CDM

In Association With:

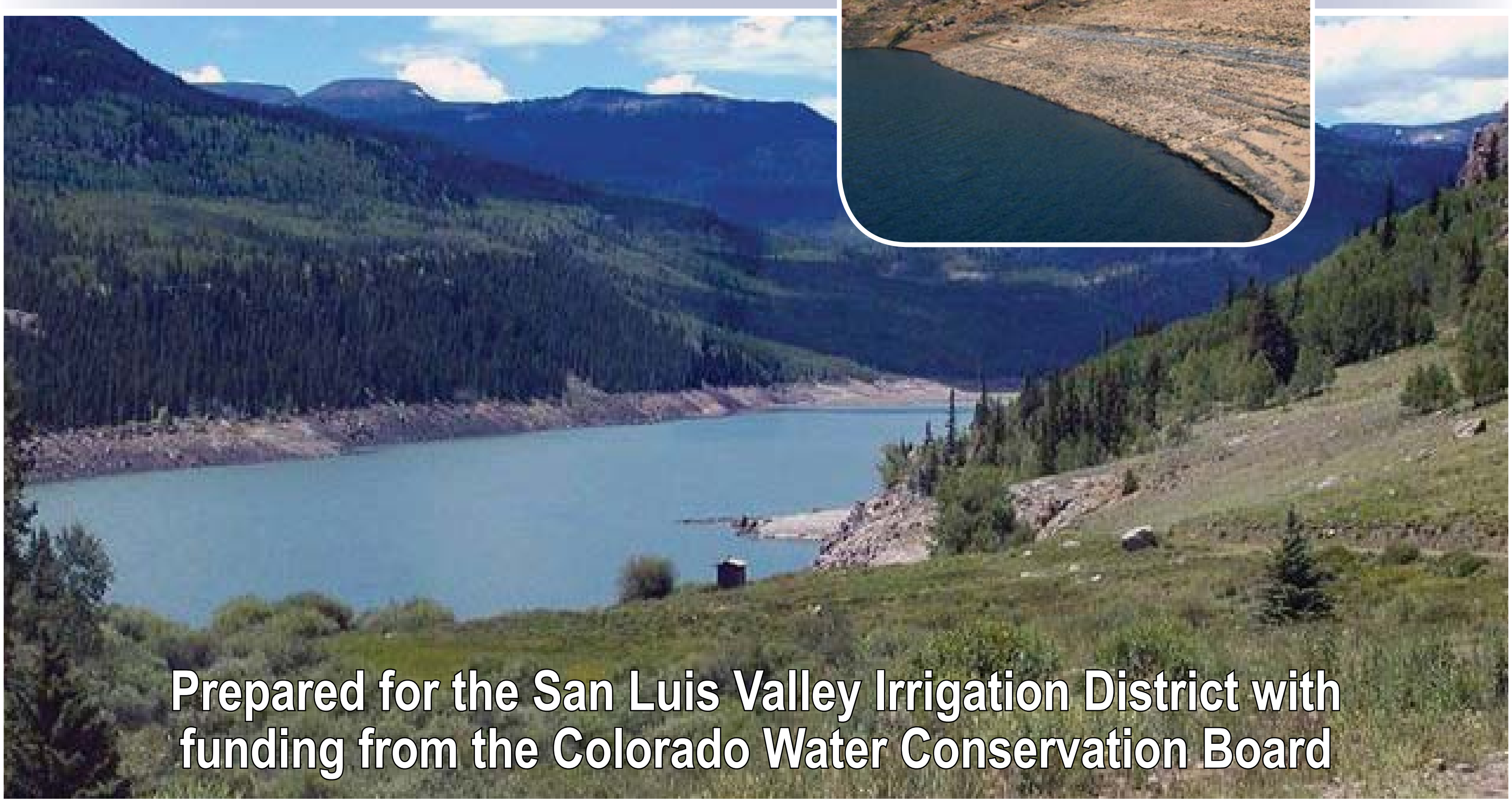
SUGNET & MOORE ENVIRONMENTAL, INC.

DEERE & AULT CONSULTANTS, INC.
Water Resources, Civil & Geotechnical Engineering

Rio Grande Reservoir

Multi-Use Enlargement Study

July 31, 2007



Prepared for the San Luis Valley Irrigation District with funding from the Colorado Water Conservation Board

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Section 1
Introduction

The San Luis Valley Irrigation District (District) serves and delivers water to land located in the San Luis Valley in Alamosa, Rio Grande, and Saguache Counties. The District owns and diverts its water through the Farmers Union Canal, which diverts from the Rio Grande River (River). It also owns and operates the Rio Grande Reservoir (Reservoir) located on the headwaters of the Rio Grande in Hinsdale County, Colorado. The District's offices are located in Center, Colorado.

The purpose of this study is to examine potential uses of an enlarged Reservoir to address multi-use needs in the Rio Grande Basin (Basin) including:

- Providing additional storage space to assist the State of Colorado in administration and management of the Rio Grande under the Rio Grande Compact (Compact) to maximize the beneficial use of Colorado's apportionment of the Rio Grande Compact for the benefit of the state;

The Rio Grande Reservoir is owned and operated by the San Luis Valley Irrigation District.

- Providing space for the storage and regulation of transmountain water to meet the growing demand for augmentation water for municipal, domestic, and commercial development;
- Storage and regulation of already developed agricultural water supplies, including direct flow storage, to better meet irrigation demands;
- Storage and regulation of high flows to more efficiently recharge the unconfined aquifer;
- Re-regulation of flows to better meet recreational and environmental needs; and
- Re-regulation of flows for flood protection.

Located on the headwaters of the Rio Grande, the Reservoir provides a unique on-stream, pre-compact facility available to better manage Colorado's apportionment of the Rio Grande for the benefit of the State, the San Luis Valley, and the River corridor. Additional storage will provide the State of Colorado with an invaluable tool to store and better manage delivery of the water it is obligated under the Compact to deliver to the Colorado-New Mexico border. It will help to assure that Colorado retains for use in Colorado all of its water available under the Compact. Re-regulation of deliveries under the Compact will also help to address instream flow needs for fish and river habitat. Additional storage can also help to reduce the wide fluctuations and result in more equitable allocation of the curtailment on irrigators in order to meet Colorado's compact obligations. This will hopefully provide irrigators with a more consistent water supply during the irrigation season while assuring that Colorado has stored water that may be needed to meet any remaining compact obligation after the irrigation season ends. Enlargement to store new water supplies for irrigation is not being considered because previous studies have concluded that there is insufficient firm yield available for this purpose.

The study is comprised of three primary components: development of potential enlargement configurations, stakeholder input, and a fatal flaw analysis in which geotechnical aspects of enlargement and jurisdictional wetlands impacts were considered. The study was funded by a grant from the Colorado Water Conservation Board (CWCB) through its non-reimbursable fund for 2006-2007.

Section 2
Rio Grande Reservoir Historical Information

The Reservoir is located approximately 20 miles southwest of Creede, Colorado, as shown in Figure 2-1. The Reservoir is located on the headwaters of the mainstem of the Rio Grande and has a present storage capacity of approximately 52,500 acre-feet (AF). Although water from the Reservoir could be delivered via the Rio Grande mainstem for use in Hinsdale, Mineral, Alamosa, Rio Grande, Costilla, and Saguache Counties, all of the water that is presently used is for irrigation and augmentation in Mineral, Rio Grande, and Alamosa Counties. Located at an altitude of approximately 9,500 feet, the Reservoir has a drainage area of approximately 165 square miles. The two water storage rights for the Reservoir are 45,833 AF under Priority No. 1916-63A and 5,280 AF under Priority No. 1934-2 for a total of 51,113 AF (Helton and Williamsen 2003). Both of these water storage rights pre-date the Compact. A study in 2003 by Helton and Williamsen of water available for reservoir enlargement determined that the existing actual capacity of the Reservoir exceeds its decreed capacity by approximately 1,135 AF.

The original outlet gates were damaged due to vibration and two were plugged with concrete (Photo courtesy San Luis Valley Irrigation District).

Construction plans for the dam were submitted to the State Engineer's Office (SEO) in 1910 and construction to a capacity of approximately 46,000 AF was completed in 1914. The earthen and rockfill dam crest stood 100 feet high, at an elevation of 9,449 feet. The original outlet works as constructed in 1914 had five slide gates that almost immediately sustained severe damage due to vibration and erosion (Deere & Ault 2006). The gates were shortly thereafter repaired and two were permanently plugged with concrete.

The emergency spillway in 1958 (Photo courtesy San Luis Valley Irrigation District).

The dam embankment and outlet works have been modified on several occasions since their initial construction. The spillway, which is 32 feet wide and 600 feet long, was excavated in rock and lined with concrete. Spillway capacity was increased in 1962 through the construction of a side channel ogee spillway weir (Deere & Ault 2006). The spillway was repaired in 1970 and again in 1972. In 1979 the dam crest was raised an additional 5 feet, which allowed for more storage in the Reservoir and additional spillway capacity (Deere & Ault 2006). In 1982 the dam crest was raised to its current height of 111 feet, or elevation 9,470. Also as part of this effort, the spillway elevation was increased by one foot. The gate structures were repaired in 1983 and then again in 1987 to correct problems with the 1983 work. The existing dam site and outlet works are shown in Figure 2-2. The capacity of the outlet works on the Reservoir is the subject of continued discussion with the SEO. The State required that the outlet works have a discharge capacity of 2,500 cubic feet per second (cfs); however, only about 1,200 cfs can currently be discharged before serious vibrations begin to occur (Deere & Ault 2006). Additionally, the current spillway capacity is just over 15,000 cfs, which represents approximately 50 percent of the probable maximum flood (PMF). New dam safety regulations promulgated by the SEO state that the spillway capacity needs to be 80 percent of the PMF. As discussed in later sections, enlargements to the Reservoir will need to address this issue.

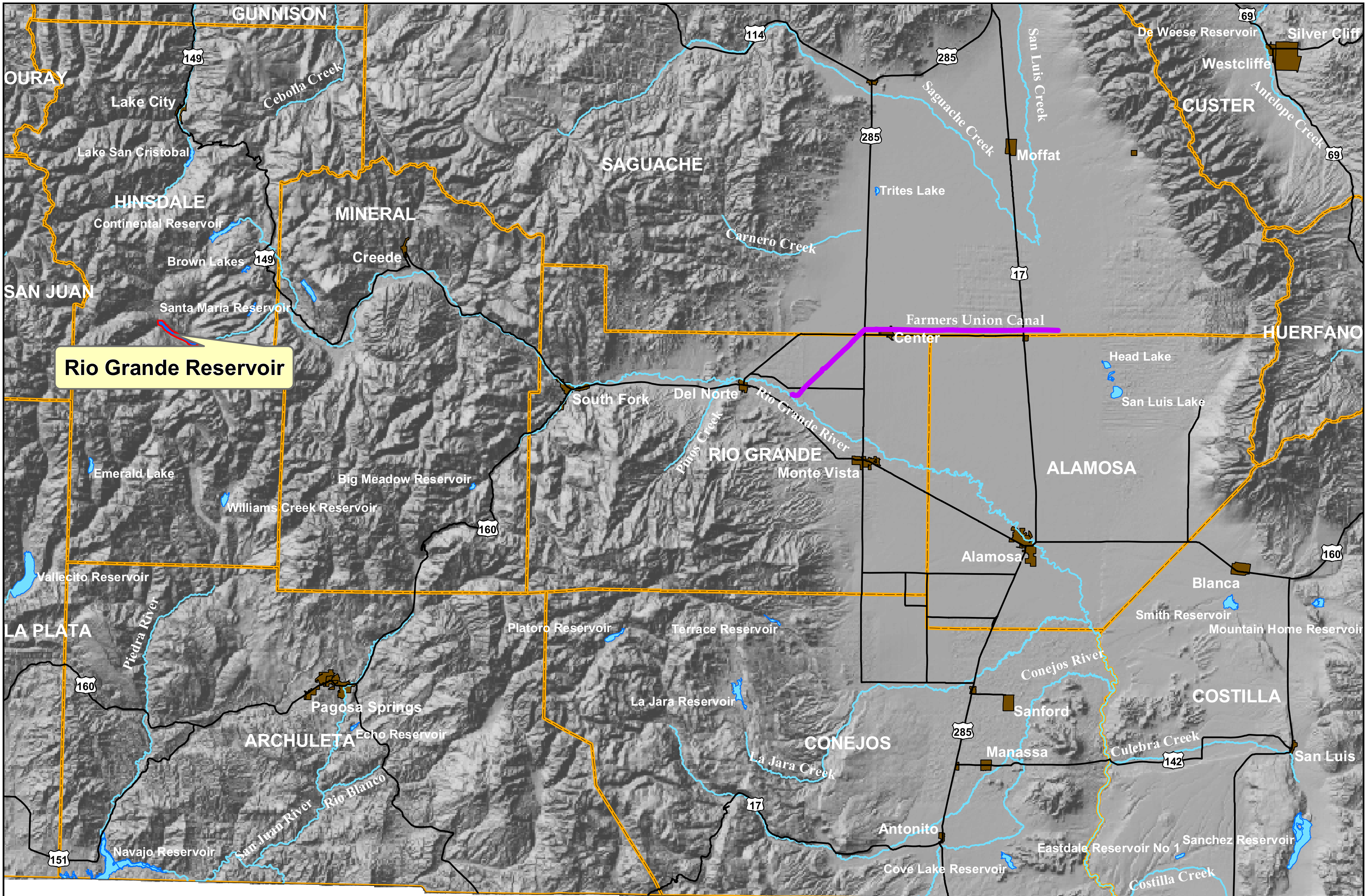

Figure 2-1
Rio Grande Reservoir Vicinity Map

Rio Grande Reservoir Existing Dam Site

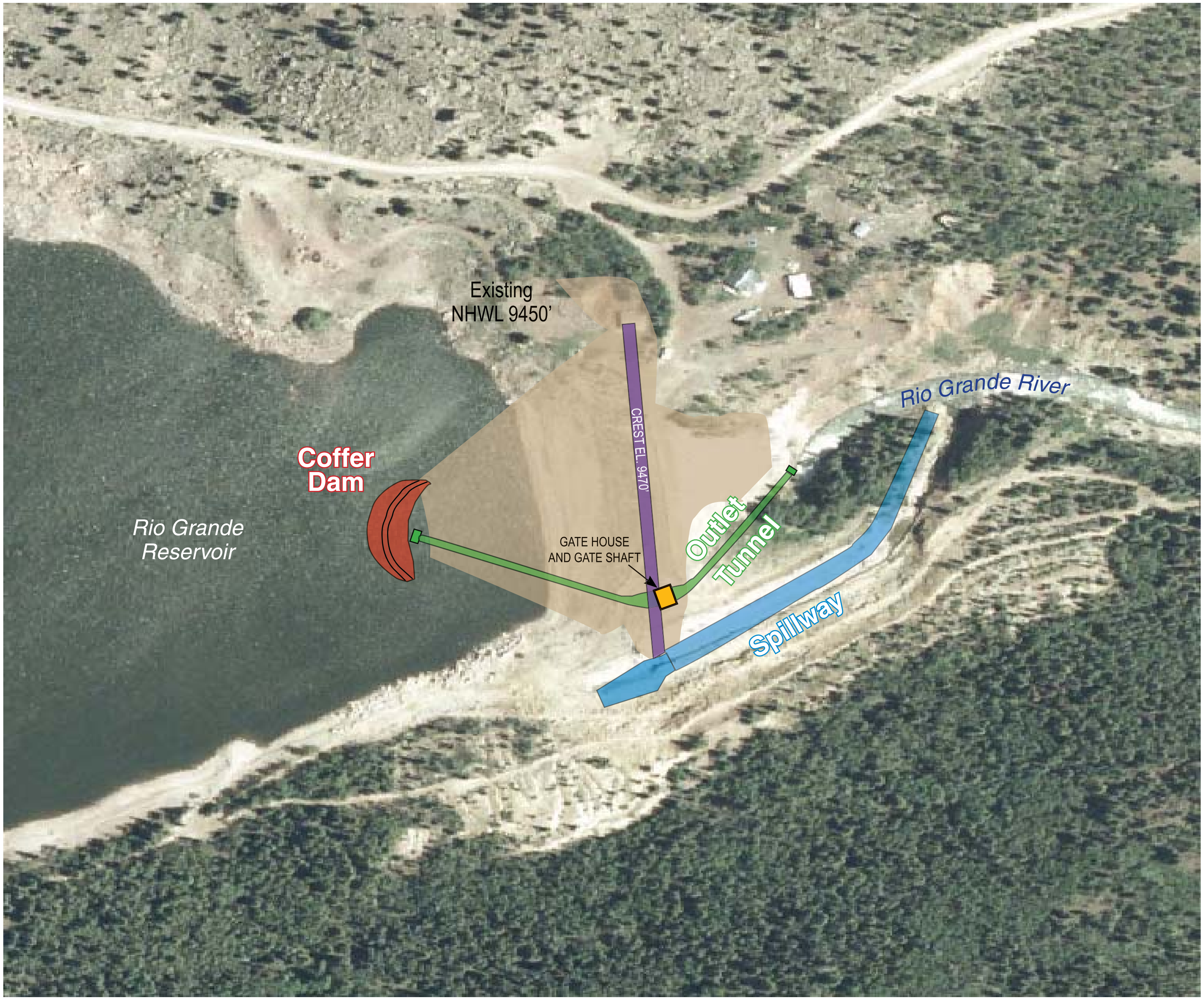

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FIGURE 2-2

Section 3
Potential Benefits of Enlargement

There are many potential benefits associated with an enlarged Reservoir that achieve many of the objectives outlined in the Statewide Water Supply Initiate (SWSI) Report (CDM 2004). This section discusses in detail the benefits of enlargement and the SWSI objectives that are achieved by enlarging the Reservoir. Table 3-1 presents in matrix form that identifies the SWSI objectives that are met through the benefits of enlargement.

Table 3-1 Benefits of Enlargement

	SWSI Objectives								
Enlargement Benefits	Sustainably Meet M&I Demands	Sustainably Meet Agricultural Demands	Optimize Existing and Future Water Supplies	Enhance Recreational Opportunities	Provide for Environmental Enhancement	Promote Cost Effectiveness	Protect Cultural Values	Provide for Operational Flexibility	Comply with All Applicable Laws, Regulations, and Water Rights
Reduce fluctuations in curtailments	✓	✓	✓			✓		✓	✓
Deliver water at periods of low-flow reducing conveyance losses	✓	✓	✓			✓	✓	✓	✓
Deliver water later in season following more definite annual flow projections	✓	✓	✓			✓		✓	✓
Storage of credit water upstream with reduced evaporation charges	✓	✓	✓			✓		✓	✓
Storage of additional transmountain water	✓	✓	✓			✓	✓	✓	✓
Meet rapidly growing demand for augmentation water	✓	✓	✓				✓		✓
Preserve existing agricultural lands		✓	✓				✓		✓
Storage and release of water for environmental and riparian enhancements				✓	✓		✓	✓	✓
Re-regulation of flows for recreational purposes				✓	✓	✓	✓	✓	✓
Permanent conservation pool				✓	✓		✓		✓

3.1 Optimize Rio Grande Compact Administration and River Management

Additional storage will provide the State of Colorado with an invaluable tool to regulate and therefore better manage the delivery of the water it is obligated under the Compact to deliver to the Colorado-New Mexico border. This regulation of flows will help to assure that Colorado retains for use in Colorado its apportionment of the Rio Grande Compact water. Regulation of water for delivery under the Compact will also help to reduce the fluctuations in the curtailments resulting from widely varying monthly flow projections that are presently imposed on irrigators to meet Colorado's Compact obligations. Re-regulation of releases for compact administration can also enhance streamflows for fish and river habitat purposes. This will hopefully provide irrigators with a more consistent water supply during the irrigation season while assuring that Colorado has stored water to meet any remaining compact obligation after the irrigation season ends.

3.2 Regulation of Transmountain Water to Meet Domestic and Commercial Demand in the Rio Grande Basin

The ability of the Reservoir to regulate additional transmountain water can assist in meeting the rapidly increasing need for augmentation of domestic and commercial development throughout the Rio Grande Basin. Transmountain water is not subject to the terms of the Compact. Increasing the ability to store and regulate transmountain water to augment depletions from domestic and commercial development from the headwaters downstream through Alamosa (and possibly to the Colorado-New Mexico border) will assist in preserving the existing agricultural economy by reducing the need to change agricultural water rights and remove land from agricultural production. Regulation of additional transmountain water may provide one source of supply for augmentation of these growing uses.

The San Luis Valley Water Conservancy District (Conservancy District) supplies most of the domestic well augmentation water in the Rio Grande Basin. The Conservancy District has agreements to store transmountain and other water in the Reservoir for augmentation purposes. Providing additional storage at the headwaters of the River for the Conservancy District's augmentation program will provide a source of augmentation water to meet the increasing demand throughout the Basin. It also will facilitate the Conservancy District's role as the principal provider of augmentation water throughout the Rio Grande Basin thereby reducing the need for a multitude of single-entity augmentation plans and simplifying administration.

3.3 High-Flow Storage for Groundwater Augmentation

As discussed in the SWSI Report, the unconfined aquifer of the Closed Basin has suffered substantial declines in recent years. The location of the unconfined aquifer is shown in Figure 3-1. The proposed preliminary design phase of study of the Reservoir multi-use enlargement will evaluate whether additional storage might, under certain hydrologic conditions, provide a source of supply that can be utilized to replenish and augment withdrawals from the groundwater aquifer pursuant to various groundwater recharge decrees held by the Rio Grande Water Users Association. Such use may assist the recently created groundwater management subdistrict in providing water to augment well withdrawals and in reducing the number of acres of agricultural land that may have to be taken out of production in the San Luis Valley because of the limited water supply.

3.4 Storage and Flow Regulation for Environmental and Recreational Purposes

An enlarged reservoir could assist in enhancing streamflows along the main channel of the River as well as addressing riparian needs and riparian restoration.

Recreational uses of the River are rapidly increasing, particularly from the headwaters downstream to South Fork, which provides a world class fishery and Class III and IV rapids for rafting and kayaking. Regulation of water delivered from the Reservoir for meeting Compact delivery obligations could enhance flows by re-timing Compact deliveries to enhance flows for recreational purposes without impacting existing water rights. An enlarged Reservoir could also assist the Colorado Division of Wildlife (DOW) in meeting its demands in the Rio Grande Basin. The Reservoir presently regulates small amounts of transmountain water owned by the DOW. Increased storage could provide significant opportunities to the DOW to obtain, store, and use greater amounts of transmountain water throughout the Basin. Additionally, increased storage in the Reservoir could potentially allow for a permanent conservation pool. At present there is not a designated conservation pool in the Reservoir, although the DOW does have the ability to maintain a pool pursuant to a temporary storage agreement with the District. A permanent conservation pool could provide both environmental and recreational benefits at the reservoir by providing a minimum reservoir pool for fishery and recreational uses.

Section 4
Stakeholder Involvement

Given the potential for enlargement of the Reservoir to benefit a variety of interests within the Rio Grande Basin, key stakeholders were informed and consulted during the study. At the outset of the study in early August 2006, a site visit was conducted for over 40 interested persons and stakeholders including representatives from the U.S. Forest Service, Colorado Division Engineer, and water users, elected officials, landowners, and recreational and environmental interests in the Basin. A preliminary presentation on the study was delivered to the Rio Grande Basin Roundtable (RGBRT), which includes a variety of environmental, recreational, agricultural, municipal, and industrial water interests through the Rio Grande Basin. A follow-up presentation was delivered to the RGBRT on January 8, 2007, to present the preliminary results of the study, receive input from the various stakeholders, and to discuss additional work to be done as part of a follow-up preliminary design phase. At this meeting, the RGBRT unanimously approved the project as an applicant for a grant from the State's Water Supply Reserve Account funds for the next phase of study, the preliminary design phase.

During the course of the study, the project team met with representatives of the following groups:

- U.S. Forest Service
- Colorado Division of Wildlife
- Colorado Water Conservation Board
- State Engineer's Office Staff
- Division Engineer, Water Division No. 3
- Rio Grande Basin Round Table
- Rio Grande Water Conservation District
- San Luis Valley Water Conservancy District
- Rio Grande Water Users Association
- Town of South Fork
- Rio Grande/Rio Bravo Basin Coalition and Colorado Rio Grande Headwaters Foundation
- San Luis Valley Wetlands Focus Area Committee
- Entz Farms

- U.S. Senator Ken Salazar's Office
- Colorado State University Cooperative Extension
- Creede America Group
- Broad Acres Ranch

Section 5
Geotechnical Investigation

A reconnaissance-level investigation of the geotechnical feasibility of a reservoir enlargement was conducted for this study that was comprised of a review of historical data on the construction of the dam and previous repair efforts, research into geological conditions with particular attention to historical landslides, a field visit to assess existing conditions of the dam and outlet works. Based on this, a proposed enlargement configuration and conceptual cost estimates for both a rehabilitation and an enlargement were developed.

The Reservoir site lies at an elevation ranging from approximately 9,200 feet at the east end to approximately 9,600 feet at the west end. Bedrock at the Reservoir site is mainly Tertiary volcanic ash deposits called "tuffs" (Deere & Ault 2006). At the dam site, the right abutment is comprised of a hard and strong, relatively massive, welded tuff. This tuff is visible in the right abutment outlet tunnel, the cliffs forming the stream valley downstream of the right abutment of the dam, and on the right reservoir banks upstream of the dam. This has been mapped on the U.S. Geological Survey (USGS) geologic map of the Durango Quadrangle Southwestern Colorado (Steven et al. 1974) as the Outlet Tunnel Member of the La Garita Tuff. This member is both underlain and overlain at the site by other tuff members.

There are three primary recent Quaternary soil deposits: glacial drift, landslide deposits, and recent alluvial deposits (Deere & Ault 2006). The steep valley setting of the Reservoir combined with the history of landslides in the area make this a particular area of concern with respect to enlargement. The four major landslides in the area as mapped by the USGS are shown in Figure 5-1. These landslides appear to be rock block glides or combination block glide-slumps that likely formed towards the conclusion of the last glacial period around 10,000 years ago (Deere & Ault 2006). Notably, there is a landslide mass on the left abutment that was studied previously by Chen & Associates as part of the 1983 outlet works repair led by W. W. Wheeler & Associates. Initial field work indicates that the landslide mass on the left abutment appears to be a fairly stable configuration that would not preclude raising the existing dam. Field observations indicate that the landslide mass on the left abutment has generally slid to a fairly stable configuration with an overall slop of 10:1. Locally, however, downstream of the dam, due to the cutting of the River, the toe of the slide slope is about 1.5:1 (Deere & Ault 2006). Piezometers in the left abutment of the dam indicate that the landslide mass is quite permeable, as the water level in the left abutment generally mimics the water level changes in the Reservoir.

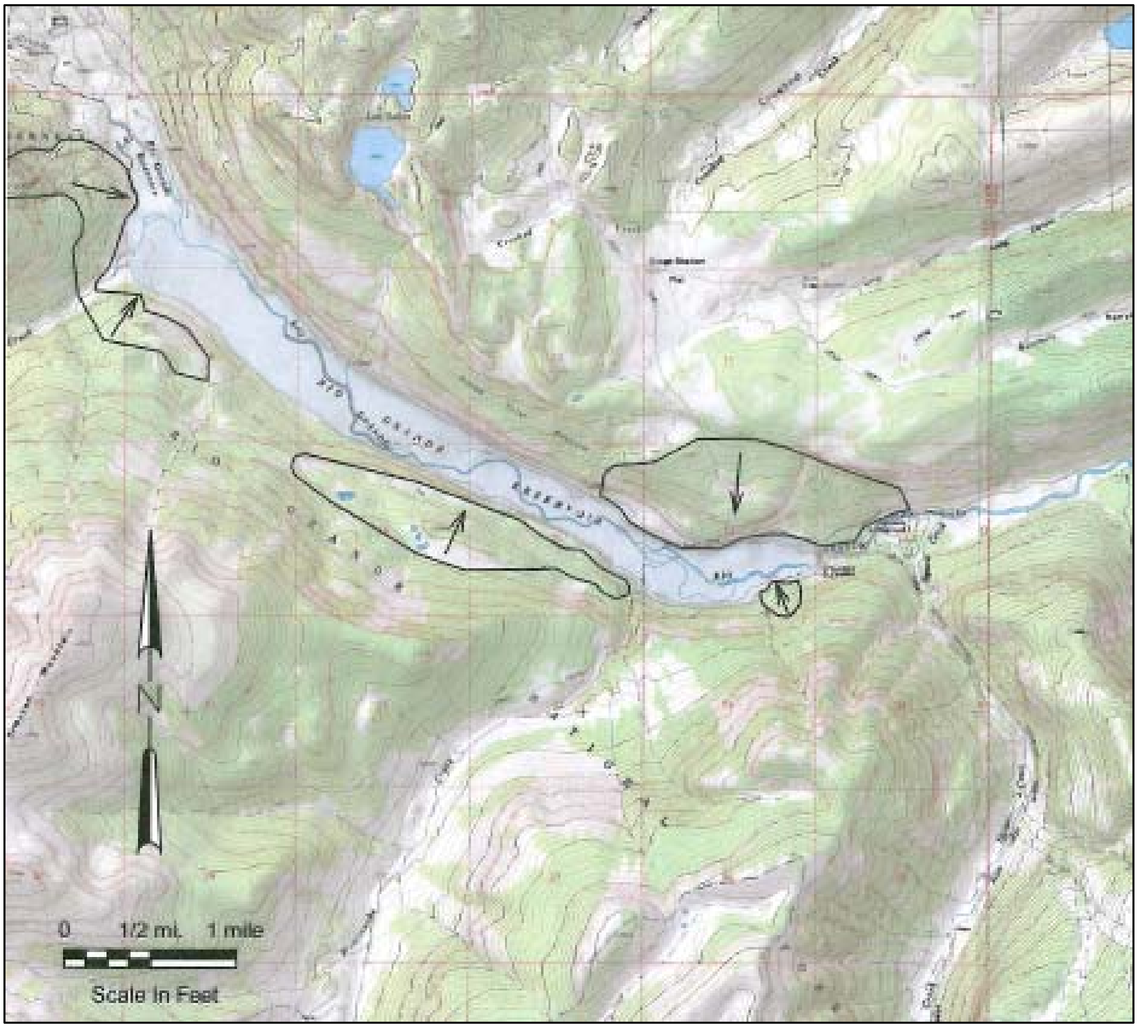


Figure 5-1 Existing landslide areas in the vicinity of the Reservoir (courtesy Deere & Ault)

In 1993, when the Reservoir was full, an instance occurred where cloudy water was seeping from the left abutment with total flows of about 2 cfs through the landslide mass (Deere & Ault 2006). This was remedied by work directed by HARZA Engineering; short horizontal drains, typically 40 feet long, were drilled into the left abutment downstream of the dam and a rock buttress was placed in the general area. Apparently due to the "chaotic" blocky nature of the landslide mass, the drains could only be installed to depths of approximately 40 feet, although the original plans called for 100-foot-long drain holes. This area of instability was apparently very small as compared to the overall landslide mass.

In addition to the historical slide at the left dam abutment, a landslide occurred in the early 1990s on West Lost Trail Creek, just a few miles upstream of the Reservoir. This may suggest that the Reservoir basin may be prone to landslides, raising concerns with respect to any dam enlargement. Fluctuating water levels within the Reservoir can promote slope instability due to increased pore water pressures. It is recommended that a more detailed landslide analysis of the area be conducted as part of the proposed preliminary design phase of the study.

Section 6
Wetlands Investigation

A preliminary wetland assessment was conducted in the area around the Reservoir and downstream of the existing dam that could be potentially impacted by a reservoir enlargement. This assessment identified waters of the U.S. that could be potentially impacted as a result of a reservoir enlargement project. The assessment included two days of field work to identify wetlands and produce preliminary mapping.

The U.S. Army Corps of Engineers (USACE) regulates impacts to wetlands through Section 404 of the Clean Water Act. The protocol set forth in the 1987 USACE Wetlands Delineation Manual (1987 Manual) was adhered to in conducting its assessment; however, an "official" wetlands delineation was not conducted, nor was the USACE contacted. The study area boundary for the wetlands assessment was defined as the area between the ordinary high water mark of the Reservoir and the maximum potential inundation limit given a 75,000 AF enlargement. A map of potential inundation limits was prepared using USGS quad maps. The ordinary high water mark was delineated in the field based on observed physical indications, such as lack of vegetation, water stains, rack lines, and historic aerial photos and mapping (Sugnet 2006). Wetland boundaries were defined based on presence of hydrophytic vegetation, hydric soils, and hydrologic indicators that under normal conditions would indicate wetland conditions (Sugnet 2006). Field investigations found that wetlands up and downstream of the Reservoir have been altered as a result of the regulated stream flows and prolonged periods of inundation. Therefore any areas located below the ordinary high water mark were considered to be a-typical areas, as defined in the 1987 Manual (Sugnet 2006).

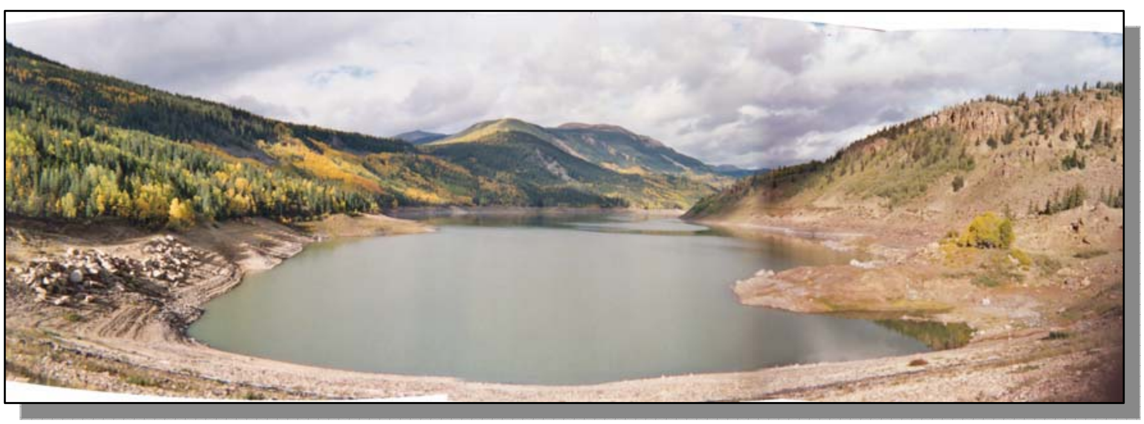


Figure 6-1. Panoramic photo looking west from the top of the dam; ordinary high water for the reservoir is marked by the vegetation line on the bank. (Photo Courtesy Sugnet Environmental)

6.1 Findings

Field investigations identified approximately 1,264 acres of "waters of the U.S." in the area during their field work, of which approximately 228 acres are classified as jurisdictional wetlands. Table 6-1 lists the jurisdictional waters of the U.S. delineated using the U.S. Fish and Wildlife Service (USFWS) classification system for wetlands and deepwater habitats.

Table 6-1 Acreage and Linear Footage of All Jurisdictional Waters of the U.S. located near the Rio Grande Reservoir Site (Sugnet 2006)

Waters of the U.S. Type	Area (ac)	Linear Feet
Palustrine Scrub-Shrub and Emergent Wetlands (PSS/PEM)	228	—
Upper Perennial Streambed (R3SB)	1.2	13,705
Intermittent Streambed (R4SB)	0.4	2,418
Open Water (OW)	1,034	30,123
Total Waters of the U.S.:	**1,263**	**46,246**

Based on the preliminary delineation, CDM estimated potential impacts to the 228 acres of jurisdictional wetlands in the area using mapping developed of potential inundation limits. CDM determined that less then 10 percent of the jurisdictional wetlands would be impacted by a 10-foot enlargement of the dam crest.

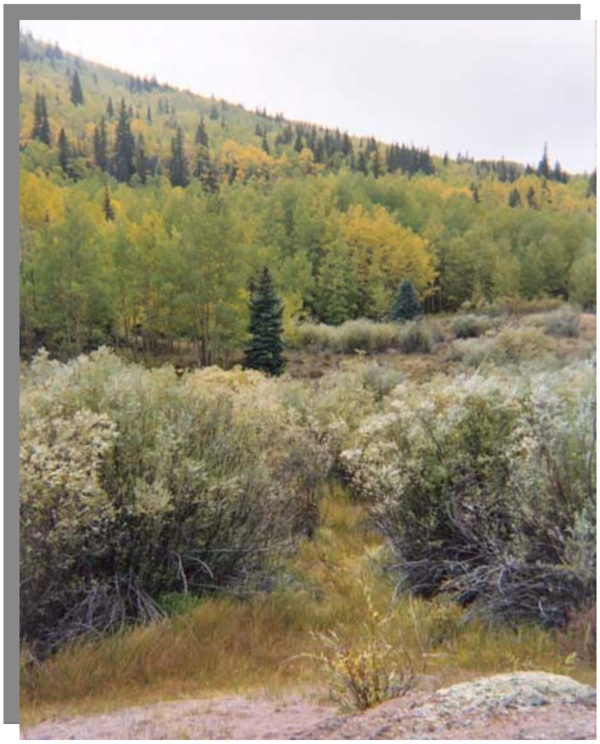


Figure 6-2. Potential fen wetland on south side of Reservoir. (Photo Courtesy Sugnet Environmental)

In addition to the delineation of perennial and intermittent streambeds, it is possible that other small ephemeral channels exist within the floodplain that may or may not be active during the spring runoff period. Additionally, this investigation did not distinguish between different types of wetlands, with the notable exception of calling out two potential fen wetland areas at the site. One of these sites is located downstream of the existing dam and the other is located on the south side of the Reservoir above the ordinary high water mark, roughly 2 miles from the west (upstream) end, as shown in Figure 6-2.

Fens are defined as "wetlands that are characterized by water logged spongy ground and contain (in all or part) soils classified as hisosols or mineral soils with a histic epipedon" (USACE 2002). Impacts to fen wetlands are of particular concern because fens are an especially important aquatic resource in Colorado and have special regulations attached to them. A 1998 memorandum from the USFWS stated that certain limited impacts to fens may be allowable if the applicant can demonstrate that "every effort has been made to avoid impacts" to the special resource and "there is no practicable alternative for non-water dependent activities." It appears that the downstream fens area will not be affected by the proposed enlargement. The fens area located on the south side of the Reservoir will require further consideration and investigation, though it is likely that an enlargement of 10 feet or less would not impact this potential fens area. The District will need to work closely with the USACE during the pre-design phase on this issue.

Vegetation

At the time of inspection, water levels in the Reservoir were very low, with approximately half of the Reservoir basin exposed (Sugnet 2006). The exposed areas were dominated by a herbaceous wet meadow populated by shortawn foxtail (Sugnet 2006). The upper transition of the Reservoir is dominated by a shrub wetland, characterized by the presence of mountain will and Geyer willow (Sugnet 2006). The floodplain wetland located below the dam is characterized by mountain willow with intermittent upland areas characterized by Engelman spruce and Idaho redtop (Sugnet 2006). Table 6-2 provides a list of dominant and characteristic species observed at the Reservoir (Sugnet 2006).

Figure 6-3. View looking northwest at tributary valley and braided stream at transition of the Reservoir to natural willow wetland area upstream of the reservoir. (Photo Courtesy Sugnet Environmental)

Table 6-2 Floral Species Observed in the Vicinity of the Rio Grande Reservoir Project Area

*Scientific Name**	Common Name	*Family*	Wetland Indicator Status**
TREES			
Acer negundo	box elder	*Aceraceae*	FACW*
Alnus incana var. tenuifolia	thinleaf alder	*Betulaceae*	FACW
Betula Fontinalis	river birch	*Betulaceae*	FACW
Picea engelmannii	Englemann spruce	*Pinaceae*	FACU-*
Picea pungens	blue spruce	*Pinaceae*	FAC-
Populus acuminata	lanceleaf cottonwood	*Salicaceae*	FAC+
Populus deltoids var. wislizeni	Rio Grandee cottonwood	*Salicaceae*	FACW*
Populus tremuloides	quaking aspen	*Salicaceae*	NI
Pseudotsuga menziesii	Douglas-fir	*Pinaceae*	NL
Quercus gambelii	Gambel oak	*Fagaceae*	NL
SHRUBS			
Alnus incana var. tenuifolia	thinleaf alder	*Betulaceae*	FACW
Amelanchier alnifolia	serviceberry	*Rosaceae*	FACU-
Cornus sericea	red osier dogwood	*Cornaceae*	FACW
Crataegus erthyropoda	redhaw	*Rosaceae*	FAC
Lonicera involucrate	twinberry honeysuckle	*Caprifoliaceae*	FAC
Mahonia repens	creeping barberry	*Berberidaceae*	NL
Ribes aureum	golden current	*Grossulariaceae*	FACW
Ribes Montigenum	mountain gooseberry	*Grossulariaceae*	NL
Rosa Woodsii	Woods' rose	*Rosaceae*	FAC-
Rubus idaeus	wild raspberry	*Rosaceac*	FACU
Pentaphylloides floribunda	shrubby dinquefoil	*Rosaceae*	FACW*
Salix geyeriana	Geyer willow	*Salicaceae*	FACW+
Salix monticola	mountain willow	*Salicaceae*	OBL
Symphoricarpos oreophilus	mountain snowberry	*Caprifoliaceae*	FACU
HERBS			
Forbs			
Achillea lanulosa	common yarrow	*Asteraceae*	FACU
Aconitum columbianum	monkshood	*Ranunculaceae*	FACW
Angelica grayi	Gray's angelica	*Apiaceae*	NL
Apocynum cannabinum	hemp dogbane	*Apocynaceae*	FAC
Argentina anserine	silverweed	*Rosaceae*	OBL
Cardamine cordifolia	heartleafed bittercress	*Brassicaceae*	FACW
Castilleja rhexiifolia	rosy paintbrush	*Scrophulariaceae*	FACU
Chrysanthemum leucanthemum	ox-eye daisy	*Asteraceae*	NL
Cirsium arvense	Canada thistle	*Asteraceae*	FACU
Cirsium parryi	Parry's thistle	*Asteraceae*	FACW
Cirsium scariosum	meadow thistle	*Asteraceae*	NI (OBL)
Clementsia rhodantha	rose crown	*Crassulaceae*	FACW+
Descurainia californica	sierra tansymustard	*Brassicaceae*	UPL
Epilobium hornemannii	willowherb	*Onagraceae*	FACW
Erigeron peregrinus	Subalpine fleabane	*Asteraceae*	FACW
Fragaria virginiana	wild strawberry	*Rosaceae*	FACU
Gentianopsis thermalis	fringed gentian	*Polemoniaceae*	OBL
Heracleum lanatum	cow parsnip	*Apiaceae*	FAC
Hippochaete hyemalis	scouring rush	*Equisetaceae*	FACW
Iris missouriensis	Rocky Mt. iris	*Iridaceae*	OBL*
Ligusticum porteri	Porter's lovage	*Apiaceae*	FACU-
Machaerantha spp.	Purple aster	*Asteraceae*	
Mentha arvensis	field mint	*Lamiaceae*	FACW
Mertensia ciliate	bluebells	*Boraginaceae*	OBL

Table 6-2 Floral Species Observed in the Vicinity of the Rio Grande Reservoir Project Area

*Scientific Name**	Common Name	*Family*	Wetland Indicator Status**
Micranthes odontoloma	brook saxifrage	*Saxifragaceae*	FACW+
Oxypolis fendleri	Fendler's cowbane	*Apiaceae*	OBL
Packera crocata	saffron ragwort	*Asteraceae*	FACW
Pedicularis groenlandica	elephantella	*Scrophulariaceae*	OBL
Physalis hederifolia	ivyleaf groundcherry	*Solanaceae*	NL
Myosurus minimus	tiny mousetail	*Ranunculaceae*	OBL
Nasturtium officinale	watercress	*Brassicaceae*	OBL
Plantago lanceolata	lanceleaf plantain	*Plantaginaceae*	FACU
Plantago major	broadleaf plantain	*Plantaginaceae*	FAC
Polygonum amphibium	water smartweed	*Polygonaceae*	OBL
Potentilla sp.	Cinquefoil	*Rosaceae*	----
Prunella vulgaris	common selfheal	*Lamiaceae*	FACU
Rudbeckia laciniata	cutleaf coneflower	*Asteraceae*	FAC+
Rumex crispus	curly dock	*Polygonaceae*	FACW
Senecio amplectens	showy alpine ragwort	*Asteraceae*	FACW
Senecio triangularis	triangleleafed senecio	*Asteraceae*	OBL
Taraxacum officinale	dandelion	*Asteraceae*	FACU
Thalictrum fendleri	Fendler's meadow rue	*Coptaceae*	UPL
Trifolium pretense L.	red clover	*Fabaceae*	FACU
Veratrum tenuipetalum	false hellebore	*Liliaceae*	FACW*
Verbascum thapsus	common mullein	*Scrophulariaceae*	NL
Graminoids			
Agrostis idahoensis	Idaho redtop	*Poaceae*	FAC
Agrostis stolonifera	creeping bentgrass	*Poaceae*	FACW
Alopecurus aequalis	shortawn foxtail	*Poaceae*	OBL
Alopecurus pratensis	meadow foxtail	*Poaceae*	NI (FACW)
Bromis inermis subsp. Pumellianus	smooth brome	*Poaceae*	NL
Calamagrostis Canadensis	bluejoint	*Foaceae*	OBL
Calamagrostis stricta	northern reedgrass	*Poaceae*	FACW
Carex aquatilis	water sedge	*Cyperaceae*	OBL
Carex utriculata	beaked sedge	*Cyperaceae*	OBL
Dactylis glomerata	orchard grass	*Poaceae*	FACU
Deschampsia caespitosa	tufted hairgrass	*Poaceae*	FACW
Eleocharis macrostachya	common spiked rush	*Cyperaceae*	OBL
Elymus bakeri	Baker's wheatgrass	*Poaceae*	NL
Elymus smithii	western wheatgrass	*Poaceae*	FACU
Festuca idahoensis	Idaho fescue	*Poaceae*	NI
Festuca thurberi	Thurber fescue	*Poaceae*	NL
Juncus arcticus	wire rush	*Juncaceae*	FACW
Juncus mertensianus	Merten's rush	*Juncaceae*	OBL
Juncus parryi	Parry's rush	*Juncaceae*	FAC*
Muhlenbergia Montana	mountain muhly	*Poaceae*	
Phleum alpinum	alpine timothy	*Poaceae*	FAC
Phleum pretense	timothy	*Poaceae*	FACU
Poa leptocoma	marsh bluegrass	*Poaceae*	FACW
Poa sp.	**bluegrass**	***Poaceae***	----

Table 6-2 Floral Species Observed in the Vicinity of the Rio Grande Reservoir Project Area

*Scientific Name**	Common Name	*Family*	Wetland Indicator Status**
FERN / FERN ALLIES / BRYOPHYTES			
Moss I (unidentified)			
Liverwort I (unidentified)			
Sphagnum spp.			

Notes:

OBL	Obligate Wetland	99% probability of occurrence in wetlands
FACW	Facultative Wetland	67%-99% probability of occurrence in wetlands
FAC	Facultative	34%-66% probability of occurrence in wetlands
FACU	Facultative Upland	1%-33% probability of occurrence in wetlands
UPL	Obligate Upland	> 99% non-wetlands in this region
NI	No Indicator	Insufficient information available
NL	Not Listed	Generally indicates upland species

* Scientific names according to USDA NRCS National PLANTA Database (1999)

** Wetland Indicator Status follows Reed 1988 for Region 8: Intermountain (CO western, UT, NV)

Soils

No soil maps have been published by the Natural Resources Conservation Service (NRCS) for the subject area; however, the site investigation included periodic soil pits to examine the soil profiles. The wetland soils located within the floodplain of the Rio Grande are problematic (based on USACE Delineation Manual) due to their dynamic nature and coarse textures, which have the affect of making potential hydric indicators (Sugnet 2006); however, the soil profiles examined within the floodplain did contain some faint redoximorphic features that were used during the delineation process to indicate prolonged periods of saturation or inundation. Upland soils located outside of the floodplain generally consisted of loam to sandy loam with gravel, gobble, and shallow bedrock. The wetland soil located in the "potential fen" on the south side of the Reservoir contained 8 to 12 inches of organic soil, which was the primary determinant for this classification (Sugnet 2006).

Hydrology

The presence of the dam embankment has altered the hydrology of the River. This artificial hydrologic regime has had a substantial impact on the plant communities of the steep banks of the Reservoir, which are largely unvegetated. Below the dam the floodplain hydrology is also artificial; the dam eliminates the natural high flow events that are important for the sediment transport and fluvial morphology of the floodplain (Sugnet 2006). The metered release of water from the Reservoir also creates a more consistent water table. Despite this altered hydrologic regime, the downstream floodplain maintains a much more natural appearance than the areas above the Reservoir (Sugnet 2006). Stream flow, shallow groundwater, and Reservoir (lacustrine) water are the primary source of hydrology for the delineated wetlands. Direct precipitation and surface runoff are secondary sources of hydrology (Sugnet 2006). According to data produced at the NRCS Snotel Site, the average annual water equivalent in this area is approximately 45 inches a year of snow, which does not include rain in the summer and fall, which would likely bring the total annual precipitation to approximately 60 inches a year. Other indicators of hydrology within the project boundaries include drainage patterns, drift lines, and matted vegetation (Sugnet 2006).

During the proposed pre-design phase, an official wetland delineation verification by the USACE or NRCS will be required. This will require additional field work, including a visit with USACE staff, an official determination on the potential fens area, a biological assessment, a cultural resources survey, and investigation of suitable mitigation sites. It is likely that a Clean Water Act Section 404 Permit (Section 404 Permit) will be required if the dam is enlarged, as the loss of existing wetland habitat is a likely outcome of such action.

Figure 6-4. Willow islands downstream of dam. Although these are designated as wetlands, they are highly dynamic and likely more established than normal due to altered hydrologic regime.. (Photo Courtesy Sugnet Environmental)

Section 7
Hydrologic Characteristics

As part of this study, an investigation into the hydrologic characteristics of the Basin downstream of the Reservoir was conducted to analyze the potential benefits of an enlarged reservoir. Current conditions were examined and several analyses were performed, including stream gain/loss, curtailment history, and flood protection. The operation of the Reservoir and Compact delivery practices could be modified to realize the several benefits an enlarged reservoir would yield to the River system and Basin water users.

7.1 Historical Conditions

There are several stream flow gages along the River and measurements are available at the larger diversion structures through HydroBase, the State's hydrologic database. Table 7-1 presents a summary of monthly flows at three gage locations downstream of the Reservoir. The Thirty-Mile gage is located less than a mile downstream of the Reservoir and primarily measures outflow from the Reservoir, as there are no significant inflows between the Reservoir and this gage. The Del Norte gage is located six miles west of Del Norte, Colorado, and is the primary gage used by the Division Engineer for administration of water rights and the Compact. The Del Norte gage is above the principal diversions in the San Luis Valley. The Lobatos gage is located just north of the New Mexico border, and is named in the Compact as the gage at which Colorado must deliver its water obligation to New Mexico. Figure 7-1 shows the location of several gages and reservoirs in the San Luis Valley. Figures 7-2, 7-3, and 7-4 chart average monthly flow data at Thirty-Mile, Del Norte, and Lobatos gages, respectively, for 1998, 2002, and 1999. For purposes of this analysis, 1998 is considered an average year in terms of total annual basin runoff. Using this approach, 2002 is considered a dry year, and 1999 a wet year. The 1999 plot (Figure 7-4) shows an irregular shape in the Lobatos hydrograph, where there is a dip in July, and an increase in flows in August. Two main factors contribute to this shape; first, the rising curtailment from the end of July to through September (increasing from 30% to over 60%) left more water in the stream to reach Lobatos than when a lower curtailment was in place in June and early July. Second, rains in August increased flows in the River above July flows. The ordinate on all three figures is the same to highlight the difference in magnitude between dry and wet years.

Table 7-1 Monthly Gage Data on the Rio Grande for Period 1945 - 2003

	Thirty Mile			Del Norte			Lobatos		
Month	Avg (cfs)	Min (cfs)	Max (cfs)	Avg (cfs)	Min (cfs)	Max (cfs)	Avg (cfs)	Min (cfs)	Max (cfs)
Jan	6	0	41	166	90	285	263	76	521
Feb	7	0	44	178	111	299	315	102	595
Mar	10	0	50	246	153	425	409	66	884
Apr	92	6	368	672	317	1,381	475	59	2,326
May	515	168	907	2,356	505	4,395	936	31	4,958
Jun	877	76	1,619	2,973	222	5,878	1,095	20	4,418
Jul	499	25	1,246	1,332	142	3,451	418	1	2,754
Aug	196	16	612	693	117	1,800	188	3	1,281
Sept	99	26	527	462	135	1,427	142	2	938
Oct	75	4	232	402	134	1,238	172	13	1,203
Nov	19	0	259	253	114	646	313	60	948
Dec	7	0	57	185	99	372	268	62	654

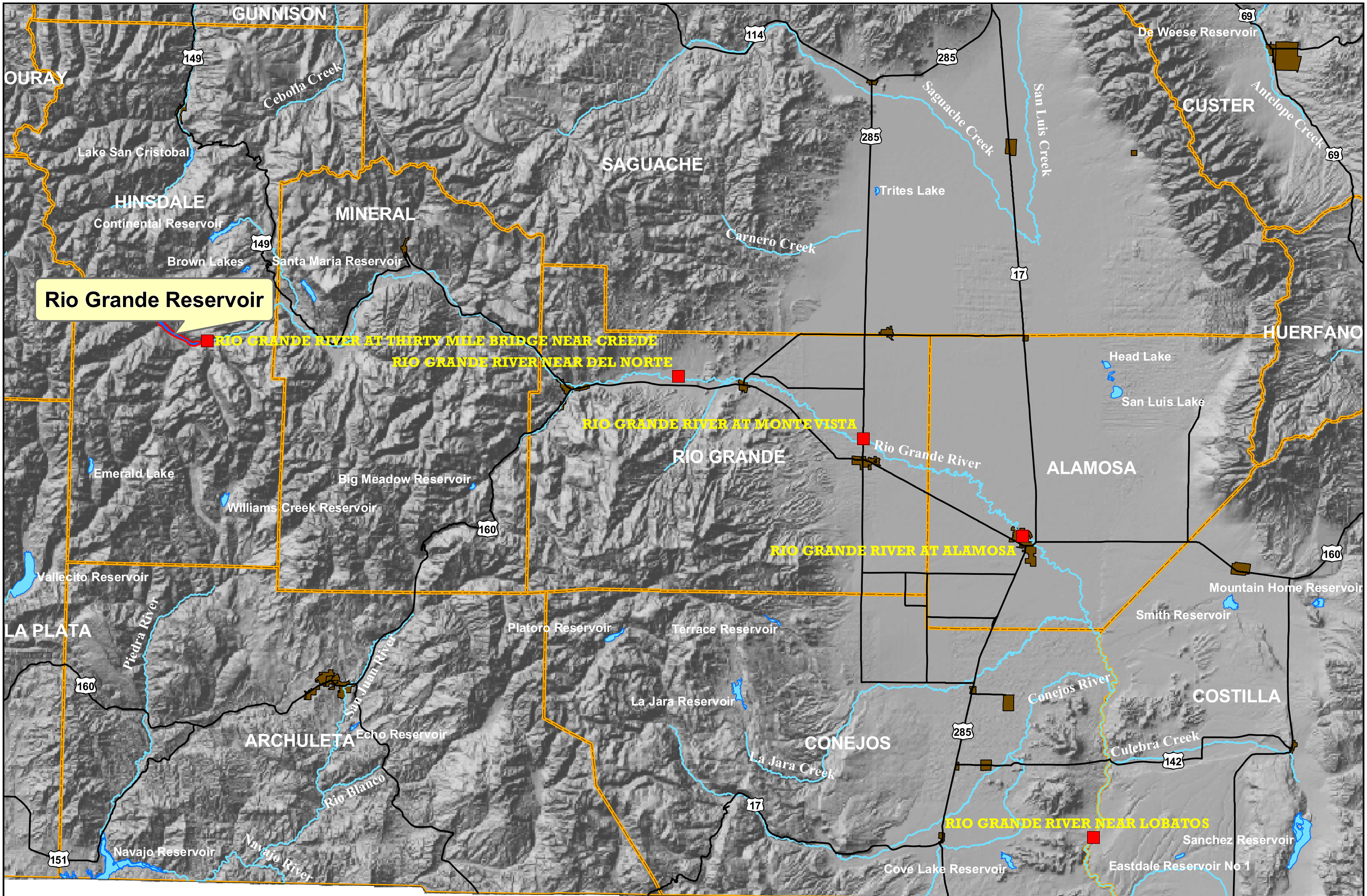


Figure 7-1
Rio Grande River Flowstations

Figure 7-2 Rio Grande Monthly Flows 1998 (Normal Year)

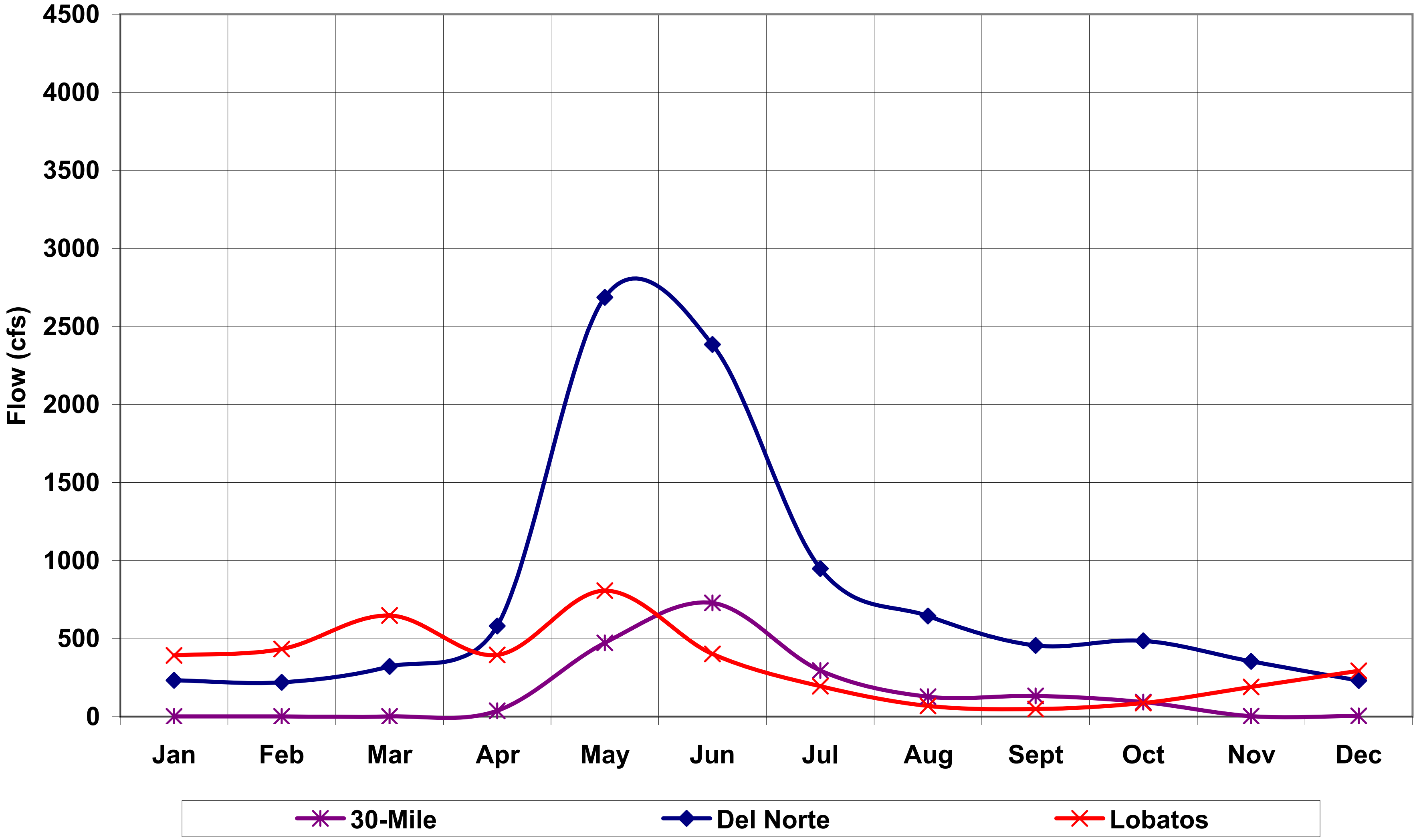


Figure 7-3 Rio Grande Monthly Flows 2002 (Dry Year)

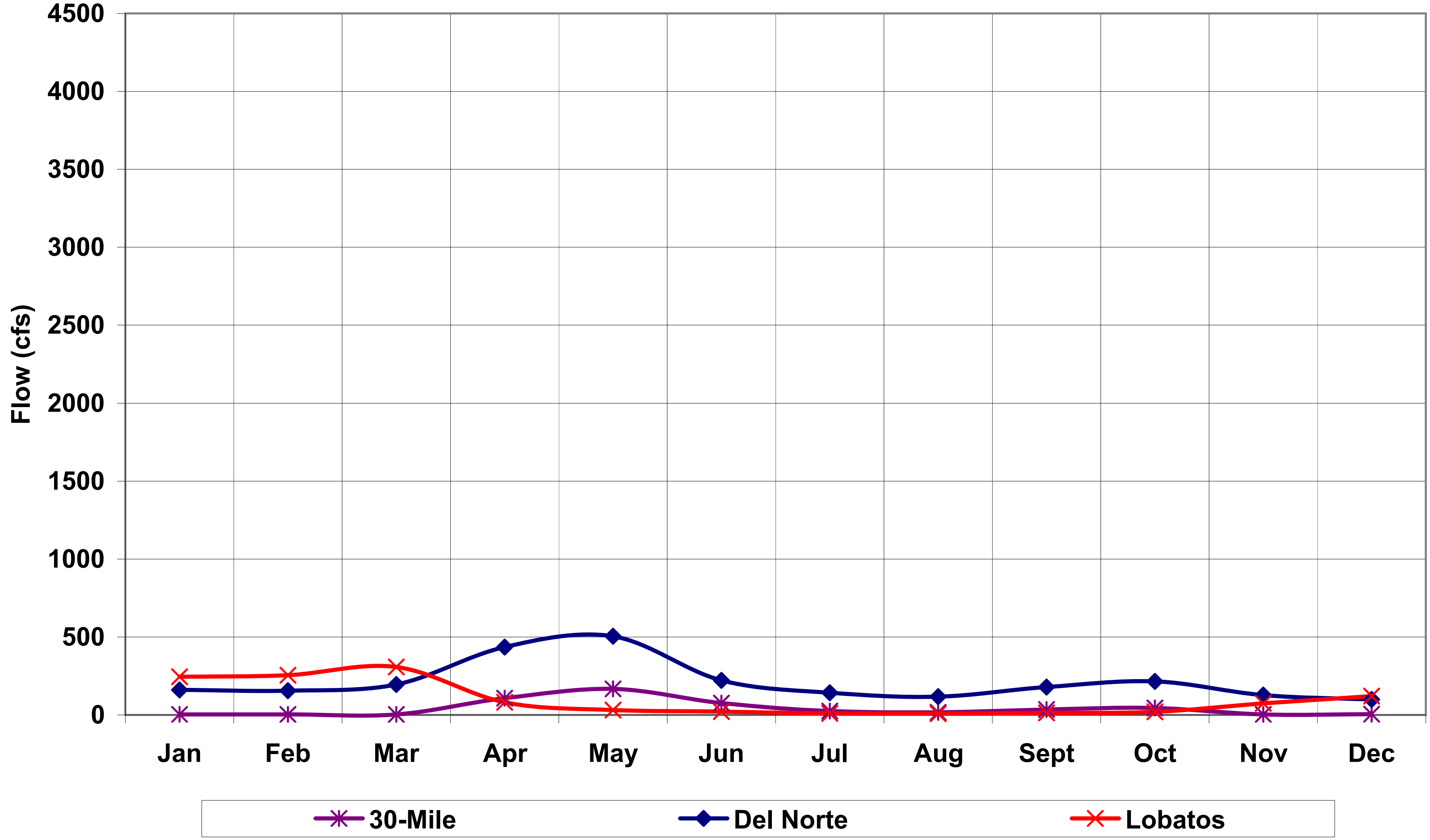
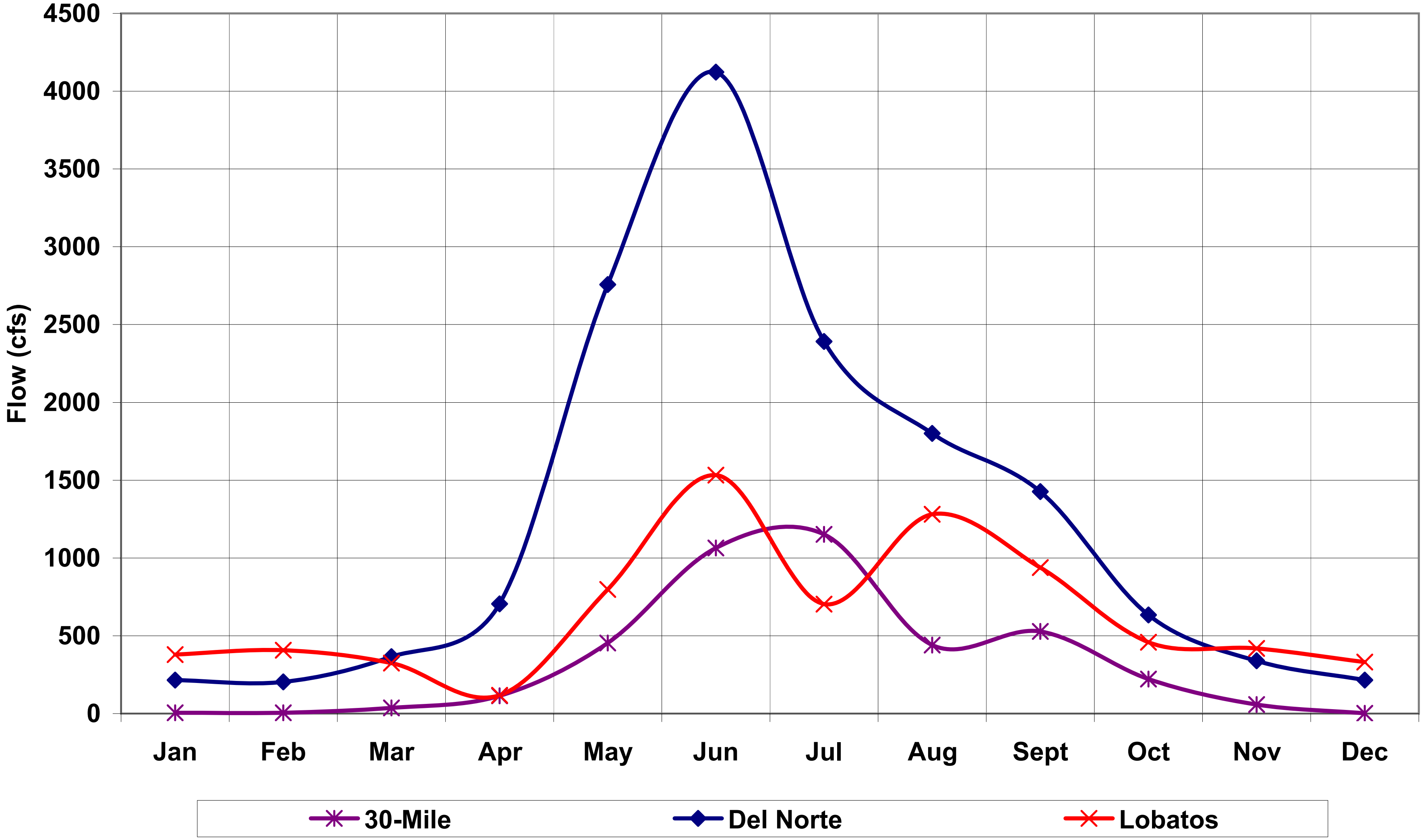


Figure 7-4 Rio Grande Monthly Flows 1999 (Wet Year)

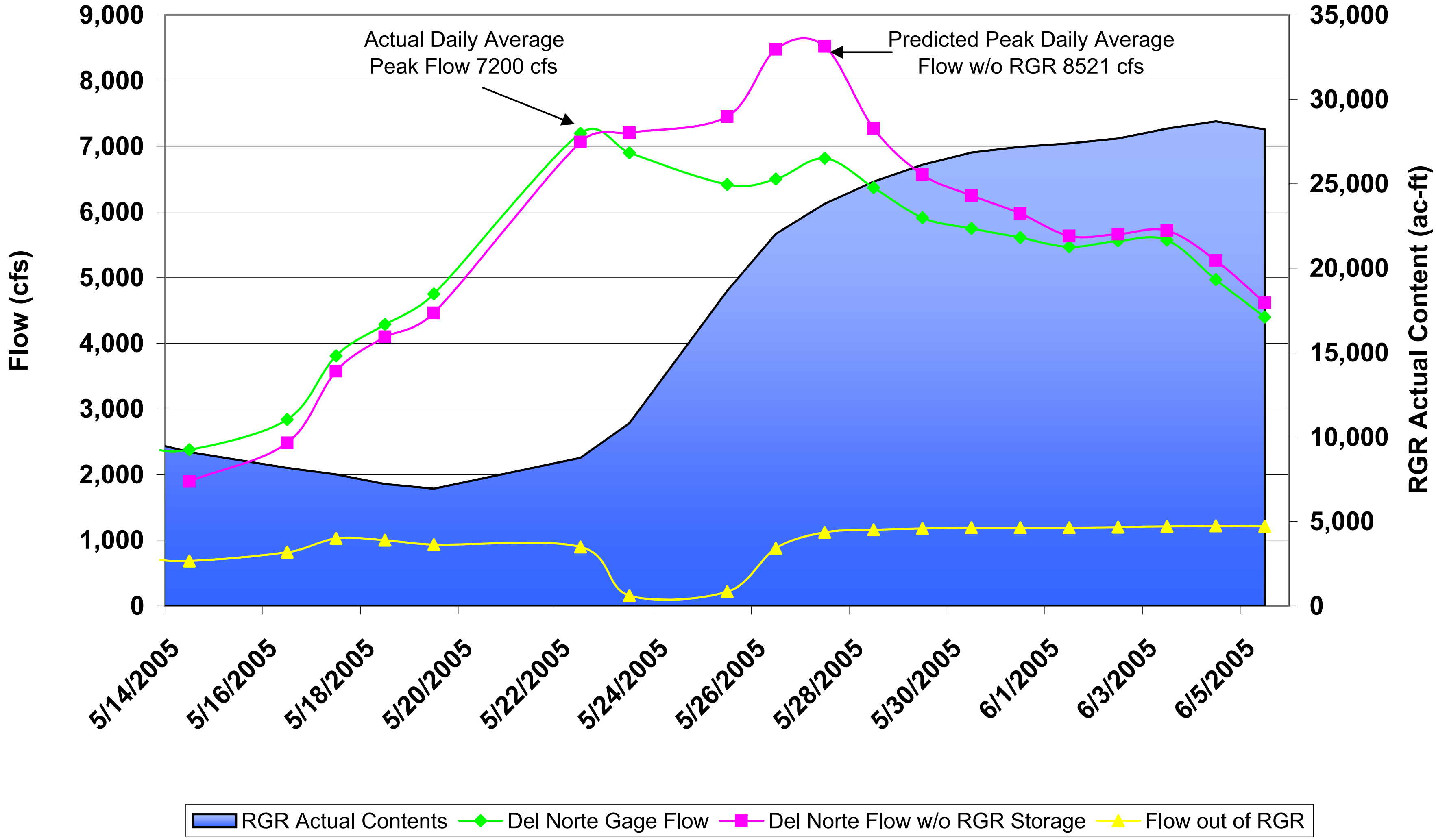


The Reservoir is not required to pass any flow during the winter months when its storage right is in priority. It normally starts storing water on November 1st, at which point its gates are shut and the entire flow of the River is stored. As a result, immediately downstream of the dam, there is almost no flow in the River, except for a small flow varying from <1 to 5 cfs. This flow is water that seeps through the dam embankment. That seepage increases as storage in the Reservoir increases. Downstream of the dam winter flow typically ranges from <1 to 10 cfs as measured at the Thirty-Mile gage. This flow consists of dam seepage, gate leakage, and miscellaneous stream gains.

During the winter months, the flow in the River increases between the Reservoir and Del Norte from tributary inflow. In December through February, flow at Del Norte is nearly 25 times higher than flow at the Thirty-Mile gage. In contrast, in April through September, flow at the Del Norte gage is approximately three to four times higher than at Thirty-Mile. During the runoff season, approximately 25 percent of the flow at Del Norte comes from the drainage area above the Reservoir, which makes up only 12 percent of the entire drainage area above Del Norte. Flows on the River typically peak around May or June, coinciding with melting of the snow pack in the headwaters.

The Reservoir is useful for flood protection for downstream residents and businesses particularly those in South Fork, Del Norte, Monte Vista, and Alamosa. Daily sheets were obtained for a period of high flows from May 12, 2005, through June 5, 2005, showing reservoir content and flows at the Del Norte gage. Flows at Del Norte are daily average flows as reported by the USGS. Actual daily peak flows are even higher than the daily average flows presented. Flows out of the Reservoir are the USGS Thirty-Mile daily average gage data. The flow at Del Norte, had the Reservoir not stored any water, was predicted by adding the change in storage at the Reservoir to the flow at Del Norte with a one-day travel time lag. Figure 7-5 presents the results of this analysis. The highest flow at Del Norte would have been more than 1,300 cfs greater had the Reservoir not stored water. In a discussion with the Division 3 Engineer's Office, it was noted that, "two more drops in the river would have flooded people out." More than 1,000 cfs was stored in the Reservoir to keep flows around 7,000 cfs at Del Norte. The Division 3 Engineer intimated that, had the flows in the River reached over 8,000 cfs, there could have been serious damage to persons and property as a result of flooding. Additionally, the Division Engineer noted that there are numerous houses in the reach between South Fork and Del Norte that are situated very close to the River shore in the floodplain on elevated pads. These homeowners have built elevated driveways to provide access at flood stage, and concern was expressed that these elevated roads will create dams in the floodplain at higher flows (personal communication, phone conversation with Division 3 staff, April 25, 2007). The highest flow ever recorded in the Rio Grande through this stretch is 14,000 cfs in October of 1911 due to a thunderstorm.

Figure 7-5 Flow at Del Norte Gage With and Without Storage at Rio Grande Reservoir



The majority of water diverted from the River and used for irrigation is diverted between the Del Norte and Monte Vista gages. These diversions are within water District 20 and deliver water to District 20 and neighboring water districts. The Rio Grande Decision Support System Project (RGDSS) determined that there were approximately 613,000 irrigated acres in the San Luis Valley, and that approximately 489,000 acres are in the District 20 ditch service areas (Agro Engineering 2000). The largest diverters are known collectively as the "Big Six:" Rio Grande Canal, Farmers Union Canal, Prairie Ditch, San Luis Valley Canal, Monte Vista Canal, and Empire Canal. Figure 7-6 shows the service area of the Big Six ditches and other service areas within the basin. The annual diversions into these ditches from the Rio Grande has averaged approximately 385,000 acre-feet per year (AFY) from 1911 to 1995 (Helton and Williamsen 2003). During this timeframe River administration practices have varied. The Compact study period, lasting from 1928 to 1937, was used to develop the Compact delivery schedules. During the period from 1938 to 1967, the River operated under the Compact, but no curtailments were made and Colorado accrued a nearly 1,000,000 AF debit. At this point, Colorado was sued by New Mexico and Texas and hence imposed significant curtailments on water users to meet the Compact delivery schedule. Colorado complied with the Compact after 1967. During this period, the San Luis Valley Canal and the Rio Grande Canal diverted on average 15 percent less than they had from 1938 to 1967. In 1985 Project Storage at Elephant Butte Reservoir spilled, cancelling Colorado's remaining debt of approximately 500,000 AF. Since 1985, Colorado has attempted to meet the Compact obligations on an annual basis and curtailments have been variable during the irrigation season – as low as zero percent in several years, and as high as 38 percent for a 3-week period in 2005.

In 2003, Helton & Williamsen investigated an enlargement to the Reservoir from a hydrologic and water rights perspective. This report analyzed water levels in the Reservoir and gage data for water years 1946 through 2002. In general, water levels in the Reservoir are typically highest around June or July and lowest around October or November. The report concluded that storage in an enlarged reservoir under a post-compact right would be severely limited due to the Compact. Water would have been available in only four years between 1946 and 2002. However, water stored as "Compact Water" would not be subject to the same limitations as a post-Compact water right and would produce several benefits: reduction of fluctuations in curtailment during the irrigation season; reduction of conveyance losses that occur when compact water is delivered at high flows; and storage of credit water, which reduces the evaporation losses charged to Colorado if credit is stored at Elephant Butte Reservoir and eliminates the chance of spilling credit water from Project Storage. Additionally, proper management of an enlarged reservoir would increase the storage space available for direct flow storage by several water users in the Rio Grande Basin, including the District.

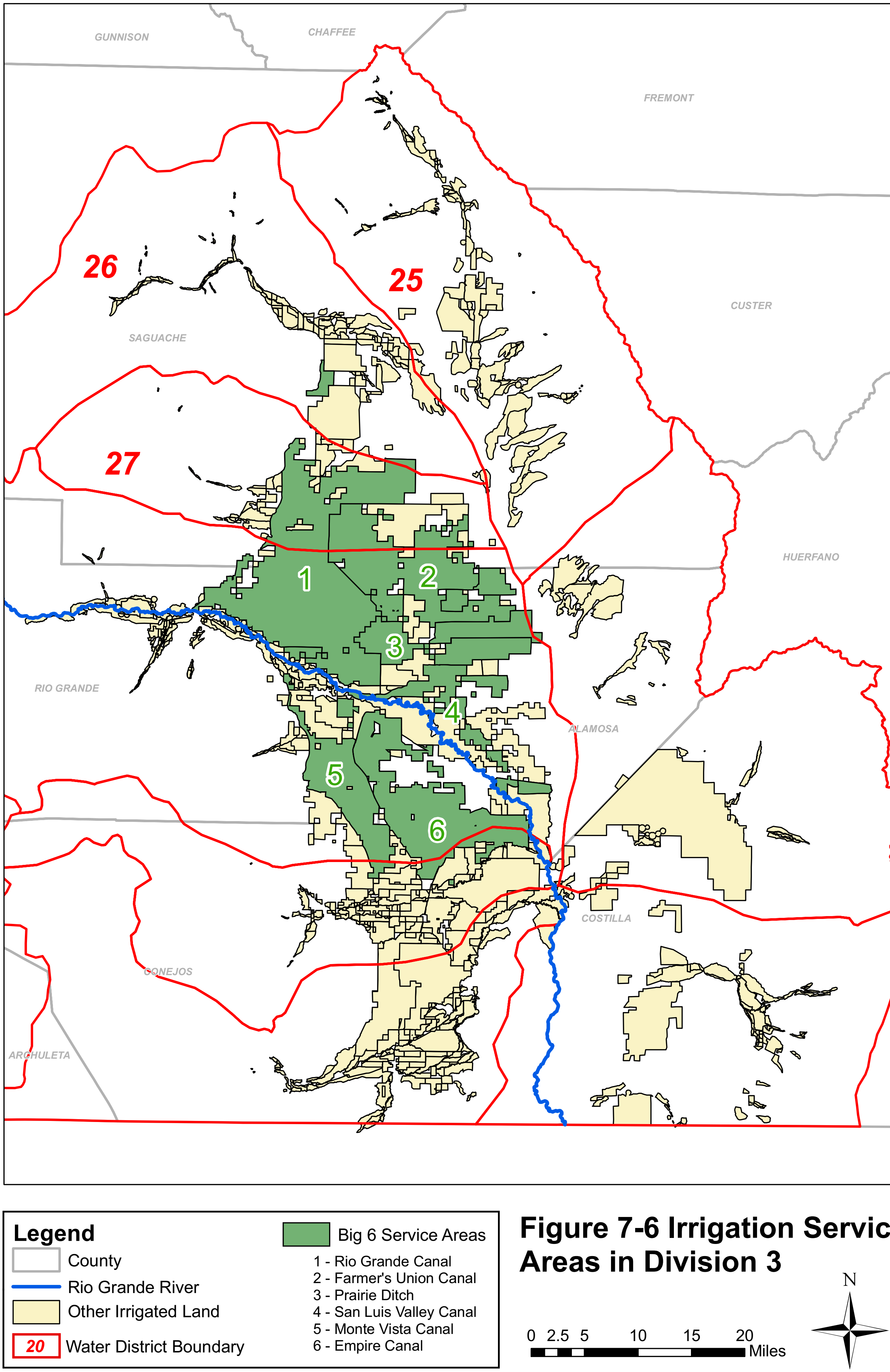


Figure 7-6 Irrigation Service Areas in Division 3

Additional analyses were carried out as part of this report to examine the feasibility of using an enlarged reservoir to store Compact water, as suggested by the Helton and Williamsen report, and to evaluate the additional benefits thereof.

Previous Reports on Reservoir Release Conveyance Losses

In the 1970s, the USGS, in cooperation with the CWCB and the Southeastern Colorado Water Conservancy District, investigated transit losses along the Arkansas River (Livingston 1973; 1978). These reports cited several sources of transit loss and analyzed several controlled releases from upstream reservoirs. Their results show that transit losses are due to bank storage, channel storage, and evaporation. Along the lower Arkansas, bank storage is responsible for 80 percent of the loss, while channel storage and evaporation are each responsible for 10 percent of the loss (Livingston 1978). It was also noted that much of the bank storage loss was recovered at a downstream on-channel reservoir, but were returned slowly to the river and were not considered part of the original release. Along the upper Arkansas, inadvertent diversions are responsible for 50 percent of the loss, bank storage for 42 percent of the loss, and evaporation 8 percent (Livingston 1973). Inadvertent diversions are where the river stage is increased by a reservoir release, and the amount diverted by generally unsophisticated diversion works (e.g., rock dams) is increased. Inadvertent diversions are not a concern on the lower Arkansas due to the more sophisticated diversion works. The general conclusions from these reports show that transit losses are smallest with releases of longer duration, higher flow rates, and when antecedent flows were higher. Releases of shorter duration, smaller volume, and when antecedent flow conditions were low resulted in higher transit losses. In both studies, evapotranspiration from phreatophytes was considered negligible compared to other losses.

In 1985, Pahl and Hasfurther (1985) performed similar stream loss tests due to reservoir releases in Wyoming under a grant from the Wyoming Water Research Center. They cited the growing water demands of energy development companies and municipalities and the corresponding need to transfer agricultural water rights to a different location to meet these demands. To not harm existing appropriators, conveyance losses must be accounted for in the transfer. Since little technical knowledge was available regarding conveyance losses, they analyzed four reservoir releases on three streams in Wyoming to quantify the losses. The results of this report indicate that losses are due to bank storage and a decrease of groundwater infiltration due to the higher river stage. They noted that evapotranspiration and channel storage had a minimal effect on the losses, confirming what Livingston found on the Arkansas. Additionally, the report concluded that losses are typically highest at the beginning of a release, and, as the system comes into equilibrium, losses become smaller as less water enters into bank storage. Losses along a perennial stream are much lower than ephemeral streams. Pahl and Hasfurther hypothesized that much of the bank storage is not a true loss to the stream, as it slowly returns, but is generally unrecognizable in the hydrograph as part of the reservoir release.

It is expected that conveyance losses on the River due to evapotranspiration from phreatophytes, while not a major source of losses, is not negligible, as was assumed by Livingston and Pahl and Hasfurther. Helton and Williamson (2003) note that conveyance losses are high on the River during peak flows. In addition, there is anecdotal evidence that at peak flows below Monte Vista, the River can spill its banks, overflowing into small ponds and onto other nearby land where the water is consumed by surface evaporation or phreatophyte evapotranspiration.

Quantification of Stream Losses

To quantify the stream gains and losses along the mainstem, three different methods were analyzed and compared. The first method involves using baseflow results from the State's surface water model, StateMod, developed by the CWCB for the RGDSS project. The second uses stream-aquifer interaction data gathered by the RGDSS as part of the groundwater model. Finally, a comparison of gaged flows and curtailment rates in 2005 and 2006 were analyzed.

Baseflow output from StateMod was analyzed to calculate native gains and losses along various river reaches. Baseflow results of the model are intended to calculate the native flows as if there had been no influence of man. Baseflow is calculated by adding upstream diversions to and subtracting return flows from gaged flows (CWCB (a), 2004). Stream channel gains or losses along a particular river reach were calculated by subtracting the upstream gage's baseflow and modeled tributary inflow from the downstream gage's baseflow. Subtracting the tributary inflows isolates gains or losses that occur on the Rio Grande mainstem. Figure 7-7 presents how baseflow and channel gains and losses were calculated using this method. Channel gains and losses were calculated for each month between the Del Norte and Alamosa gages, and between the Alamosa and Lobatos gages using this method. These two calculations were summed to give the total channel loss from Del Norte to Lobatos. Figure 7-8 shows the results of these calculations averaged over the model simulation period (1969 to 2002) indicating that significant losses occur during the peak runoff (May and June) between Del Norte and Alamosa. Channel losses in this reach decrease significantly in the later summer and autumn months. The reach from Alamosa to Lobatos is a gaining reach throughout the high runoff period, but shows a decrease in stream gains, to the point of becoming a losing reach in late summer and autumn. However, the magnitude of the losses in the Alamosa to Lobatos reach is much less than the losses in the Del Norte to Alamosa reach during the peak runoff. Similar results were obtained when analyzing normal and wet years. In a dry year, channel losses are not reduced as dramatically as in normal and wet years until October.

Figure 7-7 Calculation of Baseflow and Channel Gains and Losses Using StateMod

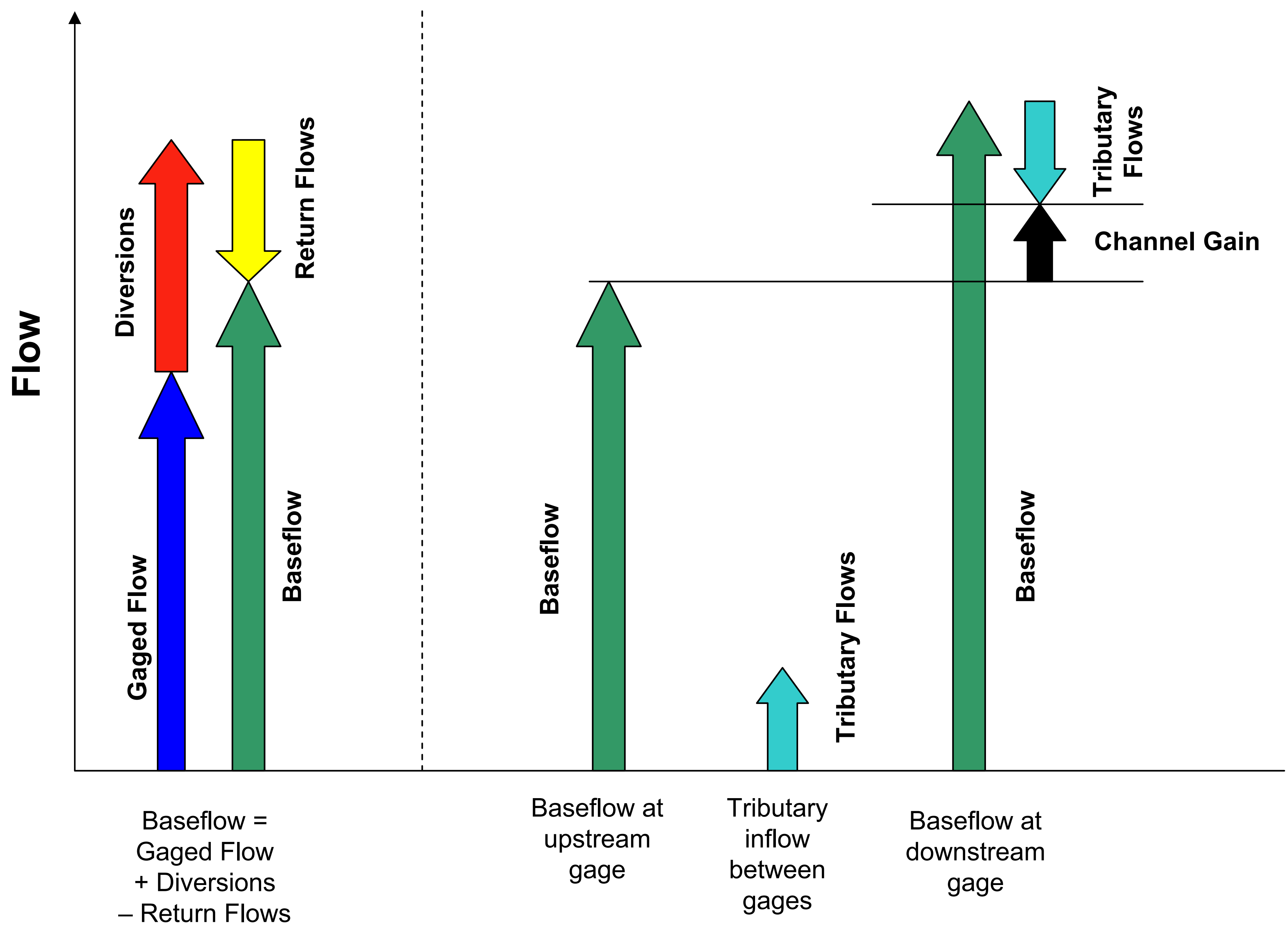


Figure 7-8: Channel Gains and Losses Using StateMod
Average 1969-2002

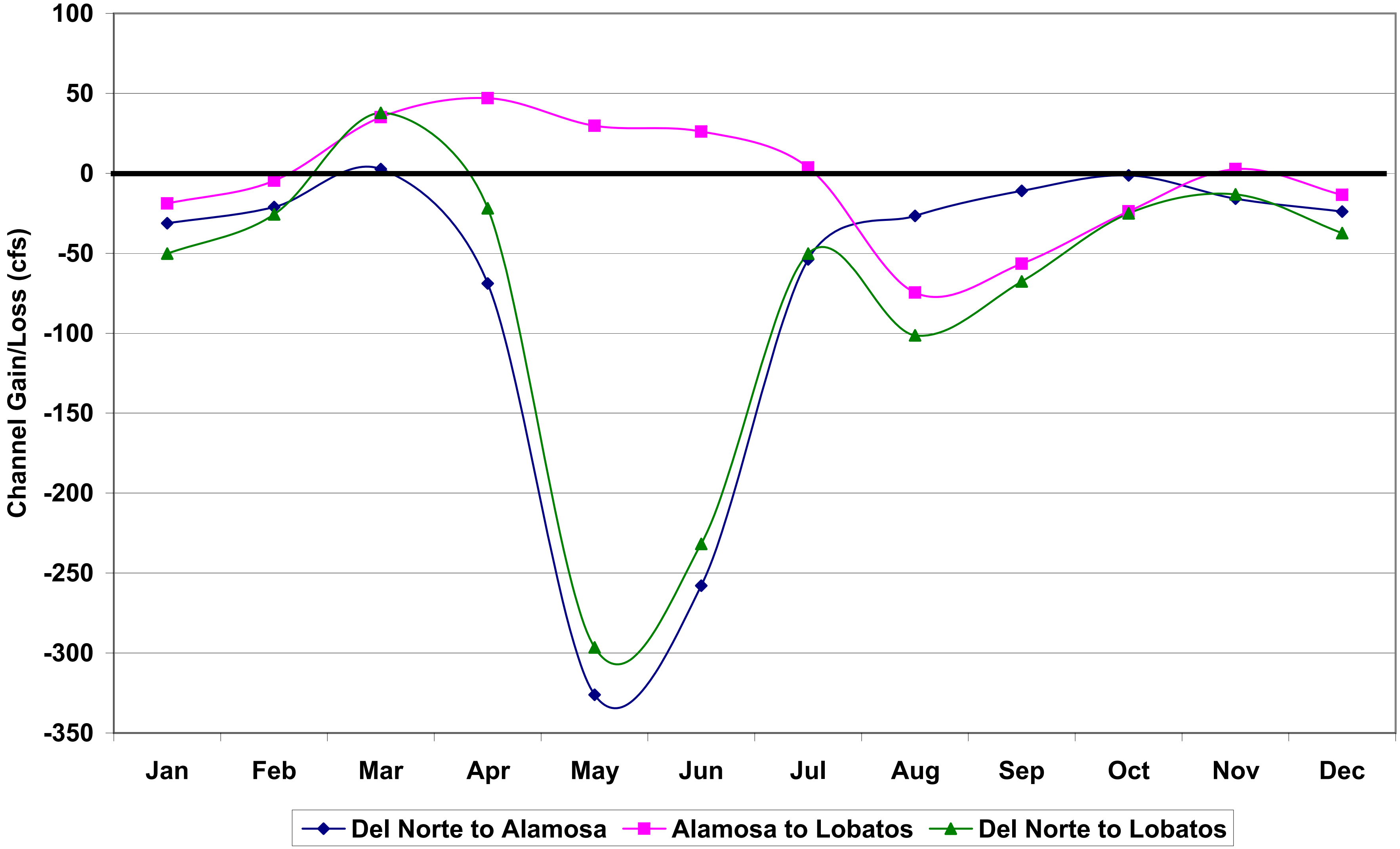
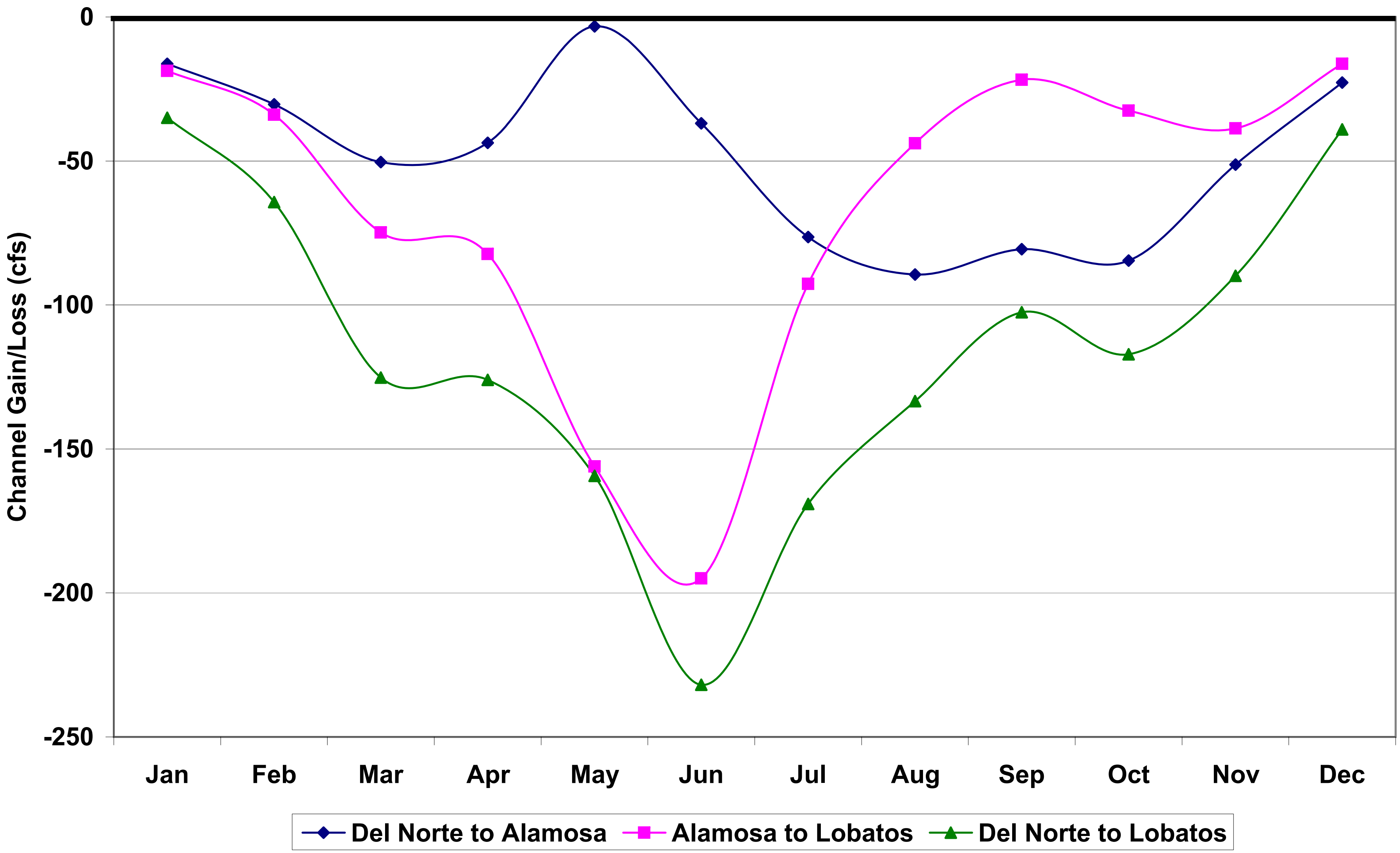


Figure 7-9: Channel Gains and Losses Using RGDSS Groundwater Model Stream-Aquifer Interaction Data



As part of the RGDSS groundwater model, stream-aquifer interaction was studied. In Appendix W of the groundwater modeling report (CWCB (b), 2004) titled, "Appendix W Daily Gain-Loss Estimates," gains and losses in the river channel that can be attributed to groundwater interaction and other ungaged inflows or outflows from the stream were calculated. Values presented in that report are presented with respect to the aquifer; a positive value means a gain to the aquifer and a loss from the stream; therefore, the sign was reversed to be comparable with the StateMod analysis. Figure 7-9 shows average monthly gain/loss with respect to the River. Comparing Figures 7-9 to 7-8, reveals large differences in the location of the losses. The gains and losses from the groundwater model analysis were adjusted to the edge of the groundwater model and therefore do not include the entire length of the Del Norte to Alamosa reach. This could explain the differences between the two analyses. It is unclear why there is such a large difference between the methods on the Alamosa to Lobatos reaches. The RGDSS groundwater model shows losses of nearly 200 cfs in the Alamosa to Lobatos reach in June, whereas StateMod shows this to be a gaining reach. The combined trend from Del Norte to Lobatos is very similar, however, for both analyses, with large stream losses occurring during the peak runoff. The groundwater model does not show the losses diminishing as rapidly as the StateMod analysis; however, in both analyses, water delivered after peak runoff will suffer substantially less loss than that delivered during the peak runoff.

Due to the differences seen in the results from the two models, gaged flows and curtailment history were examined more closely to characterize the stream gains and losses from raw data rather than from model output. It is recognized that stream gage data will be affected by irrigation diversions, return flows, and tributaries that are not considered in this analysis. The Del Norte to Alamosa stretch offers a unique opportunity to investigate the losses. Flows in the River at Del Norte are curtailed to meet compact obligations with the intent that the curtailed water will be delivered to the Lobatos gage. This water is not available for diversion and therefore remains in the channel. In addition, a large portion of the diversions serve irrigated acreage in the Closed Basin, and, consequently, a large portion of the return flows do not return to the River. Curtailment in the form of end-of-year 10-day reports from 1980 through 2004 were obtained from the Division 3 Engineer's Office in Alamosa, and 10-day reports for 2005 and 2006 were obtained from the District. Typically, the curtailment is set to 100 percent through the end of March and then again in November and December. There were several years where the curtailment was zero percent during the irrigation season (1981, 1984 - 1988, 1992 - 1996, 1998, 2000, 2002). In other years, the curtailment varied significantly. Figure 7-10 plots the curtailment against time for selected years where the curtailment was variable (1982, 1991, 2001, 2005, 2006).

Figure 7-10 Curtailment in Selected Irrigation Seasons

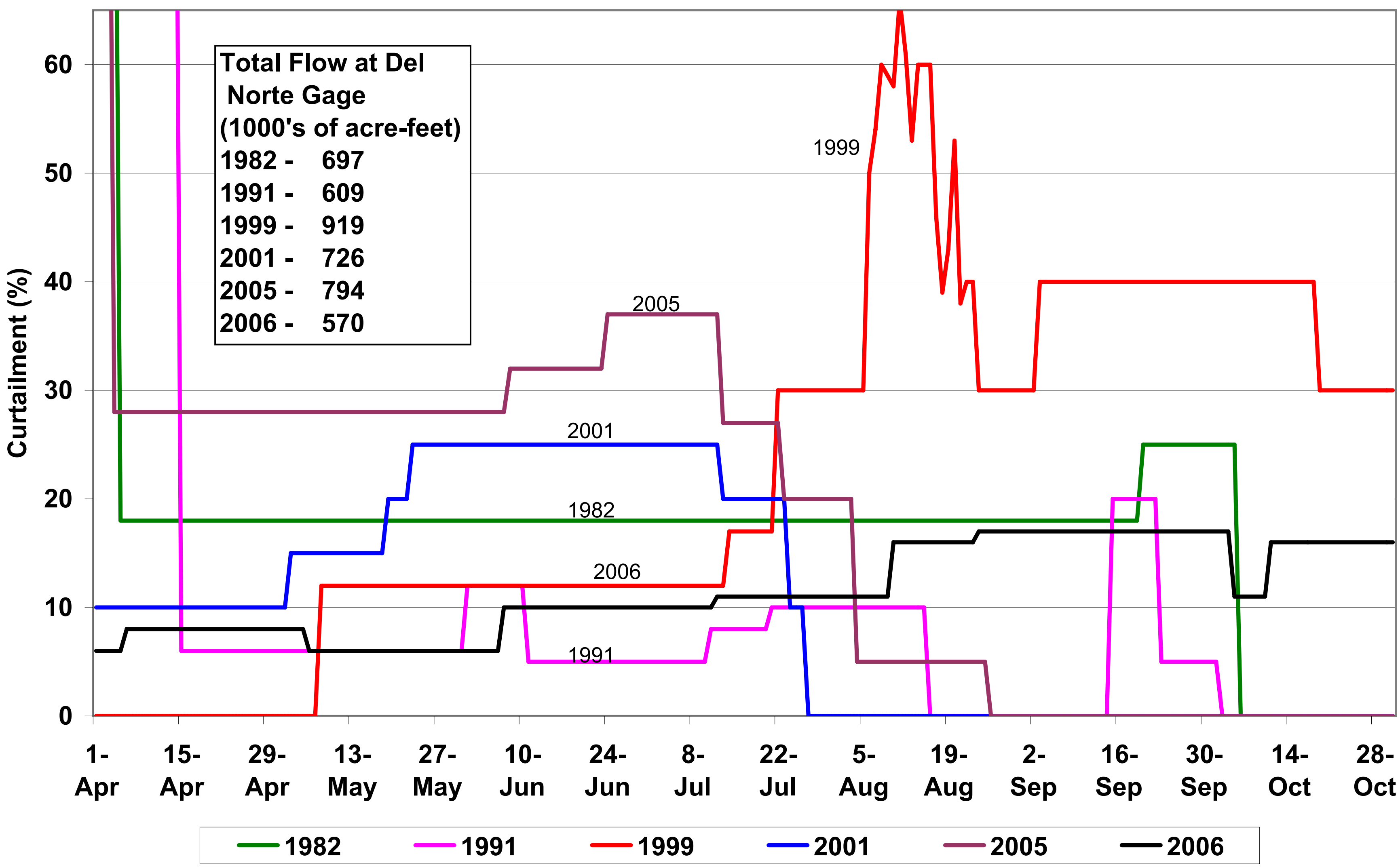


Figure 7-11 focuses on the 2005 irrigation season, when curtailments were particularly high for a portion of the irrigation season. The curtailments are plotted with the flow at the Del Norte and Alamosa gages. Higher curtailments applied at peak runoff tend to harm junior users as their rights do not come into priority when a significant portion of the river is under curtailment. In the 2005 irrigation season, curtailment was quite high during and after the peak runoff (28 to 37 percent), but then was reduced to zero in September and October. Flows at the Alamosa gage were quite high (peak flow of 1,920 cfs), which may have led to water spilling over the banks and being lost to evaporation and phreatophyte evapotranspiration.

The flow at Alamosa was compared to the amount of water at the Del Norte gage that was subject to curtailment. These quantities were subtracted to determine if a pattern of gains or losses between the two gages emerged. Figure 7-12 plots the amount of the curtailment at Del Norte against the Alamosa flow, and shows the losses between the gages. A 2-day lag was applied to the Alamosa gage to account for travel time between the gages. A 3-day lag was suggested by the RGDSS, but a 2-day lag was found to align flows better during runoff. The shorter lag is appropriate during higher flows as mean velocity is faster, and travel time shorter, than during other parts of the year. The plot shows that losses are largest during the peak runoff when a large curtailment was in place. Figure 7-13 plots the 2006 irrigation season. 2006 had a smaller peak runoff than 2005 and curtailments were initially lower. During peak runoff in 2006, losses were lower than in 2005 and peak flow at the Alamosa gage during the 2006 spring runoff was 309 cfs, compared to 1,920 cfs in 2005. These results suggest that higher flows at the Alamosa gage are an indicator of higher losses, likely due to overbank spillage and subsequent evaporation or phreatophyte evapotranspiration. Heavy rains in the San Luis Valley during the summer of 2006 increased flow in the River, showing a net gain between the Del Norte and Alamosa gages for much of the summer. Figures 7-12 and 7-13 do not account for several factors related to stream loss (precipitation, return flows, transmountain water) that would increase the accuracy of the loss calculations. It is envisioned that such factors would be incorporated into the analysis during the proposed preliminary design phase of this project.

Figure 7-11 2005 Irrigation Season Curtailment and Flows at Del Norte

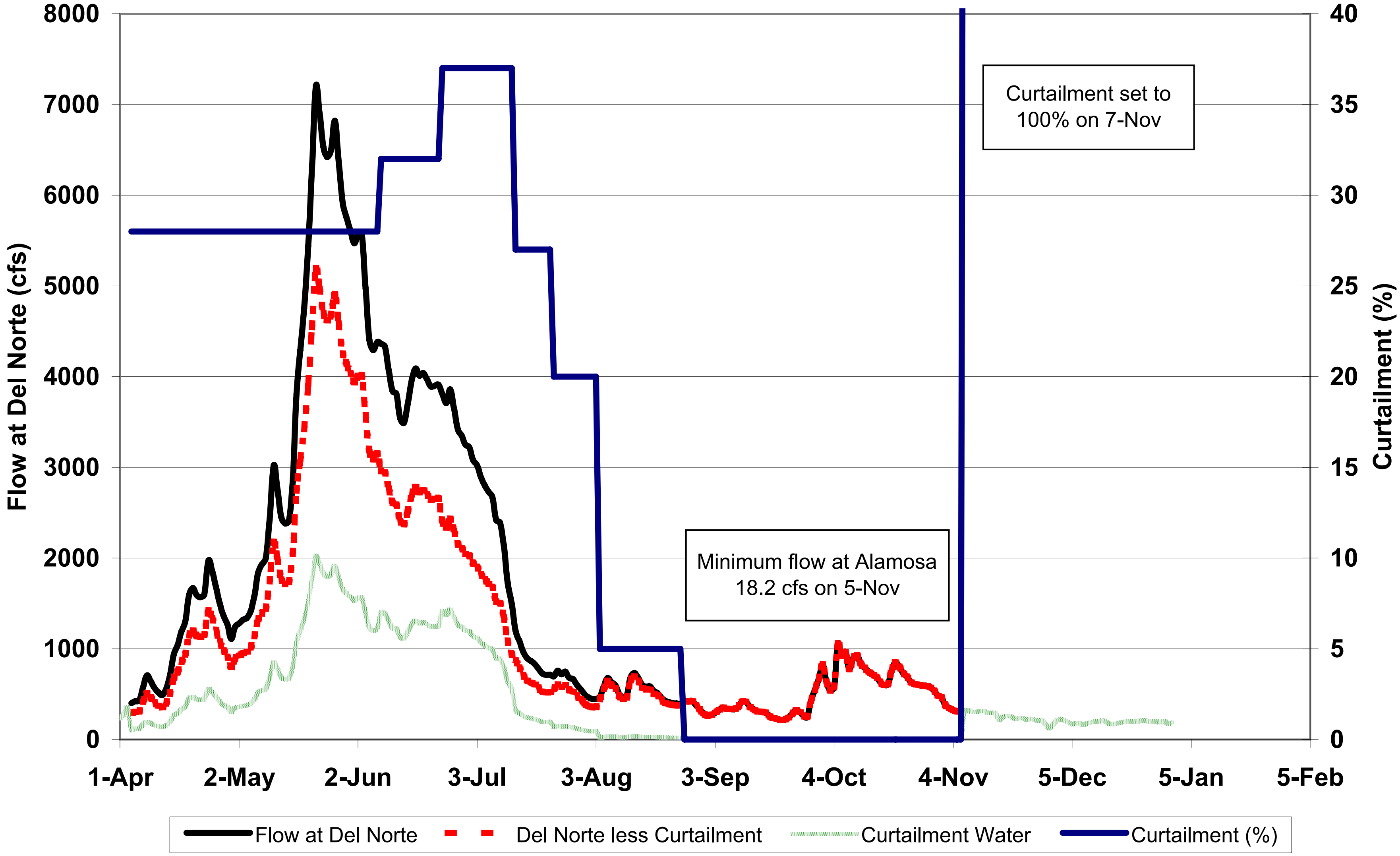


Figure 7-12 2005 Curtailment Water at Del Norte, Flow at Alamosa, and Losses Between

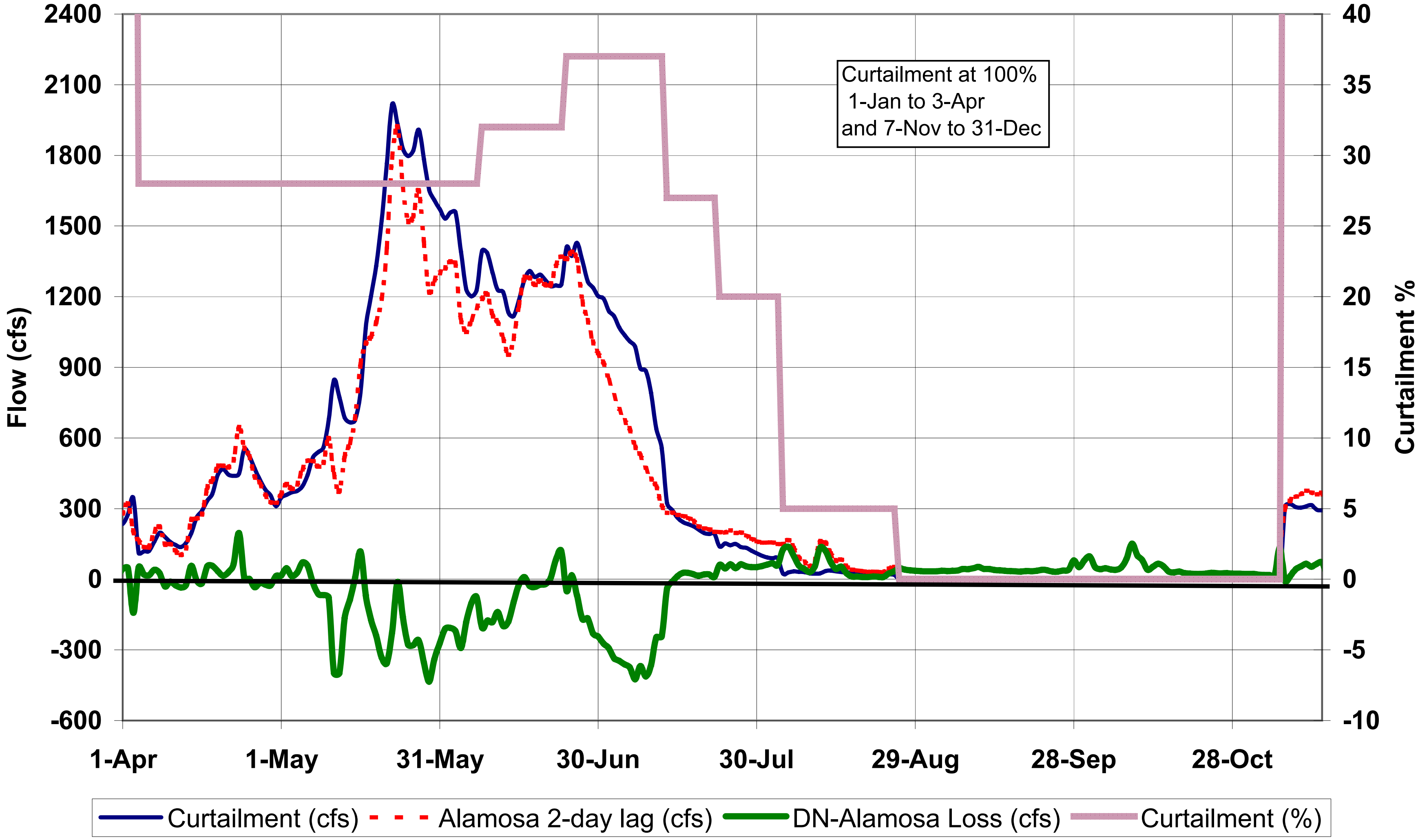
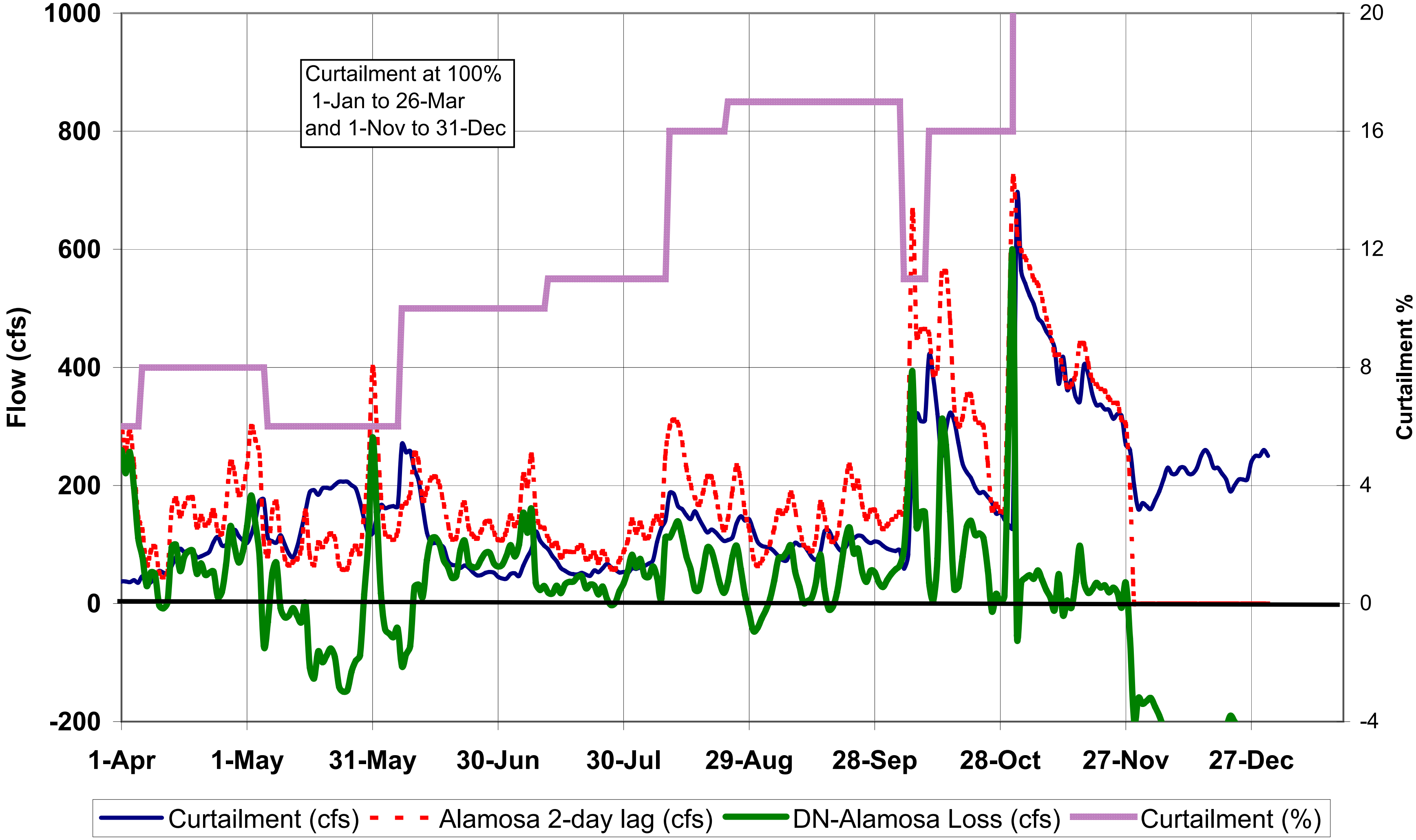


Figure 7-13 2006 Curtailment Water at Del Norte, Flow at Alamosa, and Losses Between



In summary, there are several key points to be gleaned from the gain loss analyses. First, evaporation and phreatophyte evapotranspiration can be significant at high flows. Second, losses could be reduced by controlling the flow during peak runoff and releasing additional water later in the season at lower flows. Such releases should be at a steady rate for several weeks to reduce losses. When the curtailment is set to zero percent, the reach below Alamosa has very low flow as diversions take almost the entire flow of the River. The Livingston reports and the Pahl and Hasfurther report show that stream losses are highest when antecedent flows are low and when releases are of short duration. Maintaining a low, more constant curtailment of roughly five percent throughout the irrigation season could help reduce losses when additional Compact water is released after the peak runoff. In addition, maintaining such a flow is beneficial from an ecological standpoint as fish and wildlife habitat will be sustained when the River has had very low flows historically. Periodic high flows will likely still be needed, however, for channel maintenance and other riparian purposes. It is anticipated that a more thorough analysis of gains and losses along the River channel will be performed in the proposed preliminary design phase of this project that would more definitively quantify the losses on the River at different flow rates. In addition, further analysis of the frequency and rate of high flow needed for channel maintenance and other in-channel and riparian needs will be conducted.

Benefits of an Enlarged Reservoir

Operation of the River could be changed to better meet a variety of demands and needs as a result of enlarging the Reservoir. Under one revised operational scenario, a portion of the water that comprises the curtailment could be stored at the Reservoir as Compact water, with a lower, constant curtailment. Compact water stored at the Reservoir reduces flow in the River, thereby reducing conveyance losses during peak runoff. The combination of the curtailment and the water being stored at the Reservoir could be less than the curtailment under current administration, potentially bringing more water users into priority. When this water is released later in the year, the conveyance losses are reduced. Rio Grande Basin water users and the environment benefit by avoiding the higher losses at peak flow and releasing when losses are lower. Several benefits of this operating scenario are listed below.

- Storing a portion of the current curtailment water will reduce conveyance losses, which are highest during peak runoff and allow for release of this water when conveyance losses are lower.

- A steadier curtailment provides a level of predictability and consistency to River flows and would benefit junior users who are typically affected most by a fluctuating curtailment.

- The State is able to maximize the beneficial use of the water while still meeting Compact obligations.

- Administrative flexibility is provided to the Division Engineer in administering water rights in Colorado and for compact deliveries
- Storage of Colorado Compact credit water is provided with less evaporation loss than at Elephant Butte Reservoir in New Mexico (average annual lake evaporation 24 inches or less and 72 inches, respectively).
- Closed Basin water could be exchanged to the Reservoir.
- The chance of spilling Compact credit water in Project Storage is eliminated.
- Additional space needed for direct flow storage by several water users in the San Luis Valley is provided.
- Additional storage space for use by the Colorado Division of Wildlife and the San Luis Valley Water Conservancy District is provided.
- Improvement to fish and other riparian habitat, especially below the Alamosa gage, are provided because the River would not be dried-up due to constant curtailment applied to River flows and to later season Compact deliveries.
- Enhanced flood protection during high runoff events for downstream residents and businesses is provided.
- A permanent conservation pool and/or a recreational use pool could be established at the Reservoir.

Section 8
Legal Issues

During this study, several legal issues were identified that may impact the District's ability to carry out enlargement of the Reservoir. The extent to which these issues will require further analyses and coordination with appropriate governmental agencies is dependent upon refinement of the extent to which the Reservoir may be enlarged and the area of additional inundation is better identified.

8.1 Review Under the NEPA, 42 U.S.C. " 4321 et seq.

The scope of National Environmental Policy Act (NEPA) review will be determined by the scope of the project as ultimately proposed. Raising the dam, storing additional water, and inundating additional land that surrounds the present Reservoir may result in a major federal action with significant environmental impacts, requiring preparation of an environmental impact statement (EIS). A determination to rehabilitate the existing dam structure, improve the outlet works, and spillway may not require major federal action in light of the fact that the dam location and immediately surrounding area is owned by the District and is not National Forest land. But NEPA review may be required if the impacts of rehabilitation affect the National Forest lands in the vicinity and immediately downstream of the dam or the Forest Service's instream flows below the Reservoir. Moreover, NEPA review will be required if federal funds are authorized for rehabilitation of the existing structure and outlet works. It is anticipated that the lead federal agency in any NEPA review process would be the U.S. Forest Service.

8.2 USACE Clean Water Act Section 404 Permit

Again, the need for Section 404 permitting is dependent upon the scope of the project to be determined in the pre-design phase of the study. If there is an enlargement of the dam, a Section 404 Permit may be required for raising the dam, which will inundate wetlands located at the upper reaches of the Reservoir, as determined during the preliminary wetlands assessment. The District will have to develop a mitigation proposal for any wetlands that may be lost, with particular attention to the fens area discussed in Section 7. If the scope of the project is limited to rehabilitating the existing structure and fixing the outlet works and spillway, a Section 404 permit may not be required. A Section 404 permit was not required for prior repair and rehabilitation of the dam outlet works and spillway. Under 33 C.F.R. 323.4(a)(2), "maintenance, including emergency reconstruction of recently damaged parts, of currently serviceable structures such as . . . dams . . ." is not regulated under Section 404. It does not appear that rehabilitation work will involve any modifications that change the character, scope, or size of the original fill design. Rehabilitation work also may fall within the scope of Nationwide Permit No. 2, for maintenance activities related to the repair, rehabilitation, or replacement of any previously authorized, currently serviceable, structure or fill.

8.3 Minimum Stream Flows

CWCB - Ute Creek Minimum Stream Flow

The CWCB has minimum instream flows on Ute Creek, West Lost Trail Creek, and Weminuche Creek. Each drains into the Reservoir. The minimum stream flows run from each Creek's confluence with the Reservoir to points upstream. An enlargement of the dam may cause some inundation of these creeks at their confluences with the Reservoir when the Reservoir stores near its enlarged capacity. If the potential inundation is confirmed during the pre-design phase of the study, discussions will be initiated with CWCB to develop a plan to address this issue.

Federal Reserved Water Rights Decree for Instream Flows in the National Forest

On March 30, 2000, the District Court, Water Division No. 3, entered a stipulated decree granting water rights for instream flows to the United States for those portions of the Rio Grande and Gunnison National Forests in Water Division No. 3 (the "Decree"). The Reservoir's 1903 storage priorities pre-date the creation of the National Forest in 1905. Particularly important to the Reservoir Enlargement Study are the terms and conditions in the Decree protecting existing storage in and operation of the Reservoir.

Instream Flows Below the Reservoir

The instream flow quantification point below the Reservoir, QP-37N, is located approximately 2.4 miles upstream of the confluence of Texas Creek with the Rio Grande. This point is approximately 6 miles downstream from the USGS Thirty-Mile gage. The monthly base flows for QP-37N are set out at page 4 of Appendix A to the Decree. The low monthly base flow is 64.2 cfs in January and the high monthly base flow is 633.5 in June.

The Decree's Protections for the Operation of Rio Grande Reservoir

The Decree recognizes the seniority of the District's storage rights totaling 51,113 AF. The right to store this amount of water annually cannot be curtailed by the instream flows. Current Reservoir operating practices may continue up to a total storage amount of 51,113 AFY. These practices include:

- Storage under the District's decrees
- Compact storage
- Direct flow storage under the decrees in Case Nos. W-3979 (Rio Grande Canal), W-3980 (SLVID), and 95CW18 (Empire Canal)
- Exchanges between the three reservoirs decreed in Case No. 90CW42, an exchange between the Closed Basin Project and the Reservoir decreed in Case No. 90CW45 and, the exchange from the Fun Valley Trailer Park to the Reservoir decreed in Case No. 97CW10

- Future decreed direct flow storage with certain limitations

These provisions effectively protect current Reservoir operations and future decreed direct flow storage from curtailment to meet the downstream instream flows. On page 89, the Decree states:

> *The effect of the operations of the reservoir as described above is predominantly to dampen or redistribute peak flows, but typically extend, the duration of seasonal high flows by reservoir releases. Reservoir operations consistent with the Reservoir's storage rights, the Compact Storage Agreement, and the decreed exchanges and the existing decrees allowing storage of downstream water rights in the reservoir, or future decrees allowing storage of such senior downstream water rights have no material adverse impact on the reserved instream flow water rights for National Forest purposes provided that (1) no more than 51,113 acre-feet are diverted and stored in any one water year, November 1 through October 31 . . .*

The effect of the regulation of additional water in an enlarged Reservoir on the Forest Service's instream flows will require additional study in the proposed preliminary design phase. Initial indications are that regulation can further extend the seasonal high flows as well as provide much needed flow during the winter months. The re-distribution of some flows may, therefore, provide additional water for instream flows during periods of current greatest need. The legal effects of any storage above 51,113 AF and the re-distribution of that additionally stored water during the later part of the irrigation season and the subsequent winter and early spring months will be further evaluated during the second phase of the study. That work will be coordinated with representatives of the U.S. Forest Service, and environmental and recreational interests in the Basin.

Storage of Transmountain Water

Paragraph 26 of the Decree provides:

> *The United States does not claim and is not entitled to call for or require any water from any reservoir, or any transmountain, imported, foreign, or nontributary water source in Colorado Water Division No. 3 to be used to quantify or satisfy instream flows for National Forest purposes.*

This would include transmountain water stored in the Reservoir by the Conservancy District and the Colorado DOW.

Flows to Meet Downstream Instream Flows

Water stored in the Reservoir in excess of 51,113 AF during a water year (not including carryover), may be subject to release if the downstream minimum base flow is not being met. Further analysis during the propose preliminary design phase will provide additional information on the timing and effect, both legal and physical, of storing water for delivery later in the irrigation season and during the subsequent winter and early spring.

8.4 The District's 1891 Act Right-of-Way

The District owns the land where the dam is located and holds a right-of-way for the actual reservoir under the Act of March 3, 1891, 43 U.S.C. " 946-949. That Act provided:

> *The right of way through the public lands and reservations of the United States is hereby granted to any canal ditch company, irrigation or drainage district formed for the purpose of irrigation or drainage, and duly organized under the laws of any State or Territory, . . . to the extent of the ground occupied by the water of any reservoir and of any canals or laterals, and fifty feet on each side of the marginal limits thereof,*

The 1891 Act was subsequently amended in 1898 to include other uses of water in the right-of-way grant:

> *Rights of way for ditches, canals, or reservoir heretofore or hereafter approved under the provisions of sections 946-949 of this title may be used for purposes of a public nature; and said rights of way may be used for purposes of water transportation, for domestic purposes, for the development of power, as subsidiary to the main purpose of irrigation or drainage.*

So long as the Reservoir's primary use is storing water for irrigation, it can be used to store water for 1) other purposes of a public nature; 2) for domestic purposes; and 3) for the development of power[1]. Public purposes would include storing water for the augmentation of domestic development in the Basin, the maintenance of a conservation pool at the Reservoir for use of the public, the DOW's use in maintaining its public reservoirs and wildlife habitat, and the storage of Compact water to assure that Colorado retains its full Rio Grande share of Colorado's apportionment for use within the state. It also would include the regulation of flows to support the River fishery and riparian habitat. Whether the Reservoir is enlarged or only rehabilitated, its primary purpose will remain storage for irrigation. So long as that remains the Reservoir's primary use, each of the other potential uses fall within the District's 1891 Act right-of-way as amended in 1898.

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[1] See Kern River Co. v. United States, 257 U.S. 147, 154 (1921 ([I]t is a use which the section permits only where it is subsidiary to irrigation.); Zelph S. Calder, 81 ID 339, 342-43 (June 20, 1974) (Subsidiary use must be a public use); United States v. Tujunga Water & Power Company, 18 F.2d 120, 122 (S.D.CA 1927) (The supplying of communities…with water for domestic and yard irrigation, is fairly within the main object to be accomplished.); Fleming, P., Vested Pre-FLPMA Rights of Way for Water Conveyance Facilities, 25 Colo.Law 83, 84-85 (1996).

Section 9
Hydropower Potential

A screening analysis was conducted to determine the potential for hydropower generation with an enlarged reservoir configuration. Hydropower generation in kilowatt hours/month (kWh/mo) is a function of available head, flow, and turbine efficiency. In this analysis, an efficiency of 85 percent was assumed. Figure 9-1 shows the average monthly head available at the Reservoir for power generation under estimated Reservoir levels for those hydrological conditions. Because power generation is directly proportional to available head, optimizing water levels at the Reservoir would be critical to maximizing power generation. Table 9-1 shows the average, maximum, and minimum values for a period of record from 1927 through 2007. Estimated reservoir head represents preliminary conservative estimates that will vary based on reservoir operating conditions. The proposed next phase will refine these estimates based on reservoir operating scenarios such as minimum conservation pool, compact storage, and other operating criteria.

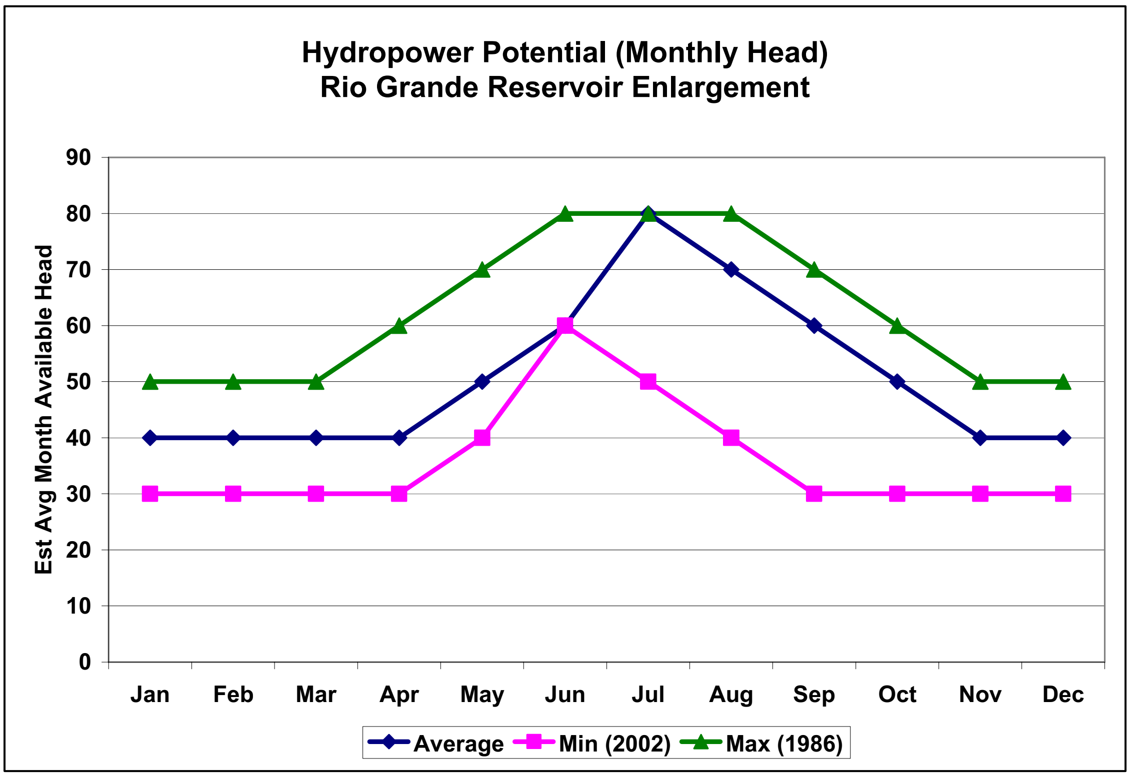


Figure 9-1 Average Monthly Head Available Under Enlarged Conditions

Table 9-1 Available Flow and Head for Hydropower Generation

	Average	Min	Max
Period of Record/Year	1927-2003	2002	1986
Estimated Average Head (ft)	61	40	76
Annual Flow (AF)	148,000	29,600	255,400
Annual Average Flow (cfs)	200	40	350
Total Power Generated (kW)	900	120	1,930
Annual Power Generated (kWh)	7,871,097	1,031,800	16,921,200
Population served	2,600	350	5,650

Additional calculations were performed to determine the potential for power generation on a monthly basis, using the same basic approach discussed above. Calculations were based on the flows at the Thirty-Mile gage. Figure 9-2 shows the potential for hydropower generation on a monthly basis using the assumed Reservoir levels in Figure 9-1.

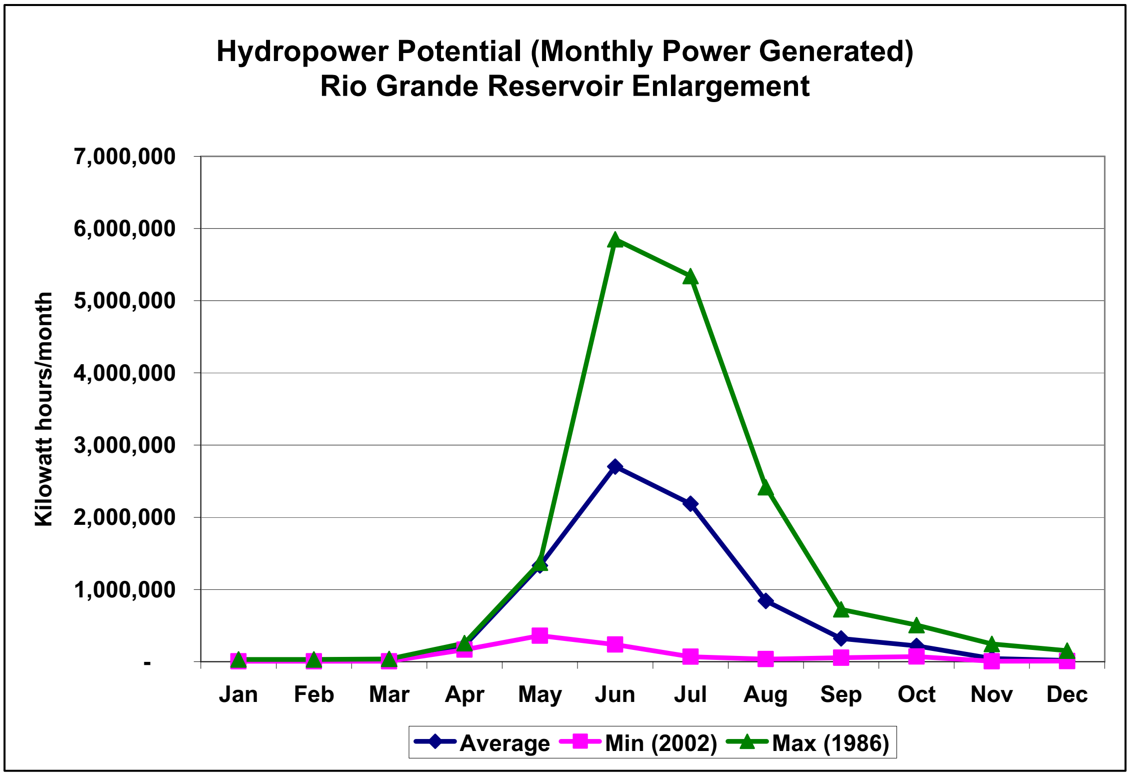
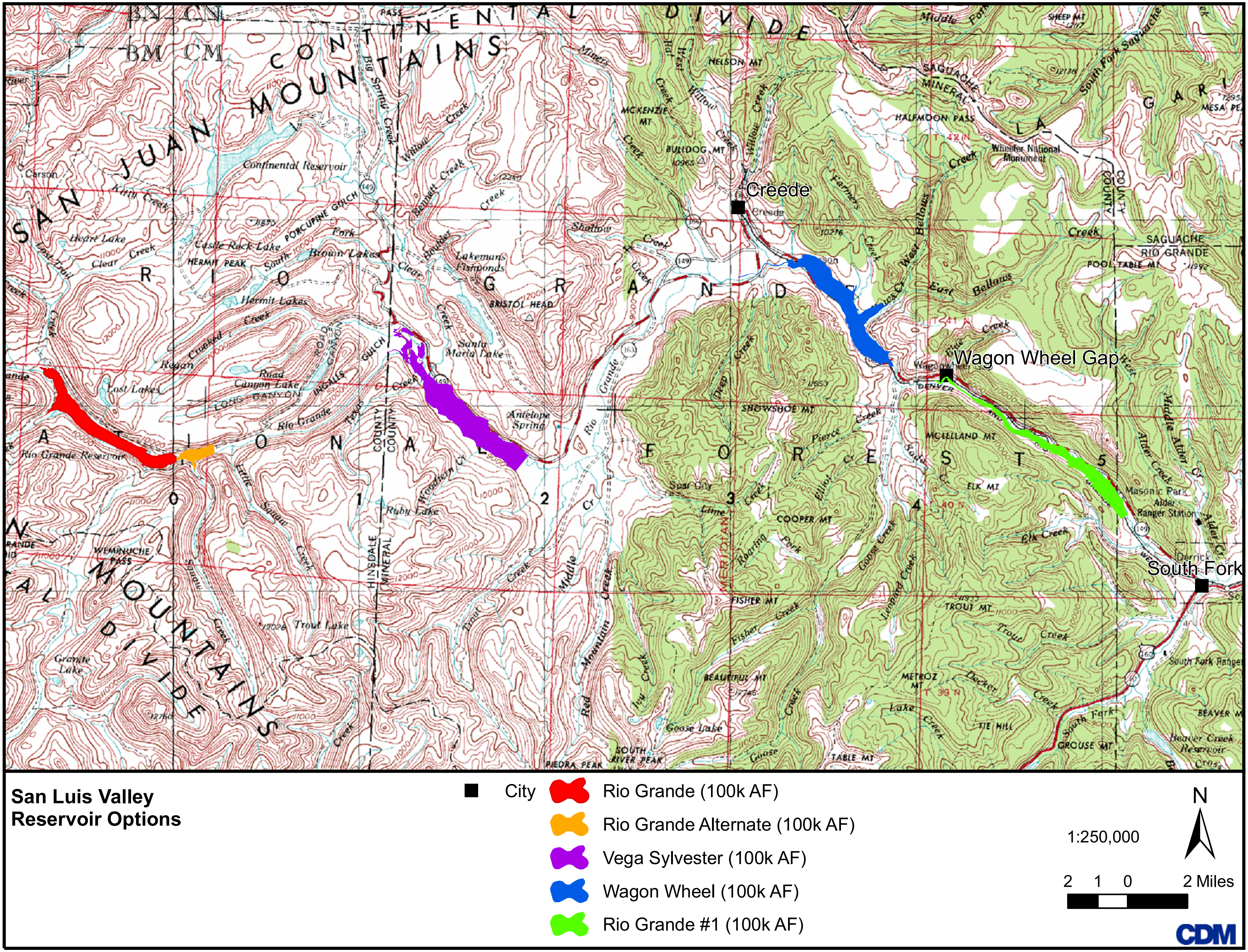


Figure 9-2 Monthly Hydropower Generation Potential at Rio Grande Reservoir Under Enlarged Conditions

These calculations assume an enlarged and rehabilitated reservoir with a minimum storage level of gage height 30. Power generation could be maximized by allowing the reservoir to fill every year during peak runoff, either in priority or with Compact curtailment flows. If the Reservoir passes water without providing for minimum Reservoir elevations, power generation will be minimized. Other key issues to be investigated in the proposed preliminary design phase include the feasibility of constructing power transmission lines, the potential for improved reservoir operations to utilize the capacity, the feasibility of a permanent pool and a turbine sizing that would be large enough to generate maximum power during peak flows but would be economically feasible given that low-flows in the winter greatly diminish or eliminate the potential for power generation.

Section 10
Alternative Storage Sites

As part of this study, alternative storage sites for the construction of a new reservoir were examined. These sites would be located downstream of the existing Rio Grande Reservoir, as shown in Figure 10-1. There are two sites located both up and downstream of Wagon Wheel Gap and a third site located upstream of Creede. The color shading on Figure 10-1 roughly shows the inundation limits for 100,000 AF of storage. It was determined that inundation of a perennial stream with a new reservoir was unlikely to be permitted and that it is likely more feasible to enlarge an existing dam rather than construct a new dam and reservoir. The environmental community in the "Facing Our Future" report in their recommended water management approach includes "smart storage" involving expansion or rehabilitation of existing dams. (Trout Unlimited, Western Resources Advocates and Colorado Environmental Coalition, 2005).



San Luis Valley Reservoir Options

Section 11
Proposed Enlargement Configuration and Recommended Rehabilitation

Two different primary alternatives for enlarging the Reservoir were initially considered; either the existing dam crest could be raised or an entirely new dam could be constructed downstream of the existing one. Based on the results of the geotechnical investigation and wetlands assessment, it was determined that the most feasible option would be to elevate the existing dam crest. Table 11-1 shows estimates of the total reservoir capacity resulting from various increases in dam height. These estimates were derived from USGS topography and additional detailed surveys will be needed to refine these values.

Table 11-1 Potential Enlargement Configurations

Spillway Elevation (ft)	Volume (acre/ft)[1]	Area (acres)	Area Change (acres)	Volume Change (acres)	Length of Dam (ft)	Max Dam Height (ft)
9,449	52,000	984	0	0	531	63
9,459	**62,160**	**1,070**	**85**	**10,160**	**585**	**73**
9,473	77,700	1,157	172	25,700	623	87
9,493	102,400	1,311	326	50,400	761	107
9,512	128,200	1,404	419	76,200	1,089	126

The geotechnical investigation determined that an enlargement of the existing dam crest by 10 feet is the recommended maximum due to concerns resulting from the landslide along the left abutment of the existing dam. Additionally, as discussed in the following subsections, the recommended rehabilitation work to the existing dam should be completed as part of any enlargement effort.

11.1 Recommended Rehabilitation

In order to maintain a full reservoir for longer periods of time, improvements to the embankment and left abutment, outlet works, and spillway are recommended. At the upstream face of the dam embankment and the left abutment, it is recommended that a PVC liner be placed to reduce seepage under full reservoir conditions from 5 cfs to less than 1 cfs. This liner should be placed on properly prepared subgrade and covered with bedding and riprap for protection.

Improvements are required to the existing outlet works so that they are capable of safely discharging at least 2,500 cfs. It is recommended that an air vent shaft be installed below the gates as proposed in 1987 by HARZA. This will reduce vibration on the gates during high flows. Additionally, a new gate structure and bypass tunnel should be constructed to improve safety and redundancy and to provide additional emergency release capacity. It is recommended that a more efficient weir configuration be implemented for the spillway in order to improve capacity. Exact improvements will depend on detailed spillway sizing calculations to be completed in the next phase of this study; however, they would include widening and deepening of the channel, construction of channel drop structures, and construction of a dam crest 4-foot high concrete parapet wall for additional freeboard. The total preliminary cost of the rehabilitation effort is estimated to be $15.8 million. An itemized cost estimate is presented in Table 11-2.

Table 11-2 Reconnaissance Level Cost Estimate to Rehabilitate Rio Grande Reservoir

	Construction Item	Quantity	Unit	Cost	Extension
1	**Mobilization (@5%)**	1	LS	$463,000	$463,000
	Subtotal				*$463,000*
2	**Dam Embankment**				
	a. Foundation Preparation (upstream)	10,000	CY	$10	$100,000
	b. Remove Existing Rip and Riprap Bedding	15,000	CY	$4	$60,000
	c. Construct Coffer Dam	1	LS	$200,000	$200,000
	d. Foundation Grouting	1	LS	$400,000	$400,000
	e. PVC Bedding	5,000	CY	$20	$100,000
	f. PVC Lining	100,000	SF	$4	$400,000
	g. Riprap Bedding	5,000	CY	$25	$125,000
	h. Riprap	15,000	CY	$40	$600,000
	Subtotal				*$1,985,000*
3	**Left Abutment**				
	a. Clearing/Grubbing/Stripping	50,000	CY	$10	$500,000
	b. Left Abutment Drainage Gallery Tunnel and Drains	250	LF	$5,000	$1,250,000
	c. PVC Bedding/Filter	15,000	CY	$20	$300,000
	d. PVC Liner	75,000	SF	$4	$300,000
	Subtotal				*$2,350,000*
4	**Outlet Works**				
	a. Construct New Lower Bypass Outlet Tunnel	150	LF	$3,500	$525,000
	b. Construct New Gate Shaft	1	LS	$500,000	$500,000
	c. Air Vent for Existing Outlet Tunnel	1	LS	$400,000	$400,000
	d. Expand Existing Outlet Building	1	LS	$150,000	$150,000
	e. Install New Gate	1	LS	$500,000	$500,000
	Subtotal				*$2,075,000*
5	**Spillway**				
	a. New Spillway Weir	1	LS	$400,000	$400,000
	b. Improve Existing Spillway Channel	1	LS	$1,500,000	$1,500,000
	c. Concrete Parapet Wall	1	LS	$100,000	$100,000
	Subtotal				*$2,000,000*
6	**Miscellaneous**				
	a. Instrumentation	1	LS	$300,000	$300,000
	b. Seeding and Fertilizing	5	Acre	$8,000	$40,000
	c. Care of the River	1	LS	$500,000	$500,000
	Subtotal				*$840,000*
				Total Construction Items	**$9,713,000**
				Miscellaneous and Unlisted Items @ 5%	$490,000
				Permitting @ 5%	$490,000
				Engineering @ 15%	$1,460,000
				Subtotal	*$12,153,000*
				Contingency @ 30%	$3,650,000
				ESTIMATED TOTAL (rounded to nearest $100,000)	**$15,800,000**

11.2 Proposed Improvements for Enlargement

Due to space constraints and concern for slope stability, the maximum dam crest enlargement recommended is 10 feet. The enlargement would be a downstream raise, as shown in Figures 11-1 and 11-2. In addition to the rehabilitation recommendations described in Section 11.1, the enlargement effort would require new fill for the dam embankment, a new redundant outlet tunnel system, and a larger spillway. The dam crest would be shifted downstream and new rockfill placed at a 2:1 slope, as shown in Figure 11-2. In order to construct a downstream raise efficiently, the River should be diverted around the work area, which would be accomplished by constructing a new outlet tunnel that exits near the spillway (Deere & Ault 2006). A new upper level inlet tunnel would also need to be constructed that would provide water quality and temperature control of releases from the Rio Grande Reservoir (Deere & Ault 2006). The outlet system would contain a 9-foot diameter steel pipe that would allow pressurized release through a jet valve at the downstream end with a capacity of 3,500 cfs (Deere & Ault 2006). The old outlet system would be used as a redundant emergency system only and bring the total release capacity of the Reservoir to 6,000 cfs.

The total preliminary cost for the enlargement, including the rehabilitation described in Section 11.2, is estimated to be $35 million. Table 11-3 presents a detailed cost estimate for enlargement. A 10-foot enlargement would yield an additional 11,000 AF of storage at an estimated cost of less than $3,200/AF. This figure is consistent with other similar size storage projects in Colorado; costs for new storage sites along the Front Range are being estimated at $5,500/AF.

11.3 Potential Funding Opportunities

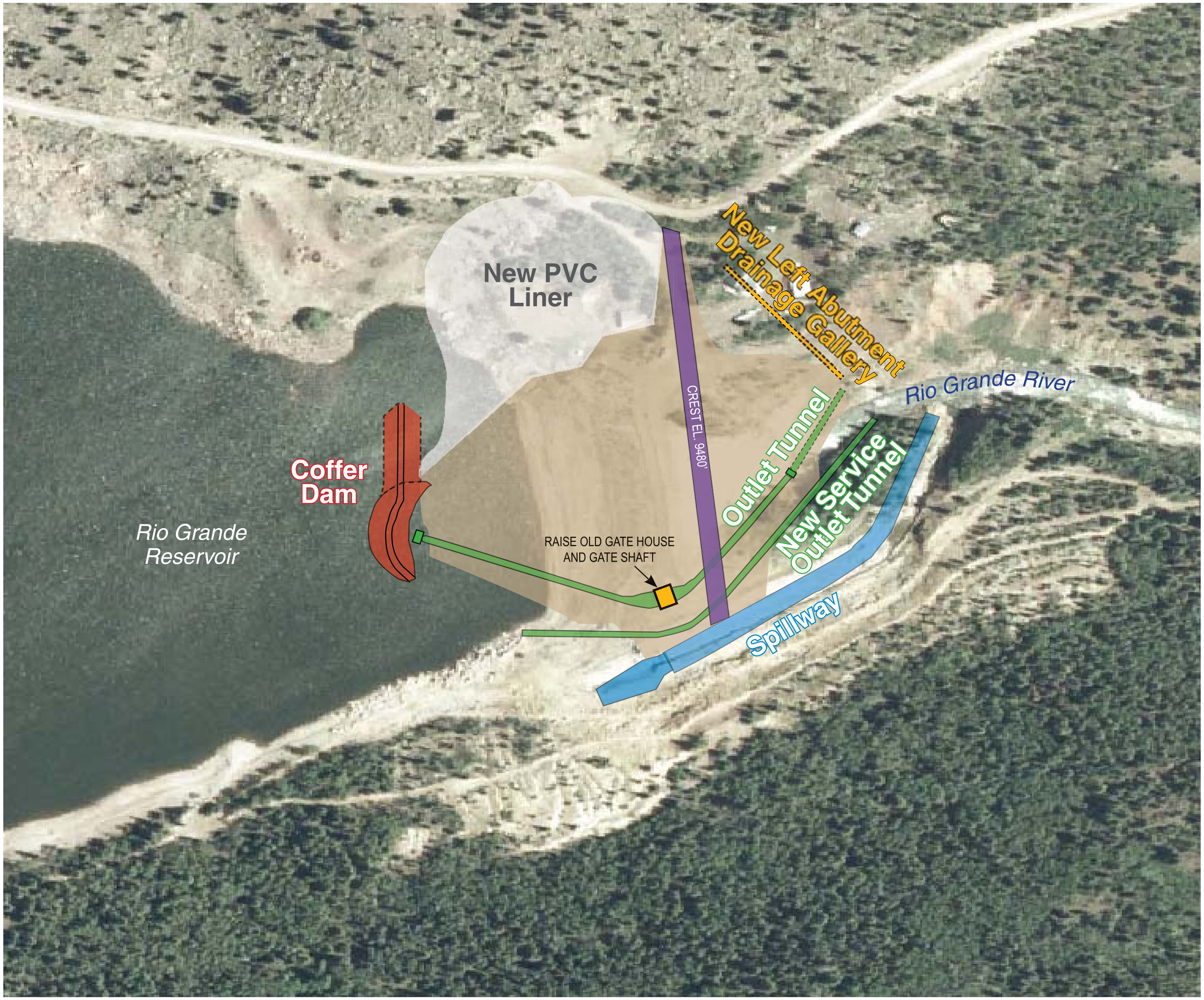
The financial needs for Colorado's smaller and rural communities, as well as agricultural and recreational and environmental uses, were highlighted in several of SWSI's key findings, including:

- Without a mechanism to fund environmental and recreational enhancement beyond the project mitigation measures required by law, conflict among users will intensify

- The ability of smaller, rural water providers and agricultural water users to adequately address their existing and future water needs is significantly affected by their financial capabilities

- In SWSI roundtable and public meetings throughout Colorado, two points were made clearly and often: 1) financial issues represent the biggest challenge in meeting Colorado's future water needs; and 2) a key role the state could play in addressing those needs is funding and financing assistance

Rio Grande Reservoir Proposed Dam Enlargement



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Water Resources, Civil & Geotechnical Engineering

FIGURE 11-1

Rio Grande Reservoir Dam Cross-Section

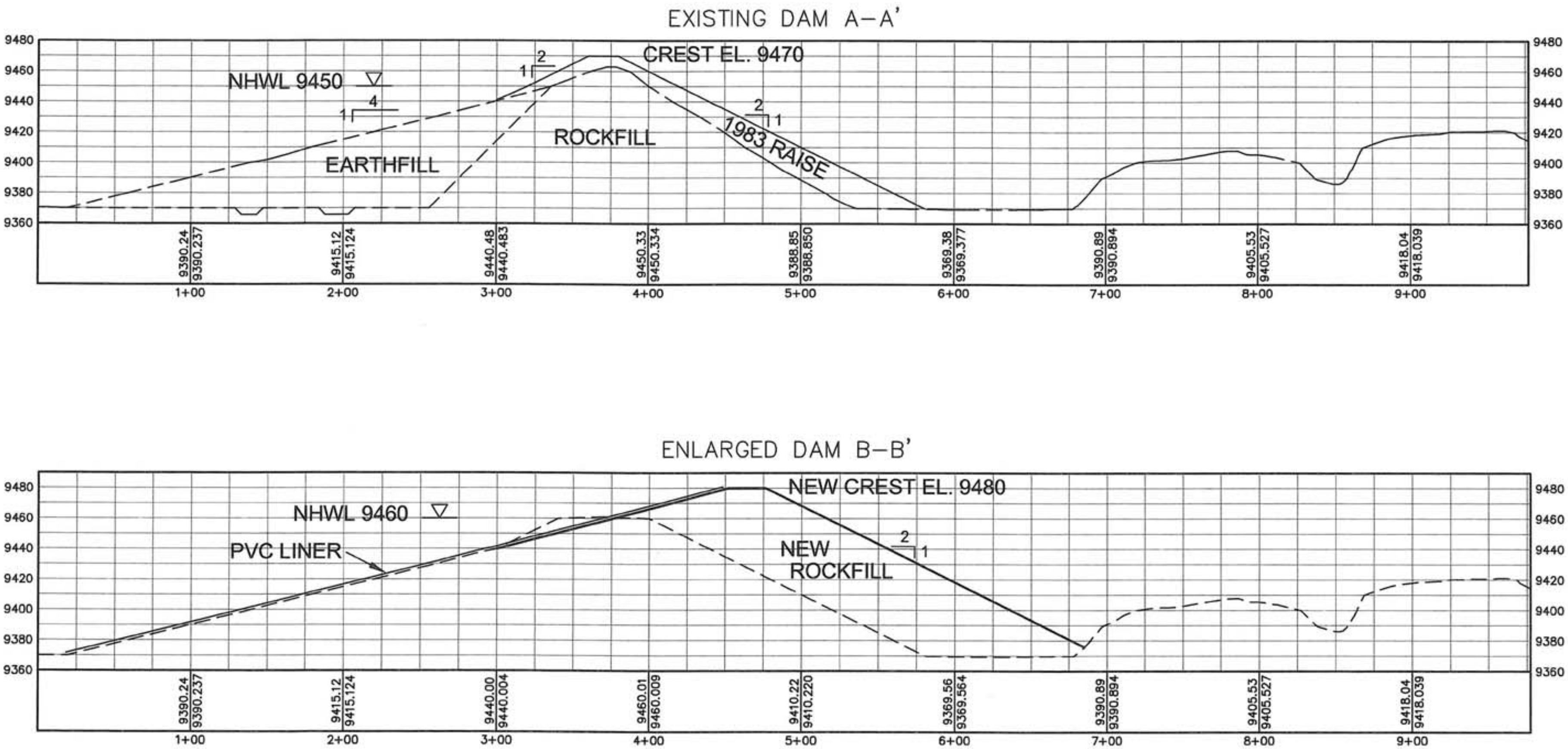

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FIGURE 11-2

Table 11-3 Reconnaissance Level Cost Estimate to Rehabilitate and Enlarge Rio Grande Reservoir

	Construction Item	Quantity	Unit	Cost	Extension
1	**Mobilization (@5%)**	1	LS	$917,000	$917,000
	Subtotal				*$917,000*
2	**Dam Embankment**				
	a. Foundation Preparation (upstream)	10,000	CY	$10	$100,000
	b. Foundation Preparation (downstream)	10,000	CY	$15	$150,000
	c. Remove Existing Rip and Riprap Bedding	15,000	CY	$4	$60,000
	d. Construct Coffer Dam	1	LS	$200,000	$200,000
	e. Foundation Grouting	1	LS	$400,000	$400,000
	f. Dam Rockfill (for Dam Raise)	115,000	CY	$8	$920,000
	g. Extend Existing Toe Drains	500	LF	$100	$920,000
	h. PVC Bedding	5,000	CY	$20	$100,000
	i. PVC Lining	100,000	SF	$4	$400,000
	j. Riprap Bedding	5,000	CY	$25	$125,000
	k. Riprap	15,000	CY	$40	$600,000
	l. Crest Road (Paved)	15,000	CY	$100	$67,000
	Subtotal				*$3,172,000*
3	**Left Abutment**				
	a. Clearing/Grubbing/Stripping	50,000	CY	$10	$500,000
	b. Left Abutment Drainage Gallery Tunnel and Drains	250	LF	$5,000	$1,250,000
	c. PVC Bedding/Filter	15,000	CY	$20	$300,000
	d. PVC Liner	75,000	SF	$4	$300,000
	Subtotal				*$2,350,000*
4	**Outlet Works**				
	a. Construct New Lower Outlet Tunnel	670	LF	$3,500	$2,345,000
	b. Construct New Upper Intake Tunnel	375	LF	$3,500	$1,312,500
	c. Existing Outlet Tunnel Extension	175	LF	$2,000	$350,000
	d. Construct New Valve Shaft	1	LS	$2,000,000	$2,000,000
	e. Air Vent for Existing Outlet Tunnel	1	LS	$400,000	$400,000
	f. Demo and Raise Existing Outlet Building and Replace Outlet Building	1	LS	$1,000,000	$1,000,000
	g. New Fixed Core Valves and Structure	1	LS	$1,000,000	$1,000,000
	h. Install New Gate	1	LS	$500,000	$500,000
	Subtotal				*$8,907,500*
5	**Spillway**				
	a. Raise Spillway Training Walls	1	LS	$400,000	$400,000
	b. New Spillway Weir	1	LS	$800,000	$800,000
	c. Improve Existing Spillway Channel	1	LS	$1,500,000	$1,500,000
	d. Concrete Parapet Wall	1	LS	$100,000	$100,000
	Subtotal				*$2,800,000*
6	**Miscellaneous**				
	a. Instrumentation	1	LS	$300,000	$300,000
	b. Seeding and Fertilizing	10	Acre	$8,000	$80,000
	c. Care of the River	1	LS	$500,000	$500,000
	d. Tree Removal Reservoir Perimeter	30	Acre	$7,500	$225,000
	Subtotal				*$1,105,000*
	Total Construction Items				**$19,251,500**
	Miscellaneous and Unlisted Items @ 5%				$960,000
	Permitting @ 5%				$3,850,000
	Engineering @ 15%				$2,890,000
	Subtotal				*$26,951,500*
	Contingency @ 30%				$8,090,000
	ESTIMATED TOTAL (rounded to nearest $100,000)				**$35,000,000**

Preliminary estimates for this study place the cost of fully rehabilitating and enlarging the dam embankment at over $35 million. Consistent with the SWSI findings regarding the ability of agricultural users to fund their water needs, the District cannot fund the entire cost of rehabilitation and enlargement on its own.

At the federal level, funding for the project could likely come from a line-item appropriation in a federal spending bill. Line item appropriations are used to fund major projects or those with unique needs. Securing federal funding through a line item appropriation allows funding to be tailored to individual needs. Additionally, Senator Ken Salazar and U.S. Representative John Salazar, are both natives of the San Luis Valley and have an understanding of the Rio Grande Basin's needs for additional storage as a way of assuring Colorado's ability to fully use its share of Rio Grande Compact water to meet a variety of needs. Due in large part to the efforts of Senator Salazar, the recently-approved Water Resources and Development Act of 2007 includes $25 million for restoration and management in the Rio Grande River Basin.

A new initiative for funding water resources projects in the western United States is the Water 2050 Program, sponsored by the U.S. Bureau of Reclamation. This program was launched in June of 2003 to encourage water-starved areas to be proactive and forward-thinking in their water supply planning. While a Water 2050 grant would not be enough to fund construction of the project, it could be enough to fund detailed design of the project. Funding for FY07 has recently been appropriated and information is not currently available for further funding cycles.

It is highly likely that a significant source of funds for construction of an enlargement will need to be secured through marketing storage for augmentation water and forming partnerships with other entities, such as the DOW and environmental interests. Furthermore, it is also likely that additional state funds will be requested, both in terms of loans and grants. In the case of this specific project, however, the state could receive storage capacity that could be used to optimize Compact management provide for a conservation pool and enhance streamflows during critical low flow periods.

Section 12
Recommendations for Additional Study

The purpose of this study was to conduct a high-level feasibility investigation of the possibility of enlarging the Reservoir and identify potential fatal flaws that would render enlargement impossible. During the course of the geotechnical investigation, wetlands assessment, and hydrology and legal investigations, it has been determined that a 10-foot enlargement of the dam may be technically and legally feasible, pending further detailed investigation. This enlargement would yield approximately 11,000 AF of additional storage space and bring the total capacity of the Reservoir to 64,000 AF. Outlined below are items that require further investigation.

A detailed investigation should be conducted of the hydrology associated with Reservoir enlargement from Compact administration, water rights, environmental, recreational, and flooding perspectives. The RGDSS developed by the CWCB can be used for purposes of developing baseline flow data, including estimates of stream gains and losses throughout the Basin under defined assumptions. A modeling tool developed based on RGDSS output will allow the evaluation of various storage allocations in the Reservoir among various interests (i.e., the District, Division of Water Resources, CWCB, DOW, the Conservancy District, water users, etc.) and for various purposes including Compact storage, minimum pool preservation, River administration, use for direct flow storage, environmental and riparian enhancement, etc. Additional modeling should be done to develop and evaluate the impacts of target releases for enhancing flows for U.S. Forest Service and CWCB instream flow rights junior to the Reservoir storage decrees as well as downstream recreational and environmental flows. In the spirit of continued collaboration and stakeholder outreach, it is recommended that further input be sought from various environmental and recreational interest groups to evaluate and determine optimum flows for maximizing recreational and environmental benefits through reservoir reoperations and the methods for achieving those flows without impairing Colorado water rights.

Detailed flood hydrology for the Reservoir under proposed conditions should be evaluated using either the Extreme Precipitation Analysis Tool (EPAT), developed by the Division of Water Resources, or an alternative methodology, depending on the stage of development of EPAT for the Basin. EPAT can be used to develop the maximum precipitation event used to calculate flood inflow, which will be routed through the Reservoir using HEC-HMS (or similar program) to determine sizing for the spillway under proposed conditions. Based on this analysis, a preliminary spillway design under proposed conditions can be prepared.

In addition to hydrologic analyses, further geotechnical investigations are required. Notably, the status of the abutment to the left of the existing dam and the potential for future landslide movement in the Reservoir basin require further evaluation. Additional field work is necessary to map the Reservoir basin and the West Lost Trail Creek basin to compare geology and determine if a slide similar to the West Lost Trail Creek event could occur in the near future under existing climatic conditions in the

Reservoir basin. A slope stability analysis of the Reservoir should be conducted. In addition to the landslide analysis, a detailed hydraulic analysis of the required outlet improvements under existing and proposed (i.e., enlarged) conditions should be conducted.

It is recommended that the preliminary wetlands investigation be followed up with a detailed wetlands delineation per the USACE 1987 Wetland Delineation Manual, including a written verification of this wetland delineation from USACE staff. In order to finalize the impacts to jurisdictional wetlands, a final decision regarding the proposed enlargement height of the dam will be required. Written verification from USACE of a final wetlands delineation map will be suitable for Clean Water Act Section 404 permitting purposes for 5 years. It is also recommended that a preliminary wetlands mitigation and monitoring plan for the impacted wetlands be prepared for enlarged conditions. A wetlands mitigation plan will be necessary as part of future NEPA and Section 404 permitting processes. Other investigations that will also be needed to address future NEPA requirements include a cultural resources assessment of the project area and an assessment of threatened and endangered species in the project area.

Further analysis of the legal issues associated with Reservoir enlargement also need to be finalized. These issues include further analysis of the impact of an enlargement on the District's 1891 Act right-of-way for the present reservoir, further analysis of the impact of the terms of the U.S. Forest Service's instream flow decree in Water Division No. 3 on an enlargement of the Reservoir, and a re-regulation of water deliveries, analysis of the impacts of enlargement on the CWCB's instream flow decree on Ute, West Lost Trail and Weminuche Creeks, and further analysis of water rights issues related to the allocation of storage to various non-irrigation uses. As part of the legal analysis, proposed operations and storage agreements with parties interested in participating in an enlargement should be developed. Additionally, building on the suggested wetlands analysis tasks described above, a detailed analysis of the NEPA processes will be required in order to enlarge and/or rehabilitate the Reservoir should be conducted.

Section 13
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