Middle Rio Grande Water Supply Study, Phase 3

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November 24, 2004

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Prepared for:

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Albuquerque District

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and

New Mexico Interstate Stream Commission

Prepared by:

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Executive Summary

Scope of Work

The Middle Rio Grande Water Supply Study Phase 3 was initiated in July 2001 for the U.S. Army Corps of Engineers, Albuquerque District, and the New Mexico Interstate Stream Commission. This study is a continuation of the previous Middle Rio Grande Water Supply Study Phases 1 and 2. The conjunctive groundwater-surface water supply derived in the earlier Phases for the region from Cochiti Dam to Elephant Butte Dam (Figure ES-1), under the constraints of the Rio Grande Compact, is refined in this study to reflect updated information and to characterize drought conditions. The study also provides support for regional water planning efforts for the Middle Rio Grande and Socorro-Sierra Planning Regions, and describes conditions relevant to maintaining compliance with the Rio Grande Compact under implementation of the Middle Rio Grande, Socorro-Sierra, and Jemez y Sangre regional water plans.

This study evaluates the regional water supply under a range of conditions, rather than average conditions or conditions in specific years. The range of water supply conditions considered reflects the climatic variability experienced in this region over the past 53 years, from 1950 through 2002.

The goals of this third phase include:

- Updating and refining hydrologic functions in the probabilistic model to reflect new information;
- Refining climate-based dependencies for key water budget terms;
- Extending hydrologic functions to represent drought conditions;
- Reviewing long-term climate trends, using proxy-based reconstructions (i.e. tree rings), ENSO (El Nino – Southern Oscillation), and PDO (Pacific Decadal Oscillation) based projections for future changes, to further characterize potential variability in water budget terms; and,
- Providing technical assistance to the Middle Rio Grande and Socorro-Sierra regional water planning groups in assessing the hydrologic impacts of chosen water planning alternatives on regional water use and on Compact deliveries.

Key products generated in this study include:

- An updated quantification of the impacts on flow of the Rio Grande from groundwater pumping under both current and proposed City of Albuquerque pumping;
- Revision of agricultural and riparian consumptive uses, based on revised acreages and consumptive use rates, scaling to translate potential agricultural consumptive use to actual consumptive use, and limitations placed on agricultural consumptive use in response to available supply;
- Revision of Elephant Butte evaporative loss, taking into account potential open water, wet sediment, and riparian losses from exposed portions of the Elephant Butte delta and northern basin;
- An updated risk analysis evaluation of the water supply, identifying the range of

expected water supply conditions under both baseline and drought conditions;

- Evaluation of the probability of achieving compliance under the Rio Grande Compact under full implementation of the Middle Rio Grande, Socorro Sierra, and Jemez y Sangre Planning Regions proposed water planning alternatives during both historic (1950-2002) and drought conditions.

These products provide an up-to-date integration of past and on-going technical studies that can be used in the regional water planning process. This study builds on the previous Water Supply Study, providing planners with improved analysis of water supply conditions and Compact compliance under both current and potential drought scenarios, and provides a clear assessment of the potential impacts of the Middle Rio Grande, Socorro-Sierra, and Jemez y Sangre planning region water planning alternatives on Compact deliveries to Elephant Butte Reservoir.

Probabilistic Description of the Water Supply

In this study, the probabilistic water budget developed in Phases 1 and 2 for the stream system in the Middle Rio Grande region was updated to reflect additional data and an improved conceptual understanding of the system, and to provide output in a format to support the regional water planning process. Water inflows and depletions in the model are quantified to reflect climatic variability and present development conditions. For each water budget term exhibiting climate dependency, the range and nature of this variability is described based on historic (1950-2002) data. Water budget terms that are predominantly influenced by land use or development conditions were quantified according to the present (Year 2000) development condition.

Groundwater conditions are linked to the stream flow system using the updated 2002 groundwater model of the Albuquerque Basin (McAda and Barroll, 2002). Through this approach, hydrologic processes occurring in the aquifer that have effects on the river, for example, precipitation, recharge and groundwater pumping, are integrated into the water supply analysis.

The probabilistic water budget model is designed to evaluate the range of possible outcomes that result from the range of possible input flows and demands that occur under a given development condition (i.e. year 2000 or year 2040) and under a known range of climatic and hydrologic conditions (1950-2002, or drought conditions). Model results, are presented as a distribution of possible outcomes, such as range of agricultural demand, or range of Compact delivery Credit/Debit status, under the specified development condition and climatic variability. The results can not be compared to conditions experienced in New Mexico over the past decade or 50 years, nor can they be used to predict conditions for any given year or span of years in the future. The study results, instead, describe the range of conditions that could be experienced either currently or in 2040. Results can be used to answer question such as, "given the predicted 2040 demand, what is the probability that Compact Deliveries can be made during a drought similar to that of the 1950s". Knowing these probabilities, in turn, allows us to assess the risk associated with continuing operations as proposed, and to estimate the conditions under which system operations will fail.

The average results of the Phase 3 probabilistic analysis are shown in Figure ES-2, where it can be seen that the water supply is, on average, insufficient to meet Year 2000 water demand. Average annual Compact debit under the Base Case analysis is 39,600 acre-feet per year, with an additional 71,000 acre-feet per year of groundwater removed from storage in the aquifer which will result in future lagged river deletions. This implies that for the region to achieve a balance between renewable supply and demand, demands need to be reduced by 110,600 acre-feet per year, or additional supply found to satisfy these demands.

Figure ES-3 shows the distribution of calculated credit/debit under the Rio Grande Compact for the Base Case (and Drought) analysis. This type of graph is used to show how often a particular event will occur. In this case, the graph indicates the magnitude of credit or debit that will likely occur at various percentiles, given the climatic variability of water inflow and depletion terms. These analyses indicate that over the long term, debits are expected to occur roughly 6 out of every 10 years (Compact deliveries are negative at and below the 60^{th} percentile for the Base Case scenario) given the present water use conditions and the historic climatic variability.

Figure ES-4 graphically summarizes the depletion terms (as presently manifested on the surface water system) included in the Base Case Scenario. These pie graphs are based on the mean values of the model simulations. The percentages in the water use categories will vary to some degree, depending on climatic and water supply conditions in a given year. In particular, the reservoir evaporation is subject to a high degree of variation. Nonetheless, they illustrate the relative magnitudes of consumptive uses affecting the river system within the region and highlight the differences in demands between the model sections. In addition, an annual depletion rate of 71,000 acre-feet per year is estimated to be impacting the aquifer at present; impacts of this will shift to the river system over time.

Sensitivity and Uncertainty

In completing the Base Case analysis described above, the most recent data for water demand was used. However, the absolute accuracy of some of the water demand estimates included in the model is unknown. Terms such as riparian and agricultural consumptive use rates are subject to much debate, and small changes in the consumptive use rates for these terms have a large impact on the overall regional water budget when multiplied by the acreage involved. Accordingly, two sensitivity analyses are included, based on the variability in riparian and agricultural consumptive use for the region as reported in the recent literature.

In the agricultural sensitivity analysis, average agricultural consumptive use was alternatively set at 2.36 acre-feet per acre, as compared to 2.9 acre-feet per acre in the Base Case analysis. This change reflects an alternate method for agricultural consumptive use calculation from that used by the USBR ET Toolbox. Under this alternate assumption, the resulting average Compact credit/debit improved, with a resulting average debit of 8,000 acre-feet per year. This outcome is also sensitive to assumptions regarding the number of irrigated acres. Some information sources suggest that actual acreage is lower than that taken from the USBR sources used for this study. If so, then estimated depletions would be accordingly reduced and the credit/debit balance would shift favorably. In the riparian sensitivity analysis, an alternate average riparian evapotranspiration was set at 3.2 acre-feet per acre, as compared to the Base Case value of 3.8 acre-feet per acre. The resulting average Compact credit/debit was a debit of 1,600 acre-feet per year. In both cases, if consumptive use rates are closer to the Sensitivity values than to the Base Case values, the outlook for Compact deliveries under Year 2000 conditions is significantly improved.

Several other model terms are also subject to uncertainty, but unlike agricultural and riparian consumptive use, a means to quantify the uncertainty is lacking. These terms include the ungaged tributary inflow and effective precipitation. Ungaged tributary inflow, as estimated for the model, averages about 28,000 acre-feet per year. These terms are evaluated based on the literature and comparison with neighboring drainages. Values could easily vary by 50% or more in either direction. Effective precipitation is estimated at about 50,000 acre-feet per year. Effective precipitation is assessed as 50% of the measured precipitation; it is not considered likely to be significantly higher than this amount given that much precipitation occurs in the form of "monsoons" that generate significant run-off. This term may be lower than that assumed, which would negatively impact the projected water balances. Another significant term subject to uncertainty is the evaporation from Elephant Butte Reservoir. Although pan evaporation is measured, the extrapolation from these data to evaporation over this large body of water is subject to some uncertainty. Because this term is so large in the water budget, even a small percentage change, i.e., 10%, can provide a sizeable shift in the water balance.

Both Base Case and Sensitivity model results indicate that water demands in the Middle Rio Grande region currently exceed the available renewable water supply by a minimum of 71,000 acre-feet per year (groundwater withdrawals that have not yet impacted the river), and perhaps by as much as 110,600 acre-feet per year. Despite that these results are accompanied by uncertainty as noted above, the analysis suggests that New Mexico faces significant challenges with respect to meeting both water demands in the Middle Rio Grande and Compact obligations in future years.

Water Supply Under Implementation of the Regional Water Plans

As part of the Water Supply Study work presented here, the Middle Rio Grande Planning Region (MRGPR) Preferred Scenario (Middle Rio Grande Water Assembly and Middle Rio Grande Council of Governments, 2003) and the Socorro-Sierra Planning Region (SSPR) planning alternatives (Socorro Soil and Water Conservation District, 2003) were analyzed. The publicly available Jemez y Sangre Planning Region (JySPR) water planning alternatives (Jemez y Sangre Water Planning Council, 2003) were also reviewed, and the estimated hydrologic impact of implementation of the JySPR water plan incorporated into a joint analysis of the regional water plans. (Planning region boundaries are shown in Figure ES-5.)

It should be noted that, in presenting and analyzing the regional water planning alternatives, alternatives, as provided by the regional planning groups, were interpreted into hydrologic impacts based on numbers consistent with the rest of the Water Supply Study presented in this report. This analysis was performed to allow for meaningful comparison between current conditions and future conditions under implementation of the regional water plans. This analysis does not address the feasibility of the proposed planning alternatives, nor does it serve as recommendation or approval of the proposed plans.

The probabilistic water budget model, as discussed previously, uses development conditions for the present or a selected future time, and analyses how the historically available water supply meets demands under those development conditions. In the analysis of the water planning alternatives, the Planning Region alternatives are evaluated under assumed Year 2040 development conditions. The key elements included in the Planning Region alternatives are listed below. "Full implementation" of the regional water plans assumes implementation of all of the listed alternatives.

Region	Alternative	Impact on water budget in acre-feet per year (af/y)
JySPR	Municipal use of contracted SJC Project water and water-righted native water	New demand term of 19,730 af/y
MRGPR	Importation of desalinated water	Increase in supply of 22,500 af/y
MRGPR	Restoration of 17,000 acres of native bosque, Cochiti to Valencia-Socorro county line	Reduction in demand of 17,000 af/y
MRGPR	Restoration of 17,500 acres of native bosque, Valencia-Socorro county line to Elephant Butte Reservoir	Reduction in demand of 17,500 af/y
MRGPR	Retire 25% of agricultural lands within MRGPR	Reduction in demand of 32,665 af/y
MRGPR	Retire 7,500 acres of agricultural lands in SSPR	Reduction in demand of 21,375[1] af/y
MRGPR	City of Albuquerque use of SJC water with native carriage water	New demand terms of 89,000 af/y
MRGPR	Use of water in excess of Year 2000 values for MRGPR municipalities outside of Albuquerque	New demand term of 31,556 af/y
MRGPR	Wastewater returns to river, MRGPR	Increase in supply of 41,351 af/y
MRGPR	Combined impacts of other alternatives with small hydrologic impact	Reduction in demand of 4,893 af/y
SSPR	Restoration of 20,300 acres of native bosque, Valencia-Socorro county line to Elephant Butte Reservoir	Reduction in demand of 20,300 af/y
SSPR	Sub-surface drainage of Elephant Butte Reservoir north basin, when empty, resulting in 40% of exposed area remaining devoid of riparian plants	Average reduction in demand of 12,000 af/y
SSPR	Combined impacts of other alternatives with small hydrologic impact	Reduction in demand of 4,417 af/y

[1] This alternative included in analysis of MRGPR Preferred Scenario, but not included in analysis of Joint Alternatives because it is inconsistent with the SSPR intent to avoid transfer of water outside the region.

Under implementation of the MRGPR Preferred Scenario (implementation of all MRGPR alternatives listed above), the average Compact debit is 2,700 acre-feet per year, rather than the Base Case average debit of 39,600 acre-feet per year. Aquifer storage impacts are 39,900 acre-feet in Year 2040, a significant reduction from the current 71,000 acre-feet in Year 2000, but not zero. Compact Credit/Debit under the MRG Preferred Scenario in Year 2040 is negative below the 50th percentile, indicating that New Mexico, on average, can meet it's Compact delivery requirements in this time frame. However, the lagged effects of the 39,900 acre-foot per year of aquifer mining implies that, were Year 2040 demand held constant into the future, with no additional changes in supply the region would, on average, move into deficit conditions.

Under implementation of the SSPR alternatives (implementation of all SSPR alternatives listed above), the average Compact debit is 3,000 acre-feet per year, and aquifer storage impacts remain at 71,000 acre-feet per year. As for the MRGPR Preferred Scenario, regional demand is met at the 50th percentile and above

Joint analysis of the MRGPR, SSPR, and JySPR alternatives results in a Year 2040 average Compact deficit of 7,100 acre-feet per year (Figure ES-6), with aquifer storage impacts of 39,900 acre-feet per year. More troublesome, joint implementation of the regional plans calls for restoration of over 54,000 acres of riparian vegetation between Cochiti Dam and Elephant Butte Reservoir, and relies on that restoration resulting in 54,000 acre-feet of increase in river flow. This may be an unrealistic goal. Joint implementation also assumes the retirement of 25% of MRGPR agricultural lands, with no water demands (other than those included in M&I expansion) occurring on retired lands. Maintaining 11,073 acres of retired farmland free of riparian growth may be unfeasible.

The joint analysis of the planning region alternatives highlights the severity of the water issues facing the State. By 2040, without stringent measures taken to control phreatophyte water usage, a dramatic reduction in agricultural acreage, importation of water, and on-going groundwater mining, the region will be unable to meet its projected demands.

Probabilistic Description of the Water Supply under Drought Conditions

In the drought analysis, input distributions are based on the 1950 to 1972 and 2000 to 2002 period of record for key inflow and depletion terms, including the Otowi Index Supply, Jemez River, Rio Puerco, Rio Salado, ungaged tributaries, Elephant Butte losses, and agricultural consumptive use. San Juan Chama Project water is reduced to 75% of it's Base Case value; other model terms remained unchanged from their Base Case values.

Model results indicate that under extended drought conditions, the average Compact debit increases from an average of 39,600 acre-feet per year (Base Case scenario) to 48,300 acre-feet per year, and the probability of meeting Compact delivery requirements shift slightly, with Compact deliveries being met at the 65th percentile and above (Figure ES-3). In addition, agricultural consumptive use demands are more constrained under drought conditions than under the Base Case scenario; during extended drought, agricultural demands can not be fully met with available supply, resulting in reduced agricultural irrigation one year out of every five (20th percentile and below), and irrigation at half normal values or less one of every ten years (10th percentile and below).

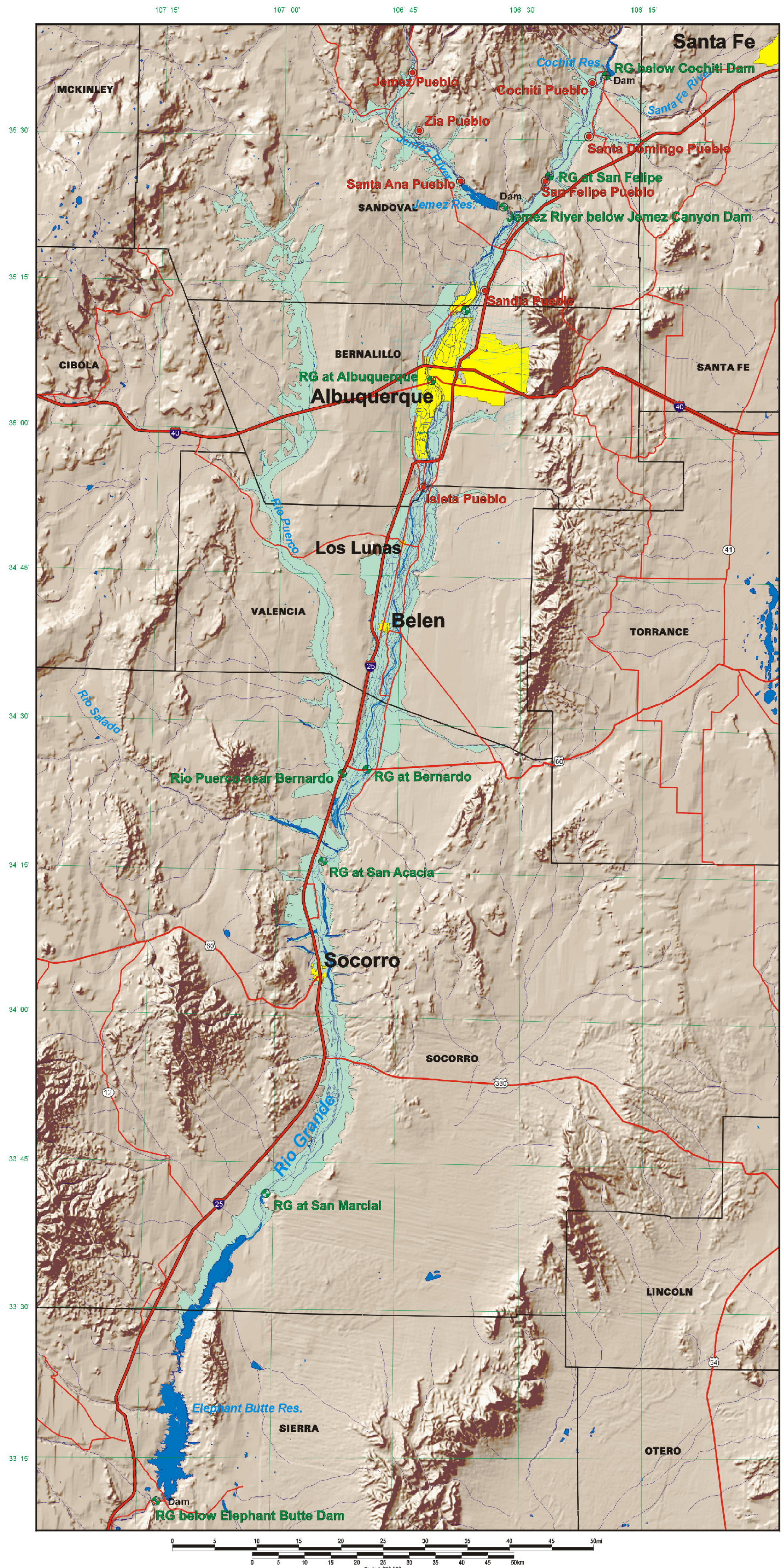
Extended drought conditions have a greater impact on the joint planning region alternatives analysis. In Year 2040, under extended drought conditions and under implementation of the joint planning region alternatives, average Compact deliveries are a 41,000 acre-foot deficit (Figure ES-6).

Summary of Conclusions

Key water supply and hydrologic concepts illustrated or derived from this study, with implications for water planning are:

- On average, *the historically available water supply is not adequate* (including San Juan-Chama Project water and groundwater withdrawals) to meet the present demands in the Middle Rio Grande region.
- To achieve a balance between *renewable supply* and Year 2000 demand, a minimum of 71,000 acre-feet per year, and perhaps as much as 110,600 acre-feet per year of additional supply or reduction in demand is required.
- Given the historic variability of water budget terms, under Year 2000 conditions Rio Grande Compact *debit conditions are expected to occur 3 out of every 5 years.*
- *Under conditions of increased water use in any sector, a reduction of water use from other sectors is required* to avoid increasing the Rio Grande Compact debit.
- The groundwater supply within the Study Area is not an independent, disconnected water supply. *Use of groundwater*, *regardless of location, results in diminished flows of the Rio Grande* that will occur in the present and continue into the future.
- *The water supply is only depleted by consumptive use*; reductions in diversions and return flows resulting in better delivery efficiency do not necessarily improve the water supply.
- *Under drought conditions, annual Compact debits increase in frequency and magnitude,* and water availability limits irrigated agricultural usage 1 year out of every 5.
- Assuming implementation of regional water planning alternatives, Compact deliveries are significantly improved, with Compact deliveries being met at the 50th percentile. However, *implementation of the joint alternatives as proposed and included in the planning region reports will be challenging, if feasible*.

In summary, the water supply of the Middle Rio Grande is marked by limitation and variability. Supply appears inadequate to meet demand, and though the regional water plans are a strong beginning in addressing regional water issues, further measures will probably be required to meet regional demand in 2040.



Middle Rio Grande Water Supply Study

Figure ES-1
Map of Study Area: Cochiti Reservoir to Elephant Butte Reservoir

LEGEND

- State Highway
- U.S. Highway
- Interstate
- County Line
- Perennial Stream/River
- Intermittent Stream/River
- Latitude/Longitude
- City
- Lake/Reservoir
- Valley Alluvium
- Pueblo
- Gage Station

The purpose of the Middle Rio Grande Water Supply Study is to prepare a quantitative description of the conjunctive-use ground and surface water supply available to the Middle Rio Grande from Cochiti Reservoir to Elephant Butte Reservoir. This will be conducted under the constraints of the Rio Grande Compact and upstream Rio Grande basin water use with New Mexico. The Middle Rio Grande Water Supply Study will identify, assemble, and evaluate existing pertinent water supply and water budget data sets and present them in a form that can be used by regional water planning entities in the Middle Rio Grande. The product of the study will be used by others to develop and evaluate alternatives that reconcile projections of water demand with available water supply by the Interstate stream Commission in developing strategies to meet new Mexico's delivery obligations to Elephant Butte Reservoir under the Rio Grande Compact.

Sources: Base data compiled from USGS 1:100000k DLG and DEM files. Land use data provide by the Earth Data Analysis Center and was derived from the 1992 Land Use Trend Analysis study performed by the Bureau of Reclamation. Note:Land use coverages not available south (approx.) of 33 33'

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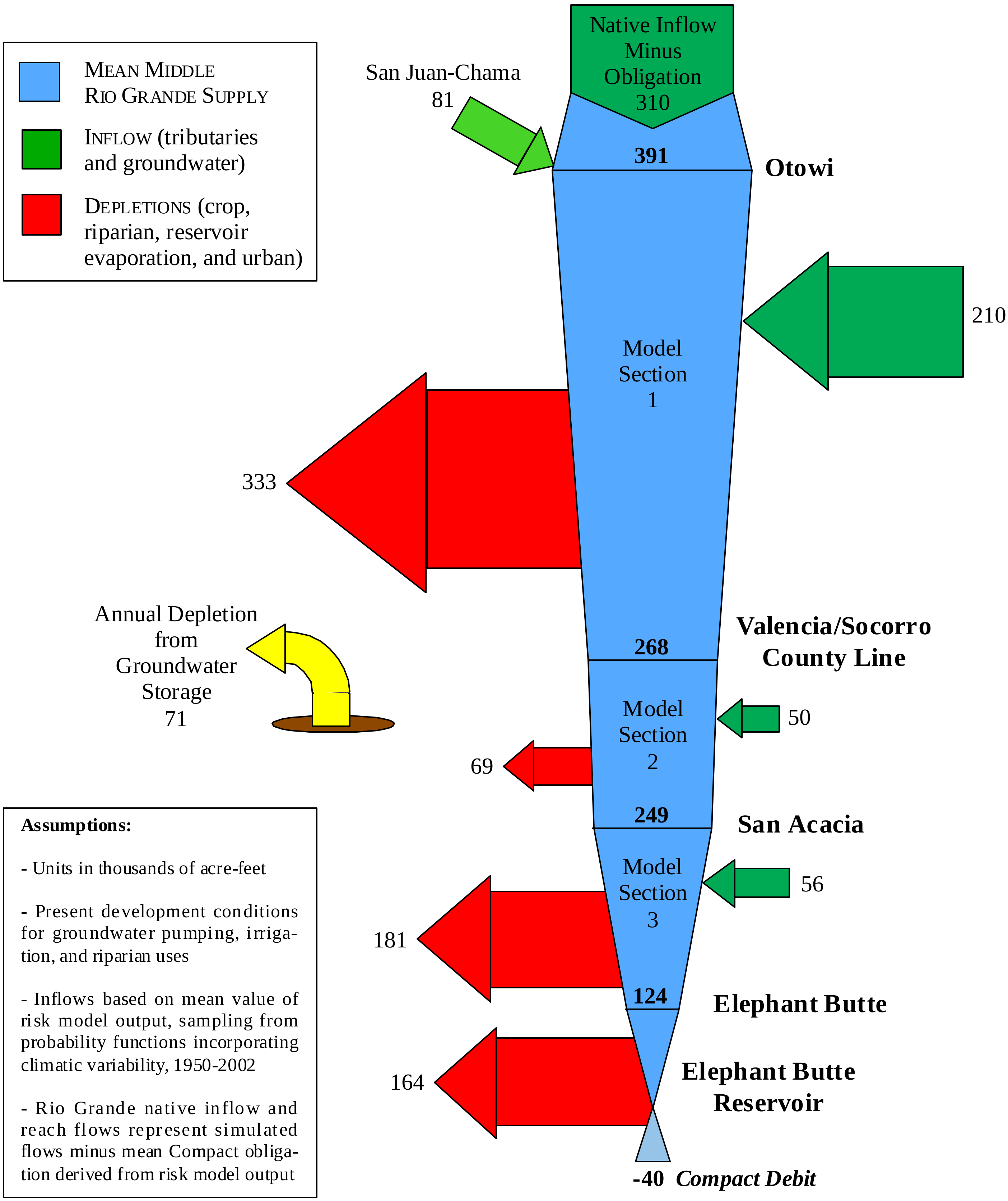
Figure ES-2
Mean Annual Middle Rio Grande Water Supply
Present Development Condition



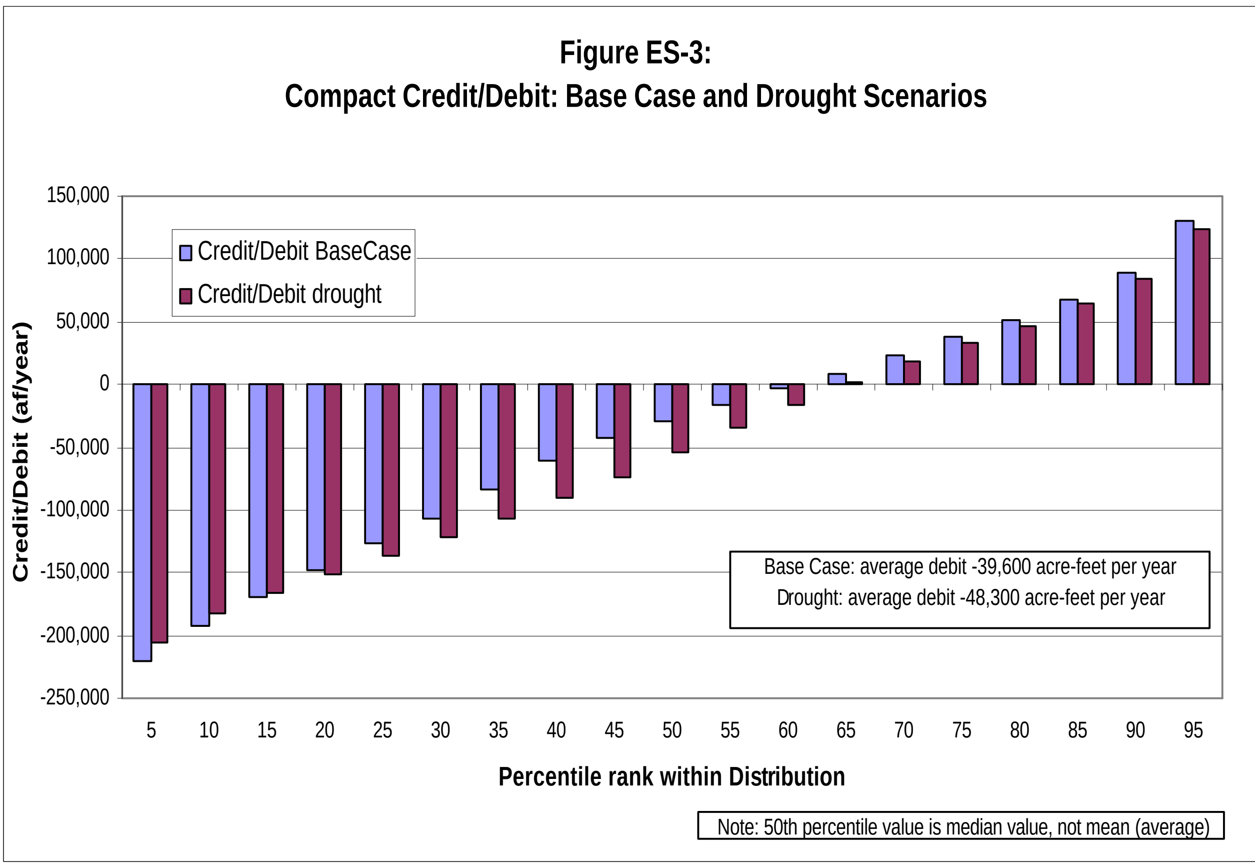


Figure ES-3:
Compact Credit/Debit: Base Case and Drought Scenarios
Credit/Debit BaseCase
Credit/Debit drought
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
Credit/Debit (af/year)
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Percentile rank within Distribution
Base Case: average debit -39,600 acre-feet per year
Drought: average debit -48,300 acre-feet per year
Note: 50th percentile value is median value, not mean (average)

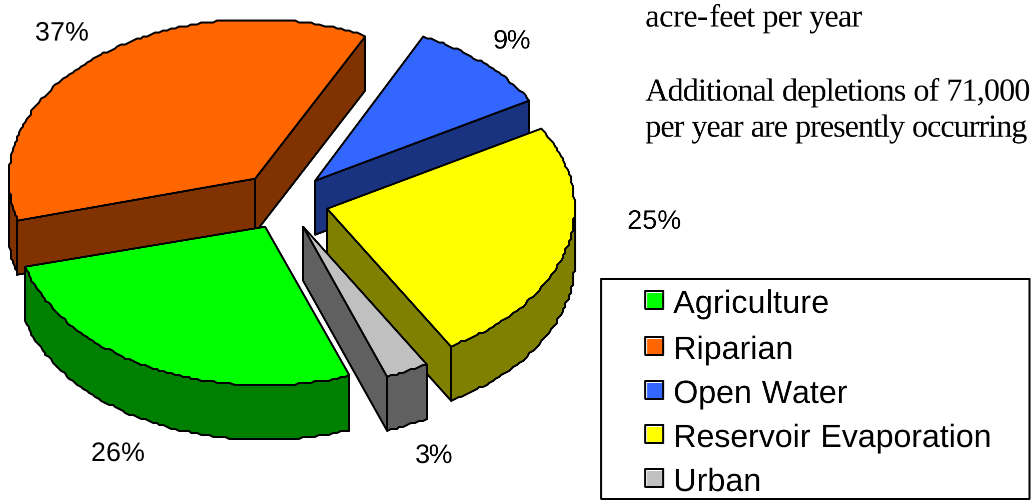
Figure ES-4

Summary of Mean Depletions, Grouped by Use

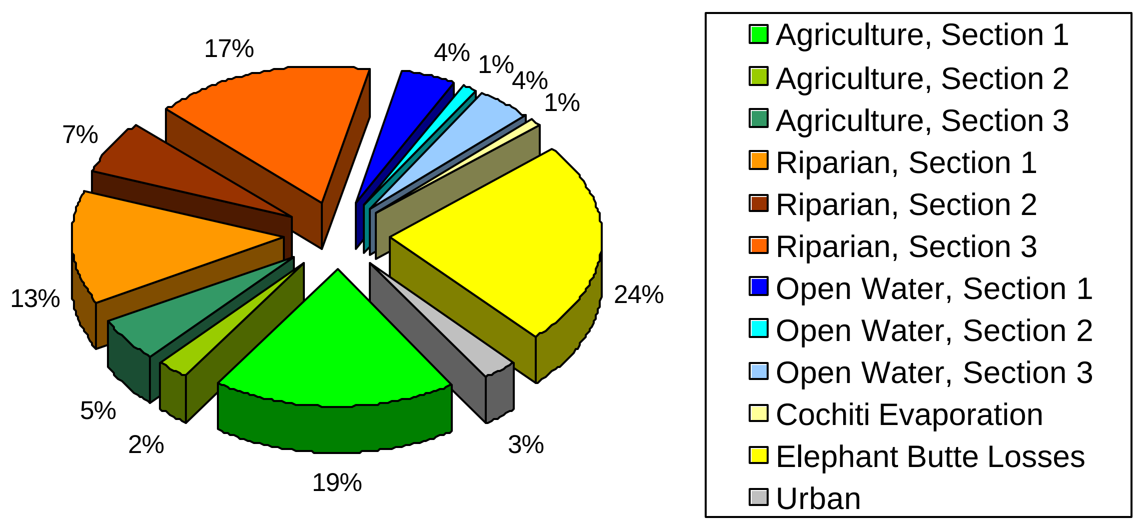
a) Mean depletions to River System (acre-feet per year)
(Year 2000 Land Use and Groundwater Development Conditions)

Note: Shown are percentages of total mean river depletions of approximately 680,000 acre-feet per year

Additional depletions of 71,000 acre-feet per year are presently occurring to aquifer



b) Mean depletions to River System (acre-feet per year), Detailed View



*Sections are:

Model section 1 – Cochiti to Valencia/Socorro county line
Model section 2 – Valencia/Socorro county line to San Acacia
Model section 3 – San Acacia to Elephant Butte Reservoir

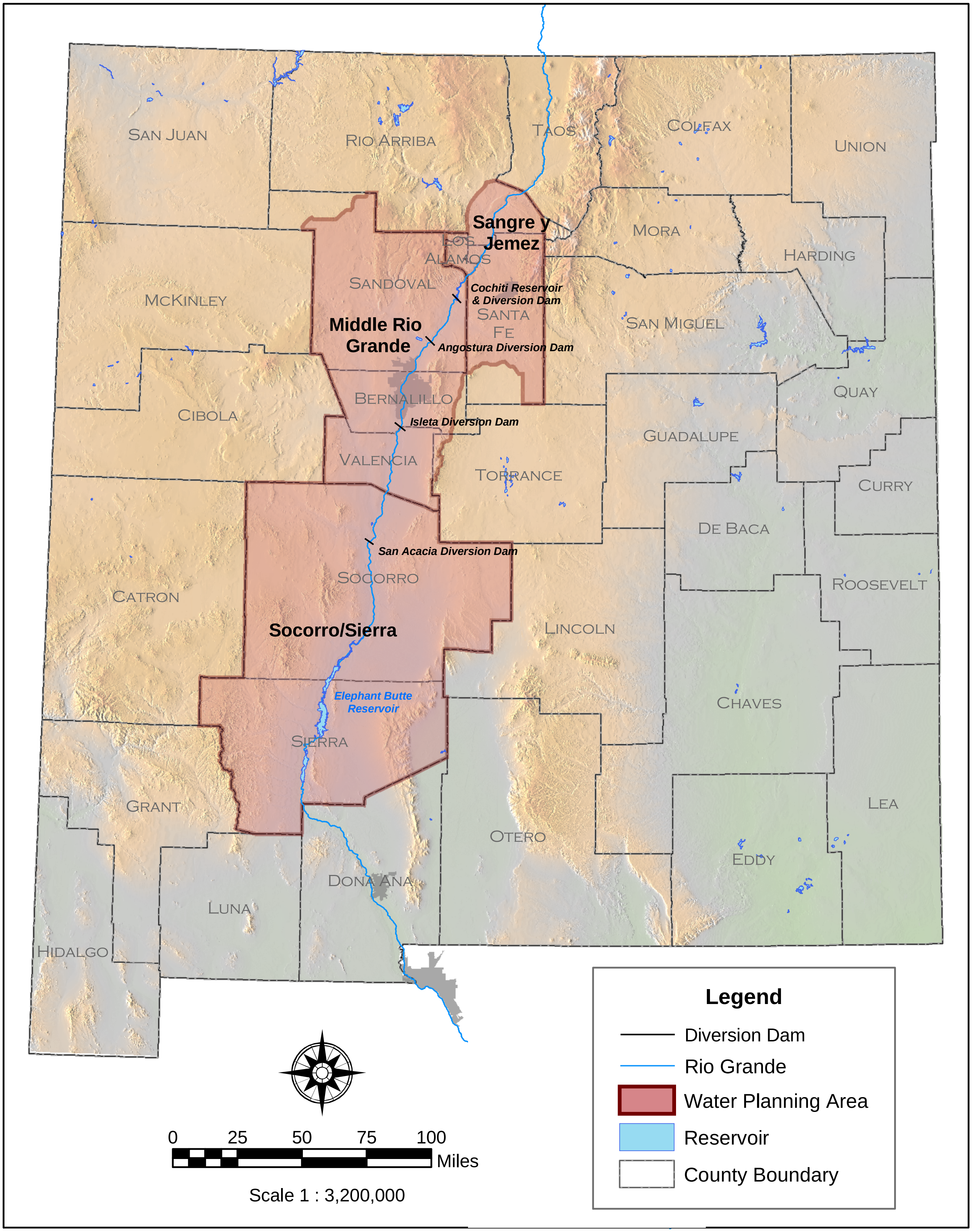


Figure ES-5. New Mexico Water Planning Regions

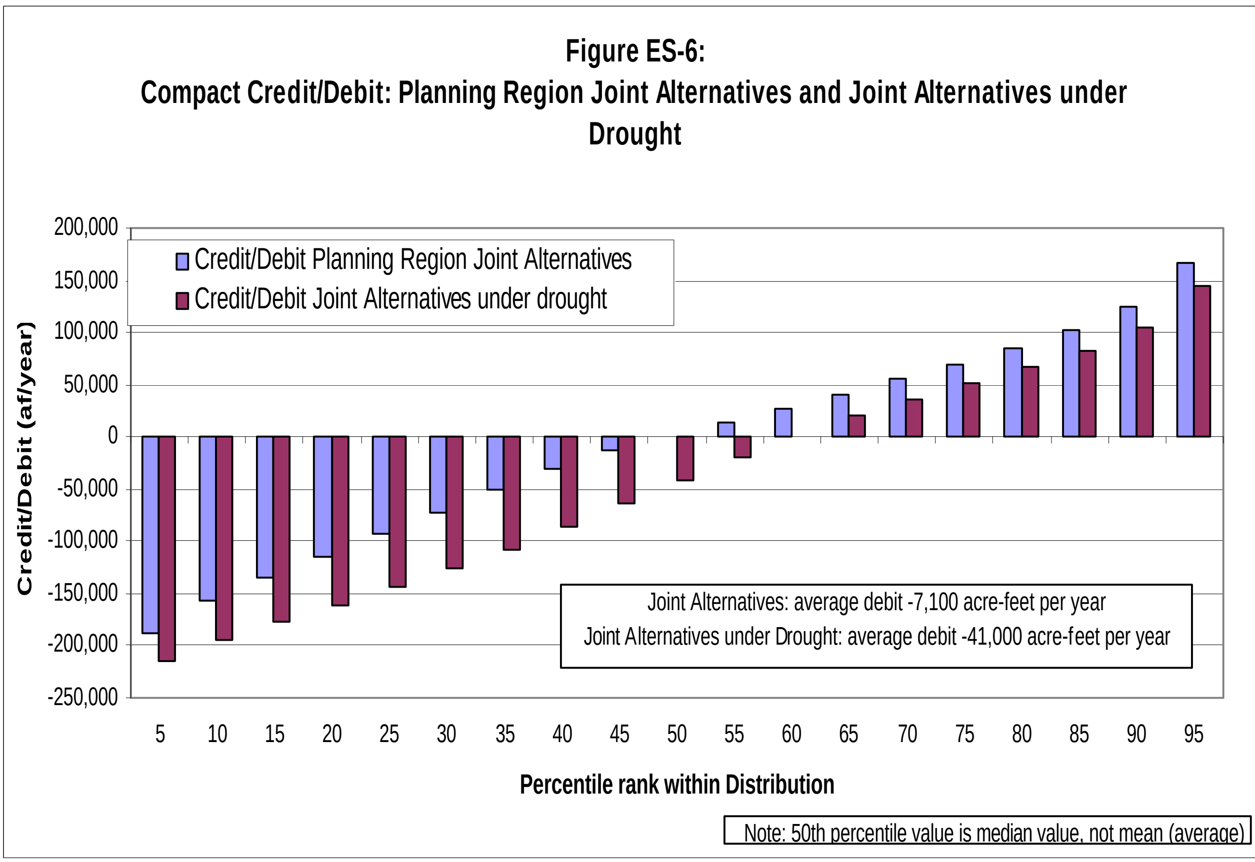


Figure ES-6:
Compact Credit/Debit: Planning Region Joint Alternatives and Joint Alternatives under Drought
Credit/Debit Planning Region Joint Alternatives
Credit/Debit Joint Alternatives under drought
Credit/Debit (af/year)
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Joint Alternatives: average debit -7,100 acre-feet per year
Joint Alternatives under Drought: average debit -41,000 acre-feet per year
Percentile rank within Distribution
Note: 50th percentile value is median value, not mean (average)