande that are linked with stormwater discharges from the North Diversion Channel (Van Horn 2008).

August 5, 2009. AMAFCA provides a report that reviewed DO concentrations in the North Diversion Channel upstream, in the Embayment, and in the Rio Grande nearby (Daniel B. Stephens and Associates, Inc. (DBS&A) (2009). This report identified that as long as the Embayment remains in place, oxygen-depleted water from the Embayment will continue to cause short-term decreases in oxygen concentrations in the Rio Grande and recommended possible solutions to the problem.

July 16, 2010. The United States Environmental Protection Agency, Region 6 (EPA) provides the Service a revised Biological Evaluation (BE) and letter affirming that issuance of a CWA permit for the discharge of stormwater by way of the North Diversion Channel and other outfalls in Albuquerque, New Mexico (Albuquerque stormwater permit), “may affect, but is not likely to adversely affect” the flycatcher, the silvery minnow, or their critical habitats.

December 15, 2010. After discussions with the Service, the EPA requests formal consultation on the Albuquerque stormwater permit (i.e., Albuquerque Municipal Separate Stormwater Sewer System (MS4) Permit No. NMS000101” (EPA 2010a,b,c)).

March 7–9, 2011. The Service, AMAFCA, EPA, and Corps discuss mixing zone size calculations and a potential remedy for the low DO conditions found in the Embayment. AMAFCA provides information on the DO concentrations in the Embayment and the Middle Rio Grande upstream.

March 11, 2011. AMAFCA, Corps, and Pueblo of Sandia staff meets to discuss a new conceptual plan for the Embayment. The idea of completely filling in the Embayment was abandoned in favor of regrading the Embayment.

June 3, 2011. During a meeting of AMAFCA, the Corps, and the Pueblo of Sandia, the Corps requests that Embayment sediment be sampled and tested for hazardous pollutants.

September 21, 2011. AMAFCA, Corps, and Service discuss the potential adverse effects to silvery minnows and agree that formal consultation will be undertaken.

September 26, 2011**.** AMAFCA begins work on the BA to evaluate the potential impacts of regrading the Embayment as the preferred remedial action required by the EPA as part of the Albuquerque MS4 permit (EPA 2010b).

September 29, 2011. The Service issues the final BO on the EPA’s proposed issuance of the Albuquerque stormwater permit that requires implementation of the remedial action within 1.5 years of the permit’s effective date as a term and condition.

October 24, 2011. AMAFCA, Corps, and the Service meet to discuss how to evaluate the potential effects using the density of silvery minnows within the Embayment and how to minimize adverse effects during dewatering and construction activities.

November 2, 2011. AMAFCA and the Service meet at the Embayment Project Area to discuss the proposed action and options for fish and aquatic life rescue efforts and timing before and during dewatering activities.

November 9, 2011. Corps provides to the Service the final BA and requests formal consultation.

November 28, 2011. AMAFCA provides analytical chemistry data on Embayment sediment quality to the Corps, Pueblo of Sandia, and Service.

December 4-5, 2011. The USGS (Buhl 2011a) provides to AMAFCA, Corps, Pueblo of Sandia, and the Service, preliminary analytical chemistry data on Embayment sediments collected during toxicity studies conducted on June 11, 2004.

December 9, 2011. Service provides an electronic copy of the draft Embayment Project BO to AMAFCA and the Corps, and the Corps provides a copy to the Pueblo of Sandia.

December 28, 2011. Staff of AMAFCA, Pueblo of Sandia, the Corps, and the Service discuss project planning efforts and logistics with coordination of fish rescue and other activities.

Action Area

This BO uses the term "Middle Rio Grande" to refer to the river channel and its floodplain (within the levees) in the Rio Grande-Albuquerque Watershed (USGS Hydrologic Cataloging Unit 13020203; Seaber et al. 1987) in central New Mexico. The Middle Rio Grande is often divided into river reaches identified by an upstream diversion dam (Figure 2). Therefore, we refer to the Angostura Reach as that portion of the Middle Rio Grande between the Angostura and Isleta Diversion Dams. The North Diversion Channel discharges through the Embayment and into the Angostura Reach of the Middle Rio Grande (at the north end of the City of Albuquerque; Figure 1). To clarify the various spatial areas of impact associated with the proposed Embayment Project activities, we will use the following terms in this BO:

- The Embayment, includes wetted and riparian areas east of the confluence of the outfall of the North Diversion Channel with the Rio Grande to the Equipment Crossing, an earthen feature just west of the Settling Basin. The Embayment is outlined on Figure 1.
- The Embayment Project Area, includes all areas affected by the Embayment Project construction and dewatering activities, including, the Embayment, lease areas around the Embayment, portions of the Settling Basin that receive pumped water, the various transportation routes used, and the sediment stockpile area. The Embayment Project Area is depicted on Sheet 2 of 6 of the AMFACA Application (Corps 2011)
- The Action Area, includes the Embayment, the Embayment Project Area, and the Angostura Reach of the Middle Rio Grande beginning at the confluence of the outfall of the North Diversion Channel with the Rio Grande and downstream. The Angostura Reach of the Middle Rio Grande is considered part of the action area, as beneficial water quality effects are expected from the Embayment Project as it is the remedial action identified to reduce the severity and frequency of low oxygen events in the Rio Grande after its completion (see Service 2011c).

The action area includes all areas to be affected directly or indirectly by the proposed action (50 CFR 402.02). The Embayment Project Area was described in Application No. SPA-2010-435-ABQ (Corps 2011, Sheet 2 of 6), includes the Embayment, the sediment disposal area and its haul route (Corps 2011, Sheet 5 of 6). With installation of silt fences at outfall of the Embayment, as well as the installation of the coffer dams, no detrimental water quality impacts to the Rio Grande are anticipated by the Embayment Project activities. However, we determined that the Angostura Reach of the Middle Rio Grande would be indirectly affected as beneficial effects to water quality downstream of the Embayment are expected after construction and after its reconnection to the Rio Grande. Additionally, silvery minnows rescued from the Embayment during Embayment Project activities will be released into the Middle Rio Grande nearby.

II. STATUS OF THE SPECIES

The proposed action considered in this BO may affect the silvery minnow that is provided protection as an endangered species under the ESA. A description of this species, its status, and designated critical habitat are provided below and informs the effects analysis.

Rio Grande Silvery Minnow

Description

The silvery minnow currently occupies a 275-km (170-mi) reach of the Rio Grande, New Mexico, from Cochiti Dam in Sandoval County, to the headwaters of Elephant Butte Reservoir in Socorro County (Service 1994). Silvery minnows were also introduced into the Rio Grande near Big Bend, Texas, in December 2008 as an experimental, nonessential population under section 10(j) of the ESA. Silvery minnows are a stout fish, with a small, subterminal mouth, with long pharyngeal dentition with a distinct grinding surface and a pointed snout that projects beyond the upper lip (Sublette et al. 1990). The back and upper sides of silvery minnow are silvery to olive, the broad middorsal stripe is greenish, and the lower sides and abdomen are silver. Maximum total length attained in New Mexico specimens is about 90 millimeters (mm) (3.5 in) (Sublette et al. 1990). Sexual differences are generally not observed except during spawning when the body cavity of females is expanded with eggs (Bestgen and Propst 1994).

In the past, the silvery minnow was included with other species in the genus *Hybognathus* due to morphological similarities, including a distinct, convex jaw. Phenetic and phylogenetic analyses corroborate the hypothesis that *Hybognathus amarus* is a distinct valid taxon, and separate from other species of *Hybognathus* (Cook et al. 1992; Bestgen and Propst 1994), particularly the placement of its subterminal mouth. It is now recognized as one of seven species in the genus *Hybognathus* in the United States and was formerly one of the most widespread and abundant minnow species in the Rio Grande basin of New Mexico, Texas, and Mexico (Pflieger 1980; Bestgen and Platania 1991). Currently, *Hybognathus amarus* is the only remaining endemic, pelagic-spawning minnow in the Middle Rio Grande. The speckled chub (*Macrhybopsis aestivalis*), Rio Grande shiner (*Notropis jemezanus*), phantom shiner (*Notropis orca*), and bluntnose shiner (*Notropis simus simus*) are either extinct or have been extirpated from the Rio Grande (Bestgen and Platania 1991).

Legal Status

The silvery minnow was federally listed as endangered under the ESA on July 20, 1994 (58 Federal Register [FR] 36988, see Service 1994). Primary reasons for listing the silvery minnow are described below in the *Reasons for Listing/Threats to Survival* section. The Service designated critical habitat for the silvery minnow on February 19, 2003 (68 FR 8088, Service 2003b). See description of designated critical habitat below. The species is also listed as an endangered species by the State of New Mexico.

Habitat

Silvery minnows travel in schools and tolerate a wide range of habitats (Sublette et al. 1990), yet generally prefers low velocity (less than 10 centimeters per second [cm/s] (0.33 feet per second [ft/s])) areas over silt or sand substrate associated with shallow (less than 40 cm [15.8 in]) braided runs, backwaters, or pools (Dudley and Platania 1997). Habitat for silvery minnows includes stream margins, side channels, and off-channel pools where water velocities are low or reduced. Stream reaches dominated by straight, narrow, incised channels with rapid flows are not typically occupied by silvery minnows (Sublette et al. 1990; Bestgen and Platania 1991). Adult silvery minnows are most commonly found in backwaters, pools, and habitats associated with debris piles; whereas, age-0 fish occupy shallow, low velocity backwaters with silt substrates (Dudley and Platania 1997). A study conducted between 1994 and 1996 characterized habitat availability and use at two sites in the Middle Rio Grande, one near Rio Rancho, New Mexico and the other near Socorro, New Mexico. From this study, Dudley and Platania (1997) reported that silvery minnows were most commonly found in habitats with depths less than 50 cm (19.7 in). Over 85 percent were collected from low-velocity habitats (less than 10 cm/s [0.33 ft/s]) (Dudley and Platania 1997; Watts et al. 2002).

Designated Critical Habitat

Silvery minnow critical habitat designation extends approximately 252 km (157 mi) from Cochiti Dam in Sandoval County, New Mexico, downstream to the utility line crossing the Rio Grande, which is a permanent identified landmark in Socorro County, New Mexico. The Pueblos of Cochiti, Sandia, Santo Domingo, Santa Ana, and Isleta within the Middle Rio Grande are not included in the designated critical habitat because each Pueblo has management plans to protect silvery minnows. The remaining portion of the silvery minnow's occupied range in the Middle Rio Grande is designated as critical habitat.

The critical habitat designation defines the lateral extent (width) as those areas including the Rio Grande and riparian zone bounded by existing levees or, in areas without levees, 91.4 m (300 ft) of riparian zone adjacent to each side of the bankfull stage of the Rio Grande. Some developed lands within the riparian zone are not considered designated critical habitat, as they do not contain the appropriate PCEs, and are therefore not essential to the conservation of the silvery minnow. Lands located within the lateral boundaries of the critical habitat designation, but not considered critical habitat include: developed flood control facilities, existing paved roads, bridges, parking lots, dikes, levees, diversion structures, railroad tracks, railroad trestles, water diversion and irrigation canals outside of natural stream channels, the Low Flow Conveyance Channel, active gravel pits, cultivated agricultural land, and residential, commercial, and industrial developments.

The Service determined the PCEs of silvery minnow designated critical habitat based on studies on silvery minnow habitat and population biology. These PCEs include:

1. a hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats, such as, but not limited to the following: backwaters (a body of water connected to the main channel, but with no appreciable flow), shallow side channels (anabranches), pools (that portion of the river that is deep with relatively little velocity compared to the rest of the channel), and runs (flowing water in the river channel without obstructions) of varying depth and velocity, all of which are necessary for each of the particular silvery minnow life history stages in appropriate seasons (e.g., the silvery minnow requires habitat with sufficient peak flows from early spring (March) to early summer (June) to trigger spawning, flows in the summer (June) and fall (October) that do not increase prolonged periods of low or no flow, and relatively constant winter flow (November through February));
2. the presence of eddies created by debris piles, pools, or backwaters, or other refuge habitat within unimpounded stretches of flowing water of sufficient length (i.e., river miles) that provide a variation of habitats with a wide range of depth and velocities;
3. substrates of predominantly sand or silt; and
4. water of sufficient quality to maintain natural, daily, and seasonally variable water temperatures in the approximate range of greater than 1 degree Centigrade (C) (35 degrees Fahrenheit [°F]) and less than 30 °C (85 °F) and reduce degraded conditions (e.g., decreased DO, increased pH).

These PCEs provide for the physiological, behavioral, and ecological requirements essential to the conservation of the silvery minnow.

Life History

The species is a pelagic spawner and a female may produce as many as 3,000 to 6,000 semibuoyant, nonadhesive eggs during a spawning event (Platania 1995; Platania and Altenbach 1998; Platania and Dudley 2008). The majority of adults in the wild spawn in about a 1-month period in late spring to early summer (May to June) in association with spring runoff. Platania and Dudley (2000) found that the highest collections of silvery minnow eggs occurred in mid- to late May. In 1997, Smith (1999) collected the highest number of eggs in mid-May, with lower frequency of eggs being collected in late May and June. These data suggest multiple silvery minnow spawning events during the spring and summer, perhaps concurrent with peak flows. Artificial flow spikes have apparently induced silvery minnows to spawn (Platania and Hoagstrom 1996). In captivity, silvery minnows have been induced to spawn as many as four times in a year (Altenbach 2000); however, it is unknown if individual silvery minnows spawn more than once per year in the wild or if multiple spawning events suggested during spring and summer represent the same or different individuals.

The spawning strategy of releasing semibuoyant eggs can result in the downstream displacement of eggs, especially in years or locations where overbank-flooding opportunities are limited. The presence of irrigation water diversion dams (Angostura, Isleta, and San Acacia Diversion Dams) prevents the movement of adults to recolonize habitats upstream of these dams (Platania 1995) and has reduced the species' effective population size to critically low levels (Alò and Turner

2005; Osborne et al. 2005). Adults, eggs, and larvae may also be transported downstream and into to Elephant Butte Reservoir. It is believed that few to none of these fish survive because of poor habitat conditions and predation from reservoir fishes (Service 2010a).

Platania and Dudley (2000) found that development of larval fish and hatching of eggs are correlated with water temperature. Eggs of silvery minnows raised in water at 30 °C (86 °F) hatched in approximately 24 hr while eggs reared in 20 to 24°C (70 to 75 °F) water hatched within 50 hr. Eggs were 1.52 mm (0.06 in) in diameter upon fertilization, but quickly swelled to 3.05 mm (0.12 in) during water exposure. Recently hatched larval fish are about 3.81 mm (0.15 in) in standard length and grow about 0.13 mm (0.005 in) per day during development though various larval stages. Eggs and larvae have been estimated to remain in the drift for 3 to 5 days, and could be transported from 216 to 359 km (134 to 223 mi) downstream depending on river flows and availability of nursery habitat (Platania and Dudley 2000). Approximately 3 days after hatching the larvae move to low velocity habitats where food (mainly phytoplankton and zooplankton) is abundant (Pease et al. 2006). The Age-0 attain lengths of 39 to 41 mm (1.53 to 1.61 in) by late autumn (Service 2010a). Age-1 fish are approximately 46 mm (1.8 in) by the start of the spring spawning season. Most growth occurs between June (post spawning) and October, but there is some growth during the winter months. Maximum longevity is about 30 months for wild fish (inferred from length-frequency), up to 36 months based on findings from a study of otolith and scale examinations on wild fish (Horwitz et al. 2011), and up to 36 months for hatchery-released fish (Service 2010a). Based on estimated length groups for assigning an age class, it is possible that some individuals in the wild survive to be Age-3 fish; however greater than 95 percent of the population in any given year is estimated to comprise Age-0 and Age-1 fish (Service 2010a). In the wild, the silvery minnow is a very short-lived species that exhibits similar patterns of growth, survival, and longevity as compared with several other closely related species of *Hybognathus* (Horwitz et al. 2011). In comparison to longevity in the wild, it is not uncommon for captive silvery minnows to live beyond 2 years, especially at lower water temperature. The USGS Columbia Environmental Research Center research station in Yankton, South Dakota, has several silvery minnows in captivity with a maximum age of 11 and that range in size from 46 to 73 mm (1.8 to 2.9 in) standard length (Service 2010a).

Silvery minnow foraging strategies are often demersal (feeding along or near the river substrate) and primarily herbivorous (largely feeding on algae and other plant materials); this is indicated indirectly by the elongated and coiled gastrointestinal tract (Sublette et al. 1990); also Shirey (2004) and Magaña (2009) found diatoms (algae with cell walls made of silica) were a main component of their identifiable gut contents. Additionally, organic detritus, larval insect exuvia, and small invertebrates, as well as sand, and silt are often filtered from the bottom and ingested (Sublette et al. 1990; Service 1999; Magaña 2009). The presence of this sand and silt in the gut of wild-captured specimens suggests that epipsammic algae (algae growing on the surface of sand, such as species of diatoms) is an important food (Magaña 2009; Service 2010a). Silvery minnows reared in a laboratory have been directly observed grazing on algae in aquaria (Platania 1995; Magaña 2009; Service 2010a).

Population Dynamics

Generally, a population of silvery minnows consists of only two age classes: Age-0 and Age-1 fish (Service 2010a; Horwitz et al. 2011). The majority of spawning silvery minnows is 1 year in age, with 2 year-old fish and older estimated to comprise less than 5 percent of the spawning population (Service 2010a). High mortality of silvery minnows occurs during or subsequent to spawning, consequently very few adults are found in late summer and fall. By December, in general, the majority of surviving silvery minnows are represented by Age-0 fish, those that hatched during the previous spring (Dudley and Platania 2007; Remshardt 2007, 2008a,b).

Platania (1995) found that a single female in captivity could broadcast 3,000 eggs in 8 hr. Females produce 3 to 18 clutches of eggs in a 12-hr period. The mean number of eggs in a clutch is approximately 270 (Platania and Altenbach 1998). In captivity, silvery minnows have been induced to spawn as many as four times in a year (Altenbach 2000). It is not known if they spawn multiple times in the wild. The high reproductive potential of this fish appears to be one of the primary reasons that it has not been extirpated from the Middle Rio Grande. However, the short life span of silvery minnows and environmental variation in their habitat increases the instability of the population. For example, when two below-average flow years occur consecutively, a short-lived species such as the silvery minnow can be impacted, if not eliminated from drying reaches of the Rio Grande (Service 1999, 2003a, 2010a).

Distribution and Abundance

Historically, the silvery minnow occurred in 3,967 km (2,465 mi) of rivers in New Mexico and Texas. The species was known to have occurred upstream to Española, New Mexico (upstream from Cochiti Lake); in the downstream portions of the Rio Chama and Jemez River; throughout the Middle and Lower Rio Grande to the Gulf of Mexico; and in the Pecos River from Sumner Reservoir downstream to the confluence with the Rio Grande (Sublette et al. 1990; Bestgen and Platania 1991). The current distribution of the silvery minnow is limited to the Rio Grande between Cochiti Dam and Elephant Butte Reservoir, which amounts to approximately 7 percent of its historical range. In December 2008, 2009, and 2010, silvery minnows were introduced into the Rio Grande near Big Bend, Texas, as a nonessential, experimental population under section 10(j) of the ESA (73 FR 74357, Service 2008a). The success of these efforts is evaluated through monitoring of the silvery minnows reintroduced into that portion of the Rio Grande.

The construction of mainstem dams, such as Cochiti Dam and several irrigation diversion dams, have contributed to the decline of the silvery minnow (Service 2010a). Cochiti Dam was constructed on the main stem of the Rio Grande in 1973 for flood control and sediment retention (Julien et al. 2005). The construction of Cochiti Dam affected the silvery minnow by reducing the magnitude and frequency of peak flow events and floods that help to create and maintain habitat for the species (Dudley and Platania 1997; Julien et al. 2005). In addition, the construction of Cochiti Dam has resulted in degradation of silvery minnow habitat within the Cochiti Reach downstream of the Cochiti Dam. Water released through Cochiti Dam is now generally clear, cool, and free of sediment. Below Cochiti Dam, there is relatively little channel braiding, and areas with reduced velocity and sand or silt substrates are now uncommon (Julien et al. 2005). Cochiti Dam also created a barrier for movement upstream by silvery minnows

(Service 2010a). As recently as 1978, silvery minnows were collected upstream of Cochiti Lake; however surveys since 1983 suggest that the fish is now extirpated from that area (Service 1999, 2010a; Torres et al. 2008).

Substrate immediately downstream of the dam is often composed of gravel and cobble (rounded rock fragments generally 8 to 30 cm [3 to 12 in] in diameter). Farther downstream, the riverbed is gravel with some sand and silt substrate. Tributaries including Galisteo Creek and Tonque Arroyo introduce sand and silt during stormwater runoff to the lower sections of the Cochiti Reach, and some of this sediment is transported further downstream along with flows (Salazar 1998; Service 1999, 2001). The Rio Grande becomes a predominately sand-bed river with low, sandy banks in the downstream portion of the Angostura Reach and in the Isleta Reach.

Long-term monitoring of silvery minnows in the Middle Rio Grande began in 1993 and has continued annually, with the exception of 1998 (Dudley and Platania 2010a). The long-term monitoring of silvery minnows has recorded substantial fluctuations (order of magnitude increases and decreases) over time (Figure 3). Silvery minnow catch rates declined two to three orders of magnitude between 1993 and 2003, but then increased three to four orders of magnitude by 2005 and continue to fluctuate (Figure 3). Catch rate data presented in Figure 3 indicate that population of silvery minnow declined through early 2000, increased by 2005, but by 2010 and 2011, were below the levels at the time of their listing as an endangered species in 1994. In 2008, population size was positively correlated with the magnitude and duration of the spring runoff (Dudley and Platania 2008b). The capacity of the species to respond to good hydrologic years (e.g., 2005) is dependent on a variety of factors including the previous year's survivorship, number of adults available to reproduce, good habitat conditions, and fecundity.

Augmentation has likely sustained the silvery minnow population throughout its range over the last decade (Remshardt 2008b). Over 1,136,100 silvery minnows have been released since 2002. Hatchery-propagated and released fish supplement the native adult population, most likely prevented extinction during the extremely low water years of 2002 and 2003, and allowed for quicker and more robust population response in all reaches due to improved water conditions observed in recent years (Service 2010a). If the overall average catch rate for Angostura Reach drops to below 0.1 per 100 m^2 (1.2 per 100 ft^2) during October, then augmentation will be reinitiated for this reach the following year (Remshardt 2008b). Dudley and Platania (2011b) reported the catch rate of silvery minnows from 0 to 0.4 per 100 m^2 in the Angostura Reach, with an average catch rate of 0.2 per 100 m^2 during October 2011.

During 2001 through 2007, the Angostura Reach was the focus of augmentation efforts; however, beginning in 2008, augmentation shifted to the Isleta and San Acacia Reaches (Remshardt 2010a). The success of these augmentation efforts during a period of 5 years (2008–2012) without intensive stocking is currently being evaluated.

Middle Rio Grande Distribution Patterns

During the early 1990s, the catch rates of silvery minnows generally increased from upstream (Angostura Reach) to downstream (San Acacia Reach). During surveys in 1999, over 98 percent of the silvery minnows captured were downstream of San Acacia Diversion Dam (Dudley and

Platania 2002). This distributional pattern can be attributed to downstream drift of eggs and larvae and the inability of adults to repopulate upstream reaches because of diversion dams.

This pattern shifted in several more recent years. In 2004, 2005, and 2007, catch rates were highest in the Angostura Reach and lower in the Isleta and San Acacia Reaches. Routine augmentation of silvery minnows in the Angostura Reach (the focus of augmentation efforts started in 2001) may partially explain this pattern. Transplanting of silvery minnows (approximately 802,700 through 2009) rescued from drying reaches has also occurred since 2003. It is not possible to quantify the effects of those rescue efforts on the silvery minnow population distribution patterns (Remshardt 2010b). Good recruitment conditions (high and sustained spring runoff) throughout the Middle Rio Grande during April and May followed by wide-scale drying in the Isleta and San Acacia Reaches from June to September may also explain the shift. High spring runoff greater than 86 m^3/s (3,000 cubic feet per second [cfs]) for 7 to10 days and perennial flow tends to lead to increased nursery habitat and survivorship in the Angostura Reach. In contrast, portions of the Rio Grande south of the Isleta and San Acacia Diversion Dams, have had large stretches of river (48 km [30 mi]) routinely dewatered. Silvery minnows in these areas were subjected to poor recruitment conditions (lack of nursery habitats during low flows) or were trapped in drying pools where they perished.

In 2006, densities of silvery minnows were again highest downstream of the San Acacia Diversion Dam. Spring runoff volumes were exceedingly low in 2006. Flows at the Albuquerque gage never exceeded 65 m^3/s (2,300 cfs) in 2006 (USGS 2010), and likely little nursery habitat was inundated during critical recruitment times.

In 2007, population monitoring of silvery minnow densities indicated the highest densities occurred in the Angostura Reach. Reports for 2008 indicated high recruitment, at all 20 sampling sites along the Middle Rio Grande, and strong runoff over an extended duration from May to July lead to elevated numbers of this species. Sampling in October 2009, indicated high recruitment, at 19 of the 20 sampling sites. The highest densities were noted to persist in the San Acacia Reach during the population monitoring census in October of 2008, 2009, 2010, and 2011. The lack of extensive river drying in 2008 and 2009, and favorable spring flows, was likely an important factor in this distribution shift from highest densities in the Angostura Reach in 2007 to the San Acacia Reach in 2008 and 2009 (Dudley and Platania 2008a, 2008b, 2009). During 2010, the silvery minnow was most common fish species caught in the San Acacia Reach and least common in the Angostura Reach during monitoring. In late 2010, the Isleta and San Acacia Reaches were stocked with hatchery-raised silvery minnows, and this activity was apparently the primary cause for increased silvery minnow catch rates in those reaches (Dudley and Platania 2011a).

Reasons for Listing and Threats to Survival

The silvery minnow was federally listed as endangered for the following reasons:

1. regulation of stream waters, which has led to severe flow reductions, often to the point of dewatering extended lengths of stream channel;

2. alteration of the natural hydrograph, which impacts the species by disrupting the environmental cues the fish receives for a variety of life functions, including spawning as well as food availability during larval fish development;
3. both the stream flow reductions and other alterations of the natural hydrograph throughout the year can severely impact habitat availability and quality, including the temporal availability of habitats;
4. actions such as channelization, bank stabilization, levee construction, and dredging result in both direct and indirect impacts to the silvery minnow and its habitat by severely disrupting natural fluvial processes throughout the floodplain;
5. construction of diversion dams fragment the habitat and prevent upstream migration;
6. introduction of nonnative fishes that directly compete with, and can totally replace the silvery minnow, as was the case in the Pecos River, where the species was totally replaced in a time frame of 10 years by its congener the plains minnow (*Hybognathus placitus*); and
7. degraded water quality caused by industrial, municipal, or agricultural discharges also affects the species and its habitat (Service 1994).

These reasons for listing continue to threaten the species throughout its currently occupied range in the Middle Rio Grande.

<u>Recovery Efforts</u>

Recovery efforts are currently guided by the First Revision of the Rio Grande Silvery Minnow Recovery Plan, which was finalized and issued on February 22, 2010 (75 FR 7625, Service 2010b). The revised Recovery Plan describes recovery goals for the silvery minnow and actions to complete these (Service 2010b). The three goals identified for the recovery and delisting of the silvery minnow are:

1. prevent the extinction of the silvery minnow in the Middle Rio Grande of New Mexico;
2. recover the silvery minnow to an extent sufficient to change its status on the List of Endangered and Threatened Wildlife from endangered to threatened (downlisting); and
3. recover the silvery minnow to an extent sufficient to remove it from the List of Endangered and Threatened Wildlife (delisting).

Downlisting (Goal 2) of the silvery minnow may be considered when the criteria have been met resulting in three populations (including at least two that are self-sustaining) that have been established within the historical range of the species and have been maintained for at least 5 years.

Delisting (Goal 3) of the species may be considered when the criteria have been met resulting in three self-sustaining populations have been established within the historical range of the species and have been maintained for at least 10 years (Service 2010a,b).

Conservation and recovery efforts targeting the silvery minnow are also summarized in the revised Recovery Plan and elsewhere (Tetra Tech 2004; Service 2010b). These efforts have included habitat restoration activities; research and monitoring of the status of the silvery minnow, its habitat, and the associated fish community in the Middle Rio Grande; and programs to stabilize and enhance the species, such as tagging fish and egg monitoring studies, salvage operations, captive propagation, and augmentation efforts (for more information see www.middleriogrande.com). In addition, specific water management actions in the Middle Rio Grande valley over the past several years have been used to meet river flow targets and March 2003 BO requirements for silvery minnow.

Propagation and Augmentation

In 2000, the Service identified captive propagation as an appropriate strategy to assist in the recovery of the silvery minnow. Captive propagation is conducted in a manner that will, to the maximum extent possible, preserve the genetic and ecological distinctiveness of the silvery minnow and minimize risks to existing wild populations.

Facilities at Dexter National Fish Hatchery and Technology Center and the City of Albuquerque's BioPark conduct captive propagation of silvery minnows. Silvery minnows are held at the Service's New Mexico Fish and Wildlife Conservation Office, the Interstate Stream Commission Refugium in Los Lunas, New Mexico, and USGS Columbia Environmental Research Center Laboratory in Yankton, South Dakota; however, there are no active spawning programs at these facilities.

Since 2002, over 1 million silvery minnows have been propagated and released into the Rio Grande (Remshardt 2010b). Wild gravid adults are successfully spawned in captivity at the City of Albuquerque's propagation facilities. Eggs are raised and released as larval fish. Marked fish have been released into the Middle Rio Grande by the Service's New Mexico Fish and Wildlife Conservation Office since 2002 under an augmentation effort funded by the Middle Rio Grande Endangered Species Collaborative Program. Eggs left in the wild have a very low survivorship, and captive propagation ensures that an adequate number of spawning adults are present to repopulate the river each year. Wild eggs are also collected and reared to maximize the genetic diversity of the minnows released (Remshardt 2008b).

Silvery Minnow Salvage and Relocation

During river drying, staff from the Service's New Mexico Fish and Wildlife Conservation Office often captures and relocates silvery minnows to nearby perennial water (Remshardt 2010b). Through 2009, approximately 802,700 silvery minnows have been rescued and relocated to wet reaches, the majority of which were released in the Angostura Reach. Studies have been conducted to determine survival rates for salvaged fish. Caldwell et al. (2009) reported on studies that assessed the physiological responses of wild silvery minnows subjected to collection and transport associated with salvage. The authors examined primary (plasma cortisol), secondary (plasma glucose and osmolality), and tertiary indices (parasite and incidence of disease) and concluded that the effects of stressors associated with river intermittency and salvage resulted in a cumulative stress response in wild silvery minnows. They also concluded that fish in isolated pools experienced a greater risk of exposure and vulnerability to pathogens (parasites and bacteria), and that the stress response and subsequent disease effects were reduced through a modified salvage protocol that applied specific criteria to determine which wild fish are to be rescued from pools during river intermittency (Caldwell et al. 2009).

III. ENVIRONMENTAL BASELINE

Under section 7(a)(2) of the ESA, when considering the effects of the action on federally listed species, we are required to take into consideration the environmental baseline. Regulations implementing the ESA (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area; the anticipated impacts of all proposed Federal actions in the action area that have already undergone formal or early section 7 consultation; and the impact of State and private actions that are contemporaneous with the consultation in process. Given that the scale of environmental baseline information available on silvery minnows is generally associated with a reach of river, in this case, the Angostura Reach, and the proposed action takes place within a backwater inlet normally and is subsequently connected to the Angostura Reach of the Rio Grande, we will include environmental baseline information on the silvery minnow in the Angostura Reach as well as in the Embayment. This environmental baseline will help define the effects of the project and other activities in the action area on the status of the species and its habitat to provide a platform to assess the effects of the action now under consultation.

Status of the Species in the Action Area

<u>Status of the Species in the Angostura Reach of the Middle Rio Grande</u>

Long-term monitoring for the silvery minnow in the Middle Rio Grande began in 1993 and has continued annually, with the exception of 1998 (Dudley and Platania 2010a, Figure 3). This includes monitoring of silvery minnows in the Angostura Reach. The most recent data indicate an average silvery minnow density of 0.2 per 100 m^2 within the Angostura Reach during October 2011 (Dudley and Platania 2011b).

Several activities have contributed to the status of the silvery minnow and its habitat in the action area, and are believed to affect the survival and recovery of silvery minnows in the wild. These include the current weather patterns, changes to the natural hydrology of the Rio Grande, changes to the morphology of the channel and floodplain, water quality, storage of water and release of spike flows, captive propagation and augmentation, silvery minnow salvage and relocation, ongoing research, and past projects in the Angostura Reach.

<u>Status of the Species in the Embayment</u>

Post-augmentation monitoring for silvery minnows in the Middle Rio Grande has been carried out since 2002 (Remshardt and Davenport 2003; Remshardt 2005, 2007, 2008a, 2008b, 2010b, 2011a). One of the monitoring sites is within the action area and near the Embayment (at River Mile [RM] 193.2) (Remshardt 2010b, 2011a). Monitoring in the Angostura Reach showed a general increase in numbers of silvery minnows sampled since 2002 (Remshardt and Davenport

2003), when the overall catch rate was 0.4 silvery minnow per 100 m^2; with considerable annual and seasonal variation. Remshardt (2011a) reported the overall catch rate for Angostura Reach was 7.8 silvery minnow per 100 m^2. The most consistent seasonal peak in catch rates was noted during June and July, following silvery minnow spawning.

The catch rate of silvery minnows within the Embayment (BA, p. 23; based on Remshardt 2011b) ranged from 0 to 127 silvery minnow per 100 m^2 and averaged 13 per 100 m^2. However, these data (n=15) were highly skewed (Figure 4), as the median was 0.2 silvery minnow per 100 m^2, the standard deviation was 32.8, and the 95 percent confidence interval of the mean ranged from -5.2 to 31.2 per 100 m^2 over four years of monitoring during November through March. The 90th percentile of the catch rate data for the winter months in the Embayment was 30 silvery minnow per 100 m^2. This suggests that, on average, there was a greater catch rate of silvery minnows in the Embayment than found in the river nearby, that catch rate varied widely over 4 years, and that 90 percent of the catch rates were less than 30 silvery minnow per 100 m^2.

Factors affecting the Species Environment

Changes in Hydrology

There have been two primary changes in hydrology because of the construction of dams on the Rio Chama and Rio Grande that affect the silvery minnow: 1) loss of water in silvery minnow habitat, and 2) changes to the magnitude and duration of peak flows.

Loss of Water in Silvery Minnow Habitat

Prior to measurable human influence on the system, up to the 14th century, the Rio Grande was a perennially flowing, aggrading river with a shifting sand substrate (Biella and Chapman 1977). There is now strong evidence that the Middle Rio Grande first began drying up periodically after the development of Colorado’s San Luis Valley in the mid- to late 1800s (Scurlock 1998). After humans began exerting greater influence on the river, there are two documented occasions when the river became intermittent during prolonged, severe droughts in 1752 and 1861 (Scurlock 1998). The silvery minnow historically survived low-flow periods because such events were infrequent and of lesser magnitude than they are today. There were also no diversion dams to block repopulation of upstream areas, the fish had a much broader geographical distribution, and there were oxbow lakes, cienegas, lagoons, and sloughs associated with the Rio Grande that supported fish until the river became connected again.

Water use and management has resulted in a large reduction of suitable habitat for the silvery minnow. Agriculture accounts for up to 90 percent of surface water consumption in the Middle Rio Grande (Bullard and Wells 1992). The average annual diversion of water in the Middle Rio Grande by the Middle Rio Grande Conservancy District (MRGCD) was 0.7×10^7 m^3 (535,280 acre-feet [af]) for the period from 1975 to 1989 (U.S. Bureau of Reclamation [BOR] 1993). In 1990, total water withdrawal (groundwater and surface water) from the Rio Grande Basin in New Mexico was 2.3×10^9 m^3 (1,830,628 af), significantly exceeding input (Schmandt 1993). Water withdrawals have not only reduced overall flow quantities, but also caused the river to become locally intermittent or dry for extended reaches. Irrigation diversions and drains, riparian evapotranspiration, as well as a declining water table, significantly reduce water volumes in the river. However, the total water use (surface and groundwater) in the Middle Rio Grande by the MRGCD may range from 28 to 37 percent (S.S. Papadopulos & Associates, Inc. 2000; Bartolino and Cole 2002). A portion of the water diverted by the MRGCD returns to the river (through drains) and may be diverted from the river again for other uses, sometimes more than once (Bullard and Wells 1992). Although the river below Isleta Diversion Dam may be drier than in the past, small inflows may contribute to maintaining flows.

Since 2001, improvements to physical and operational components of the irrigation system have contributed to a reduction in the total diversion of water from the Middle Rio Grande by the MRGCD. Prior to 2001, average annual diversions were $0.8x10^7$ m^3 (630,000 af) and now they are approximately $0.5x10^7$ m^3 (370,000 af). The change was possible because of the considerable efforts by MRGCD and farmers to reduce crop irrigation, schedule and rotate water diversions among water users, and improve record keeping by installing new gages and automating gates at diversions. The new operations reduce the amount of water diverted; however, this also reduces return flows that previously supported flow in the river. In February 2007, the City and Albuquerque Bernalillo County Water Utility Authority with six conservation groups established a fund that will provide the opportunity to lease water from Rio Grande farmers and have that water remain in the river channel to support the silvery minnow and other beneficial uses of the water. The Pilot Water Leasing Project supports the need for reliable sources of water to support conservation programs as identified by the Middle Rio Grande Endangered Species Collaborative Program (for more information, see middleriogrande.com).

Groundwater withdrawals also affect flow in the Middle Rio Grande. However, under New Mexico State law, the municipal and industrial users are required to offset the effects of groundwater pumping on the surface water system (BOR 2003).

River reaches particularly susceptible to drying occur immediately downstream of the Isleta Diversion Dam (RM 169), a 8-km (5-mi) reach near Tome, New Mexico (RM 150–155), a 8-km (5-mi) reach near the U.S. Highway 60 Bridge (RM 127–132), and an extended 58-km (36-mi) reach from near Brown’s Arroyo (downstream of Socorro, New Mexico) to Elephant Butte Reservoir. Extensive fish kills, including tens of thousands of silvery minnows, have occurred in these lower reaches when the river has dried (Service 2003a). It is assumed that mortalities during river intermittence are likely greater than those documented, for example, due to predation by birds in isolated pools (Service 2010a). From 1996 to 2007, an average of 51 km (32 mi) of the Rio Grande dried each year, mostly in the San Acacia Reach. The most extensive drying occurred in 2003 and 2004 when 97 and 110.6 km (60 and 68.7 mi) respectively, were dewatered. Most documented drying events lasted an average of 2 weeks before flows returned. In contrast, 2008 was considered a wet year, with above average runoff and an average monsoon season. As a result, there was no river intermittency and no salvage of silvery minnow that year, which was the first time there has been no river drying since 1996. Intermittent river conditions in 2009, 2010, and 2011 resulted in approximately 20, 28 and 40 miles of dewatered channel.

Changes to Magnitude and Duration of Peak Flows

Water management has resulted in a loss of peak flows that historically triggered the initiation of silvery minnow spawning. The reproductive cycle of the silvery minnow is tied to the natural river hydrograph. A reduction in peak flows or altered timing of flows may inhibit reproduction. Since completion of Elephant Butte Dam in 1916, additional dams have been constructed on the Middle Rio Grande (Scurlock 1998). Construction and operation of these dams, which are either irrigation diversion dams (Angostura, Isleta, San Acacia) or flood control and water storage dams (Elephant Butte, Cochiti, Abiquiu, El Vado), have modified the natural flow of the river. Mainstem dams store spring runoff and summer inflow, which would normally cause flooding, and release this water back into the river channel over a prolonged period. These releases are often made during the winter months, when low flows would normally occur. For example, release of carryover storage from Abiquiu Reservoir to Elephant Butte Reservoir during winter 1995–96 represented a substantial change in the flow regime. The Corps consulted with the Service on the release of water from November 1, 1995 to March 31, 1996, during which time $0.1x10^7$ m^3 (98,000 af) of water was released at a rate of 9.2 m^3/s (325 cfs). Such releases depart significantly from natural, historical winter flow rates, and can substantially alter the habitat for silvery minnows. In spring and summer, artificially low flow may limit the amount of habitat available to the species and dispersal of the species (Service 1999).

In the spring of 2002 and 2003, an extended drought raised concerns that silvery minnows would not spawn because of a lack of spring runoff. River discharge was artificially elevated through short-duration reservoir releases during May to induce silvery minnow spawning. In response to the releases, significant silvery minnow spawning occurred in all reaches except the Cochiti Reach (Service 2010a).

By contrast, spring runoff in 2005 was above average, leading to a peak of over 170 m^3/s (6,000 cfs) at Albuquerque and sustained high flows greater than 85 m^3/s (3,000 cfs) for more than 2 months. These flows improved conditions for both spawning and recruitment (Dudley et al. 2005). October 2005 monitoring indicated a significant increase in silvery minnows in the Middle Rio Grande compared to 2003 and 2004. In 2006, however, October numbers declined again after an extremely low runoff period and channel drying in June and July (Dudley et al. 2006). October samples that year yielded no age-0 silvery minnows, indicating poor recruitment in the spring. Runoff conditions in 2007 to 2009 were average or above average and maintained a high catch rate (Dudley and Platania 2009).

Mainstem dams and the altered flows they create can affect habitat by preventing overbank flooding, trapping nutrients, altering sediment transport and temperature regimes, reducing and dewatering main channel habitat, modifying or eliminating native riparian vegetation, and creating reservoirs that favor nonnative fish species. These changes may affect the silvery minnows by reducing its food supply and quality; altering its preferred habitat, preventing dispersal, and providing a continual supply of nonnative fish that may compete with or prey upon silvery minnows. Altered flow regimes may also result in improved conditions for other native fish species that occupy the same habitat, causing those populations to expand at the expense of the silvery minnow (Service 1999).

In addition to providing a cue for spawning, flood flows maintain a channel morphology to which the silvery minnow is adapted. The changes in channel morphology that have occurred from the loss of flood flows are discussed below.

Changes in Channel and Floodplain Morphology

Historically, the Rio Grande was sinuous, braided, and freely migrated across the valley floodplain. Changes in natural flow regimes, narrowing and deepening of the channel, and restraints (jetty jacks) to channel migration adversely affected the silvery minnow. These effects result directly from constraints placed on channel capacity by structures built in the floodplain. These anthropogenic changes have and continue to degrade and eliminate spawning, nursery, feeding, resting, and refugia areas required for species' survival and recovery (Service 1993).

The active river channel within occupied habitat is also being narrowed by the encroachment of vegetation, resulting from continued flow reductions and the lack of overbank flooding. The lack of flood flows has allowed nonnative riparian vegetation, such as salt cedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*), to encroach on the river channel (BOR 2001). These nonnative plants are very resistant to erosion, resulting in channel narrowing and a subsequent increase in water velocity. Higher velocities result in fine sediment (e.g., silt and sand) being swept into the water column and redeposit further away, which leaves coarser bed materials such as gravel and cobble as the predominant substrate. Habitat studies during the winter of 1995 and 1996 (Dudley and Platania 1997), demonstrated that a wide, braided river channel with low velocities resulted in higher catch rates of silvery minnows, and narrower channels with higher velocities resulted in fewer fish captured. The availability of wide, shallow habitats that are important to the silvery minnow is decreasing. Narrow channels have few backwater habitats with low velocities that are important for silvery minnow fry and age-0 fish.

Within the current range of the silvery minnow, human development and use of the floodplain have greatly restricted the width available to the active river channel. A comparison of river area between 1935 and 1989 shows a 52 percent reduction, from 10,764 ha (26,598 acres) to 5,626 ha (13,901 acres) (Crawford et al. 1993). These data refer to the Rio Grande from Cochiti Dam downstream to the "Narrows" in Elephant Butte Reservoir. Within the same stretch, 378 km (235 mi) of levees occur, including levees on both sides of the river. Analysis of aerial photography taken by BOR in February 1992, for the same river reach, shows that of the 290 km (180 mi) of river, only 1.6 km (1 mi), or 0.6 percent of the floodplain has remained undeveloped. Development in the floodplain also makes it difficult, if not impossible, to send large quantities of water downstream that would create low velocity side channels that the silvery minnow prefers. As a result, reduced releases have decreased available habitat for the silvery minnows and allowed encroachment of nonnative species into the floodplain.

Water Quality

Many natural and anthropogenic factors affect water quality in the Middle Rio Grande. Water quality in the Middle Rio Grande varies spatially and temporally throughout its course primarily due to inflows of groundwater, as well as surface water discharges and tributary deliveries to the river (Ellis et al. 1993). Factors that are known to contribute to degraded fish habitat include temperature changes, sedimentation, runoff, erosion, organic loading, reduced oxygen content, pesticides, and an array of other toxic or hazardous substances. Both point source pollution (pollution discharges from a pipe or other discreet conveyances) and nonpoint source pollution (from diffuse sources such as urban stormwater runoff) affect the MRG (NMED 2007, 2009, 2010). Major point sources include discharges from wastewater treatment plants (WWTPs) and potentially from confined animal feeding operations (i.e., feedlots). Major nonpoint sources include agricultural activities, such as, fertilizer and pesticide application, excessive grazing; urban stormwater; atmospheric deposition; and mining activities (Ellis et al. 1993).

Effluents from WWTPs contain pollutants that may affect the water quality of the Rio Grande (Passell et al. 2007). It is anticipated that WWTP effluent may be a source of perennial flow during extended periods of drought or intermittency in the lower portion of the Angostura Reach. For that reason, the water quality of effluent discharges is extremely important. Near the project area, the largest WWTP discharges are from SWRP, followed by two WWTPs in Rio Rancho and Bernalillo (Bartolino and Cole 2002). Since 1989, ammonia and chlorine have been discharged unintentionally at concentrations that exceed protective levels for silvery minnows (Passell et al. 2007) as recently as 2011 (Chwirka 2011; Lusk 2011a). In addition to ammonia and chlorine, WWTP effluents may also include cyanide, chloroform, organophosphate pesticides, semivolatile compounds, volatile compounds, heavy metals, and pharmaceuticals and their derivatives, which can pose a health risk to silvery minnows when discharged in concentrations that exceed the water quality criteria or guidelines (Lusk 2003; NMED 2010). Additionally, even if the concentration of a single chemical compound is not harmful by itself, chemical mixtures can be more than additive in their toxicity to silvery minnows (Buhl 2002). Marcus et al. (2010) described the concentrations of chemicals in the Middle Rio Grande that may affect fish health or produce localized mortalities. However, the long-term effects and population-level impacts of toxic chemical discharges or other degraded water quality conditions in the Middle Rio Grande on silvery minnow over time have not been fully evaluated.

Dissolved Oxygen

DO is the amount of oxygen as measured dissolved in the water column (Benson and Krause 1980). The amount of DO in water depends upon the water temperature, atmospheric pressure, the surface area of water exposed to the atmosphere, and the oxygen byproduct of photosynthesis by aquatic plants (Odum 1956; Bott 1996). The capacity of water to hold oxygen in solution is inversely proportional to the water temperature (Benson and Krause 1980). DO is critical to the aquatic community and for the breakdown of organic matter in the Rio Grande. DO, at appropriate saturation, is essential to keeping fish and other aquatic organisms alive, and for sustaining their reproduction, development, vigor, immune capacity, behavior, movement, and predator response actions (Hughes 1973; Kramer 1987; Breitburg 1992; Pörtner and Peck 2010). DO can be lost from the water column because of aquatic life respiration and the oxygen demand of substances oxidizing in the water or sediment (Odum 1956; Bott 1996). Diurnal fluctuations in DO concentrations result from photosynthesis as a source of oxygen in excess of saturation during the day, and at night, when photosynthesis ceases and respiration consumes oxygen and reduces the DO concentrations in the water column (Ignjatovic 1968; Bott 1996). Hypoxia occurs when DO concentrations are below those expected at 100 percent saturation of oxygen between the air and water. Critically low DO levels (below 2 mg/L), are often termed anoxic.

Fish can attempt to compensate for low DO conditions by behavioral responses, such as increased use of ventilation of the aquatic surface, changes in activity level or habitat use, and avoidance behaviors, though these activities are known to come at a higher energy cost (Kramer 1987; British Columbia Ministry of the Environment (BCME) 1997). Below some threshold oxygen saturation, fish will be expending excess energy to maintain homeostasis and that some degree of physiological stress will occur (Heath 1995). For example, ventilation rates are often increased, reduced feeding and movement activity are decreased and increased glycolysis and cortisol release can be induced by short-term low DO conditions (Kramer 1987; Heath 1995; BCME 1997). Eventually fish suffocate at critically low DO concentrations and begin to die. Additionally, hypoxic conditions may also cause a wide range of chronic effects and behavior responses in fish (Downing and Merkens 1957; Davis 1975; Kramer 1987; Breitburg 1992).

Oxygen Demanding Substances

The depletion of oxygen from the water overlying the bottom sediment is primarily caused by the decomposition of organic matter in sediments. Sediment oxygen demand (SOD) has been defined as the rate of oxygen consumption, biologically or chemically, on or in the sediment at the bottom of a water body (Veenstra and Nolen 1991). The primary sources of SOD are often reduced or recalcitrant compounds (e.g., iron, manganese, ammonia, sulfides, etc.) in the sediments as well as algae, bacteria, and other sources of organic matter that settle out of the water column, or are resuspended with increased flow (Fillos and Molof 1972; Kreutzberger et al. 1980; Wang 1980; Walker and Snodgrass 1986, Caldwell and Doyle 1995). The sources of these compounds include erosion from stream banks, from bed sediment and as attached to suspended sediment, particulate organic matter, and constituents added from point and nonpoint sources, biotic deposits, and biotic activity. Kreutzberger et al. (1980) reported that low DO in the Milwaukee River was SOD churned up by the stormwater discharges scouring sediment into the water column. Another consequence of low DO conditions is that organic matter and sediments can also release ammonia, which can affect fish and their prey, thereby reducing the quality of suitable habitat (Merkens and Downing 1957; Fillos and Molof 1972; Thurston et al. 1981; Caldwell and Doyle 1995).

Floodplain Flooding and Hypoxic Water Return

Flooding of the floodplain during spring runoff is likely highly beneficial to the development and recruitment of silvery minnows as the flooded habitats provide cover, food, and low velocity nursery habitat. However, in the Middle Rio Grande, Valett et al. (2005) found that flooding of the riparian forest soils (Rio Grande floodplain or “bosque”) increased the rates of respiration during the flood pulse. In floodplains that were infrequently flooded, inundation of the forest resulted in widespread low DO in the floodwaters capable of affecting fish. For example, Abeyta and Lusk (2004b) reported a fish kill due to low DO in a large stagnant floodplain pool after flooding along the Middle Rio Grande. Contributions from the stagnant floodwaters into the main channel would also be expected to decrease the DO content within the Rio Grande downstream. Depending on how the annual cycle of the flood pulse influences primary productivity, plant respiration, decomposition of woody and other vegetation, and water residence time, floodplains may produce and retain enough organic matter to reduce the DO of floodwaters on an annual basis (Valett et al. 2005; DBS&A 2009). However, these flood events are not necessarily a "natural phenomena" as the flood frequency and depositional character of the Rio Grande floodplain has been substantially changed, and frequently flooded areas did not experience low DO conditions to the same extent as did infrequently flooded areas (Ellis et al. 1998; Valett et al. 2005).

Precipitation events of sufficient intensity can result in increased turbidity, increased or decreased water temperatures, and increased input of oxygen demanding substances (Huggins and Anderson 2005). Conditions in the Rio Grande that have led to increased erosion and sedimentation including natural or anthropogenic-induced variation in water and sediment discharge due to high and low flows, poor land management, flooding, catastrophic wildfires, or other activities (Graf 1994; Scurlock 1998; Julien et al. 2005; Massong et al. 2007). When tributaries and riverbeds are scoured by stormwater runoff or other events of sufficient velocity, and sediments are redistributed, the actions of sedimentation and elevated SSC likely creates mixing zones that may scour or smother sessile organisms (algae, bacteria, some invertebrates), and turbidity that shades light levels and reduces algae production, and creates stressful or suffocating conditions for fish at least temporarily until the sediment-water interface is stabilized and DO again increases (Huggins and Anderson 2005: Bixby and Burdett 2009). Moderate to large changes in any one of these factors as a result of a single or multiple events that can affect the level of DO in the Rio Grande and potentially adversely affect silvery minnows.

Petroleum, Hydrocarbons, and Spills

There are concerns about the potential petroleum spills (and other chemicals) from pipelines or during transportation in vehicles or by rail along and across the Rio Grande. Based on information reported in the National Response Center database (http://www.nrc.uscg.mil Accessed April 27, 2011), one spill incident involving crude oil occurred in the action area (upstream). In April 1999, a 41-cm (16-inch) transmission pipeline fitting was ruptured by a backhoe, releasing crude oil into the environment; reports indicated that some might have entered the Rio Grande. Fuels, such as diesel, that are carried by pipelines have documented toxicity to aquatic life due in part to semivolatile compounds. PAHs are known to occur during petroleum spills and may persist in contaminated sediments. These may be transported to fish tissues through foraging on contaminated sediments or prey where they can be toxic to fish (Eisler 1987; Schein et al. 2009). A petroleum pipeline break, if it were to spill into the Rio Grande, has the potential to reduce DO in the water column as well as contaminate the water, sediment and habitats of fish and wildlife, and could contribute to adverse effects on downstream water quality and silvery minnow habitat (Lusk 2010). However, the lack of available information on past spill events does not allow the estimation of these effects to silvery minnow or to forecast future frequency of spill events.

To understand the potential effects of polycyclic aromatic hydrocarbons (PAHs) on sediment, the data on PAHs in Rio Grande sediments can be compared to numerical sediment quality criteria (such as Threshold Effect Concentrations or Probable Effect Concentrations [PECs]) such as those proposed by MacDonald et al. (2000). Using sediment PAH concentrations in the Middle Rio Grande compared with guidelines similar to PECs, Marcus et al. (2010) identified heavy metal- and PAH-contaminated sediment as posing the greatest toxicity threat to silvery minnow.

PAH compounds have been detected in sediment for decades, and are widespread in the Rio Grande (Levings et al. 1998; NMED 2009; Marcus et al. 2010). PAHs can be associated with petroleum spills, parking lot runoff, but wet and dry atmospheric deposition from combustion activities is often a predominant source in the environment (Eisler 1987). PAHs in sediment are often toxic to aquatic life and may reduce prey populations, and when incorporated into prey or through sediment ingestion can become carcinogenic to fish and other predators (Eisler 1987).

According to MacDonald et al. (2000), most of the PECs provide an accurate basis for predicting toxicity to populations of aquatic life, and can form a reliable basis for assessing sediment quality in freshwater ecosystems. Levings et al. (1998) found one or more PAH compounds at 14 sites along the Rio Grande with high concentrations found below the City of Albuquerque, New Mexico. Using guidelines similar to PECs, the NMED (2009) identified PAHs as sediment contaminants of concern to silvery minnows, particularly at Alameda below the North Diversion Channel. Concentrations of naphthalene, an indicator PAH, ranged up to 17 µg/kg wet weight were found in silvery minnows collected from the Middle Rio Grande (Lusk 2011b). Except for evaluating the PAH concentrations in sediment quality criteria (e.g., PECs), there are few diagnostic criteria for the evaluation of PAHs in silvery minnows or methods of evaluation for potential effects to their prey, and how specifically silvery minnow behaviors, habitat, feeding, or health may be affected by their widespread exposure to PAHs in the Middle Rio Grande.

Sediment Quality

Sediment is inorganic (sand, silt, and clay are used to describe sediment particle sizes) and organic matter deposited below the water column in a river or other water body. It is an important component of fish habitat in the Rio Grande (Service 1999). Sediment suspended in the water column, from erosion and other processes, can be described in terms of suspended sediment concentration (SSC) or as total suspended solids (TSS), but these measurements are not identical (Gray et al. 2000). Sediment concentrations and suspended sediment loads are important sources of sediment contamination often conveyed by stormwater (Harwood 1995; EPA 2002). EPA (2002) identified a number of pollutants that are more likely to partition into sediment than remain dissolved in the water column, such as heavy metals, certain semivolatile organic compounds such as PAHs, PCBs, and organochlorine pesticides. Large precipitation events wash sediment and pollutants that adhere to sediment into the river from surrounding lands through storm drains and intermittent tributaries. Stormwater produces high levels of SSC and TSS, and consequently high levels of contaminants for those constituents that commonly bound to sediment particles, for example, metals, radionuclides, and PCBs (NMED 2009, 2010).

We reviewed the sediment quality baseline of the North Diversion Channel Embayment collected in 2011 (Hall Environmental Analysis Laboratory (HEAL) Inc., 2011), and collected in 2004 (Buhl 2011a), and sediment quality from the Angostura Reach of the Rio Grande (Abeyta and Lusk 2004a; Marcus et al. 2005) and compared the average concentrations from those areas with effect concentrations (e.g., PECs) that are described above and by MacDonald et al. (2000) or Marcus et al. (2005) (Appendix A). Several chemicals in sediments collected from the Embayment, or collected from the Rio Grande exceed thresholds such as PECs or TECs that are thought to be protective of silvery minnow habitat. However, many of the chemical analyses conducted on the sediments were not conducted with adequate quantification in order to detect the concentrations of those chemicals and compare them with PECs, TECs, or other effect thresholds. For example, concentrations of chlordane, mercury, and a variety of PAHs and pesticides were analyzed at detection levels well above those concentrations that may adversely affect fish and aquatic life (Appendix A). Therefore, additional and more sensitive analytical chemistry would be necessary to evaluate the quality of the sediment and its potential effects to silvery minnow habitat. Some chemicals, such as beta benzenehexachloride (BHC; a byproduct of the insecticide lindane previously used on crops and now banned), appeared to increase in the Embayment sediments. This could be attributed to additional sources within the basin, or variation in its measurement or the sample collection technique, or possibly, beta BHC accumulates in sediment under sunlight and anoxic conditions (Stenerson 2004) that have been reported in the Embayment. Additional information on the chemicals in sediment, at detection levels adequate to compare with effect thresholds would be necessary to adequately evaluate the quality of substrate used by silvery minnows in the Embayment and any potential effects.

Heavy Metals

The EPA (2010a) reviewed the ambient stormwater quality data for the Albuquerque stormwater permit (see NPDES Permit Number NMS000101. www.epa-otis.gov/otis/. Accessed April 27, 2011). The EPA (2010a) reported lead, zinc, bacteria, and cold temperature exceeded applicable water quality standards. There are no controls in place or proposed to reduce lead and zinc other than Best Management Practices (BMPs) for pollution prevention and reduction (EPA 2010b,c). In their Biological Evaluation, the EPA (2010a) reviewed the accumulation of lead and zinc in fish tissue and sediment. The lack of acute toxicity reported by Bio-Aquatic Testing Inc. (2010) and the lack of concentrations greater than those that are lethal to 50 percent of test animal populations was used in support of EPAs decision that that no additional controls for these heavy metals were necessary. The NMED (2010) confirmed that lead and zinc were below levels of concern in the action area during monitoring in 2007 to 2009. Numerous researchers (Roy et al. 1992; Schmitt et al. 2004; Buhl 2011b) have reported high zinc concentrations in fish collected from the Rio Grande and other large rivers in the West (Hinck et al. 2006). However, zinc concentrations in silvery minnows rarely exceed concentrations associated with adverse effects in those fish used in laboratory studies (Buhl 2011b).

PCBs

The chemicals known as PCBs are mixtures of synthetic organic chemicals with the same basic chemical structure and similar physical properties that range from oily liquids to waxy solids (EPA 2011). There are no known natural sources of PCBs. Because they are nonflammable with properties of chemical stability, high boiling point, and electrical insulation, PCBs were used in hundreds of industrial and commercial applications. Prior to 1974, PCBs were used both for nominally closed applications (e.g., capacitor and transformers, and heat transfer and hydraulic fluids) and in open applications (e.g., flame retardants, inks, adhesives, paints, pesticide extenders, plasticizers, surface coatings, wire insulators, and metal coatings) (see ASTDR 2001). While the production of PCBs was banned in 1979, there are many PCB containing applications still in use, which can become sources for PCBs in the environment (EPA 2011). PCBs enter aquatic environments from wet and dry atmospheric deposition, river inflows, groundwater flow, and discharges from industrial facilities. Deposition may be the most important source to water bodies such as large lakes, reservoirs and rivers (Wenning et al. 2010).

PCBs have been detected in the Middle Rio Grande samples from below the North Diversion Channel and in stormwater the San Jose Drain during stormwater runoff events (Yanicek 2006; NMED 2010). PCB concentrations in some of these stormwater samples exceeded New Mexico's water quality criteria for the protection of wildlife as well as human health criteria (NMED 2010). PCBs in suspended sediments (0.09 µg/g) in the Rio Grande at Alameda, New Mexico were 90 times the values for the Rio Grande above the North Diversion Channel. This indicates that stormwater likely conveyed PCBs to the Rio Grande (NMED 2010). The NMED (2010) noted a correlation between the concentrations of PCBs in suspended sediment and stormwater discharges, suggesting that management techniques that reduce suspended sediment in stormwater may reduce sediment contamination loads to the Rio Grande. Comparison of sediment PCBs (Yanicek 2006) with PCBs in fish tissue samples found similar patterns collected in the Rio Grande near Albuquerque, New Mexico (NMED 2010).

All fish collected from the Middle Rio Grande by the NMED (2009) contained detectable PCBs ranging from 12.4 to 120.2 nanograms per gram (ng/g) wet weight. The New Mexico Department of Game and Fish, New Mexico Department of Health, and New Mexico Environment Department (2010) subsequently issued fish consumption advisories to protect the angling public from PCB ingestion due to health concerns. Lusk (2011b) reported that all twelve samples of silvery minnows collected from the Middle Rio Grande contained detectable concentrations ranging from 4.7 to 38.2 ng/g wet weight. Olsson et al. (1999) reported skeletal deformities associated with fish injected with 360 ng/g PCBs on a lipid basis. Lusk (2011b) reported that silvery minnows had PCBs concentrations lower than 36 ng/g on a per lipid basis. This suggests that PCB-induced deformity would be unlikely in silvery minnows unless they were more sensitive to PCBs than were the test fish (*Danio rerio*). Compared to upstream, concentrations of PCBs are elevated in stormwater, sediment, and fish collected below the North Diversion Channel mixing zone; however, while the concentrations may pose a risk to human health and piscivorous wildlife, the concentrations detected do not exceed current known toxic effect levels (Wenning et al. 2011) within the silvery minnow.

Pesticides

Pesticide contamination can occur from agricultural activities, as well as from the cumulative impact of residential and commercial landscaping and other activities (Anderholm et al. 1995). Stormwater runoff, irrigation return, and riverside drain return flows and windblown dust and drift likely contribute a portion of pesticides to the Rio Grande. The presence of pesticides in surface water can depend on the amount applied, timing, location, and method of application. Water quality standards have not been set for many pesticides, and existing standards do not consider cumulative effects of several pesticides in the water at the same time or as part of the food chain. Ong et al. (1991) recorded the concentrations of heavy metals and organochlorine pesticides in water, suspended sediment and bed sediment samples between 1978 and 1988. Several researchers (Roy et al. 1992; Anderholm et al. 1995; Abeyta and Lusk 2004a; Langman and Nolan 2005; NMED 2009; Marcus et al. 2010) have all reported various pesticide residues detected in water, fish tissues, or sediment samples in the Middle Rio Grande.

Roy et al. (1992) reported that DDE, a degradation product of DDT, was detected in whole body fish collected throughout the Rio Grande. They suggested that fish in the lower Rio Grande were accumulating DDE in concentrations that may be harmful to fish and their predators. The NMED reported that two sites in the Angostura Reach contained total DDT at levels toxic to fish (Schmitt et al. 2004, see Table 15). Lusk (2011b) analyzed silvery minnows collected in the Rio Grande for DDT residues and found that the sum of DDT residues and metabolites ranged from 8.8 to 30.7 micrograms per kilogram (µg/kg) wet weight. The concentrations of DDT residues in silvery minnows, while elevated, were not above concentrations of concern for lethality (890 µg/kg wet weight), but may be associated with sublethal effects (greater than 5 µg/kg wet weight) particularly if similar DDT residues are found in silvery minnow eggs (Beckvar and Lotufo 2011), or to other fish and those that consume them (Schmitt et al. 2004; Lusk 2011b).

Other Stressors

In addition to the compounds and conditions discussed above, several other constituents are present and affect the water quality of the Rio Grande. These include nutrients such as forms of nitrates and phosphorus, total dissolved solids (salinity), and radionuclides. Pollutants and physical stressors have the potential to affect the aquatic ecosystem and the health of silvery minnows. Other physical stressors can also affect silvery minnows. For example, as the river dries, pollutants and temperatures tend increase in isolated pools (Caldwell et al. 2009). Toxic pollutants have not eliminated all silvery minnows in the Middle Rio Grande, though some localized mortalities have been documented (Marcus et al. 2010). Papoulias et al. (2009) suggested that the amount and variety of stressors in the Middle Rio Grande, combined, may nonetheless be affecting the health of silvery minnows as observed through changes in tissues.

Climate Change

“Climate” refers to an area's long-term average weather statistics (typically for at least 20- or 30-year periods), including the mean and variation of surface variables such as temperature, precipitation, and wind. “Climate change” refers to a change in the mean and variability of climate properties that persists for an extended period (typically decades or longer), whether due to natural processes or human activity (Intergovernmental Panel on Climate Change [IPCC] 2007a). Although changes in climate occur continuously over geological time, changes are now occurring at an accelerated rate. For example, at continental, regional, and ocean basin scales, recent observed changes in long-term trends include: a substantial increase in precipitation in eastern parts of North American and South America, northern Europe, and northern and central Asia, and an increase in intense tropical cyclone activity in the North Atlantic since about 1970 (IPCC 2007a); and an increase in annual average temperature of more than 1.1 °C (2 °F) across U.S. since 1960 (Karl et al. 2009). Examples of observed changes in the physical environment include: an increase average sea level, declines in mountain glaciers and declines in average snow cover in both hemispheres (IPCC 2007a); substantial and accelerating reductions in Arctic sea-ice (e.g., Comiso et al. 2008), and a variety of changes in ecosystem processes, the distribution of species, and the timing of seasonal events (e.g., Karl et al. 2009).

The IPCC used Atmosphere-Ocean General Circulation Models and various greenhouse gas emissions scenarios to make projections of climate change globally and for broad regions through the 21st century (Meehl et al. 2007; Randall et al. 2007), and reported these projections using a framework for characterizing certainty (Solomon et al. 2007). Examples include: 1) it is virtually certain there will be warmer and more frequent hot days and nights over most of the earth's land areas; 2) it is very likely there will be increased frequency of warm spells and heat waves over most land areas, and the frequency of heavy precipitation events will increase over most areas; and 3) it is likely that increases will occur in the incidence of extreme high sea level (excluding tsunamis), intense tropical cyclone activity, and the area affected by droughts (IPCC 2007b, Table SPM.2). More recent analyses using a different global model and comparing other emissions scenarios resulted in similar projections of global temperature change across the different approaches (Prinn et al. 2011).

All models (not just those involving climate change) have some uncertainty associated with projections due to assumptions used, data available, and features of the models; with regard to climate change this includes factors such as assumptions related to emissions scenarios, internal climate variability and differences among models. Despite this, however, under all global models and emissions scenarios, the overall projected trajectory of surface air temperature is one of increased warming compared to current conditions (Meehl et al. 2007; Prinn et al. 2011). Climate models, emissions scenarios, and associated assumptions, data, and analytical techniques will continue to be refined, as will interpretations of projections, as more information becomes available. For instance, some changes in conditions are occurring more rapidly than initially projected, such as melting of Arctic sea ice (Comiso et al. 2008; Polyak et al. 2010), and since 2000 the observed emissions of greenhouse gases, which are a key influence on climate change, have been occurring at the mid- to higher levels of the various emissions scenarios developed in the late 1990's and used by the IPCC for making projections (Raupach et al. 2007, Figure 1; Pielke et al. 2008; Manning et al. 2010, Figure 1). The best scientific and commercial data available indicates that average global surface air temperature is increasing and several climate-related changes are occurring and will continue for many decades even if emissions are stabilized soon (Meehl et al. 2007; Church et al. 2010; Gillett et al. 2011).

Changes in climate can have a variety of direct and indirect impacts on species, and can exacerbate the effects of other threats. Rather than assessing "climate change" as a single threat in and of itself, we examine the potential consequences to species and their habitats that arise from changes in environmental conditions associated with various aspects of climate change. For example, climate-related changes to habitats, the quality, availability, and timing of prey to developing fish and wildlife, predator-prey relationships, disease and disease vectors, or conditions that exceed the physiological tolerances of a species, or that alter the rate of metabolic and biochemical processes within organisms, the occurring individually or in combination, may affect the status of a species. Vulnerability to climate change impacts is a function of sensitivity to those changes, exposure to those changes, and adaptive capacity (IPCC 2007a; Glick et al. 2011). As described above, in evaluating the status of a species, the Service uses the best scientific and commercial data available, and this includes consideration of direct and indirect effects of climate change. If a species is listed as threatened or endangered, knowledge regarding its vulnerability to, and impacts from, climate-associated changes in environmental conditions can be used to help evaluate expected effects of the action for this BO, as well as to help devise appropriate strategies for species recovery.

While projections from global climate model simulations are informative and in some cases are the only or the best scientific information available, various downscaling methods are being used to provide higher-resolution projections that are more relevant to the spatial scales used to assess impacts to a given species (see Glick et al. 2011). With regard to the area of analysis for the silvery minnow, the following downscaled projections are available.

The New Mexico Office of the State Engineer report (2006) made the following observations about the impact of climate change in New Mexico:

1. warming trends in the Southwest exceed global averages by about 50 percent;
2. modeling suggests that even moderate increases in precipitation would not offset the negative impacts to the water supply caused by increased temperature;
3. temperature increases in the Southwest are predicted to continue to be greater than the global average;
4. there will be a delay in the arrival of snow and acceleration of spring snow melt, leading to a rapid and earlier seasonal runoff; and
5. the intensity, frequency, and duration of drought may increase.

Most of the upper Rio Grande basin is arid or semiarid, generally receiving less than 25 cm (10 in) of precipitation per year (BOR 2011b). In contrast, some of the high mountain headwater areas receive on average over 100 cm (40 in) of precipitation per year. Most of the total annual flow in the Rio Grande basin results, ultimately, from runoff from mountain snowmelt (BOR 2011b). In the Middle Rio Grande, there is expected earlier peak streamflows, reduced total streamflows, and more water lost to evaporation (Hurd and Coonrod 2007).

Climate change predicts four major impacts on silvery minnow habitat: 1) increased water temperature; 2) decreased streamflow; 3) a change in the hydrograph; and 4) an increased occurrence of extreme events (fire, drought, and floods). These impacts may affect the amount and qualities of silvery minnow habitat, silvery minnow physiology, phrenology (the timing and availability of resources necessary for silvery minnow growth to maturity), and biological interactions with other aquatic and terrestrial species.

Increased water temperature

Kundzewicz et al. (2007) found that of all ecosystems, freshwater ecosystems will have the highest proportion of species threatened with extinction due to climate change. Small changes in water temperature are known to have considerable effects on freshwater fishes by affecting a variety of life history, behavioral, and physiological aspects (Morgan et al. 2001; Carveth et al. 2006). Alterations in the temperature regime from natural background conditions negatively affect population viability, when considered at the scale of the watershed or individual stream (McCullough 1999). Both silvery minnow hatching and larval development are affected by high temperatures (Platania 2000). The density, type and seasonal availability of prey available to developing larvae and maturing silvery minnow, the amount of primary productivity and oxygen saturation are also affected by higher temperatures. As such, the slivery minnow may be adversely affected by increased water temperature due to climate change.

Decreased streamflow

Consistent with the outlook presented for New Mexico, Hoerling and Eischeid (2007) states that, relative to 1990 through 2005, simulations indicate that a 45 percent decline in streamflow will occur from 2035 through 2060 in the Southwest. Current models suggest a decrease in precipitation in the Southwest (Kundzewicz et al. 2007; Seager et al. 2007) that would lead to reduced streamflows and a reduced amount of habitat for silvery minnows. Streamflow is predicted to decrease in the Southwest even if precipitation were to increase moderately (New Mexico Office of State Engineer 2005; Hoerling and Eischeid 2007). Winter and spring warming causes an increased fraction of precipitation to fall as rain, resulting in a reduced snow pack, an earlier snowmelt, and decreased summer base flow (Regonda et al. 2005; Stewart et al. 2005). Earlier snowmelt and warmer air temperatures can lead to a longer dry season. Warmer air temperatures lead to increased evaporation, increased evapotranspiration, and decreased soil moisture. These factors could lead to decreased streamflow even if precipitation increased moderately.

The effects of decreased streamflow on the Rio Grande include smaller wetted area; more frequent intermittent or dry conditions; and greater conflicts among water users (Hurd and Coonrod 2007). As such, there will be reduced habitat available for aquatic species. As the river becomes more intermittent, fish isolated in pools may be subject to increased stress and predation.

Change in the hydrograph

Another documented effect of climate change is that warming in the Southwest has resulted in a shift of the timing of spring snowmelt (BOR 2011b). Stewart et al. (2005) show that timing of spring streamflow in the Southwest during the last 5 decades has shifted so that the major peak now arrives 1 to 4 weeks earlier, resulting in less flow in the spring and summer. They conclude that almost everywhere in North America, a 10 to 50 percent decrease in spring-summer streamflow fractions will accentuate the seasonal summer dry period with important consequences for water supplies, ecosystems, and wildfire risks (Stewart et al. 2005). Enquist et al. (2008) found that 93 percent of New Mexico’s watersheds have become relatively drier from 1970 to 2006 and that snowpack in New Mexico’s major mountain ranges has declined over the past 2 decades. The timing of peak streamflow from snowmelt in New Mexico is an average of 1 week earlier than in the mid-20th century (Enquist et al. 2008). Watersheds with the greatest declines in snowpack are those that have experienced the greatest drying from 1970 to 2006. Dust storms, associated with drought-stricken or poorly managed land can also influence snow albedo (reflectance), which can affect snowpack and the timing of snowmelt (Breed and Reheis 1999; Yasunari et al. 2011). Increased winter temperatures can cause more precipitation to fall as rain instead of snow resulting in earlier spring peak streamflow (Regonda et al. 2005). Rauscher et al. (2008) suggest that with air temperature increases of 3 to 5 ºC (37 to 41 ºF), snowmelt runoff in the Southwest could occur as much as 2 months earlier than present. Changes in the hydrograph could potentially alter the native fish assemblages, prey availability, and affect the reproductive success of the silvery minnow that is dependent on river flow pulses to spawn (Platania and Hoagstrom 1996).

Increased occurrence in extreme events

It is anticipated that an increase in extreme events (droughts, floods, fires) will most likely affect populations living at the edge of their physiological tolerances. The predicted increases in extreme temperature and precipitation events may lead to dramatic changes in the distribution of species or to their extirpation or extinction (Parmesan and Matthews 2006). Of these extreme events, drought intensity may be most important to the silvery minnow.

Overall, the predicted effects of climate change are expected to result in degradation of the remaining silvery minnow habitat, with potential adverse consequences on species viability.

<u>Ongoing and Past Projects in the Middle Rio Grande including those in the Angostura Reach</u>

The Service has issued permits authorizing take for scientific research and enhancement purposes under ESA section 10(a)(1)(A), and incidental take under section 7 for Federal actions. Applicants for ESA section 10(a)(1)(A) permits must also acquire a permit from the State of New Mexico to “take” or collect silvery minnows. Many of the section 10 permits issued by the Service allow take for the purpose of collection and salvage of silvery minnows and their eggs for captive propagation. Eggs, larvae, and adults are also collected for scientific studies to further our knowledge about the species and how best to conserve the silvery minnow. Because of the population decline from 2002 to 2004, the Service has reduced the amount of take permitted for voucher specimens in the wild.

The Service has conducted numerous section 7 consultations on past projects in the Middle Rio Grande. In 2001 and 2003, the Service issued jeopardy biological opinions resulting from programmatic section 7 consultations with BOR and Corps, which addressed water operations and management on the Middle Rio Grande and the effects on the silvery minnow and flycatcher (Service 2001, 2003a). Incidental take of listed species was authorized associated with the 2001 programmatic BO (Service 2001), as well as consultations that tiered off that BO.

A jeopardy biological opinion was issued on March 17, 2003 (2003 BO), and is the current programmatic biological opinion on water operations for the Middle Rio Grande, and contains one RPA with multiple elements (Service 2003a). These elements set forth a flow regime in the Middle Rio Grande and describe habitat improvements necessary to alleviate jeopardy to both the silvery minnow and flycatcher. In 2005, the Service revised the incidental take statement (ITS) for the 2003 BO using a formula that incorporates October monitoring data, habitat conditions during the spawn (spring runoff), and augmentation (Service 2005a). Incidental take of silvery minnows is authorized with the 2005 BO revised ITS, and now fluctuates on an annual basis relative to the total number of silvery minnows found in October across the 20 population monitoring locations. Incidental take is authorized through consultations tiered off this programmatic BO and on projects throughout the Middle Rio Grande.

Within the Angostura Reach, the Service has conducted various section 7 consultations on past projects, including the following:

- In 1999, the Service consulted with BOR on a restoration project on the Santa Ana Pueblo in an area where the river channel was incising and eroding into the levee system. The Service anticipated that up to 36,688 silvery minnows would be harassed by construction, fill placement in the river, and movement of equipment; no mortality was expected (Service 1998).
- In 2003, the Service completed consultation with the BOR on the City's Drinking Water Project, which involved the construction and operation of a new surface diversion at Alameda in the action area, conveyance of raw water to a new treatment plant, transmission of treated water to customers throughout the Albuquerque metropolitan area, and aquifer storage and recovery. The Service anticipated that up to 20 silvery minnows would be killed or harmed during construction, up to 25,000 eggs would be entrained each year at the diversion, and up to 7,000 larval fish would be harmed, wounded, or killed during operational activities (Service 2004).
- The Service consulted on habitat restoration projects on the Rio Grande near Albuquerque, including the 2005 Phase I, the 2007 Phase II, and the 2009 Phase IIa projects (Service 2005a, 2007b, 2009a) with BOs issued that reviewed the effects on silvery minnows. Incidental take authorized included 190 silvery minnows in 2005 due to harm or harassment, in 2007 the harassment of up to 3,365 minnows and mortality of up to 341 minnows, and in 2009 the harassment of up to 4,094 minnows and mortality of up to 187 silvery minnows.
- In 2006 and 2007, the Service consulted with BOR on the Bernalillo Priority Site Project and the Sandia Priority Site Project for river maintenance activities (Service 2006b, 2006c). The Bernalillo project was anticipated to kill no more than 42 silvery minnows due to channel modification, berm removal, dewatering, and sediment deposition in the river. The most recent consultation on the Sandia Priority Site Project concluded that take of up to 539 silvery minnows, and harassment of 53,853 silvery minnows would occur due to construction activities.
- In 2007, the Service determined through consultation with the Corps on the Rio Grande Nature Center Habitat Restoration Project, that up to 10 silvery minnows would be harassed during construction and that up to 154 silvery minnows would be killed due to entrapment in constructed channels (Service 2007c).
- In 2007, consultation on the Corrales Siphon River Maintenance Project concluded that the harassment of up to 244 silvery minnows would occur during construction, fill placement in the river, and movement of equipment (Service 2007d).
- In 2008, the Service concluded an intra-Service consultation on the Pueblo of Sandia Management of Exotics for the Recovery of Endangered Species Habitat Restoration Project. The Service anticipated that up to 2,449 silvery minnows would be harassed due to construction, and up to 770 killed due to potential entrapment in channels (Service 2008b).
- In 2009, the Service concluded a consultation with the BOR on the Pueblo of Sandia Bosque Rehabilitation Project, which anticipated that up to 85 silvery minnows, would be harassed during the proposed restoration activities, and up to 269 would be killed due to potential entrapment in a restored channel (Service 2009b).

- In 2010, the Service consulted with BOR for a habitat restoration project located on the Pueblo of Sandia. The Service anticipated that take in the form of harassment may affect up to 36,318 silvery minnows due to proposed construction and river crossings, as well as the harassment and mortality of up to six silvery minnows due to potential stranding in restored features after peak flows recede (Service 2010c).
- In 2011, the Service consulted with the Army Corps of Engineers on the Middle Rio Grande Bosque Restoration Project located in Bernalillo and Sandoval Counties. The Service anticipated that up to 6,988 silvery minnows would be harassed due to the proposed construction, and up to 8,471 silvery minnows would be harassed or killed due to potential stranding in restored habitat features (Service 2011a).
- In 2011, the Service consulted with the US Forest Service and the New Mexico State Land Office on a restoration project located in the Albuquerque reach. The Service anticipated that up to 96 silvery minnows would be harassed due to the proposed construction and up to 9 silvery minnows would be harassed and killed due to potential stranding in restored habitat features (Service 2011b).
- In 2011, the Service consulted with the EPA (and AMAFCA and other applicants) on the effects of proposed issuance of the Albuquerque stormwater permit (EPA 2011a,b,c) including stormwater discharged through the North Diversion Channel. The Service anticipated that up to 10,548 would be harassed and up to 1,528 silvery minnows would likely suffocate due to low oxygen conditions as Embayment water was pushed into the Rio Grande by stormwater discharges (Service 2011c).

Summary of the Environmental Baseline

The remaining population of the silvery minnow in the Middle Rio Grande is restricted to approximately 7 percent of its historical range. With the exception of 2008, every year since 1996 has exhibited at least one drying event that has negatively affected silvery minnows. The species is unable to expand its distribution because of poor habitat quality and Cochiti Dam prevents upstream movement and Elephant Butte Reservoir blocks downstream movement (Service 1999). Augmentation of silvery minnows with captive-reared fish has been ongoing, and monitoring and evaluation of these fish provide information regarding the survival and movement of individuals.

Water withdrawals affect the survival of silvery minnow. The consumption of surface water and shallow groundwater for municipal, industrial, and irrigation uses continues to reduce the flow in the Rio Grande and degrade habitat for the silvery minnow (BOR 2003, 2011a). The effect of water withdrawals means that discharges from WWTPs and irrigation return flows will have greater importance to silvery minnows and affect water quality. Lethal levels of chlorine and ammonia have been released from the WWTPs within the last year. Stormwater discharges appear to contribute to low DO conditions in the Rio Grande that can harm the feeding and sheltering activities of silvery minnows. In addition, a variety of organic chemicals, heavy metals, and pesticides have been documented in stormwater or wastewaters feeding into the river and that cumulatively contribute to the overall degradation of water and sediment quality.

Various conservation efforts have been undertaken in the past and others are currently being carried out in the Middle Rio Grande for the benefit of the silvery minnow. Population monitoring indicates that densities of this species have increased compared to extremely low levels seen in 2002 and 2003. However, current data show catch rates are lower than levels at the time of its listing as an endangered species in 1994 (Dudley and Platania 2011b). The threat of extinction for the silvery minnow continues because of decreased water availability, increased reliance on captive propagation, the degraded, fragmented, and isolated nature of occupied habitat, and the absence of the silvery minnow throughout most of its historical range.

IV. EFFECTS OF THE ACTION

Regulations implementing the ESA (50 CFR 402.02) define the *effects of the action* as the direct and indirect effects of an action on the species or designated critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, which will be added to the environmental baseline. Indirect effects are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification; interdependent actions are those that have no independent utility apart from the action under consideration. The following section describes the anticipated effects on silvery minnows resulting from the proposed action. Designated critical habitat for the silvery minnow is present in the action area, in the mainstem downstream of the Embayment Project area; however, effects to designated critical habitat are expected to be beneficial.

Effects on Silvery Minnows

The Service anticipates that all silvery minnows entrapped in the Embayment will be adversely affected, and several hundred of those may die during dewatering and construction activities, but a large proportion of those entrapped can be rescued (though a portion of those silvery minnows that are rescued may also subsequently die as a result of the cumulative stress and handling during their capture and translocation to the river nearby). Adverse effects to silvery minnows can be expected from their entrapment in the Embayment between the silt fences and coffer dams that will significantly impair their behavioral patterns and their ability to disperse to the river. There will be additional stress associated from harassment that may occur during various mechanical activities associated with installation of the silt fences and coffer dams. During water pumping activities (dewatering the Embayment), there will be death and injury to the health of silvery minnows associated with the stress of confinement, as well as from the reduction of their sheltering and feeding habitat, and degradation of the water quality remaining in the pool. Construction activities are expected to disturb sediment and release the oxygen demanding or other chemicals into the water column and thereby degrade water quality. Other sediment disturbing activities, including the startle response activities of larger fish, and fish rescue crew operations, as well as dewatering, are also expected to further degrade water quality, and adversely affect those silvery minnows that remain in water of degraded quality.

As described earlier, the action area includes the Embayment Project Area including the Embayment, any areas associated with construction activities, sediment hauling, dust suppression, revegetation, fish rescue, and the connection of the Embayment to the Angostura Reach of Rio Grande, after the project is completed. The action area includes all areas indirectly affected by the proposed project, which include the Angostura Reach of the Middle Rio Grande downstream of the Embayment that will be benefitted by water quality improvements. Silvery minnows are present in the Embayment, as well as in the Angostura Reach of the Middle Rio Grande nearby (Remshardt 2010a). Monitoring data available from the Embayment indicate that silvery minnows will be exposed to proposed Embayment Project activities. The two most recent monitoring events in the Embayment occurred in March 2011, which indicated a catch rate of 0.4 silvery minnow per 100 m^2, whereas, data collected in November 2011, indicated a catch rate of 0 silvery minnow per 100 m^2 (Remshardt 2011b,c). During the time of year when construction will occur (originally scheduled to occur November through March), the average catch rate was 13 silvery minnows per 100 m^2 (BA, p. 23). However, as discussed below, the catch rates fluctuated widely most likely based on the patchy distribution of silvery minnows found within the Embayment (BA).

Despite the availability of monitoring data from the Embayment, the actual maximum number of silvery minnows in the Embayment is not known with certainty and has varied over time (BA; Remshardt 2011a). Complete dewatering of the Embayment, which would result in the death of all silvery minnows, if counted, would result in the certainty of the maximum number of silvery minnows that inhabit the Embayment; but such an action would be unacceptable as well as prohibited. Therefore, we assumed that the maximum density of silvery minnows in the Embayment during the proposed project activities was equal to the 90th percentile of all monitoring data conducted during winter months over the 4 years of sampling, or 30 silvery minnow per 100 m^2. Using the area of Embayment (18,899 m^2; 4.67 acres including the wetlands), times the maximum density of 30 silvery minnow per 100 m^2; we have determined that the maximum number of silvery minnows in the Embayment could be 5,670 (30/100 x 18,899 = 5,670). This is the maximum number of silvery minnows that may be adversely affected by the proposed action. The actual number of silvery minnows that may be affected could be less if , for example, some silvery minnows have sought deeper habitats in the river due to colder weather (Dudley and Platania 1997) than has occurred during the previous monitoring efforts, or the distribution of silvery minnows in the Embayment were affected by recent low oxygen events (Service 2011c). If the number of silvery minnows found in the Embayment turns out to be greater than those described in this BO (i.e., 5,670 silvery minnows), this consultation should be reinitiated as described below.

Beneficial Effects

The proposed action is anticipated to have beneficial effects on silvery minnows in the long-term by enhancing their habitat and water quality conditions (i.e., reducing low DO events) in the Embayment and downstream (Service 2011c). The area of the Embayment accessible to silvery minnows will increase 55 percent and it will be revegetated with wetland plants that will provide additional food and cover. After construction, there will be an increased amount of low velocity habitat in the Embayment; such habitat conditions would be expected to benefit silvery minnows through improved egg and larval retention, increased recruitment rates, increased feeding area, and increased survival of both YOY and adults (Dudley and Platania 1997; Service 2010b). After the Embayment Project is completed, the Embayment area surface area (with wetlands) will be increased to approximately 8.5 acres (34,398 m^2), and therefore, if proportionate, the maximum number of silvery minnows that could use the Embayment during winter would be expected to be no more than 10,319 individuals (30/100 x 34,398 = 10,319). Additional beneficial effects to silvery minnows downstream (Service 2011c) and to silvery minnow critical habitat are also expected (see effects on silvery minnow critical habitat, below).

Effects of Mechanical Activities

Short-term adverse effects on silvery minnows may occur due to disturbance during reconnaissance, and installation of the silt fences and coffer dams. We expect silvery minnows will be present during the closure of the Embayment and will be harassed temporarily as a direct effect of the proposed activities (e.g., installation of the silt fences and coffer dams). Silvery minnows are expected to exhibit an avoidance response to these activities and given the operating speed and location of equipment, as well as the small area affected, we do not expect fish will be directly injured. Avoidance behavior, or fleeing from the disturbance, represents a disruption in normal behaviors and an expenditure of energy that an individual silvery minnows would not have experienced in the absence of the proposed action. However, this form of harassment is expected to be short in duration, with pre-exposure behaviors to resume after fleeing the disturbance.

Effects of Confinement during Dewatering Activities (see also Water Quality Degradation)

As dewatering activities commence, the volume of water between the coffer dams will be reduced, and isolated pools may form along the Embayment bottom. Caldwell et al. (2009) reported on studies that assessed the physiological responses of wild silvery minnows subjected to isolation in pools (as well as their collection and transport associated with silvery minnow rescue). Caldwell et al. (2009) evaluated silvery minnows for primary (plasma cortisol), secondary (plasma glucose and osmolality), and tertiary indices (parasite and incidence of disease) and concluded that the effects of stressors associated with isolation in pools as well as rescue activities resulted in a cumulative stress response in wild silvery minnows. Caldwell et al. (2009) concluded that fish in isolated pools experienced a greater exposure and greater vulnerability to pathogens (parasites and bacteria), than fish in perennial waters, although the stress response and subsequent disease effects were reduced after modifications of the Service's rescue protocols and after silvery minnows were returned to perennial waters.

There are water quality effects on fish species, their health, abundance and assemblage structure when their habitats are reduced to isolated pools. Some of the effects have been attributed to stochastic events such as transient periods of high water temperature or low dissolved oxygen concentration (Meyerhoff and Lind 1987; Mundahl 1990; Ostrand and Marks 2000). In addition, as pools evaporated, specific conductance increased and volume and turbidity are decreased (Ostrand and Wilde 2004). Decreases in cyprinid presence and abundance occurred concurrently with increases in specific conductance and decreases in volume in pools. For example, Ostrand and Wilde (2004) found that the numbers of plains minnows decreased after the specific conductance (or salinity) had increased and as volume and turbidity decreased in isolated pools. As the volume of water is reduced, and amount of suspended solids, salts, and nutrients or other chemicals in the water column increases, the degraded water quality may affect their osmoregulatory function, plasma glucose and osmolality, increase their stress response, alter their behavior, and depending on the duration, magnitude and frequency of exposure to degraded water quality conditions in pools of reducing volume, these exposures may eventually immobilize or kill them. As pools recede, cover for silvery minnows may also be reduced exposing individuals to aquatic or avian predators. Daily survivorship of silvery minnows in isolated pools (during summer, however) ranged from 58 to 87 percent and averaged 76 percent (Valdez 2011) beginning 1 day after their isolation.

With the incorporation of fish rescue operations into the Embayment Project activities, especially during dewatering and prior to construction, the number of silvery minnows that may die will be reduced. In isolated pools, the Service's rescue activities can retrieve anywhere from 50 to 99 percent of the silvery minnows that may inhabit the isolated pool (J. Brooks, Service, oral communication, November 30, 2011), with success rates varying according to pool complexity. As the Embayment is a large, complex pool, we assume that only 50 percent of the silvery minnows that inhabit the pools during dewatering can be rescued on a daily basis with multiple seine haul passes. Therefore, after the first day of dewatering activities reduces the water to isolated pools, as many as 50 percent of the maximum number of individuals can be rescued per day (i.e., 0.50 x 5,670 = 2,836 individuals that could be rescued on Day 1; 0.5 x 2,836 = 1,418 on Day 2; etc., but see below for a full calculation that includes daily mortality rates).

However, after the first full day of isolation, we would expect some silvery minnows will experience confinement stress and water quality effects and may perish. As the dewatering activities are occurring in the winter months, thereby reducing the likelihood of high temperature and low oxygen conditions, as well as migratory bird predators may be fewer in number, we used the high estimate of survivorship (86.6 percent) provided by Valdez (2011) on a daily basis to estimate the mortality expected by their isolation and confinement stress to silvery minnows. Therefore, on Day 2 (after the first full day of isolation) we would expect 13.4 percent mortality or no more than 380 silvery minnows (0.134 x 2,836 = 380). On Day 3, we would expect (((2,836-380 mortalities =2,456) x 0.5 rescued on Day 3) = 1,228 remaining in the pool x 13.4 = 165) as many as 165 silvery minnows would perish. On Day 4, we would expect (((1,228-165 mortalities) x 0.5 rescued on Day 4) = 1,063 remaining in the pool x 13.4 = 72) as many as 72 silvery minnows would perish. On Day 5, we would expect (((532-72 mortalities = 460) x 0.5 rescued on Day 5) = 230 remaining in the pool x 13.4 = 31) as many as 31 silvery minnows would perish. [Note that during these calculations, all decimal values were rounded to the nearest whole minnow, and therefore, the sum of the total number of fish rescued and the total number of fish in Table 1, that included estimates of the numbers of rescued fish, are off by 3 silvery minnows, due to these round off errors]. Silvery minnow that avoid capture by rescue efforts will likely remain in the pools of water at the bottom of the Embayment. All of those that remain will likely perish (199 silvery minnows) due to water quality degradation (see below).

Table 1 depicts our expectation of the number of silvery minnows that may be rescued and the number of mortalities that may be expected with dewatering and construction activities. All totaled, up to 847 silvery minnow may perish during dewatering activities and confinement in isolated pools, and up to 4,826 silvery minnows may be rescued. We expect that approximately 199 silvery minnows will escape all capture attempts, and will remain in the water at the bottom of the Embayment during construction activities, and may subsequently die due to water quality degradation. Of those silvery minnows rescued, as many as 290 may die due to cumulative and handling stress. The numbers of silvery minnows used in these estimates are based on the best scientific information available; however, actual daily catch rates may vary due to the size of pool, environmental conditions in the pool, and the logistics of fish rescue operations.

Additionally, mortality associated with confinement and water quality degradation may not occur until several days after the dewatering activities and are not as described as a daily event. However, 847 individuals is the maximum estimate of the silvery minnows that are expected to die during the Embayment Project activities. If more mortalities of silvery minnows occur in the Embayment during project activities that are greater than expected (i.e., 847 silvery minnows), then this consultation should be reinitiated as described below. Subsequent adverse effects that occur to silvery minnows that are captured during the Service's rescue operations (as many as 4,826 individuals), as well as any subsequent mortalities that may occur due to cumulative and handling stress (up to 290 silvery minnows), are not attributed to the proposed Embayment Project, but will be attributed to the intentional rescue and salvage activities that are covered by the Service's 10(a)(1)(A) permit.

Table 1. Estimated number of Rio Grande silvery minnows in the Embayment, the number of silvery minnows rescued daily, the number of silvery minnows that may die, post-rescue due to cumulative and handling stress, and the number of mortalities expected in the Embayment due to confinement stress and water quality degradation associated with the proposed activities. [*Note: during division calculations all decimal values were rounded to the nearest whole number, and therefore, column sums may not total exactly due to these round off errors (i.e., 3 silvery minnows)]

Days after start of dewatering	Estimated number of silvery minnows in Embayment	Estimated number of silvery minnows rescued per day	Estimated number of silvery minnows rescued that may die, post-rescue in Angostura Reach	Estimated number of silvery minnows that escape rescue and may die daily in the Embayment
Day 1	5,670	0	0	0
Day 2	5,670	2,836	170	380
Day 3	2,456	1,228	74	165
Day 4	1,063	532	32	72
Day 5	460	230	14	31
Day 6 to 60	199	0	0	199
Sum Total	5,673*see note above	4,826	290	847

Effects of Construction Activities and Effects by Water Quality Degradation

Major construction activities will begin after dewatering and rescue activities have been completed. Some silvery minnows may persist in the water that remains and some adverse effects may occur to these animals. All construction will occur isolated from the river, but may affect those silvery minnows that remain trapped between the coffer dams. The potential number of silvery minnows affected within the immediate vicinity of the equipment should be small, as we expect an initial flight response at the onset of activities, and sustained avoidance during the duration of construction work. However, additional adverse effects are likely to occur due to construction activities on the quality of the water in the Embayment.

Adverse effects on silvery minnows may occur during dewatering or during sediment disturbance by equipment when installing the coffer dam and especially during construction activities to install the control structures and regrade the Embayment. Sediment disturbance during construction activities will affect water quality, causing localized increases in turbidity and suspended sediments, as well as various pollutant concentrations. Direct effects from excess suspended sediments on a variety of fish species have included alarm reactions, abandonment of cover, avoidance responses, reduced feeding rates, increased respiration, physiological stress, poor condition, and subsequently reduced growth, or mortality (Newcombe and Jensen 1996). In addition, indirect effects from sediment mobilization are possible, including the potential smothering and mortality of silvery minnow prey such as algae and aquatic invertebrates, which results in depressed rates of growth, and reduced physiological function of silvery minnows. Some of these effects may also be associated with decreased oxygen content of the Embayment water and its volume reduction during dewatering as well as during the disturbance of sediment (Fillos and Molof 1972; Kreutzberger et al. 1980; Wang 1980; Walker and Snodgrass 1986, Veenstra and Nolen 1991, Caldwell and Doyle 1995).

Fish can attempt to compensate for low DO conditions by behavioral responses, such as increased use of aquatic surface respiration, changes in activity level or habitat use, and avoidance behaviors, though these activities are known to come at a higher energy cost (Kramer 1987; BCME 1997). Below some threshold oxygen saturation, fish will be expending excess energy to maintain homeostasis and that some degree of physiological stress will occur (Heath 1995). Ventilation rates are often increased, reduced feeding and movement activity are decreased and increased glycolysis and cortisol release can be induced by short-term low DO conditions (Kramer 1987; Heath 1995; BCME 1997). Additionally, low DO conditions may also cause a wide range of additional chronic effects and behavior responses in fish (Downing and Merkens 1957; Kramer 1987; Breitburg 1992), which are potentially adverse to silvery minnow.

Buhl (2007, 2011c) reported that 50 percent of the test population of silvery minnow larvae (6-days post-hatch in age) died when exposed to water containing DO at 0.7 mg/L (8.7 percent oxygen saturation) during 24- to 96-hr exposures, even when allowed access to the water surface. Buhl (2011c) reported that 50 percent of the test population of adult silvery minnows die when exposed to water containing DO from 0.8 mg/L (6.7 to 13.2 percent oxygen saturation) after a 3-hr exposure, without allowing the adult fish access to the water surface. Buhl (2011c) reported that the highest DO concentration observed without acute mortality to larval silvery minnows (that had no access to the water surface) was 14.3 mg/L (i.e., at 29.8 percent saturation). Buhl (2011c) reported that the highest DO concentration observed without acute mortality to adult silvery minnows (that had no access to the water surface) was 4.4 mg/L (i.e., at 54.3 percent saturation). From these data, we predict that adult silvery minnows in water at 25.7 °C (78.3 °F) with DO less than or equal to 4.4 mg/L (i.e., at 54.3 percent saturation) will begin to experience mortality as well as experience adverse effects such as changes in ventilation rates, increased surface water respiration, lack of feeding activity, metabolism changes, and the condition or position of the fish is changed so they are at an increased risk of predation. Temperature and pressure can affect the solubility of DO in water, in the Middle Rio Grande and as the activities occur in the winter months, the likelihood of extremely low DO is reduced. However, the concentration of ammonia and other oxygen demanding chemicals found in the sediment is extremely high (Appendix A). Therefore, we expect that silvery minnows will exhibit a stress response to the changes in water depth and volume, and due to the loss of oxygen by the disturbance of sediments during construction activities, as well as by the disturbance of animal activities in the Embayment. DO concentrations will likely continue plummet given the oxygen demand, and eventually suffocation of silvery minnows will occur and they will eventually die.

Some of the adverse effects associated with degraded water quality may occur during dewatering activities, and are associated with those described during confinement in isolated pools. In addition to increases in suspended solids, reduced DO, other constituents are present and may affect the water quality of the Embayment during dewatering or construction activities. These include nutrients such as nitrates and phosphorus, ammonia, dissolved metals, and other pollutants. Disturbance of some contaminants known to occur in the Embayment sediments is expected, including insecticide residues (i.e., beta-benzenehexachloride), ammonia, and oxygen demanding chemicals (HEAL 2011; Buhl 2011a). For example, the EPA's guideline (65 Federal Register 66443) for the protection of aquatic life and water ingestion from beta-BHC is 9.1 micrograms per liter (µg/L or ppb), which could be mobilized from sediment containing as much as 150 ug/kg (or ppb) dry weight (HEAL 2011). Disturbance of sediments that contain the insecticide would be expected to disperse them into solution in the Embayment water during construction or other sediment disturbing activities. As these chemicals have the potential to kill, immobilize, or stress fish, when the water or fish become concentrated with these pollutants, or when DO is removed from the water column, then fish may suffocate and eventually die, or their health condition and physiology may deteriorate (through induction of diseases, reduced immune response, or immobility with an increased likelihood of predation) and silvery minnows will die. As the Embayment is dewatered, and sediment is disturbed, various pollutants (e.g., ammonia, PAHs, oxygen demanding substances, pesticides) will become mobilized into the water column to elevated concentrations, or concentrated through dewatering activities, and reach levels that adversely affect those silvery minnows that remain. Some of these pollutants would be expected to cause the immediate death of silvery minnows (e.g., ammonia, beta BHC) when elevated concentrations are reached. Those silvery minnows that are not removed quickly from the Embayment, or that remain during construction activities, given the amount and variety of pollutants present, combined with other physical stressors, will likely die or would be expected to have their health compromised and fitness impaired such that their behavior, immune response, and metabolic state would be adversely affected (Heath 1995). The stress response from silvery minnows associated with elevated turbidity, reduced DO, and increased concentrations of other pollutants, would be expected to kill or indirectly affect the health of the silvery minnows that remain in the Embayment during construction activities. As indicated in Table 1, rescue operations are not expected to capture all silvery minnows in the Embayment. As many as 199 silvery minnows will likely escape capture, and those that remain in the Embayment during construction activities will likely be exposed to increasingly degraded water quality conditions and they will likely to succumb and die in the Embayment.

Effects of Capture, Handing, and Transfer to the Rio Grande

The Service has defined take by harassment as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering (see 50 CFR 17.3). Intentional capture of silvery minnows by the Corp, AMAFCA or others during Embayment Project activities is prohibited under section 9 of the ESA. However, during informal discussions of the proposed project, staff from AMAFCA, Corps, Service and the Pueblo of Sandia expressed a desire that silvery minnows (and other fish and wildlife) be rescued to reduce their mortalities. The Service's New Mexico Fish and Wildlife Conservation Office has a cooperative agreement with the Pueblo of Sandia to assist with fish monitoring and assessment, and it implements the Service's mission to conserve, protect, and enhance fish, wildlife, and their habitats, as well as has the staff with training, equipment, and personnel, and ESA section 10(a)(1)(A) permits necessary to collect silvery minnows for the purpose of rescue and salvage. Therefore, the intentional collection, handling, transport, and transfer the Rio Grande of silvery minnows in order to rescue them from the full suite of adverse effects that will occur during Embayment Project activities was identified early by all parties as a measure that could be incorporated into the proposed project.

However, we have identified that the physical stressors associated with the capture, handling and transport of the rescue efforts, will also result in stress that increases the vulnerability of silvery minnows to opportunistic pathogens and predation, possibly decreasing post transfer survival of some individuals in the Rio Grande. We expect that the physiological stress response to standard rescue practices subjecting the fish to individual stressors of approximately 30 seconds (s) of handling, less than 3 hours (hr) of confinement and transport will result in moderate changes in plasma glucose, plasma osmolality, and moderate osmoregulatory dysfunction in silvery minnows (Cho et al. 2009). After transfer of silvery minnows to the river nearby, we expect that silvery minnows will recover physiologically to unstressed levels within 48 hr (Cho et al. 2009) as long as the stressors are reasonable in duration and intensity. Caldwell et al. (2009) described that 94 percent of silvery minnows handled in such fashion would occur if rescue operations were conducted within 24 hr of confinement, but that isolation in pools for greater than 48 hours would reduce survival to 82 percent. Therefore, rescue efforts would need to be conducted within 24 hours of any isolation of silvery minnows in pools that occur during dewatering of the Embayment and mortality will occur for approximately 6 percent of the silvery minnows handled (4,923 x 0.06 = 295 silvery minnows). Silvery minnows that are harmed or that die because of the Service's rescue efforts shall not be attributed to the Corps Embayment Project incidental take statement.

Some interactions may occur among the fish and wildlife rescued from the Embayment and fish and wildlife in the Rio Grande, but these interactions would occur naturally, as the Embayment is an open system and therefore rescued fish and wildlife, although stressed, would be expected to exhibit a normal range of behaviors when transported to the Rio Grande this winter.

Effects of Water Temperature in the Embayment after Construction

Water temperatures in the Embayment were not reported for the months May throughout July (i.e., during silvery minnow spawning and larval development) by DBS&A (2009), although water temperatures were reported for several days of July. Water temperature averages in the Embayment during July 2008 ranged from 22 to 28C (with what appears to be variance during initial monitor installation) (DBS&A 2009). Average water temperatures in the Embayment in February 2008 were approximately 3 to 10 C (DBS&A 2009). Therefore, we assume that water temperatures in months between February and July 2008 ranged from approximately 8 to 22 C. Silvery minnow spawning appears to occur over a wide range of mean daily water temperatures (approximately 15 to 26 C), but with the majority occurring over a narrower range temperatures (approximately 17 to 22 C) (Dudley and Platania 2010b). We assume that water temperatures in the Embayment in 2008 were within this range during May through July 2008 as average daily temperatures undoubtedly increased from 8 C in February 2008 and only occasionally exceeded 26 C when measures commenced again in July 2008. It is unclear if the water temperatures in the newly designed wider, shallower Embayment will be higher or lower, on average, than those in the previous configuration, as the volume of water is slightly reduced (approximately 90 percent), but circulation with the Rio Grande is expected to increase and may help compensate temperature variation. AMAFCA has committed (BA, p. 28) to monitor water temperatures in the Embayment that will allow for review, evaluation, and adaptive management should average daily water temperatures exceed 15 to 26 C during silvery minnow spawning (i.e., approximately May through July). Therefore, the effects of the Embayment Project on water temperature are not fully known, but are expected to be monitored, evaluated, and adaptive management used to address the condition should excess average daily temperature be identified in May through July.

Summary

To summarize adverse effects to the silvery minnow: 1) 5,670 silvery minnows in the Embayment will be entrapped by the installation of the silt fences and coffer dams; 2) Dewatering will confine silvery minnows into isolated pools and reduce their health as well as degrade water quality that will stress silvery minnows that remain in the Embayment during dewatering and likely kill as many as 648 silvery minnows; 3) during construction and other sediment disturbing activities, water quality will continue to be degraded and stress the silvery minnows that remain during construction activities, and reduce their health, will eventually kill up to 199 of the silvery minnows; and, 4) the Service's rescue efforts may further stress 4,826 silvery minnows during their pursuit, capture, and subsequent transfer to Rio Grande nearby. Of those captured during rescue operations, we as many as 290 silvery minnows may also die due to cumulative stress and handling. However, without rescue, adverse effects associated with Embayment Project activities would be expected to eventually result in the mortality of the majority of silvery minnows in the Embayment.

Effects on Silvery Minnow Critical Habitat

Designated critical habitat for the silvery minnow occurs in the action area and is expected to benefit by the proposed action. Currently, the frequency of low DO events in the Rio Grande associated with low oxygen water in the Embayment adversely affects silvery minnow critical habitat in the action area (Service 2011c). Water of sufficient quality to maintain natural, daily, and seasonally variable temperature conditions and that reduce degraded conditions, such as decreased DO, are PCEs of silvery minnow critical habitat. The proposed Embayment Project action will reduce the frequency of decreased DO events in silvery minnow critical habitat downstream (Service 2011c). Therefore, effects to silvery minnow critical habitat are beneficial.

V. CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, Tribal, local or private actions that are reasonably certain to occur within the action area considered in this biological opinion (50 CFR 402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

The Service expects the natural and anthropogenic phenomena in the action area will continue to influence silvery minnows as described in the Environmental Baseline. The Service also expects the continuation of habitat restoration projects and research that will benefit silvery minnows in the action area. In addition, we expect cumulative effects to include the following:

- Increased development and urbanization in the historical floodplain may result in reduced conveyance of peak flows because of the threat of flooding damages. Development in the floodplain makes it more difficult, if not impossible, to transport large quantities of water that would overbank and create low velocity habitats that silvery minnows prefer. Development also reduces overbank flooding favorable for silvery minnows. Gradual changes in the floodplain vegetation from native riparian species to nonnative species (e.g., saltcedar), as well as riparian clearing activities or herbicide treatment for vegetation control and associated with agricultural crops could adversely affect the silvery minnow and its habitat. Silvery minnow larvae require shallow, low velocity habitats for their development. Therefore, encroachment of nonnative species will result in habitat reduction for the silvery minnow.
- Increased consumptive use of surface or ground water including for municipal and private use will reduce river flow and decrease available habitat for the silvery minnow.
- Increased groundwater pumping will reduce river recharge.
- Increased water contamination associated with WWTP effluent discharges; stormwater runoff from urban areas, runoff from feedlots and residential, industrial, and commercial activities or development, or illegal discharges will contribute to decreased water quality.
- Increased human activities (e.g., recreational use, large woody debris removal, arson, unintentional release of invasive species) that will decrease habitat quality.
- Increased effects of climate change including increases in the long-term averages and variability of temperature, snow cover, precipitation patterns, and the intensity, frequency, and duration of extreme events (droughts, floods, fire, etc.) that may change the distribution and qualities of silvery minnow habitat.

The Service anticipates the continued and expanded degradation of silvery minnow habitat because of these types of activities. Effects from these activities will continue to threaten the survival and recovery of the species by reducing the quality and quantity of minnow habitat.

VI. CONCLUSION

After reviewing the current status of the silvery minnow, the environmental baseline for the action area, the anticipated effects of the proposed action, and the cumulative effects, it is the Service's biological opinion that the Corps proposed authorization of the Embayment Project (Corps 2011; BA) is not likely to jeopardize the continued existence of the silvery minnow. We expect the level and type of take associated with this action is unlikely to appreciably diminish the silvery minnow population. We expect harassment of up to 5,670 silvery minnows may occur, but the duration and intensity of this effect will be short term, with no long-term effects on silvery minnow behaviors such as breeding, feeding, or sheltering. Several hundred (i.e., 847) silvery minnows are expected to die during Embayment Project activities; however, we do not expect these mortalities to result in any significant long-term effects on the silvery minnow population in the Middle Rio Grande.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The measures described below are nondiscretionary, and must be undertaken by the Corps so that they become binding conditions of any permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this incidental take statement. If the Corps 1) fails to assume and implement the terms and conditions or 2) fails to require adherence to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Corps or AMAFCA must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement (50 CFR 402.14(i)(3)).

Amount or Extent of Take Anticipated

The Service has developed the following incidental take statement based on the premise that the authorization under the Clean Water Act will be implemented as proposed (Corps 2011; BA). Take of silvery minnows is expected in the form of harm and harassment due to entrapment between the coffer dams, confinement during dewatering, and water quality degradation during construction activities. The Service expects that no more than 5,670 silvery minnow (i.e., the 90th percentile catch rate of 30 silvery minnow per 100 m^2 times the surface area of the Embayment and wetlands affected; 18,899 m^2 = 5,670) will be adversely affected by entrapment and confinement during dewatering activities. Fish rescue operations conducted by the Service's Fish and Wildlife Conservation Office are expected to reduce the mortalities of silvery minnows in the Embayment. However, dewatering and construction activities would nonetheless be expected to kill no more than 847 silvery minnows prior to their rescue due to confinement stress and water quality degradation. If the actual incidental take exceeds this predicted level (i.e., the number of silvery minnows that are observed to die in the Embayment is greater than 847 or the total number of silvery minnows observed exceed 5,670), then the Corps shall reinitiate consultation as described below.

Note that additional adverse effects are expected by the Service's rescue operations, including the intentional pursuit, harassment, and capture of up to 4,826 silvery minnows. Cumulative and handling stress during the Service's rescue operations may compromise their health condition and result in additional 290 silvery minnow mortalities. The adverse effects associated with the rescue operation, including silvery minnow mortality, will not be attributed to the Corp's incidental take statement for the Embayment Project, but attributed to the Service's ESA section 10(a)(1)(A) permit for salvage and rescue.

Effect of Take

The Service has determined that this level of anticipated take is not likely to result in jeopardy to the silvery minnow. The proposed action is likely to have adverse effects on silvery minnows, but those effects are not anticipated to result in long-term impacts on the population. The Service notes that this represents a best estimate of the extent of take that is likely during the proposed action. The estimated incidental take may be modified through reinitiation of consultation and amendment, if the actual catch rate or observations of dead silvery minnows in the Embayment differ significantly from our estimate.

Reasonable and Prudent Measures

The Service believes the following reasonable and prudent measures (RPMs) are necessary and appropriate to minimize impacts of incidental take of the silvery minnows resulting from the proposed action:

1. Reduce mortalities of silvery minnows during Embayment Project activities.
2. Work collaboratively with the Service's New Mexico Fish and Wildlife Conservation Office and the Pueblo of Sandia on silvery minnow rescue operations during Embayment Project activities.

Terms and Conditions

Compliance with the following terms and conditions must be achieved in order to be exempt from the prohibitions of section 9 of the ESA. These terms and conditions implement the Reasonable and Prudent Measures described above. These terms and conditions are nondiscretionary.

To implement RPM 1, the Corps or AMAFCA shall:

1. Ensure that all Embayment Project activities are conducted within the timeframes described in the BA (e.g., between October through March, revegetation in April).
2. Ensure that all conservation measures described in the BA and BO are implemented, including those pertaining to equipment, operations, and monitoring water quality.
3. Ensure monitoring of silvery minnow mortalities in the Embayment on a daily basis.
4. Ensure that a qualified biologist, on a daily basis, working safely and appropriately with Embayment Project Managers, shall attempt to remove and enumerate any and all dead silvery minnows from the Embayment area. The biologist shall then place those dead individuals into labeled containers, along with chain-of-custody forms, and freeze them at or below 4 °C. After all dead or immobile silvery minnows have been collected from the Embayment Project activites, AMAFCA shall coordinate and transport the frozen silvery minnows to the University of New Mexico, Museum of Southwestern Biology (MSB) at:

   MSB, Division of Fishes, Collection Manager (Attn. A.M. Snyder)
   1 University of New Mexico
   302 Yale Boulevard NE
   CERIA Building 83, Room 204,
   Albuquerque, New Mexico 87131-0001
   Telephone: 505-277-6005 or 505-277-1360

5. Ensure that oral, written, or electronic reports are provided to the Service's New Mexico Ecological Services Field Office within 24 hours on all findings of injured or dead silvery minnows in the Embayment. Oral reports can be provided in person, or by voicemail, at 505-761-4709 or 505-346-2525. If an oral report is provided, a written or electronic report shall also be provided within 48 hours. Written reports can be provided to the Services New Mexico Ecological Services Field Office address, above. Electronic reports can be provided to nmesfo@fws.gov or to joel_lusk@fws.gov.

To implement RPM 2, the Corps or AMAFCA shall:

1. Ensure the coordination of the Service's rescue operations with Embayment Project activities, including the management of dewatering rates, to maximize the observation of and Service's capture of silvery minnows such that adverse effects in the Embayment are reduced.
2. Ensure coordination of the Service's rescue operations with the Pueblo of Sandia.
3. Ensure that any permits or reports for the Service's rescue operations of silvery minnow in the Embayment Area required by the Pueblo of Sandia are completed.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or designated critical habitat, to help implement recovery plans, or to develop information. The Service recommends the following conservation activities:

1. Evaluate the hydraulic efficiency of the Embayment to verify that mowing of all riparian vegetation banks has significant effects during all expected stormwater discharges and increase riparian vegetation heights, as appropriate, over time.
2. Identify suspended solid and sediment sources and transport pathways in the storm runoff events from urban area basins.
3. Identify pollutant concentrations on bedded or suspended sediment in the North Diversion Channel basin using sensitive analytical chemistry and develop BMPs to reduce suspended sediment containing pollutants effects on silvery minnow habitat.
4. Estimate chemical and carbonaceous oxygen demand, suspended sediment concentrations, and ammonia associated with stormwater and their relationship to low DO events in the Rio Grande and potential effects to silvery minnows.
5. Improve mixing model accuracy of stormwater runoff and its effects on DO and other pollutant concentrations in the Middle Rio Grande.
6. Identify the chronic effects or avoidance of low DO concentrations to silvery minnows under a range of water temperatures from 5 to 35 °C (41 to 95 °F).
7. Amend the Stormwater Management Plan to include PCB monitoring according to methods recommended by NMED (2010) within North Diversion Channel, and the Middle Rio Grande both upstream and downstream of the Albuquerque urban area.
8. Measure PCBs in insect prey of the flycatcher, conduct PCB accumulation studies on the flycatcher or a surrogate, including collection of abandoned (addled) flycatcher eggs by the permittee through Service's issuance of ESA 10(A)1(a) permits, and then analyze them for PCBs and other pollutants.
9. Implement recovery actions identified in the flycatcher and silvery minnow recovery plans.
10. Encourage volunteers, educators, and classrooms to "adopt-a-watershed" for the stormwater basins that their schools reside in.

In order for the Service to be kept informed of actions minimizing or avoiding adverse or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on the action of issuance of the authorization by the Corps to AMAFCA for Embayment Project activities under the Clean Water Act (Action No. SPA-2010-0435-ABQ). As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: 1) the amount or extent of incidental take of silvery minnows is exceeded; 2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this BO; 3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this BO; 4) water temperature measured in the Embayment during May through June, as averaged on a daily basis, exceeds 26 °C or drops below 15 °C; or 5) a new species is listed or critical habitat designated that may be affected by the proposed action. In instances where the amount or extent of incidental take is exceeded, the Corps shall immediately implement actions necessary to cease operations from causing such take, pending reinitiation.

Thank you for your concern for endangered species and New Mexico's wildlife habitats. The Service appreciates the Corps and AMAFCA's coordination efforts associated with this proposed project to reduce and minimize adverse effects to the Rio Grande silvery minnow as well as avoid adverse effects to other federally listed species and their critical habitats. If you have any questions regarding this BO or if we can be of further assistance, please contact Joel D. Lusk of my staff at the letterhead address, by email at joel_lusk@fws.gov, or telephone at (505) 761-4709.

Sincerely,

for Wally Murphy
Field Supervisor

cc:
Executive Engineer, AMAFCA, Albuquerque, New Mexico (Attn. K. Daggett)
Governor, Pueblo of Sandia, Bernalillo, New Mexico (Attn. S. Bulgrin)
Office of the Superintendent, Bureau of Indian Affairs, Southern Pueblos Agency, Albuquerque, New Mexico.
Assistant Regional Director, Ecological Service, Region 2, Albuquerque, New Mexico (Attn. D. Montaño)
Chief, Division of Habitat Conservation/Environmental Contaminants, Region 2, Albuquerque, New Mexico (Attn. D. Baker/L. Wellman)

LITERATURE CITED

Abeyta, C. G., and J. D. Lusk. 2004a. Hydrologic and biologic data for the water-quality assessment in relation to Rio Grande silvery minnow habitats, Middle Rio Grande, New Mexico, 2002-2003. U.S. Fish and Wildlife Service. New Mexico Ecological Services Field Office, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=2q3NVvv0wG0%3D&tabid=272&mid=676. Accessed April 28, 2011.

Abeyta, C. G., and J. D. Lusk. 2004b. A water-quality assessment in relation to Rio Grande silvery minnow habitats in the Middle Rio Grande, New Mexico, December 7, 2004. Presentation to the Middle Rio Grande Endangered Species Act Collaborative Program Advisory Panel Workshop. http://www.middleriogrande.com/LinkClick.aspx?fileticket=rgg72DuHkPs%3d&tabid=216&mid=554. Accessed April 28, 2011.

Agency for Toxic Substances and Disease Registry (ASTDR). 2001. ToxFAQs for Polychlorinated Biphenyls (PCBs). U.S. Public Health Service, Atlanta, Georgia. http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=140&tid=26. Accessed April 28, 2011.

Alò, D., and T. F. Turner. 2005. Effects of habitat fragmentation on effective population size in the endangered Rio Grande silvery minnow. Conservation Biology 19:1138–1148.

Altenbach, C. 2000. BioPark Silvery Minnow Refugium Manager, City of Albuquerque, Albuquerque, New Mexico Personal communication to J. Smith, Service, Albuquerque, New Mexico. .

Anderholm, S. K., M. J. Radell, and S. F. Richey. 1995. Water-quality assessment of the Rio Grande Valley study unit, Colorado, New Mexico, and Texas – Analysis of selected nutrient, suspended sediment, and pesticide data. Water-Resources Investigations Report 94-4061. U. S. Geological Survey, Albuquerque, New Mexico.

Bartolino, J. R., and J. C. Cole. 2002. Ground-water resources of the Middle Rio Grande Basin, New Mexico. U.S. Geological Survey Circular 1222. Albuquerque, New Mexico. http://pubs.usgs.gov/circ/2002/circ1222/#pdf. Accessed April 28, 2011.

Beckvar, N., and G. R. Lotufo. 2011. DDT and other organohalogen pesticides in aquatic organisms. Pages 47–101 in W.N. Beyer and J. P. Meador, editors, Environmental Contaminants in Biota: Interpreting Tissue Concentrations. Second Edition. CRC Press, Boca Raton, Florida.

Benson, B. B. and D. Krause. 1980. The concentration and isotopic fractionation of gases dissolved in freshwater in equilibrium with the atmosphere. 1. Oxygen. Limnology and Oceanography 25:662-671.

Bestgen, K., and S. P. Platania. 1991. Status and conservation of the Rio Grande silvery minnow, *Hybognathus amarus*. Southwestern Naturalist 26:225–232.

Bestgen, K., and D. R. Propst. 1994. Redescription, geographic variation, and taxonomic status of the Rio Grande silvery minnow, *Hybognathus amarus* (Girard, 1856). Contribution 69. Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado.

Biella, J. V., and D. C. Chapman. 1977. Archeological investigations in Cochiti Reservoir, New Mexico. University of New Mexico, Albuquerque, New Mexico.

Bio-Aquatic Testing, Inc. 2010. City of Albuquerque municipal storm sewer system outfall MS4 48-hr acute biomonitoring report 42962. Bio-Aquatic Testing, Inc., Carrollton, Texas.

Bixby, R., and A. Burdett. 2009. Effects of nutrient availability on periphyton growth and diversity in the Middle Rio Grande: top-down and bottom up factors. Annual Report 2007-2008. University of New Mexico, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=aoRNvRt%2FM%2Bw%3D&tabid=272&mid=678. Accessed April 27, 2011.

Bott, T. 1996. Primary productivity and community respiration. Pages 533-556 in R. Hauer and G. Laberti, editors. Methods in Stream Ecology. Academic Press, New York, New York.

Breitburg, D. L. 1992. Episodic hypoxia in Chesapeake Bay: interacting effects of recruitment, behavior, and physical disturbance. Ecological Monographs 62:525–546.

British Columbia Ministry of the Environment (BCME). 1997. Water Quality: Ambient water quality criteria for dissolved oxygen. Technical Appendix. Government of British Columbia, British Columbia, Canada. http://www.env.gov.bc.ca/wat/wq/BCguidelines/do/index.html. Accessed April 28, 2011.

Buhl, K. J. 2002. The relative toxicity of waterborne inorganic contaminants to the Rio Grande silvery minnow (*Hybognathus amarus*) and fathead minnow (*Pimephales promelas*) in a water quality simulating that in the Rio Grande, New Mexico. Final Report to the U.S. Fish and Wildlife Service, Study No. 2F33 9620003. U.S. Geological Survey, Columbia Environmental Research Center, Yankton Field Research Station, Yankton South Dakota. http://www.cerc.usgs.gov/pubs/center/pdfDocs/Silvery_Minnow.pdf/. Accessed April 28, 2011.

Buhl, K. J. 2005. Preliminary results of the on-site acute toxicity test with stormwater and Rio Grande silvery minnow. U.S. Geological Survey, Columbia Environmental Research Center, Yankton Field Research Station, Yankton South Dakota.

Buhl, K. J. 2007. Toxicity of adverse water quality conditions to Rio Grande silvery minnow. Presentation, U.S. Geological Survey, Columbia Environmental Research Center, Yankton Field Research Station, Yankton, South Dakota.

Buhl, K. J. 2011a. Preliminary analytical data of sediments collected from the North Diversion Channel Embayment on June 11, 2004. In-house working draft spreadsheet, provided December 4, 2011. U.S. Geological Survey, Columbia Environmental Research Center, Yankton Field Research Station, Yankton, South Dakota.

Buhl, K. J. 2011b. On-site evaluation of the suitability of a wetted instream habitat in the Middle Rio Grande, New Mexico, for the Rio Grande silvery minnow (*Hybognathus amarus*). U.S. Geological Survey Scientific Investigations Report 2011-5061, Reston, Virginia.

Buhl, K. J. 2011c. Preliminary results of studies on the relative tolerance of Rio Grande silvery minnows to low dissolved oxygen concentrations. In-house working draft, March 2011. U.S. Geological Survey, Columbia Environmental Research Center, Yankton Field Research Station, Yankton, South Dakota.

Bullard, T. F., and S. G. Wells. 1992. Hydrology of the Middle Rio Grande from Velarde to Elephant Butte Reservoir, New Mexico. Resource Publication 179. U.S. Fish and Wildlife Service. Washington, D.C.

Caldwell, C. A., S. J. Cho, and W. J. Remshardt. 2009. Effects of propagation, augmentation, and salvage activities on recovery and survival of Rio Grande silvery minnow (*Hybognathus amarus*). USGS New Mexico Cooperative Fish and Wildlife Research Unit, Las Cruces, New Mexico.

Caldwell, J. M., and M. C. Doyle. 1995 Sediment Oxygen Demand in the Lower Willamette River, Oregon, 1994. USGS Water-Resources Investigations Report 95–4196, Portland, Oregon.

Carveth, C. J., A. M. Widmer and S. A. Bonar. 2006. Comparison of upper thermal tolerances of native and nonnative fishes in Arizona. Transaction of the American Fisheries Society 135:1433–1440.

Church, J.A., et al. 2010. Sea-level rise and variability: synthesis and outlook for the future. Pages 402-419 in J. A. Church, P. L. Woodworth, R. Aarup, and W. S. Wilson, editors. Understanding sea-level rise and variability. Wiley-Blackwell, New York, New York.

Chwirka, J. D. 2011. Re: NPDES Permit No. NM0022250. Letter to inform you about of a process upset condition that occurred at the Southside Water Reclamation Plant on Saturday, March 12, 2011, to S. Hall. Albuquerque Bernalillo County Water Utility Authority, Albuquerque, New Mexico.

Comiso, J. C., C. L. Parkinson, R. Gersten, and L. Stock. 2008. Accelerated decline in the Arctic sea ice cover. Geophysical Research Letters 35(L01703):1–6.

Cook, J. A., K. R. Bestgen, D. L. Propst, and T. L. Yates. 1992. Allozymic divergence and systematics of the Rio Grande silvery minnow, *Hybognathus amarus* (Teleostei: Cyprinidae). Copeia 1992:36–44.

Crawford, C., et al. 1993. Middle Rio Grande ecosystem: Bosque biological management plan. Middle Rio Grande Biological Interagency Team, Albuquerque, New Mexico. http://www.fws.gov/southwest/mrgbi/Resources/BBMP/Bbmp.pdf. Accessed September 9, 2011.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2009. Investigation of dissolved oxygen in the North Diversion Channel, Embayment, and Rio Grande. Albuquerque Metropolitan Arroyo Flood Control Authority, Albuquerque, New Mexico.

Downing, K. M., and J. C. Merkens. 1957. The influence of temperature on the survival of several species of fish in low tensions of dissolved oxygen. Annals of Applied Biology 45:261–267.

Dudley, R. K., and S. P. Platania. 1997. Habitat use of the Rio Grande silvery minnow. Report to U.S. Bureau of Reclamation, Albuquerque, New Mexico.

Dudley, R. K., and S. P. Platania. 2002. Summary of population monitoring of Rio Grande silvery minnow (1994–2002). Report to New Mexico Ecological Services Field Office, Albuquerque, New Mexico.

Dudley, R. K., and S. P. Platania. 2007. Rio Grande silvery minnow population monitoring program results from October 2005 to October 2006. Report to Middle Rio Grande Endangered Species Collaborative Program, U.S. Bureau of Reclamation, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=xpW68rQc99Y%3D&tabid=181&mid=1106. Accessed April 28, 2011

Dudley, R. K., and S. P. Platania. 2008a. Summary of the Rio Grande silvery minnow population monitoring program results from October 2008. Report to U.S. Bureau of Reclamation, Albuquerque, New Mexico. http://www.asirllc.com/rgsm/rgsm2008/pdf/RGSM_October2008.pdf. Accessed September 9, 2011.

Dudley, R. K., and S. P. Platania. 2008b. Summary of the Rio Grande silvery minnow population monitoring program results from August 2008. Report to U.S. Bureau of Reclamation, Albuquerque, New Mexico. American Southwest Ichthyological Researchers, LLC, Albuquerque, New Mexico. http://www.asirllc.com/rgsm/rgsm2008/pdf/RGSM_August2008.pdf. Accessed September 9, 2011.

Dudley, R. K., and S. P. Platania. 2009. Summary of the Rio Grande silvery minnow population monitoring program results from October 2009. Report to U.S. Bureau of Reclamation, Albuquerque, New Mexico. American Southwest Ichthyological Researchers, LLC, Albuquerque, New Mexico. http://www.asirllc.com/rgsm/rgsm2009/pdf/RGSM_October2009.pdf. Accessed September 9, 2011.

Dudley, R. K., and S. P. Platania. 2010a. Summary of the Rio Grande silvery minnow population monitoring program results from October 2010. American Southwest Ichthyological Researchers, L.L.C., Albuquerque, New Mexico. http://www.asirllc.com/rgsm/rgsm2010/pdf/RGSM_October2010.pdf. Accessed September 9, 2011.

Dudley, R. K., and S. P. Platania. 2010b. Spatial spawning periodicity of Rio Grande silvery minnow during 2010. American Southwest Ichthyological Researchers, LLC, Albuquerque, New Mexico.

Dudley, R. K., and S. P. Platania. 2011a. Summary of the Rio Grande silvery minnow population monitoring program results from December 2010. American Southwest Ichthyological Researchers, L.L.C, Albuquerque, New Mexico. Available online at http://www.asirllc.com/rgsm/rgsm2010/pdf/RGSM_December2010.pdf.

Dudley, R. K., and S. P. Platania. 2011b. Summary of the Rio Grande silvery minnow population monitoring program results from October 2011. American Southwest Ichthyological Researchers, LLC, Albuquerque, New Mexico. Available online at http://www.asirllc.com/rgsm/rgsm2011/pdf/RGSM_October2011.pdf. Accessed November 29, 2011.

Dudley, R. K., S. P. Platania, and S. J. Gottlieb. 2005. Summary of the Rio Grande silvery minnow population monitoring program results from September 2005. American Ichthyological Researchers, LLC, Albuquerque, New Mexico. http://www.asirllc.com/rgsm/rgsm2005/pdf/2005_RGSM_September.pdf. Accessed September 9, 2011.

Dudley, R. K., S. P. Platania, and S. J. Gottlieb. 2006. Summary of the Rio Grande silvery minnow population monitoring program results from October 2006. American Southwest Ichthyological Research Foundation, LLC, Albuquerque, New Mexico. http://www.asirllc.com/rgsm/rgsm2006/pdf/RGSM_October2006.pdf. Accessed September 9, 2011.

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. Contaminant Hazard Reviews Report No. 11. Biological Report 85(1.11), U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, Maryland. http://www.pwrc.usgs.gov/oilinla/pdfs/CHR_11_PAHs.pdf. Accessed April 28, 2011.

Ellis, L. M., C. S. Crawford, and M. C. Molles. 1998. Comparison of litter dynamics in native and exotic riparian vegetation along the middle Rio Grande of central New Mexico, USA. Journal of Arid Environments 38:283–296.

Ellis, S. R., et al. 1993. Rio Grande Valley, Colorado, New Mexico, and Texas. Water Resource Bulletin 29:617-646.

Enquist, C. A. F., E. H. Girvetz, and D. F. Gori. 2008. A climate change vulnerability assessment for biodiversity in New Mexico, Part II: Conservation implications of emerging moisture stress due to recent climate changes in New Mexico. The Nature Conservancy. http://www.wcs.org/about-us/grants-and-opportunities/~/media/Files/pdfs/CC_report2_final.ashx. Accessed November 2, 2010.

Fillos, J., and A. H. Molof. 1972. Effect of benthal deposits on oxygen and nutrient economy of flowing waters. Journal of the Water Pollution and Control Federation 44:644–662.

Geochemical & Environmental Research Group (GERG). 1993. ECDMS Analytical Report for Catalog 2020047, Purchase Order 85830-3-1456. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Gillett, N. P., V. K Arora, K. Zickfeld, S. J. Marshall, and W. J. Merryfield. 2011. Ongoing climate change following a complete cessation of carbon dioxide emissions. Nature Geoscience 4:83–87.

Glick, P., B. A. Stein, and N. A. Edelson, editors. 2011. Scanning the conservation horizon: a guide to climate change vulnerability assessment. National Wildlife Federation, Washington, DC. http://www.nwf.org/~/media/PDFs/Global%20Warming/Climate-Smart-Conservation/ScanningtheConservationHorizon_Jan18.ashx. Accessed July 25, 2011.

Graf, W. L. 1994. Plutonium and the Rio Grande: environmental change and contamination in the nuclear age. Oxford University Press, New York, New York.

Gray, J. R., G. D. Glysson, L. M. Turcios, and G. E. Schwarz. 2000. Comparability of suspended-sediment concentration and total suspended solids data. USGS Water-Resources Investigations Report 00-4191, Reston, Virginia. http://water.usgs.gov/osw/pubs/WRIR00-4191.pdf. Accessed April 28, 2011.

Harwood, A. K. 1995. The urban stormwater contribution of dissolved trace metal from the North Floodway Channel, Albuquerque, NM, to the Rio Grande.

Hall Environmental Analysis Laboratory. 2011. Analytical report 1106991 for the NDC Recon Study dated July 6, 2011. Daniel B. Stephens & Associates, Albuquerque, New Mexico.

Heath, A. G. 1995. Water pollution and fish physiology. CRC Press, Boca Raton, Florida.

Hoerling, M., and J. Eischeid. 2007. Past peak water in the southwest. Southwest Hydrology January/February 2007:18–35.

Horwitz, R. J., D. H. Keller, P. F. Overbeck, S. P. Platania, and R. K. Dudley. 2011. Age and Growth of Rio Grande Silvery Minnow. Academy of Natural Sciences, Philadelphia, Pennsylvania, and American Southwest Ichthyological Researchers, L.L.C, Albuquerque, New Mexico. Report to U.S. Bureau of Reclamation, Albuquerque, New Mexico.

Huggins, D., and J. Anderson. 2005. Dissolved oxygen fluctuation regimes in streams of the Western Corn Belt Plains Ecoregion. University of Kansas, Central Plains Center for Bioassessment, Report No. 130, Lawrence, Kansas. http://www.cpcb.ku.edu/datalibrary/assets/library/KBSreports/KBSRept130_DO.pdf. Accessed April 28, 2011.

Hughes, G. M. 1973. Respiratory responses to hypoxia in fish. American Zoologist 13:475–489.

Hurd, B. H., and J. Coonrod. 2007. Impacts of global warming on New Mexico's water resources. An Assessment of the Rio Grande Basin. http://www.bipartisanpolicy.org/sites/default/files/NM%20Climate.pdf. Accessed July 18, 2011.

Ignjatovic, L. R. 1968. Effect of photosynthesis on oxygen saturation. Journal of the Water Pollution Control Federation 40:R151–R161.

Intergovernmental Panel on Climate Change (IPCC). 2007a. Synthesis Report. In Core Writing Team, R. K. Pachauri, and A. Reisinger, editors. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change, Geneva, Switzerland. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf. Accessed July 25, 2011.

Intergovernmental Panel on Climate Change (IPCC). 2007b. Summary for Policymakers. In S. Solomon, et al., editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf. Accessed July 18, 2011.

Julien, P., R. Gigi, and J. Albert. 2005. Stream restoration and environmental river mechanics. International Journal of River Basin Management 3:191–202.

Karl, T. R., J. R. Melillo, and T. C. Peterson, editors. 2009. Global climate change impacts in the United States. Cambridge University Press. New York, New York.

http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf. Accessed July 25, 2011.

Kelly, T., and O. Romero. 2003. Rainfall, runoff, and water-quality data for the urban storm-water program in the Albuquerque, New Mexico, metropolitan area, Water Year 2001. U.S. Geological Survey, Open-File Report 03-169, Albuquerque, New Mexico. http://pubs.usgs.gov/of/2003/ofr03-169/. Accessed April 28, 2011.

Kelly, T., O. Romero, and M. Jimenez. 2006. Rainfall, runoff, and water-quality data for the urban storm-water program in the Albuquerque, New Mexico, metropolitan area, water year 2004. Open-File Report 2006-1105. U.S. Geological Survey, Albuquerque, New Mexico. http://pubs.usgs.gov/of/2006/1105/. Accessed April 28, 2011.

Kramer, D. L. 1987. Dissolved oxygen and fish behavior. Environmental Biology of Fishes 18:81–92.

Kreutzberger, W. A., R. A. Race, T. L. Meinholz, M. Harper and J. Ibach. 1980. Impact of sediments on dissolved oxygen concentrations following combined sewer overflows. Journal of the Water Pollution Control Federation 52:192–201.

Kundzewicz, Z. W., et al. 2007. Freshwater resources and their management. Pages 173–210 in M. L. Parry, et al., editors. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter3.pdf. Accessed July 18, 2011.

Langman, J. B., and E. O. Nolan. 2005. Streamflow and water-quality trends of the Rio Chama and Rio Grande, Northern and Central New Mexico, Water Years 1985 to 2002. USGS, Scientific Investigations Report 2005-5118, Albuquerque, New Mexico. http://pubs.usgs.gov/sir/2005/5118/. Accessed April 28, 2011.

Levings, G. W., D. F. Healy, S. F. Richey, and L. F. Carter. 1998. Water quality in the Rio Grande Valley, Colorado, New Mexico, and Texas, 1992-95. USGS Circular 1162. http://pubs.usgs.gov/circ/circ1162/. Accessed April 28, 2011.

Lusk, J. D. 2003. Wastewater treatment plant effluents pose a health risk to silvery minnows. Email communication. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lusk, J. D. 2004. North Diversion Channel fish kill, June 27, 2004. Presentation to the Albuquerque Metropolitan Flood Control Authority, July 6, 2004. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lusk, J. D. 2010. Pipeline leak has the potential for lethal effects on silvery minnows as well as adverse effects downstream on critical habitat. Email communication. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lusk, J. D. 2011a. 10 ABQ Ammonia permit exceedances for April/May. Email dated May 4, 2011. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lusk, J. D. 2011b. Chemical residues in Rio Grande silvery minnow collected during the Rio Grande Silvery Minnow Health Study 2006-2008. U.S. Fish and Wildlife Service Draft Report, Albuquerque, New Mexico.

MacDonald, D. D., C. G. Ingersoll, and T. A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Toxicology and Chemistry 39:20–31.

Magaña, H. A. 2009. Feeding preference of the Rio Grande silvery minnow (*Hybognathus amarus*). Reviews in Fisheries Science 17:468–477.

Marcus, M. D., S. Covington, B. Liu, and N. R. Smith. 2010. Use of existing water, sediment and tissue data to screen ecological risks to the endangered Rio Grande silvery minnow. Science of the Total Environment 409:83–94.

Massong, T., P. Makar, and T. Bauer. 2007. Geomorphic summary of the Middle Rio Grande: Velarde to Caballo. U.S. Bureau of Reclamation, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=LQ6pzOneklU%3D&tabid=467&mid=1132. Accessed April 28, 2011.

McCullough, D. A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon. EPA 910-R-99-010. U.S. Environmental Protection Agency. Seattle, Washington. http://www.critfc.org/tech/EPAreport.pdf. Accessed January 21, 2011.

Meehl, G. A., et al. 2007. Global climate projections. Pages 747–845 in S. Solomon, et al., editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter10.pdf. Accessed July 25, 2011.

Merkens, J. C., and K. M. Downing. 1957. The effect of tension of dissolved oxygen on the toxicity of un-ionized ammonia to several species of fish. Annals of Applied Biology 45:521–527.

Meyerhoff, R. D., and O. T. Lind. 1987. Factors affecting the benthic community structure of a discontinuous stream in Guadalupe Mountains National Park, Texas. Hydrobiologia 72:283–29

Morgan, I. J., D. G. McDonald, and C. M. Wood. 2001. The cost of living for freshwater fish in a warmer, more polluted world. Global Change Biology 7:345–355.

Mundahl, N. D. 1990. Heat death of fishes in shrinking stream pools. American Midland Naturalist 123:40-46.

Mussetter Engineering Inc (MEI). 2008. FLO-2D Model Development—Existing Conditions and Restoration Alternatives 1 to 5 Albuquerque Reach, New Mexico. MEI Project 05-03 Report submitted to the U. S. Army Corps of Engineers, Fort Collins, Colorado. http://www.spa.usace.army.mil/FONSI/bosque/Engineering%20Appendix/App%20A_H&H%20Main%20report.pdf. Accessed May 3, 2011.

Neigh, A. M., et al. 2009. Exposure and multiple lines of evidence assessment of risk for PCBs found in the diets of passerine birds at the Kalamazoo River Superfund Site, Michigan. Human and Ecological Risk Assessment 12:924–946.

New Mexico Department of Game and Fish, New Mexico Department of Health, and New Mexico Environment Department. 2010. New Mexico Fish Consumption Advisories-February 2010. New Mexico Environment Department, Surface Water Quality Bureau, Santa Fe, New Mexico. ftp://ftp.nmenv.state.nm.us/www/swqb/MAS/Advisories/FishConsumptionAdvisories-2010.pdf. Accessed April 28, 2011.

New Mexico Environment Department (NMED). 2007. Record of decision (ROD) for the 2006-2008 State of New Mexico §303(d)/§305(b) integrated list for assessed surface waters. New Mexico Environmental Department, Surface Water Quality Bureau, Santa Fe, New Mexico. http://www.nmenv.state.nm.us/swqb/303d-305b/2006-2008/2006-2008_303d-305bROD.pdf. Accessed April 28, 2011.

New Mexico Environment Department (NMED). 2009. Water quality monitoring of the Middle Rio Grande, Annual baseline condition and trends of key water quality parameters, October 2006-July 2008. New Mexico Environment Department, Surface Water Quality Bureau Final Report, Santa Fe, New Mexico. ftp://ftp.nmenv.state.nm.us/www/swqb/MAS/Surveys/MiddleRioGrande-2009.pdf. Accessed April 28, 2011.

New Mexico Environment Department (NMED). 2010. Environment Department finds elevated levels of PCBs in Rio Grande near Albuquerque during storm flows. New Mexico Environment Department, Office of the Secretary, Santa Fe, New Mexico. http://www.nmenv.state.nm.us/OOTS/documents/PR-MRG--PCB-Final-4-10-10_3_.pdf. Accessed April 28, 2011.

New Mexico Office of the State Engineer. 2006. The impact of climate change on New Mexico's water supply and ability to manage water resources. Santa Fe, New Mexico. http://www.nmdrought.state.nm.us/ClimateChangeImpact/completeREPORTfinal.pdf. Accessed July 18, 2011.

Odum, H. T. 1956. Primary production in flowing waters. Limnology and Oceanography 1:102–117.

Olsson, P., et al. 1999. Effects of maternal exposure to estrogen and PCB on different life stages of zebrafish (*Danio rerio*). Ambio 28:100–106.

Ong, K., T. F. O'Brien, and M. D. Rucker. 1991. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Middle Rio Grande and Bosque del Apache National Wildlife Refuge in New Mexico 1988–89. U.S. Geological Survey Water-Resources Investigations Report 91-4036, Albuquerque, New Mexico.

Osborne, M. J., M. A. Benavides, and T. F. Turner. 2005. Genetic heterogeneity among pelagic egg samples and variance in reproductive success in an endangered freshwater fish, *Hybognathus amarus* (Cyprinidae). Environmental Biology of Fishes 73:463–472.

Ostrand, K. G., and D. E. Marks. 2000. Mortality of prairie stream fishes confined in an isolated pool. Texas Journal of Science 52:255–258.

Ostrand, K. G., and G. R. Wilde. 2004. Changes in prairie stream fish assemblages restricted to isolated streambed pools. Transactions of the American Fisheries Society 133:1329-1338.

Papoulias, D. M., et al. 2009. Health and histopathological evaluation of Rio Grande silvery minnow from the Rio Grande, New Mexico. USGS Columbia Environmental Research Center, Columbia, Missouri.

Parmesan, C., and J. Matthews. 2006. Biological Impacts of Climate Change. Pages 333–374 in M. J. Groom, G. K. Meffe, and C. R. Carroll, editors. Principles of Conservation Biology. Sinauer Associates, Inc. Sunderland, Massachusetts.

Passell, H. D., C. N. Dahm, and E. J. Bedrick. 2007. Ammonia modeling for assessing potential toxicity to fish species in the Rio Grande, 1989–2002. Ecological Applications 17:2087–2099.

Pease , A. P., J. J. Davis, M. E. Edwards, and T. Turner. 2006. Habitat and resource use by larval and juvenile fishes in an arid-land river (Rio Grande, New Mexico). Freshwater Biology 51:475–486.

Pflieger, W. 1980. *Hybognathus nuchalis* Agassiz. Page 177 in D. S. Lee, et al., editors. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History, Raleigh, North Carolina.

Pielke Jr., R., T. Wigley, and C. Green. 2008. Dangerous assumptions. Nature 452:531–532.

Platania, S. P. 1995. Reproductive biology and early life-history of Rio Grande silvery minnow, *Hybognathus amarus*. Report to U.S. Army Corps of Engineers, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=jFCovo%2Ba7R4%3D&tabid=467&mid=1124. Accessed September 12, 20011

Platania, S. P. 2000. Effects of four water temperatures treatments on survival, growth, and developmental rates of Rio Grande silvery minnows, *Hybognathus amarus*, eggs and larvae. Report to U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Platania, S. P., and C. S. Altenbach. 1998. Reproductive strategies and egg types of seven Rio Grande Basin cyprinids. Copeia 1998:559–569.

Platania, S. P., and R. Dudley. 2000. Spatial spawning periodicity of Rio Grande silvery minnow during 1999. Report to Bureau of Reclamation, Albuquerque, New Mexico. http://asirllc.com/rgsm/pdf/periodicity_1999_final.pdf. Accessed September 12, 2011.

Platania, S. P. and R. Dudley. 2008. Spatial spawning periodicity of Rio Grande silvery minnow during 2008. Report to Bureau of Reclamation, Albuquerque, New Mexico. http://asirllc.com/rgsm/pdf/2008%20Final%20RGSM%20Spawning%20Report.pdf . Accessed September 9, 2011.

Platania, S. P., and C. W. Hoagstrom. 1996. Response of Rio Grande Fish community to and artificial flow spike. Report to U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Polyak, L., et al. 2010. History of sea ice in the Arctic. Quaternary Science Review 29:1575–1778.

Pörtner, H. O., and M. A. Peck. 2010. Climate change effects on fishes and fisheries: towards a cause-and-effect understanding. Journal of Fish Biology 77:1–35.

Prinn, R., et al. 2011. Scenarios with MIT integrated global systems model: significant global warming regardless of different approaches. Climatic Change 104:515–537.

Randall, D. A., et al. 2007. Climate models and their evaluation. Pages 589–662 in S. Solomon, et al., editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf. Accessed July 25, 2011.

Raupach, M. R., et al. 2007. Global and regional drivers of accelerating CO_2 emissions. Proceedings of the National Academy of Sciences 104:10,288–10,293. http://www.pnas.org/content/104/24/10288.full.pdf+html?with-ds=yes. Accessed July 25, 2011.

Rauscher, S. A., J. S. Pal, N. S. Diffenbaugh, and M. M. Benedetti. 2008. Future changes in snowmelt-driven runoff timing over the western US. Geophysical Research Letters 35(L16703):1–5.

Regonda, S. K., B. Rajagopalan, M. Clark, and J. Pitlick. 2005. Seasonal shifts in hydroclimatology over the Western United States. Journal of Climate 18:372–384.

Remshardt, W .J. 2005. Experimental augmentation and monitoring of Rio Grande silvery minnow in the Middle Rio Grande, New Mexico. Annual Report June 2003 - May 2004. U.S. Fish and Wildlife Service Annual Report prepared for the Middle Rio Grande Endangered Species Collaborative Program, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=5xvm4R7W3o4%3D&tabid=272&mid=676. Accessed July 15, 2011.

Remshardt, W. J. 2007. Experimental augmentation and monitoring of Rio Grande silvery minnow in the Middle Rio Grande, New Mexico. Annual Report 2005. Report to U.S. Bureau of Reclamation, Albuquerque, New Mexico. U.S. Fish and Wildlife Service, New Mexico Fish and Wildlife Conservation Office, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=eZLC666blwU%3D&tabid=272&mid=676. Accessed July 15, 2011.

Remshardt, W .J. 2008a. Rio Grande silvery minnow augmentation in the Middle Rio Grande, New Mexico. Annual Report 2006. U.S. Fish and Wildlife Service Annual Report prepared for the Middle Rio Grande Endangered Species Collaborative Program, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=nV5xwRv5Y5s%3D&tabid=273&mid=679. Accessed July 15, 2011.

Remshardt, W. J. 2008b. Rio Grande silvery minnow augmentation in the Middle Rio Grande, New Mexico – Annual Report 2007. Report to Bureau of Reclamation, Albuquerque, New Mexico. U.S. Fish and Wildlife Service, New Mexico Fish and Wildlife Conservation Office, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=NQFe3I2WwG8%3D&tabid=390&mid=1004. Accessed April 28, 2011.

Remshardt, W. J. 2010a. Rio Grande silvery minnow augmentation shifted focus to the Isleta and San Acacia Reaches. Personal communication, 2010, to U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico. U.S. Fish and Wildlife Service, New Mexico Fish and Wildlife Conservation Office, Albuquerque, New Mexico.

Remshardt, W .J. 2010b. Rio Grande silvery minnow augmentation in the Middle Rio Grande, New Mexico. Annual Report 2008. U.S. Fish and Wildlife Service Annual Report prepared for the Middle Rio Grande Endangered Species Collaborative Program, Albuquerque, New Mexico. http://www.mrgesa.com/LinkClick.aspx?fileticket=C3W7Onfx0Ww%3D&tabid=273&mid=679. Accessed July 15, 2011.

Remshardt, W. J. 2011a. Rio Grande silvery minnow augmentation in the Middle Rio Grande, New Mexico. Annual Report 2009. U.S. Fish and Wildlife Service Annual Report prepared for the Middle Rio Grande Endangered Species Collaborative Program, Albuquerque, New Mexico.

Remshardt, W. J. 2011b. Field notes on fish monitoring of the North Diversion Channel over 4 years for the Pueblo of Sandia (reviewed by permission and summarized in the BA, p. 23). U.S. Fish and Wildlife Service, Conservation Office, Albuquerque, New Mexico.

Remshardt, W. J. 2011c. Email proved to J.Lusk, Service, dated November 28, 2011. Subject November RGSM Monitoring [of the North Diversion Channel Embayment]. U.S. Fish and Wildlife Service New Mexico Fish and Wildlife Conservation Office, Albuquerque, New Mexico.

Remshardt, W. J., and S. R. Davenport. 2003. Experimental augmentation and monitoring of Rio Grande silvery minnow in the Middle Rio Grande, New Mexico. Annual Report prepared for the Middle Rio Grande Endangered Species Collaborative Program, Albuquerque, New Mexico.

Root, R. A. 2000. Lead loading of urban streets by motor vehicle wheel weights. Environmental Health Perspectives 108:937-940. Available online at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240125/pdf/ehp0108-000937.pdf

Roy, R., T. F. O'Brien, and M. Rusk-Maghini. 1992. Organochlorine and trace element contaminant investigation of the Rio Grande, New Mexico. U.S. Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/Documents/R2ES/Rio_Grande_1992_Contaminant_Study.pdf. Accessed April 28, 2011.

Salazar, C. L. 1998. Morphology of the Middle Rio Grande from Cochiti dam to Bernalillo bridge, New Mexico. Master's thesis. Colorado State University Fort Collins, Colorado. http://www.engr.colostate.edu/~pierre/ce_old/resume/Theses%20and%20Dissertations/Claudia%20Leon%20Thesis.pdf. Accessed April 28, 2011.

Schein, A., J. A. Scott, L. Mos, and P. V. Hodson. 2009. Oil dispersion increases the apparent bioavailability and toxicity of diesel to rainbow trout (*Oncorhynchus mykiss*). Environmental Toxicology and Chemistry 28:595–602.

Schmandt, J. 1993. Water and development in the Rio Grande/Río Bravo Basin. University of Texas Press, Austin, Texas.

Schmitt, C. J., et al. 2004. Biomonitoring of Environmental Status and Trends (BEST) program: environmental contaminants and their effects on fish in the Rio Grande Basin. USGS Scientific Investigations Report 2004-5108, Columbia, Missouri. http://www.cerc.usgs.gov/pubs/center/pdfdocs/BEST-RioGrande.pdf. Accessed April 28, 2011.

Scurlock, D. 1998. From the Rio to the Sierra: an environmental history of the Middle Rio Grande Basin. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado. http://www.fs.fed.us/rm/pubs/rmrs_gtr005.html. Accessed April 28, 2011.

Seaber, P. R., F. P. Kapinos, and G. L. Knapp. 1987. Hydrologic Unit Maps. USGS Water-Supply Paper No. 2294, Denver, Colorado. http://pubs.usgs.gov/wsp/wsp2294/. Accessed May 2, 2011.

Seager, R., et al. 2007. Model projections of an imminent transition to a more arid climate in SW North America. Science 316:1181–1184.

Shirey, P. D. 2004. Foraging habits and habitat utilization of Rio Grande Silvery Minnow (*Hybognathus amarus*) as inferred by diatom frustules. Masters Thesis. New Mexico State University, Las Cruces, New Mexico.

Smith, J. R. 1999. Summary of easy egg catching in the Low Flow Conveyance Channel in the 9 mile study reach during spring 1998 operation. Report to Bureau of Reclamation, Albuquerque, New Mexico. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Sogge, M. K., D. Ahlers, and S. J. Sferra, S.J. 2010. A natural history summary and survey protocol for the Southwestern Willow Flycatcher. U.S. Geological Survey Techniques and Methods 2A-10, Reston, Virginia. Available at http://pubs.usgs.gov/tm/tm2a10/pdf/tm2a10.pdf

Solomon, S., et al. 2007: Technical Summary. In S. Solomon, et al., editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf. Accessed July 25, 2011.

S.S. Papadopulos & Associates, Inc. 2000. Middle Rio Grande Water Supply Study. Report to New Mexico Interstate Stream Commission and the U.S. Army Corps of Engineers, Albuquerque, New Mexico. Contract no. DACW47-99-C-0012. Boulder, Colorado.

Stenerson, J. 2004. Chemical Pesticides: Mode of Action and Toxicology. CRC Press, Boca Raton, Florida.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. Changes toward earlier streamflow timing across Western North America. Journal of Climate 18:1136–1155.

Sublette, J., M. Hatch, and M. Sublette. 1990. The Fishes of New Mexico. University of New Mexico Press, Albuquerque, New Mexico.

SWCA Environmental Consultants (SWCA). 2004. Maintenance of existing and future stormwater conveyances in the Middle Rio Grande, New Mexico. Biological Evaluation prepared for the U.S. Army Corps of Engineers, Albuquerque, New Mexico.

SWCA Environmental Consultants (SWCA). 2011. Biological Assessment for the proposed regarding of the North Diversion Channel Embayment. Report submitted to U.S. Army Corps of Engineers, Albuquerque, New Mexico. Albuquerque Metropolitan Arroyo Flood Control Authority, Albuquerque, New Mexico.

Tetra Tech. 2004. Habitat restoration plan for the Middle Rio Grande. Report to Middle Rio Grande Endangered Species Act Collaborative Program, Habitat Restoration Subcommittee. Tetra Tech, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=i3A%2FWl1sWIU%3D&tabid=263&mid=659. Accessed April 28, 2011.

Thurston, R. V., G. R. Phillips, R. C. Russo, and S. M. Hinkins. 1981. Increased toxicity of ammonia to rainbow trout (*Salmo gairdneri*) resulting from reduced concentrations of dissolved oxygen. Canadian Journal of Fisheries and Aquatic Sciences 38:983–988.

Torres, L. T., W. J. Remshardt, and D. C. Kitcheyan. 2008. Habitat assessment for Rio Grande silvery minnow (*Hybognathus amarus*) in the Cochiti Reach, at Peña Blanca, New Mexico. Final Report to U.S. Corps of Engineers, Albuquerque Division, Albuquerque, New Mexico. U.S. Fish and Wildlife Service, New Mexico Fish and Wildlife Conservation Office, Albuquerque, New Mexico. http://www.middleriogrande.com/LinkClick.aspx?fileticket=PtdypuTTD3k%3D&tabid=468&mid=1159. Accessed April 28, 2011.

U.S. Bureau of Reclamation (BOR). 1993. Final supplement to the final Environmental Impact Statement: River maintenance program for the Rio Grande-Velarde to Caballo Dam-Rio Grande and Middle Rio Grande projects. U.S. Bureau of Reclamation, Albuquerque New Mexico.

U.S. Bureau of Reclamation (BOR). 2001. U.S. Bureau of Reclamation's discretionary actions related to water management, U.S. Army Corps of Engineers water operations rules, and non-Federal actions related to ordinary operations on the Middle Rio Grande, New Mexico: June 30, 2001 through December 31, 2003. U.S. Bureau of Reclamation, Albuquerque New Mexico.

U.S. Bureau of Reclamation (BOR). 2003. U.S. Bureau of Reclamation's Water and river maintenance operations, Army Corps of Engineers' flood control operation, and non-Federal actions on the Middle Rio Grande, New Mexico: March 1, 2003 through February 28, 2013. U.S. Bureau of Reclamation, Albuquerque New Mexico.

U.S. Bureau of Reclamation (BOR). 2011a. 2011-2016 Supplement to the Rio Grande Supplemental Water Programmatic Final Environmental Assessment and Finding of No Significant Impact. U.S. Bureau of Reclamation, Albuquerque, New Mexico.

U.S. Bureau of Reclamation (BOR). 2011b. SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water, Report to Congress, 2011. Denver Colorado. http://www.usbr.gov/climate/SECURE/index.html. Accessed July 18, 2011.

U.S. Environmental Protection Agency (EPA). 2002. A guidance manual to support the assessment of contaminated sediments in freshwater ecosystems. 3 Volumes. Report EPA-905-B02-001-A-B-C. U.S. Environmental Protection Agency, Great Lakes National Program Office Chicago, Illinois. http://www.epa.gov/glnpo/sediment/reports.html. Accessed April 28, 2011.

U.S. Environmental Protection Agency (EPA). 2010a. Effects determination for National Pollutant Discharge Elimination Systems Authorized Large Municipal Separate Storm Sewer System (MS4), NPDES Permit No. NMS000101. Discharges in the Albuquerque Urbanized Area (UA) in Bernalillo County, New Mexico. U.S. Environmental Protection Agency, Region 6, Dallas, Texas.

U.S. Environmental Protection Agency (EPA). 2010b. Authorization to discharge under the National Pollutant Discharge Elimination System. U.S. Environmental Protection Agency, Region 6, Water Quality Protection Division NPDES Permit No. NMS000101, Parts I through Part VII. U.S. Environmental Protection Agency, Region 6, Dallas, Texas.

U.S. Environmental Protection Agency (EPA). 2010c. NPDES Permit No. NMS000101. Fact sheet for the draft National Pollutant Discharge Elimination System (NPDES) permit for the Albuquerque Municipal Separate Storm Sewer System to discharge to waters of the United States. U.S. Environmental Protection Agency, Region 6, Dallas, Texas.

U.S. Environmental Protection Agency (EPA). 2011 Polychlorinated Biphenyls (PCBs). http://www.epa.gov/pbt/pubs/pcbs.htm. Accessed April 18, 2011.

U.S. Fish and Wildlife Service (Service). 1993. Proposal rule to list the Rio Grande silvery minnow as endangered, with critical habitat. Federal Register 58:11821–11828.

U.S. Fish and Wildlife Service (Service). 1994. Endangered and threatened wildlife and plants; Final rule to list the Rio Grande silvery minnow as an endangered species. Federal Register 59:36988–37001.

U.S. Fish and Wildlife Service (Service). 1999. Rio Grande silvery minnow (*Hybognathus amarus*) recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

U.S. Fish and Wildlife Service (Service). 2001. Programmatic biological opinion on the effects of actions associated with the U.S. Bureau of Reclamation's, U.S. Army Corps of Engineers', and non-Federal entities' discretionary actions related to water management on the Middle Rio Grande, New Mexico. U.S. Fish and Wildlife Service, Regional Office, Albuquerque, New Mexico. http://www.usbr.gov/uc/albuq/library/eis/pdfs/bo_mrg_june_2001.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2003a. Biological and conference opinions 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 actions on the Middle Rio Grande, New Mexico. March 17, 2003. As amended on August 15, 2005, and June 15, 2006. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/ES_bio_op.cfm. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2003b. Endangered and threatened wildlife and plants; final rule for the designation of critical habitat for the Rio Grande silvery minnow. Federal Register 68:8088–8135.

U.S. Fish and Wildlife Service (Service). 2004. Biological opinion on the effects of actions associated with the programmatic biological assessment for the City of Albuquerque Drinking Water Project. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2003-0146_CABQ_Drinking_Water_Final_BO.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2005a. Biological opinion on the effects of the Middle Rio Grande riverine habitat restoration project proposed by the Interstate Stream Commission. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2006-0002_ISC_BO_for_Phase_I_Final.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2006a. Presentation for the Environmental Protection Agency MS4 public meeting, November 29, 2006. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

U.S. Fish and Wildlife Service (Service). 2006b. Biological opinion on the effects of the Bernalillo priority site project proposed by the Bureau of Reclamation. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2006-0009_Bernalillo_Priority_Site_BO.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2006c. Biological opinion on the effects of the Sandia priority site project proposed by the Bureau of Reclamation. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2006-0039%20Sandia%20Priority%20Site%20Project.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2007a. Notice of availability of the draft revised recovery plan for the Rio Grande silvery minnow (*Hybognathus amarus*). Federal Register 72:2301–2302.

U.S. Fish and Wildlife Service (Service). 2007b. Biological opinion on the effects of the Middle Rio Grande riverine habitat restoration Phase II project proposed by the Interstate Stream Commission. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2006-0160_ISC_BO_Phase_II_FINAL.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2007c. Biological opinion on the effects of the action described in the biological assessment for the Rio Grande Nature Center habitat restoration project for the Albuquerque Reach of the Rio Grande in Bernalillo County, New Mexico. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2006-0161_COE_Nature_Center_BO.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2007d. Biological opinion on the effects of actions associated with the biological assessment for the Corrales Siphon river maintenance project. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2007-0056_Corrales_siphon_BO.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2008a. Endangered and threatened wildlife and plants; establishment of a nonessential experimental population of Rio Grande silvery minnow in the Big Bend Reach of the Rio Grande in Texas. Federal Register 73:74357–74372.

U.S. Fish and Wildlife Service (Service). 2008b. Intra-Service biological opinion on the effects of actions associated with the MERES Sandia restoration project. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2008-0004%20Pueblo%20of%20Sandia%20MERES%20Habitat%20Restoration.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2009a. Biological opinion on the effects of the Middle Rio Grande riverine habitat restoration Phase IIa project proposed by the Interstate Stream Commission. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2009-0016_ABq2a_Final_BiOp.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2009b. Biological opinion on the Pueblo of Sandia bosque rehabilitation project. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/NewMexico/documents/BO/2009-0022_Sandia_Restoration_Final_BiOp.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2010a. Revised Rio Grande Silvery Minnow (*Hybognathus amarus*) recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. http://ecos.fws.gov/docs/recovery_plan/022210_v2.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2010b. Rio Grande silvery minnow (*Hybognathus amarus*) recovery plan, first revision. Federal Register 75:7625–7626.

U.S. Fish and Wildlife Service (Service). 2010c. Biological opinion on the Pueblo of Sandia bosque rehabilitation project. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/newmexico/documents/BO/2010-0083_Sandia_Pueblo_HR_final.pdf. Accessed April 28, 2011.

U.S. Fish and Wildlife Service (Service). 2011a. Biological opinion on the Middle Rio Grande Restoration Project, Bernalillo and Sandoval Counties, New Mexico. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/newmexico/ [available online soon].

U.S. Fish and Wildlife Service (Service). 2011b. Biological opinion on the New Mexico State Trust Land Riverine Restoration Project within the Albuquerque Reach of the Middle Rio Grande. U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/newmexico/ [available online soon].

U.S. Fish and Wildlife Service (Service). 2011c. Biological opinion on U.S. Environmental Protection Agency's (EPA) action authorizing the discharge of pollutants in stormwater and certain nonstormwater discharges from the Large Municipal Stormwater Sewer Systems (MS4) in the Albuquerque urbanized area in Bernalillo County, New Mexico (Albuquerque MS4 permit or Albuquerque stormwater permit). U.S Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico. http://www.fws.gov/southwest/es/newmexico/ [available online soon].

U.S. Geological Survey (USGS). 2010. Gage data for the USGS 08330000 Rio Grande at Albuquerque, New Mexico. National Water Information Service: Web Interface. http://waterdata.usgs.gov/nwis/inventory/?site_no=08330000&agency_cd=USGS&amp. Accessed April 28, 2011.

Valdez, R. 2011. Putative survival of Rio Grande silvery minnow in isolated pools of the Middle Rio Grande. Presented to the Middle Rio Grande Endangered Species Act Collaborative Program PVA Workgroup on January 28, 2011, Albuquerque, New Mexico. Available online at: http://www.middleriogrande.com/LinkClick.aspx?fileticket=%2bi7gbW1nhhc%3d&tabid=390&mid=1299

Valett, H. M., et al. 2005. Biogeochemical and metabolic responses to the flood pulse in a semiarid floodplain. Ecology 86:220–234.

Van Horn, D. 2008. Water quality in the Middle Rio Grande. Rio Grande seminar series presentation, May 2, 2008. University of New Mexico, Biology Department, Albuquerque, New Mexico. http://bioannexlabs.unm.edu/BIOL/DVH_Rio_Grande_Seminar_Final_2.pdf. Accessed April 28, 2011.

Veenstra, J. N., and S. L. Nolen. 1991. In-situ sediment oxygen demand in five Southwestern U.S. Lakes. Water Research 25:351–354.

Walker, R. R., and W. J. Snodgrass. 1986. Model for sediment oxygen demand in lakes. Journal of Environmental Engineering 112:25–43.

Wang, W. 1980. Fractionation of sediment oxygen demand. Water Research 14:603–612.

Watts, H. E., C. W. Hoagstrom, and J. R. Smith. 2002. Observations on habitat associated with Rio Grande silvery minnow, *Hybognathus amarus* (Girard). Report to Army Corps of Engineers, Albuquerque, New Mexico. U.S. Fish and Wildlife Service, New Mexico Fishery Resources Office, Albuquerque, New Mexico.

Wenning, R. J., L. Martello, and A. Prusak-Daniel. 2011. Dioxins, PCBs, and PBDEs in aquatic organisms. Pages 95–158 in W. N. Beyer and J. P. Meador, editors. Environmental contaminants in biota: interpreting tissue concentrations. Second Edition. CRC Press, Boca Raton, Florida.

Yanick, S. 2006. 2002–2003 Cooperative Polychlorinated Biphenyl (PCB) study data. Elevated levels of PCBs in Rio Grande near Albuquerque during storm flows. Correspondence, June 6, 2006, to G. Turner, U.S. Department of Energy. New Mexico Environment Department, Department of Energy Oversight Bureau, Santa Fe, New Mexico.

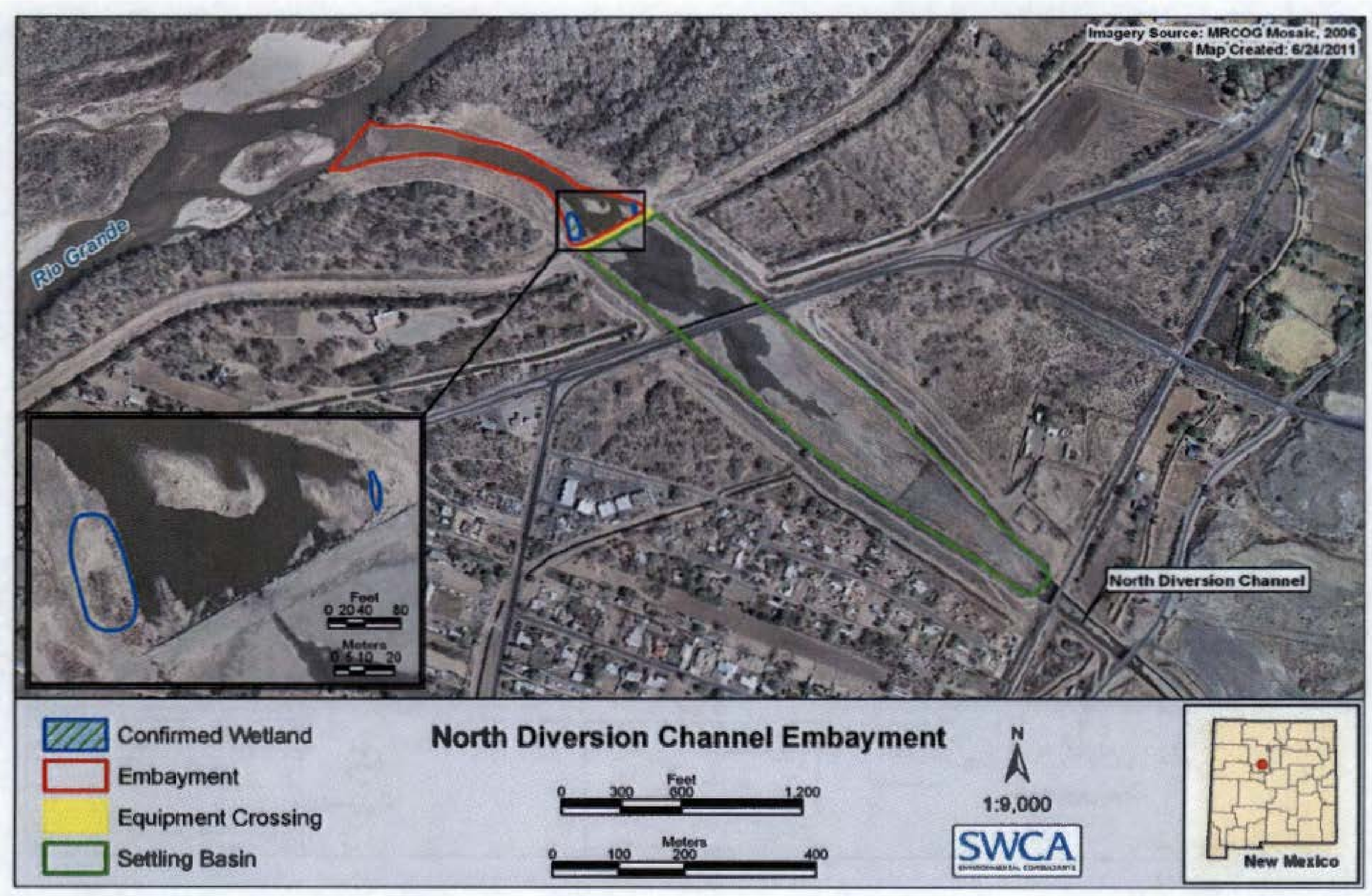

Figure 1. Map of the North Diversion Channel Embayment in Bernalillo County, New Mexico. Source: SWCA Environmental Consultants 2011.

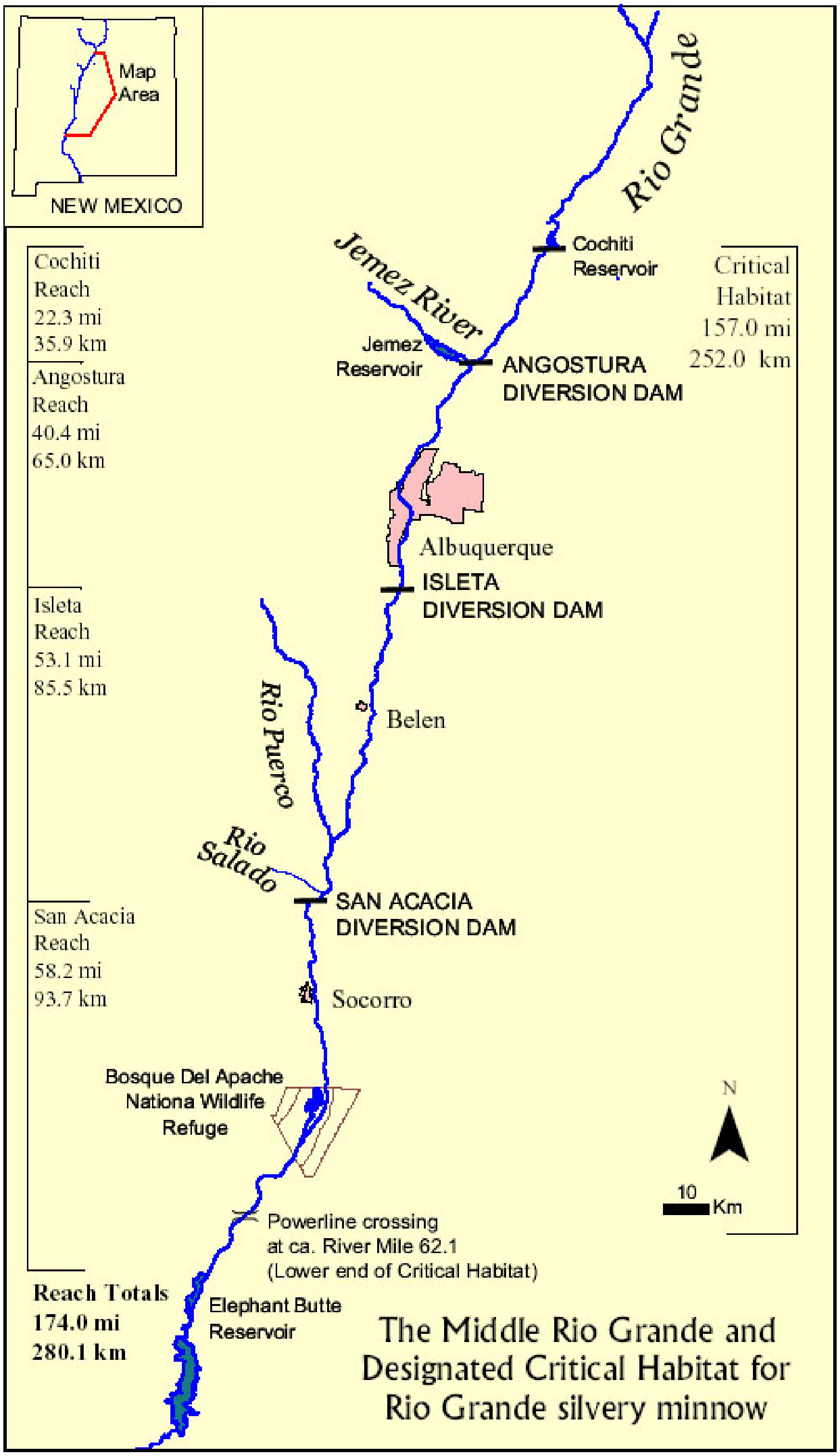

Figure 2. Location of the Angostura (and Cochiti, Isleta, San Acacia) Reach and selected major features in the Middle Rio Grande, New Mexico.

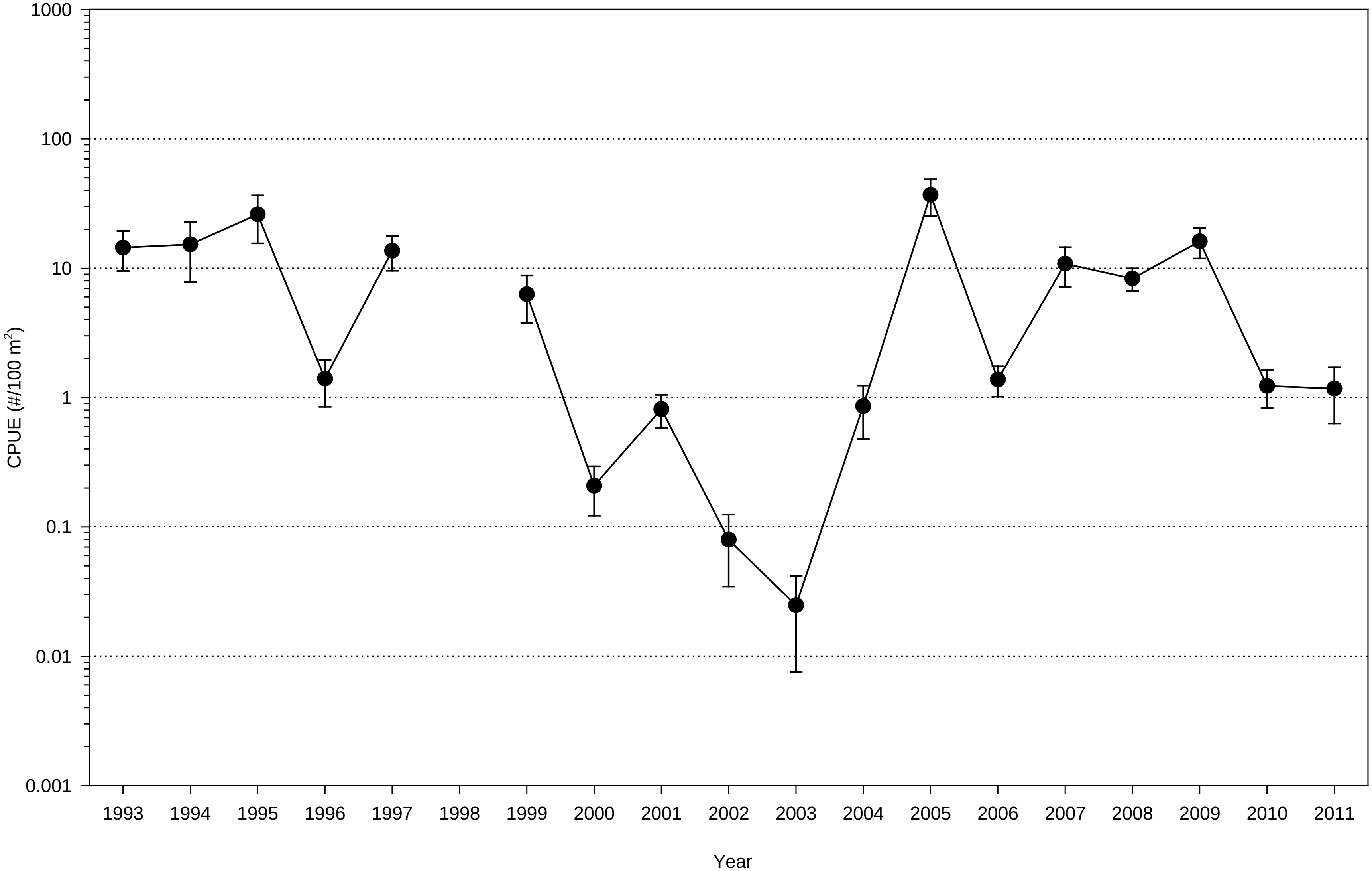

Figure 3. Rio Grande Silvery Minnow Monitoring Data (1993-2011) based on October catch per unit effort (CPUE) (values are numbers of individual silvery minnow caught per 100 m^2) (Dudley and Platania 2011).

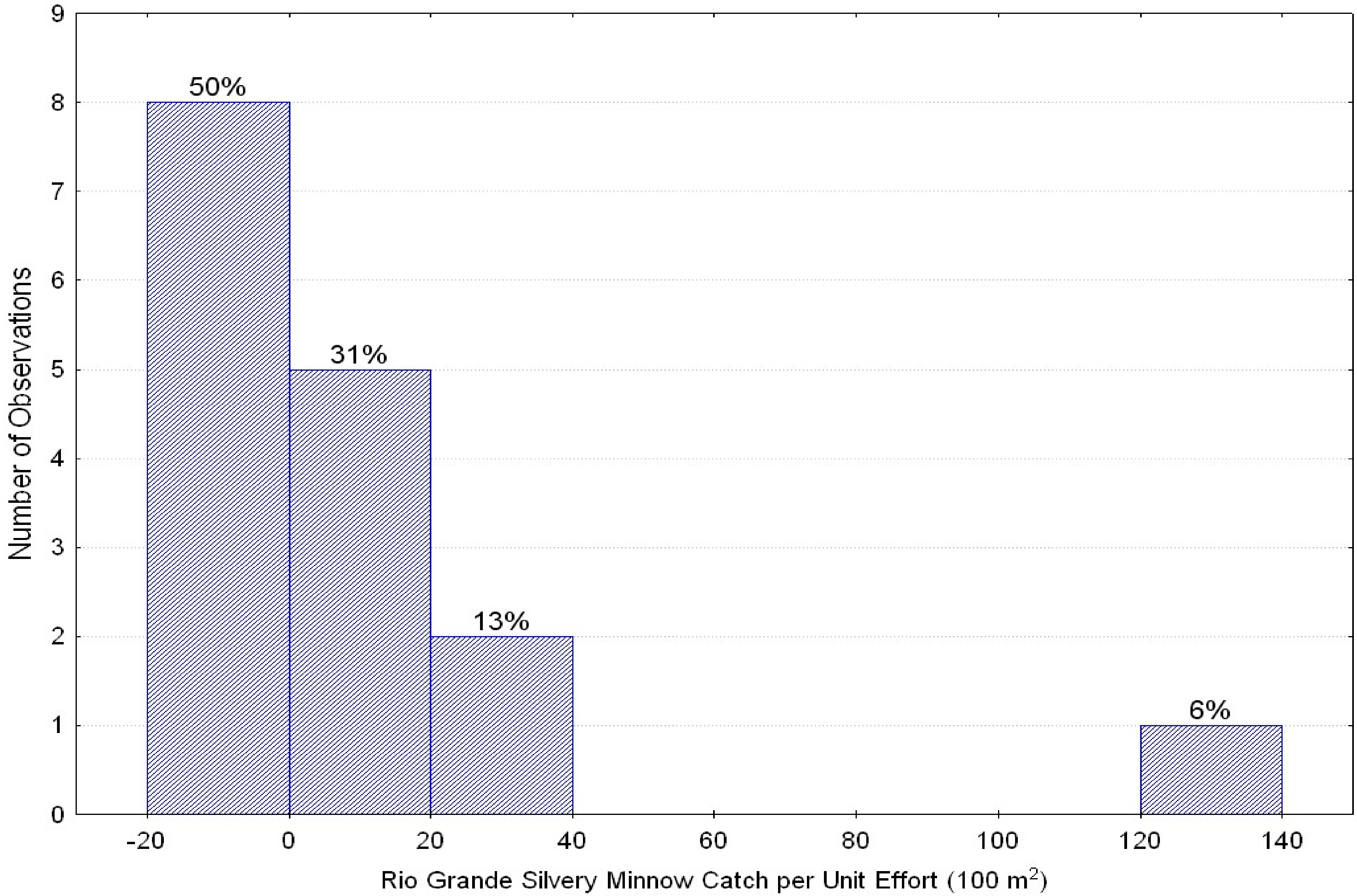

Figure 4. Histogram of the observation of individual Rio Grande silvery minnow caught (per 100 m^2) in the North Diversion Channel Embayment during November to March monitoring in 2008-2011 (based on data provided in Remshardt b,c),

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	NDC Embayment (HEAL 2011)	NDC Embayment (Buhl 2005)	Rio Grande Angostura Reach 1985-2000 (Marcus et al. 2005)	Rio Grande Angostura Reach 2002-2003 (Abeyta and Lusk 2004a)
1,1,1-Trichloroethane	<46	<0.8	---	<7.5
1,1,2,2-Tetrachloroethane	<46	<1.7	---	<7.5
1,1,2-Trichloroethane	<46	<1	---	<7.5
1,1-Dichloroethane	<91	<0.6	---	<7.5
1,1-Dichloroethene	<46	<0.9	---	<7.5
1,2,4-Trichlorobenzene	<46	0.5	---	---
1,2-Dichlorobenzene	<46	<0.7	---	---
1,2-Dichloroethane	<91	<0.6	---	<7.5
1,2-Dichloropropane	<46	<0.6	---	<7.5
1,4-Dichlorobenzene	<46	<1.0	---	---
1-Methylnaphthalene	<180	---	---	22.46
1-Methylphenanthrene	<180	---	---	---
2,4-D	---	---	<0.1	---
2,4-Dimethylphenol	---	---	---	---
2,4-Dinitrotoluene	---	---	<50	---
2,6-Dinitrotoluene	---	---	<500	---
2-Chloronaphthalene	---	---	---	---
2-Chlorophenol	---	---	<50	---
2-Hexanone	---	7	---	---
2-Methylnaphthalene	---	---	---	---
4-Methyl-2-pentanone	<46	<6.1	---	---
Acenaphthene	<990	<112	<50	13.6
Acenaphthylene	<990	<77.1	<50	19
Acetone	---	10.5	---	23.1
Acridine	---	---	---	---
Aldrin	<8.1	<12.4	---	<26.6
alpha-BHC	<8.1	<12.6	---	<2.03
Ammonia as Nitrogen	---	14.4	---	---
Aluminum	1500	24600	---	9550
Anthracene	<990	<70.1	---	<7.8
Antimony	<13	---	---	<0.02
Arsenic	<13	5.8	---	2.86

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	NDC Embayment (HEAL 2011)	NDC Embayment (Buhl 2005)	Rio Grande Angostura Reach 1985-2000 (Marcus et al. 2005)	Rio Grande Angostura Reach 2002-2003 (Abeyta and Lusk 2004a)
Barium	150	226	585	102.7
Benzene	<46	<0.3	---	<0.5
Benzo[a]anthracene	<990	135	---	<12.8
Benzo[a]pyrene	<990	245.6	---	<21.24
Benzo[b]fluoranthene	<990	280.7	32	33.5
Benzo[g,h,i]perylene	<990	<142	---	21.6
Benzo[k]fluoranthene	<990	152.6	---	19.3
Benzyl n-butyl phthalate	---	---	---	---
beta-BHC	150	<22.8	---	<2.2
Bis(2-ethylhexyl) phthalate	<2500	---	460	---
Bromoform	<46	<0.8	---	---
Cadmium	<0.5	0.22	1	0.09
Carbon disulfide	<46	<0.7	---	<0.5
Carbon tetrachloride	<46	<0.5	---	<7.5
Chlordane	<1000	<10.8	---	<267
Chlorobenzene	<46	<0.5	---	<0.42
Chloroform	<46	<0.7	---	<0.52
Chromium	10	20.9	47.5	7.7
Chrysene	<990	298.2	---	26.6
Cobalt	6.3	8.2	---	3.5
Chemical Oxygen Demand	---	3684	---	---
Copper	15	23.9	---	6
Cyanide, Total	---	---	---	0.22
delta-BHC	<8.1	---	---	<4.9
Diazinon	---	---	---	---
Dibenzo[a,h]anthracene	<990	<192	<50	---
Dieldrin	<8.1	---	---	<2.0
Diethyl phthalate	---	---	---	---
Dimethyl phthalate	---	---	---	---
Di-n-octyl phthalate	<1200	---	---	---

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	NDC Embayment (HEAL 2011)	NDC Embayment (Buhl 2005)	Rio Grande Angostura Reach 1985-2000 (Marcus et al. 2005)	Rio Grande Angostura Reach 2002-2003 (Abeyta and Lusk 2004a)
Endosulfan I	<8.1	<12.9	---	<5.9
Endosulfan II	<8.1	<11.4	---	<6.8
Endosulfan sulfate	<8.1	<12.9	---	<6.3
Endrin	<8.1	<11.4	---	<6.5
Endrin aldehyde	<8.1	<14.9	---	<6.8
Ethylbenzene	<46	<0.8	---	<1.4
Fluoranthene	<990	263.1	---	<51.8
Fluorene	<990	<38.5	---	<21.4
Heptachlor	<8.1	<17.3	<1	<5.0
Heptachlor epoxide	---	<11.2	---	2.3
Hexachlorobenzene	<990	---	---	---
Indeno(1,2,3-cd)pyrene	<990	166.6	---	16.6
Iron	---	---	---	9250
Isodrin	---	---	---	---
Isophorone	<2500	---	---	---
Lead	35	20.4	<100	6
Lindane	<8.1	<12.6	---	<4.0
Malathion	---	---	---	---
Manganese	---	374	680	217
Mercury	<33	<0.02	---	0.004
Methoxychlor	<8.1	<19.2	---	<6
Methyl parathion	---	---	---	---
Methylene chloride	---	<1.2	---	---
Mirex	---	---	---	---
m-Xylene & p-Xylene	---	---	---	<2.1
Naphthalene	<91	<170	---	<29.8
Nickel	9	15.2	---	6.2
Nitrobenzene	<2500	---	---	---

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	NDC Embayment (HEAL 2011)	NDC Embayment (Buhl 2005)	Rio Grande Angostura Reach 1985-2000 (Marcus et al. 2005)	Rio Grande Angostura Reach 2002-2003 (Abeyta and Lusk 2004a)
o,p'-DDD	---	---	---	---
o,p'-DDE	---	---	---	---
o-Xylene	---	---	---	---
p,p'-DDD	<8.1	<10	---	2.8
p,p'-DDE	<8.1	<10.1	---	3.8
p,p'-DDT	<8.1	<15.4	<2	<3.8
Parathion	---		---	---
Phenanthrene	<990	143.8	---	15.7
Pyrene	<990	438.5	---	24
Silver	<1.3	0.56	---	0.08
Silvex	---	---	---	---
Styrene	---	<0.6	---	<0.8
Tetrachloroethene	---	<0.7	---	<1.1
Toluene	<46	0.8	---	0.8
Total DDT	---	---	---	---
Total PAH	---	---	---	---
Total PCB	<81	<99.4	<100	---
Toxaphene	<1000	<684	<136	<157
Vinyl chloride	<46	<0.7	---	<1.2
Xylenes (total)	<91	<1.7	---	<3.1
Zinc	89	96.1	---	27.7

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	Threshold Effect Concentration (TEC)	Probable Effect Concentration (PEC)	Unit (Dry Weight)	TEC or PEC Source (See Marcus et al. 2005 for References Below)
1,1,1-Trichloroethane	170	---	ug/kg	EPA 1997 (as cited in Macdonald et al. 1999)
1,1,2,2-Tetrachloroethane	850	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,1,2-Trichloroethane	518	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,1-Dichloroethane	0.575	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,1-Dichloroethene	19.4	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,2,4-Trichlorobenzene	5062	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,2-Dichlorobenzene	294	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,2-Dichloroethane	260	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,2-Dichloropropane	333	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1,4-Dichlorobenzene	318	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
1-Methylnaphthalene	130	---	ug/kg	Jones et al. 1997 (as cited in Hellyer and Balog 1999)
1-Methylphenanthrene	204	---	ug/kg	Benchmarks for Phenanthrene
2,4-D	0.038	---	ug/kg	Stortelder et al. 1989
2,4-Dimethylphenol	6.21	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
2,4-Dinitrotoluene	14.4	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
2,6-Dinitrotoluene	39.8	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
2-Chloronaphthalene	417	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
2-Chlorophenol	31.9	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
2-Hexanone	58.2	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
2-Methylnaphthalene	70	---	ug/kg	Buchman 1999
4-Methyl-2-pentanone	25.1	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Acenaphthene	6.7	---	ug/kg	CCME 1999 (6) as cited in MacDonald et al. 2003
Acenaphthylene	5.9	---	ug/kg	CCME 1999 (6) as cited in MacDonald et al. 2003
Acetone	8.7	---	ug/kg	U.S. EPA. 1996. OSWER. Ecotox Thesholds. ECO Update.
Acridine	1000	---	ug/kg	MacDonald et al. 1999 - Georgia Basin
Aldrin	2	---	ug/kg	Persaud et al.1992 LEL and SEL (assumed 2% TOC)
alpha-BHC	6	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Ammonia as Nitrogen	---	---	mg/kg	---
Aluminum	25519	---	mg/kg	Ingersoll et al. 1996
Anthracene	57.2	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Antimony	150	---	mg/kg	Barrick et al. 1988
Arsenic	9.79	---	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	Threshold Effect Concentration (TEC)	Probable Effect Concentration (PEC)	Unit (Dry Weight)	TEC or PEC Source (See Marcus et al. 2005 for References Below)
Barium	20	---	mg/kg	USEPA 1977as cited in MacDonald et al. 2003
Benzene	57	---	ug/kg	U.S. EPA. 1996. OSWER. Ecotox Thesholds. ECO Update.
Benzo[a]anthracene	108	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Benzo[a]pyrene	150	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Benzo[b]fluoranthene	27.2	---	ug/kg	USEPA 1996b (7) as cited in Hellyer and Balog 1999
Benzo[g,h,i]perylene	290	---	ug/kg	USEPA 1996b (7) as cited in Hellyer and Balog 1999
Benzo[k]fluoranthene	27.2	---	ug/kg	USEPA 1996b (7) as cited in Hellyer and Balog 1999
Benzyl n-butyl phthalate	1970	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
beta-BHC	5	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Bis(2-ethylhexyl) phthalate	180	---	ug/kg	MacDonald et al. 1996 (11) as cited in MacDonald et al. 2003
Bromoform	650	---	ug/kg	MacDonald et al. 1999
Cadmium	0.99	---	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Carbon disulfide	23.9	---	ug/kg	Marcus et al. 2005
Carbon tetrachloride	1200	---	ug/kg	EPA 1997 (as cited in Macdonald et al 1999)
Chlordane	3.2	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Chlorobenzene	820	---	ug/kg	EPA 1997 (as cited in Macdonald et al 1999)
Chloroform	0.4	---	ug/kg	Stortelder et al. 1989 (as cited in MacDonald et al. 1999)
Chromium	43.4	---	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Chrysene	166	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Cobalt	50	---	mg/kg	Persaud et al. 1993
Chemical Oxygen Demand	---	---	mg/kg	---
Copper	31.6	---	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Cyanide, Total	0.1	---	mg/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
delta-BHC	71500	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Diazinon	0.38	---	ug/kg	Stortelder et al. 1989 (as cited in MacDonald et al. 1999)
Dibenzo[a,h]anthracene	33	---	ug/kg	MacDonald et al. (2000a)/CCME (1999)
Dieldrin	1.9	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Diethyl phthalate	630	---	ug/kg	USEPA 1997 (9) as cited in MacDonald et al. 2003
Dimethyl phthalate	160	---	ug/kg	Barrick et al. 1988 (8) as cited in Hellyer and Balog 1999
Di-n-octyl phthalate	40600	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	Threshold Effect Concentration (TEC)	Probable Effect Concentration (PEC)	Unit (Dry Weight)	TEC or PEC Source (See Marcus et al. 2005 for References Below)
Endosulfan I	2.9	---	ug/kg	U.S. EPA. 1996. Ecotox Thesholds. ECO Update.
Endosulfan II	14	---	ug/kg	U.S. EPA. 1996. Ecotox Thesholds. ECO Update.
Endosulfan sulfate	34.6	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Endrin	2.2	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Endrin aldehyde	480	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Ethylbenzene	175	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Fluoranthene	423	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Fluorene	77.4	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Heptachlor	0.6	---	ug/kg	EPA R5 RCRA Ecological Screening Levels 2003 & Buchman 1999
Heptachlor epoxide	2.5	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Hexachlorobenzene	20	---	ug/kg	Persaud et al . 1993 (as cited in MacDonald et al. 2003)
Indeno(1,2,3-cd)pyrene	78	---	ug/kg	USEPA 1996b (as cited in Hellyer and Balog 1999)
Iron	188400	---	mg/kg	Ingersoll et al. 1996
Isodrin	55.2	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Isophorone	2400	---	ug/kg	Bolton et al. 1985 (as Cited in MacDonald et al. 1999)
Lead	35.8	---	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Lindane	2.4	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Malathion	0.67	---	ug/kg	USEPA 1997 (9) as cited in MacDonald et al. 2003
Manganese	631	---	mg/kg	Ingersoll et al. 1996
Mercury	0.18	---	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Methoxychlor	19	---	ug/kg	U.S. EPA. 1996. Ecotox Thesholds. ECO Update.
Methyl parathion	7.2	---	ug/kg	Stortelder et al. 1989 (as Cited in MacDonald et al. 1999)
Methylene chloride	500	---	ug/kg	Bolton et al. 1985 (as cited in Macdonald et al. 1999)
Mirex	11	---	ug/kg	MENVIQ/EC 1992 (As cited in Macdonald et al. 1999)
m-Xylene & p-Xylene	25	---	ug/kg	EPA 1997
Naphthalene	176	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Nickel	22.7	---	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Nitrobenzene	145	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003

Appendix A. Average Sediment Quality in North Diversion Channel Embayment, and Rio Grande Angostura Reach compared to Effect Thresholds. ["---", data unavailable; "<", less than. Based on Marcus et al. 2005]

Parameter	Threshold Effect Concentration (TEC)	Probable Effect Concentration (PEC)	Unit (Dry Weight)	TEC or PEC Source (See Marcus et al. 2005 for References Below)
o,p'-DDD	16	---	ug/kg	Barrick et al. 1988 (8) as cited in Hellyer and Balog 1999
o,p'-DDE	9	---	ug/kg	Barrick et al. 1988 (8) as cited in Hellyer and Balog 1999
o-Xylene	25	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
p,p'-DDD	3.54	---	ug/kg	Smith et al. 1996 (12) as cited in Hellyer and Balog 1999
p,p'-DDE	1.42	---	ug/kg	Smith et al. 1996 (12) as cited in Hellyer and Balog 1999
p,p'-DDT	1.19	---	ug/kg	FDEP 1994 (13) as cited in Hellyer and Balog 1999
Parathion	0.81	---	ug/kg	EPA 1988 (as cited in Macdonald et al. 1999)
Phenanthrene	204	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Pyrene	195	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Silver	1	---	mg/kg	NYSDEC 1999 (2) as cited in MacDonald et al. 2003
Silvex	675	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Styrene	254	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Tetrachloroethene	1600	---	ug/kg	EPA 1997 (as cited in MacDonald et al. 1999)
Toluene	890	---		EPA 1997 (as cited in Macdonald et al. 1999)
Total DDT	5.3	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Total PAH	1600	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Total PCB	60	---	ug/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000
Toxaphene	0.1	---	ug/kg	NYSDEC 1999 (2) as cited in MacDonald et al. 2003
Vinyl chloride	202	---	ug/kg	USEPA Region 5 RCRA Ecological Screening Levels 2003
Xylenes (total)	25	---	ug/kg	EPA 1997 (as cited in Macdonald et al. 1999)
Zinc	121	459	mg/kg	MacDonald DD, Ingersoll CB, Berger TA. 2000