Review of Findings of PEIA and Recommendations for Detailed Agricultural Economic Assessment

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DATE: November 15, 2013

PROJECT NUMBER: 408366.R2.EA.01

Introduction

These recommendations have been prepared for the U.S. Army Corps of Engineers (USACE) to guide an economic assessment of salinity reduction alternatives in the Lower Rio Grande. Specifically, it recommends an overall approach to estimate potential benefits to agricultural producers receiving irrigation water from the Lower Rio Grande between San Acacia, New Mexico, and Fort Quitman, Texas. This memorandum reviews previous methods developed and applied in Phase 1 of the study; provides recommendations for use, modification, and extension of the previous methods; and describes a scope of work to implement the recommendations.

Review of Preliminary Economic Impact Assessment

The Preliminary Economic Impact Assessment (PEIA) was prepared by a team of researchers from Texas and New Mexico (Michelson et al., 2009). It includes an assessment of the economic damages resulting from salinity for both agricultural and urban water uses. This brief review focuses on the approach used to estimate damages from high salinity in crop irrigation water.

Summary of PEIA Analysis of Agricultural Salinity Impacts

The PEIA evaluated the benefit from improved irrigation water salinity in two ways. The main body of the report estimated both crop yield effects and irrigation and drainage management costs by assuming that growers minimize the cost of leaching plus the loss in net return due to yield decrements. The PEIA relied on widely used relationships between irrigation water salinity, leaching fraction, and soil (root zone) salinity and between soil salinity and crop yield. These relationships have been described in an irrigation and drainage manual produced for the United Nations Food and Agriculture Organization (Ayers and Westcot, 1985). The two key equations are as follows:

- An approximation originally developed by Rhoades (1974) to calculate leaching fraction based on irrigation water salinity and a desired target soil salinity
- Relative crop yield response to soil salinity using threshold and linear response functions developed by Maas and Hoffman (1977)

These relationships are discussed more fully in the section on transient versus steady state modeling of soil salinity.

The PEIA used this cost minimizing approach to evaluate total economic damages (crop yield losses and cost of leaching) resulting from the existing, or baseline, level of salinity in Rio Grande water delivered for irrigation. It relied on annual average total dissolved solids (TDS) in parts per million (ppm) or milligrams per liter (mg/L), converted to an approximate electrical conductivity (EC). The PEIA did not have specific scenarios of salinity reduction on which to base its impact analysis. In an addendum, the team evaluated the effect of a hypothetical reduction of 200 ppm TDS in the salinity of applied irrigation water in different portions of the study area.

The PEIA noted that a third important potential cost from salinity would result if farmers restricted production to a less profitable set of crops. Crops vary in sensitivity to soil salinity. For example, alfalfa, corn, beans, and many vegetable crops such as peppers do not have significant salt tolerance, and in many cases cannot be grown profitably if salinity is too high.

To provide some indication of this effect, the addendum to the PEIA further evaluated the potential effects of improved salinity on crop selection. The PEIA recognized that this approach would raise the level of complexity substantially. Estimating crop mix changes in a plausible way generally would require a sophisticated simulation and/or statistical analysis that should include an assessment of the local crop markets and how they could restrict crop mix changes or affect prices. For illustrative purposes, the PEIA evaluated the net revenue benefit if the crop mix in one high-salinity sub-region could shift to replicate the crop mix in a lower-salinity sub-region, but without any effect on markets or prices.

The PEIA used crop acreage data from New Mexico county crop reports; for Texas counties, the data were developed in a previous study completed by some of the PEIA authors. It is not clear from the discussion in the PEIA what, if any, adjustments were made or were needed to convert county crop acreages to acreages irrigated by Rio Grande water. Costs, yields, prices, and net returns to crop production were estimated based on costs and return budgets prepared by New Mexico Cooperative Extension and Texas AgriLife Extension.

The PEIA listed seven recommendations for additional work to improve estimates of salinity damages. Two recommendations were specifically related to agricultural water use. Recommendation 1 urged assessment of “economic damages in agriculture from the inability to grow higher value crops suitable to this climate and soils because of current salinity concentrations”; Recommendation 5 concerned “economic damages to agriculture and urban use from salinity during the low-flow season when no water is released from Rio Grande Project reservoirs.” The PEIA also stated that future estimates should be based on refined estimates of salinity concentrations (Recommendation 6) and should be applied to specific salinity reduction alternatives (Recommendation 7).

Recommendations for Use of PEIA Analytical Approach

The analytical choices made for the PEIA were reasonable and relied on standard agronomic techniques. This approach has been used in other planning and feasibility studies, including the Central Arizona Salinity Study (2003) cited by the authors. Data used for analysis were appropriate and generally adequate for a preliminary assessment. The authors adequately described the limitations of their assessment and recommended changes for a more detailed analysis.

This scope for the detailed study recommends adoption of the basic approach used in the PEIA, but has identified a number of modifications or additional levels of detail to consider. These are discussed in more detail below; following is a summary of the modifications:

- Although it is recognized that steady-state calculations may not capture the salinity effects on crop yields, especially if salinity spikes occur when the crop is under water stress and/or in a particularly sensitive growth stage, it is not likely feasible to conduct a transient analysis at the scale required. Therefore, the salinity effects analysis will be steady state, similar to the PEIA. However, the analysis will also consider a revised steady-state approach recommended to regulators in California by a working group of leading salinity researchers.

- Use an estimate of the marginal value of water in agricultural production to evaluate the avoided cost of leaching water reduction. Districts price their water to recover costs; if water supply is limited during all or part of the growing season, the marginal value can exceed the district’s price. Statistical analysis can be used to estimate the marginal value. As an approximation, the marginal value can be estimated as the maximum of the actual price paid, the unit cost of other water supplies in the district (such as groundwater or water entitlement purchased from another grower), or the residual net return to water using a crop budgeting calculation.

- At this stage, the economic analysis is not being conducted as part of a federal project. However, if a federal agency such as USACE or the Bureau of Reclamation (Reclamation) becomes a partner in projects resulting from the salinity studies, the agency is likely to require that economic analysis adhere to the federal Economic and Environmental Principles and Guidelines (P&G) (WRC, 1983) and other agency planning guidelines. The P&G provides guidelines to evaluate projects from the perspective of a nationwide benefit-cost analysis. The PEIA's analytical approach estimated crop-specific benefits as avoided cost of leaching water and avoided damage to crop yield. This approach is consistent with the P&G (see Chapter 2, Section III) (WRC, 1983). Data sources used in the PEIA should be evaluated and updated as needed.
- As indicated above and in the PEIA Addendum, crop selection decisions could be affected if substantial improvements in salinity conditions were provided. The analysis ought to include some assessment of crop selection. One approach could implement a simulation or statistical model of crop selection, which should also include other factors such as soils and climate, and should account for market constraints and price effects. A simpler approach is recommended here based on the hypothetical crop shift evaluated in the PEIA Addendum. Local experts should be surveyed to develop an estimate of the market effect of increased acreage of alfalfa, chile, corn, onions, and other crops that could increase in production. Contacts should include university and extension experts, and local commodity market representatives. From this information, an upper limit on expansion of the crops would be set. If no reasonable limit can be estimated, then only changes to acreage of basic crops defined in the P&G, such as alfalfa and corn, would be considered.
- Apply the analytical approach to specific salinity reduction alternatives. The PEIA evaluated the total damages resulting from salinity effects on leaching or crop yields. The benefits from salinity reduction alternatives must be analyzed based on the change in salinity from the baseline to levels provided by each alternative. The PEIA simulated this for a hypothetical reduction of 200 mg/L TDS in all production areas. Appendix B to the 2011 report entitled Alternatives Analysis for the Rio Grande Salinity Management Program (CH2MHILL, 2011) applied the analytical approach developed for the PEIA to water quality changes estimated for a set of salinity reduction alternatives.

Potential Approaches for the Detailed Estimation of Agricultural Benefits

Guidance/Limitations from Principles and Guidelines

Benefits to producers of agricultural products. The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (WRC, 1983) provide for a range of approaches to estimate the benefits of water-related improvements, such as salinity reduction, to production agriculture. Where the improvements would not affect cropping pattern or total acreage, the benefits include cost or damage reduction (including reduced yield impacts from salinity). When crops might change, the recommendation is to use a farm budget approach (i.e., evaluate changes in net revenues by crop type or production activity) or a land value comparison. These approaches are summarized in Figure 2.3.5 of the P&G.

Benefits to consumers of agricultural products. Where increased crop production from a project can be claimed legitimately, effects of the increased production on market prices of crops should also be considered. One approach is to estimate the market effects of increasing or decreasing production of certain crops. Where price responsiveness to production changes are already or can be estimated, the price effect of changes in production can be calculated, both within the project area and in other production regions affected by the price change. Price changes affect both revenues to producers and prices paid by consumers.

Basic crops versus non-basic crops. Non-basic crops are defined in the P&G as those for which increased production is likely to cause a change in market price (conversely, basic crops are defined as those for which increased production by the proposed project would not affect market price; these are identified as rice, cotton, corn, soybeans, wheat, milo (grain sorghum), barley, oats, hay, and pasture). The approach recommended by the P&G is to consider only basic crops when evaluating benefits from increases or shifts in crop production. Note that the PEIA Addendum evaluates the benefits of crop shifts toward more profitable crops. Two of those, alfalfa and corn, are considered basic crops, while the others (chile, onions, lettuce, and pecans) are not.

Appropriate methods for estimating prices, costs, discounting future benefits. Good standards of practice for economic analysis and research are broadly allowed when estimating agricultural prices, costs, and yields. Acceptable data sources include government agencies and universities. Statistics on crop prices and yields are available from the National Agricultural Statistics Service (NASS) or affiliated state agencies. In cases where state or even county averages may not be representative for the project area, local information should be sought through interviews. Crop production and enterprise budgets produced by state cooperative extension services are generally the preferred source when that information is required for the benefits analysis. Prices and costs should be escalated or deflated to a common point in time for analysis. Neither the P&G nor USACE planning guidelines specify the economic index to use for escalation.

Future benefits are discounted to the present (or another common point in time) using standard formulas for present net worth. Project justification under the P&G requires that a specific discount rate be used so that the formula is set by statute and updated annually (e.g., the rate for fiscal year 2013 is 3.75 percent). The discount rate is applied to real, or constant dollar, benefits and costs.

Summaries of Approaches for Irrigated Crop Production

Several different approaches have been used in past studies to evaluate the benefits of salinity reduction on irrigated crop production. The approaches generally fall into three categories, discussed below.

Avoided Costs and/or Avoided Damages with Fixed Cropping Pattern

Salinity in irrigation water adds salt to the root zone of growing crops. The soil salinity can usually be controlled by adding irrigation water to leach salts out of the root zone into lower levels of the soil or into groundwater. If salts are not leached out and instead are allowed to concentrate in the root zone, crop yield can suffer, especially for crops sensitive to salinity. Higher salinity levels in irrigation water require more water for leaching. One way to assess benefits of reduced salinity in irrigation water is to calculate the savings in cost of irrigation water needed for leaching. Another approach is to calculate the lost net return to crop production from the yield reduction caused by salinity.

The PEIA implemented an approach that combined the avoided leaching cost and avoided damage to crop yield. Benefits would be estimated by comparing the costs and yield decrement associated with the improved condition to those of the baseline condition. Costs would include higher leaching fractions to control soil salinity. Other costs could include higher soil moisture monitoring and management costs to maintain irrigation uniformity over the field, irrigation hardware or purchased management services, and drainage costs where needed.

Yield decrement costs are incurred by planned or unavoidable reductions in crop yield resulting from soil salinity. The value lost is the lower yield times the farm gate value, net of any changes in yield-related costs such as harvesting. Sometimes the market price of the crop can also be affected by salinity damages. Reduced yields can be estimated using data from similar production areas with and without salinity; however, more commonly such data do not exist, so standard salinity-yield functions such as the Maas-Hoffman crop-specific relationships are used.

Avoided Costs, Avoided Damages, and Net Revenue with Variable Cropping Pattern

Benefits would be estimated by comparing the net revenue to agricultural production under the current and future no-project baseline water quality to the net revenue under improved water quality provided by a project alternative. For both the baseline and alternative, growers would be assumed to maximize net return by selecting crop mix, irrigation management, and yield subject to water supply, quality, and other resource and market conditions. The difference in expected net returns between baseline and alternative would be the annual benefit, and the discounted present value of annual benefit would be the total project benefit. The following approaches could be used to evaluate the change in net returns:

1. Compare cropping patterns and net returns in areas of different water quality: a statistical comparison of cropping patterns in two or more areas having different water quality could be undertaken. Data on other

characteristics of production, including soils and microclimate, should be included to avoid attributing all differences to water quality. An example of this kind of analysis appears in the Economic Sustainability Plan for the Sacramento-San Joaquin Delta (Delta Protection Commission, 2012). A multinomial logit model was used to predict crop selection based on current land use, water salinity, soil and slope, field size, and other location and site conditions. The estimated model was used to evaluate the differences in cropping patterns under different water quality scenarios. Other statistical techniques could also be used. Estimates of costs and revenues by crop (such as from local extension service crop budgets) would provide a total expected change in net return to each crop mix.

2. Use economic simulation of grower production decisions to assess changes in net returns from improved water quality. Grower decisions would include crop selection, irrigation management, and yield. Such simulation models are complex and data intensive. An example of this approach was used to assess the benefits of drainage and salinity control policies in the western San Joaquin Valley of California (SJVDP, 1990; Reclamation, 1991).
3. Implement the basic analysis of avoided costs and avoided damages, but allow for limited changes in cropping pattern. Rather than using an economic simulation model to determine cropping changes, the following simple two-step approach would be used for each alternative:
   - First, assess whether irrigation water salinity appears to be a significant limit on crop selection within each region. This would be done through a combination of agronomic assessment of irrigation practices, water quality, and crop yields, along with interviews with local growers, extension experts, and others.
   - Second, for regions determined to be limited in crop selection, evaluate the effect of the change in irrigation water salinity on basic crops (as defined by the P&G) that could come into production. For those crops that could profitably increase in acreage, estimate the increase in net revenue using the method developed in the PEIA Addendum.

Land Value

A third general approach to estimate benefits from reduced salinity would compare the market values of otherwise similar cropland that has access to different irrigation water salinities. The market value of cropland with “good” quality irrigation water should be higher, all else being equal, to the value of land using poorer quality water. If crop production is the most profitable use of land, then the land prices should reflect the stream of expected net return from crop production. In concept, the better-quality irrigation water would allow for a more profitable mix of crops, better yields, and/or lower irrigation management costs. Therefore, the expected net return from production would be higher, and the land‘s market value would also be higher.

In practice, comparison of land values can require sophisticated statistical analysis with associated data challenges. Ideally, land in the proposed project area would be essentially identical in soils, microclimate, improvements, access to transportation and markets, and other key production characteristics to an area that has water quality equal to that of the proposed project. Then, the difference in the market value (based on a statistically significant sample of selling prices) would reflect the value of the water quality improvement. In reality, few if any of the ideal conditions hold: lands differ in soil quality and microclimate; parcels have a wide range of structures and other improvements; and lands vary in proximity to markets and suppliers. To avoid attributing the value of these other determining factors to water quality, statistical analysis using multiple regression or another technique is required. In turn, relatively large data sets with good measurements of the other key determining factors are required. This approach could be considered if a more extensive study, such as a feasibility study, is undertaken.

Recommendation

The analytical approach developed in the PEIA and the Addendum is recommended, with the suggested modifications and data updates. This approach is Option 3 in the above section on avoided costs, avoided damages, and net revenue.

Option 3 has several significant advantages: it is based on well-accepted agronomic principles; it can be implemented in a way that is consistent with federal planning principles; it has already been developed and tested; and it uses data that have already been developed, although the data should be updated.

Transient vs. Steady-state Models of Salinity Impact on Irrigated Crops

The impact of salinity on crop establishment, growth, and yield has been modeled with transient and steady-state tools depending on the study objectives, budget, and available data.

Although soil water content, soil salinity, and crop growth are never really steady state, the steady-state approaches have been considered excellent first approximations (Hoffman, 2009). The overall objective of the steady-state approaches is to evaluate for a given irrigation water quality and a given crop tolerance to salinity, how much additional water (leaching fraction) must be applied to avoid salt accumulation and yield loss (also known as the leaching requirement [Hoffman, 2009]). Hoffman notes that there are at least five variations of the steady-state model approach in the literature, all of which are based on the mass balance of water and salt.

The PEIA report used widely cited works of Mass and Hoffman (1977) and Ayers and Westcott (1985) and an assumption of steady-state conditions to estimate yield impacts of irrigation water salinity and leaching fractions required by different levels of salinity. The results of this analysis were used as a guide to assess shifts in cropping that may occur with reductions in irrigation water salinity. Leaching fractions were determined for each crop based on the amount of additional water that would be required to maintain 100 percent yield with a given irrigation water salinity. To determine the volume of water required for each crop, and to determine leaching volumes, crop coefficients for alfalfa, cotton, corn, and sorghum in PEIA were taken from Sammis et al. (1985). However, it is not clear what data were used for the periodic engineering test or for the source of the crop coefficient for chile in the PEIA study.

Two key equations in the steady-state approach are as follows (Mass and Hoffman, 1977; Ayers and Westcott, 1985):

$$LR = \frac{EC_w}{(5(EC_e) - EC_w)}$$

Where EC_w is the salinity of the applied water (dS/m), LR is the leaching requirement needed to maintain soil salinity at the given EC_e; and EC_e is the salinity of the soil saturation extract (deciSiemens per meter [dS/m]).

$$Y = 100 - b(EC_e - a)$$

Where Y is the relative crop yield, a is the constant representing the soil salinity threshold value for yield loss, and b is the slope of the yield decline, or the yield loss per unit increase in soil salinity.

It has recently been shown that the traditional, steady-state approach and current guidelines are overly conservative, overestimating leaching requirements and exaggerating adverse effects on crops (Letey et al., 2011; White and White, 2011). Transient models that incorporate the effect of time are able to more accurately capture the soil water and salinity dynamics that result from irrigation practices; therefore, these models better represent economic impacts.

Transient models can reflect the reality that a number of important processes affecting crop water use and crop yield change with time. Irrigation water quality may change with time; crop sensitivity may change with crop growth stage; salts precipitate and dissolve; and plant water uptake varies with soil salinity and water content (Hoffman, 2009). For transient models, detailed data are required regarding irrigation amount and frequency, soil physical and chemical properties, and crop evapotranspiration (Hoffman, 2009). Generally, these models use a daily time step for applied water, drainage, and crop evapotranspiration. Example models include Grattan, Corwin, Simunek, SALTMED, SWAGMAN, SDB, and Letey (ENVIRO-GRO) (Hoffman, 2009).

Despite the many advantages of the transient models in better representing soil processes, it is not practical to apply them in large-scale basin studies, partly because of the lack of data. Liu and Barroll (2011) note that "the available data (i.e., for the lower Rio Grande) on observed groundwater and root zone salinity trends is highly limited." The compromise approach that has been recommended to regulatory agencies such as the California State Water Resources Control Board is a modified steady-state analysis that corrects for much of the error inherent in the traditional Ayers and Westcot approach (White and White, 2011). The major changes are the use of a water-uptake-weighted average root zone salinity instead of a linear average, and accounting for average annual rainfall. Table 1 provides the recommended adjusted approach.

TABLE 1
Salinity of Irrigation Source Waters that Can be Applied to Obtain Maximum Yields in Crops with a Salinity Tolerance Threshold of 1.0 dS/m.

	Annual Rainfall as Fraction of Total Water Applied						
	0%	10%	15%	20%	25%	30%	35%
Leaching Fraction	---------------------------------- dS/m ---						
0.05	0.63	0.70	0.74	0.79	0.84	0.90	0.97
0.1	0.78	0.86	0.91	0.98	1.04	1.11	1.20
0.15	0.9	1.0	1.05	1.12	1.20	1.28	1.38
0.20	1.0	1.11	1.17	1.25	1.33	1.43	1.54
0.25	1.06	1.17	1.25	1.32	1.41	1.51	1.63
0.30	1.18	1.31	1.39	1.48	1.57	1.68	1.81

*Note that values can be scaled on a linear basis for crops with a threshold other than 1.0. For example, if the crop's salinity threshold for 100% yield is 2.0, values in Table 1 would be double the values shown.

Source: Adapted from White and White, 2011.

Recommendation

The overall recommendations are the traditional, steady-state approach used in the PEIA (Ayers and Westcot, 1985; Maas and Hoffman, 1977) and the Table 1 approach to bracket the range of likely impacts. For a given irrigation water salinity and leaching fraction and specific crop, the Maas and Hoffman slope coefficient of the yield response will be the same; however, the two approaches will be defined by two different Maas and Hoffman threshold values to determine yield decreases. It is understood that the traditional Ayers and Westcot (1985) approach will show greater yield reductions and/or greater leaching volumes required at a given level of salinity than the Table 1 approach. Although the Table 1 approach may be controversial and is not widely known, it is believed to represent the best available science that can be applied without the data requirements of a transient model.

Observations of Current Conditions

General observations of the dominant agricultural areas in the Rio Grande Valley from San Acacia to near Ft. Quitman were made on November 6 and 7, 2012. Flood irrigation was clearly the dominant practice in all regions, although some drip and microspray irrigation is used, and one hard hose reel was also seen.

Middle Rio Grande Conservancy District, Socorro Division, Socorro County, New Mexico (San Acacia to San Marcial)

This region is dominated by flood-irrigated hay and pasture, and alfalfa is the dominant crop. There are some small acreages of corn, chile, and other crops. Fields and farms appear to be somewhat smaller and less industrialized than is common further downstream. A small flow remains in the Rio Grande River in this reach.

Elephant Butte Irrigation District, Rincon Division, Sierra and Doña Ana Counties, New Mexico (Caballo Dam to a few miles southeast of Rincon, New Mexico)

Fields and farms in this region tend to be larger and more industrialized than in the Socorro Division. There is still a great deal of alfalfa production; however, the acreage of other crops is much more extensive, including large areas of pecans, chile, corn, cotton, and other vegetable crops. Flood irrigation is by far the dominant means of irrigation. There was no flow whatsoever in the Rio Grande River in this reach, because all is retained in winter behind the reservoirs just upstream.

Elephant Butte Irrigation District, Mesilla Division, Doña Ana County, New Mexico (Near Radium Springs, New Mexico, to El Paso, Texas)

The agriculture in this region appears to be similar to the Rincon Division in that it remains very diverse cropping with alfalfa, cotton, chile, lettuce, corn, and pecans. However, it appears that the pecans are especially important because many very large plantations are present. Other than that, the large, industrial scale of operations in the Rincon Division is less evident. Flood irrigation again is dominant. At the lower end of the region (Distal Mesilla near El Paso), some pecan trees appeared to be water- and/or salt stressed, at least around the perimeter of some of the plantations. It is not known whether the observed adverse effects are the result of a quality, supply, or local distribution issue.

El Paso Water Improvement District, Texas (El Paso to Alamo Alta, near Hudspeth County Line)

Tilled fields were much more common than in agricultural areas upstream, and the prior crop was often not evident. Tilled vegetable beds, cotton fields, alfalfa, and pecans were observed. Some fields of cotton were seen that appeared to have shorter plants than those seen in Elephant Butte Irrigation District (EBID), and there was non-uniformity of the stand near the field edges. Some clearly stressed pecans were apparently suffering from a combination of drought and salt stress; however, this effect appeared to be highly field-specific.

Hudspeth County Conservation and Reclamation District

Some diversity in cropping is seen in this area; however, a considerable fraction of the area has been tilled, and crop identification is difficult. Some alfalfa and other forages exist, although no chile peppers or pecans were observed. There was no clear gradient in cropping or agricultural practices within the region.

Local Perspectives on Existing Cropping versus Future Cropping if Water Quality Improves

Discussions with irrigation district staff and local Natural Resources Conservation Service (NRCS) staff conducted by CH2M HILL suggest that, at least upstream of El Paso, the major concern is reduced allocations from the Rio Grande, and the impact of higher salinity groundwater used as a substitute water supply. Salinity of the Rio Grande is not perceived as limiting the yield or choice of crops grown. In addition, some cropping choices may not be entirely driven by commodity price and yield; this would complicate economic assumptions and models of farmer behavior. Specifically, NRCS staff in the upper part of the study area indicated that chile production has become a matter of local pride and drives tourism in the area. The situation is much different downstream of El Paso, where salinity increases in the river become more significant.

Recommended Approach for Detailed Estimate

Physical Basis for the Analysis

An empirical water quality model has been developed for the San Marcial to El Paso reach by the New Mexico Interstate Stream Commission (ISC) and New Mexico Office of State Engineer (Liu and Barroll, 2011), and extensions of the model have been made to encompass the San Acacia to San Marcial and El Paso to Ft. Quitman reaches (CH2M HILL, 2011). The model has not yet been released to the public. This model appears to fit the historical data reasonably well upstream of El Paso; however because the model is not fully process based, it may not adequately represent certain perturbations such as climate change and desalination facilities. Downstream of the American Dam in El Paso, the canal network is complex, data on the functioning of the system are more limited, and site investigations will be required.

Liu and Barroll (2011) note that because the model is based on specific groundwater discharge and surface water seepage values from a historical run of the RiverWare Model, the model cannot accurately simulate changes to groundwater management. Liu and Barroll also note that the model is nevertheless useful for comparison of salinity abatement scenarios. If the Interstate Stream Commission (ISC) model is used as a basis for the detailed economic study, the limitations of the ISC model will be examined and documented in other parts of the study. In addition, the ISC model would need to be thoroughly checked, reviewed, finalized, and approved for this use before being applied to the detailed study.

Climate Change

Climate change has the potential to alter the quantity, timing, and salinity of flows in the Lower Rio Grande. Given that salinity reduction alternatives would provide benefits for many years, climate change could affect the overall benefits and the economic feasibility of alternatives.

An optional analysis of benefits in the context of climate change would use the economics methodology to assess benefits at up to two future points in time. Flow and salinity results from the ISC model (or other appropriate analysis) would be used to estimate benefits of alternatives under existing or near-term conditions and at future points in time, with and without climate change. The selection of future time periods and appropriate climate change models and assumptions for flow and salinity analysis are outside the scope of the economics analysis. However, after those decisions are made and analyzed, the economic assessment would include avoided costs, damages, and net revenue changes.

Supplemental Groundwater Irrigation

Farmers in the EBID and the El Paso County Water Improvement District #1 (EPCWID) region commonly supplement surface water from the Rio Grande with local groundwater (Liu and Barroll, 2011). Recent reduced allocations resulting from the drought appear to have significantly increased this practice, according to local NRCS and irrigation district staff, and it is not uncommon for this supplemental groundwater salinity to exceed that of the Rio Grande. As shown on Figures 2 through 8 (figures are located at the end of this tech memo), groundwater salinities range from less than 200 mg/L to more than 5,000 mg/L. The Rio Grande is well-connected hydraulically to the Rincon and Mesilla river valley aquifers (Liu and Barroll, 2011); therefore, river levels and river water quality, water level and water quality in irrigation and drainage channels, groundwater withdrawals, and irrigation practices such as leaching fraction are all interconnected.

The detailed economic analysis must therefore consider in detail supplemental groundwater irrigation practices and impacts on crop yields, required leaching fractions, and crop selection. Other portions of the study should further assess the effects of irrigation on water quality in the groundwater system and the river.

Definition of Subareas

A number of political, economic, physical, chemical, and potentially even sociological characteristics define potential subareas that could be considered in the economic analysis. Related efforts have considered the following divisions of the Lower Rio Grande:

- The ISC model divided the river reaches as San Acacia to San Marcial; San Marcial to below Caballo Dam; below Caballo Dam to El Paso; and El Paso to Ft. Quitman; however, it only modeled San Marcial to below Caballo Dam and below Caballo Dam to El Paso.
- The 2011 CH2M HILL study focused on the adjacent groundwater basins, potential locations for desalination facilities, and extending the ISC model to the remaining reaches above and below.
- The PEIA focused on agricultural impacts by county. The most complete and reliable reference data on crops grown and crop yields are provided by the NASS by county; the PEIA is therefore an important consideration. However, the county line is an imperfect boundary because a county splits the Rincon division of the EBID, and there are some important differences in sources/sinks of salinity between Doña County EBID Rincon and Doña County EBID Mesilla.

As previously noted, supplemental groundwater irrigation (much of it having greater salinity than the Rio Grande) has been an extremely important component of irrigated agriculture in the region since the advent of the prolonged drought. Therefore, the quality, location, and extent of supplemental groundwater irrigation needs to be included in the analysis even if drought conditions subside significantly for several years, because the interaction of salinity with prolonged drought conditions must be better understood. The recommended approach for considering subareas in the economic analysis and supporting rationale is as follows:

- Middle Rio Grande Conservancy District, Socorro Division (Figure 2): No subdivisions needed. Relatively homogeneous agricultural practices, and the irrigation district is entirely within Socorro County, New Mexico.
- Middle Rio Grande Conservancy District, San Marcial Division (Figure 3): No subdivisions needed. Predominantly managed for wildlife refuge. Relatively homogeneous agricultural practices, and the irrigation district is entirely within Socorro County, New Mexico.
- Elephant Butte Irrigation District, Rincon Division, Sierra and Doña Ana Counties, New Mexico (Figure 4):
    - Increasing importance of salinity, with geothermal sources contributing upstream
    - Irrigation District is split between two counties
    - Apparently variable groundwater salinity accessible in the valley, but markedly higher at distal end, southeast of Rincon
    - Therefore, the initial divisions of the study in this reach will be as follows (Figure 4):
        - EBID-Rincon, Sierra County
        - EBID-Rincon, Doña Ana County
        - EBID-Rincon, Doña Ana County, Distal Rincon
- Elephant Butte Irrigation District, Mesilla Division, Doña Ana County, New Mexico (Figure 5):
    - All one county
    - Relatively homogeneous agricultural practices
    - Zones of significantly higher groundwater salinity toward center of the district, along the eastern edge, and distal end
    - Therefore, the initial divisions of the study in this reach will be as follows (Figure 5):
        - EBID-Mesilla
        - EBID-Mesilla, Central-East
        - EBID-Mesilla, Distal Mesilla
- El Paso Water Improvement District #1, El Paso County, Texas (North) (Figure 6):
    - Physically separated from the southern part of the district by the city of El Paso.
- El Paso Water Improvement District #1, El Paso County, Texas (South) (Figure 7):
    - Physically separated from the northern part of the district by the city of El Paso.
- Hudspeth County Irrigation and Reclamation District #1 (Figure 8):
    - No additional divisions, because all except a tiny fraction of the district is contained within Hudspeth County, changes in agriculture are not marked from end to end, and there are no clear patterns in groundwater well data to justify a division for analysis on that basis.

Data Needs and Assessment of Availability

Information required to assess the salinity-related benefits to irrigated agriculture include physical and economic data describing the condition of the study area in the absence of a project (baseline); modeling or other assessment of the change in irrigation water salinity that would result from implementing the salinity reduction alternatives; and any additional data to quantify the benefit of each alternative condition relative to the baseline.

The following information is needed to implement the recommended approach to assess the benefits of salinity reduction:

- **Crop Acreage by Subarea:** The PEIA used data from the 2000 New Mexico Agricultural Statistics (NASS, various years). Data for Texas were a combination of 2000 and 2005 data. All of these estimates should be updated with the most recent data available from agricultural statistics, which is found in the 2007 Census of Agriculture (U.S. Department of Agriculture [USDA] NASS). Subarea acreage should be gathered directly from water districts, or acreage can be approximated from the 2007 county-level acreage with the assistance of local experts to account for differences among the subareas and overall trends in cropping since the 2007 Census. County-level data will be used to determine the proportion of each crop likely found in each subarea, because some parts of the county may lie outside the study area.
- **Crop Yields, Prices:** Crop price and yield data should rely on averages over a number of years (5 years is recommended) using USDA NASS county or state data that are adjusted to represent local conditions according to local experts.
- **Crop Production Costs:** New Mexico and Texas extension service crop and enterprise budgets were used in the PEIA to assess production costs. These budgets are generally the best available, and are recommended for use in this analysis. Although the budget summaries prepared for the PEIA may still be the most recent available, costs should be updated for analysis to a common point in time. If comprehensive revisions have been prepared by extension personnel, those revised versions should be used.
- **Water Costs:** Water costs are used as part of the net revenue calculation and to estimate the avoided cost of leaching to control soil salinity. For the latter purpose, the preferred approach is to use the highest value for which the grower could use the water if it were not used for leaching; this opportunity cost is the cost of using the water for leaching rather than for another use. In some cases, the actual cost that the grower pays the local district for water is a reasonable estimate. If water is scarce, the grower may place a higher value on water than is paid to the district. Where surface irrigation is supplemented with higher-cost groundwater, the variable cost of pumping better reflects the true cost. For purposes of this analysis, the higher of Rio Grande water cost or groundwater cost is recommended to approximate the opportunity cost of leaching.
- **Crop Consumptive Use:** The PEIA compiled estimates of crop consumptive use largely from Sammis et al. (1985) to calculate the leaching fractions needed to achieve different crop yields. These values should be reviewed against any more recent literature, discussed with local experts, and updated if needed.
- **Salinity of Irrigation Water:** The analysis will evaluate alternatives for salinity reduction based on river flow and salinity modeling done specifically for the study. Results from the ISC model or another model are assumed to provide the without- and with-project estimates of delivered water salinity. If available, groundwater salinity and use estimates will also be used in the assessment. As described earlier, a transient model of crop-soil interaction can capture the varying effects of different irrigation water salinity during different parts of the growing season. However, the data requirements to implement such an approach are significant and well beyond the scope of this study.

Scope for Detailed Estimate of Agricultural Benefits

This scope describes the tasks needed and the approach recommended to conduct economic analysis of salinity management alternatives and is intended to provide the next level of analysis that USACE can use to assess potential benefits of salinity reduction. The scope is not designed to support a formal feasibility study under federal standards, although methods and data sources are recommended that could readily be refined to conform to federal standards. The scope is written as if USACE staff economists (“staff”) would perform the work. However, USACE may choose to contract with the team that prepared the PEIA or with another analytical team.

Because USACE was one of the sponsors of the PEIA, this scope assumes that the methods, data, and results from that study are available for use in this next level of analysis.

Task 1: Characterize the Study Area and Subareas

The purpose of this task is to define how the analysis is organized geographically and to set the baseline agricultural conditions—acreage, production, water use, costs, and revenues—against which benefits of salinity reduction alternatives will be measured.

Task 1.1: Define the Study Area and Subareas

Define the geographical bounds and characteristics of the study area and appropriate subareas as recommended above and in Figures 1 through 8.

Task 1.2: Collect/Update Data for Current Agricultural Conditions

For each subarea, compile the most recent data on crop acreage, crop prices, yields, and production costs. The subarea data has already been gathered and incorporated into the methodology of the PEIA and Addendum. That data should be reviewed and, as needed, updated with the following data items:

- Acreage by major crop type is available in the data collected for the PEIA and from the NASS and affiliated state agricultural statistics services. In most cases, county-level data will be the smallest level of aggregation available. Data for some crops will not be available for every year and/or every county. For some information, state averages or other regional averages must be substituted.
- Crop acreage must be further divided into subareas. Staff will interview water district managers, local extension agents, and USDA representatives to develop reasonable allocations of county acreages into subarea acreages. Staff will document the assumptions and methods used to make the allocations.
- Data on crop yields and prices will be based on 5-year averages if available. When statewide averages are used, results should be verified or adjusted for local conditions through consultation with local extension agents, growers, or other local experts.
- Costs of production shall be based on the most recent and relevant crop and enterprise budgets developed by New Mexico State University or Texas Agri-life.
- All prices and costs shall be indexed to a common point in time (e.g., 2012) as needed, using commonly accepted price indexes.
- Water costs shall be obtained from local water districts. Ideally, the avoided cost of leaching water should be based on the marginal value of water, although that could require additional analysis beyond this scope. As an approximation, the highest observed cost of water within a subarea can be used. In subareas that use supplemental groundwater pumping, the unit water cost used to calculate avoided leaching costs should be the higher of the surface water or groundwater cost.
- Average and median salinity data shall be summarized for supplemental groundwater used for irrigation in each subarea.
- The percentage of annual irrigation requirements provided by supplemental groundwater in each subarea by major crop shall be summarized.
- Yield and leaching fraction relationships as a function of irrigation salinity shall be established for both the PEIA approach (Ayers and Westcot, 1985; Maas and Hoffman, 1977) and the approach described in Table 1 (White and White, 2011; Letey et al., 2011) for the major crops in each subarea. These relationships shall be applied to the analysis in each of the subsequent tasks and subtasks.

Document the data gathered and updated, including summary tables that characterize agricultural production and costs by crop and subarea.

Task 1.3: Assess Future Conditions without Project

Quantify and justify any acreage, production, or crop market changes that are expected to occur over time, even in the absence of a salinity reduction alternative. Justification could include projected conversion of agricultural land to urban uses based on existing general plans, or already approved agricultural land or water development projects that will come online soon. Prepare documentation explaining any changes relative to current conditions, and display the results.

Task 2: Review Benefits Methodology

The salinity cost method developed and implemented in the PEIA, except allowing limited crop shifting as described above, is recommended for estimating the benefits of salinity reduction alternatives. In this task, staff will obtain and review the methodology spreadsheets or other analytical tools and data sets used in the PEIA and Addendum. The purpose is to understand how the methodology works, as well as how input and output are formatted.

Task 3: Use Salinity of Rio Grande Water to Estimate Irrigation Water Salinity

Use Rio Grande salinity results from the ISC (or other selected model or analysis) and the monthly pattern of deliveries to calculate the weighted average salinity of delivered surface water by subarea. For subareas in which groundwater is a significant component of irrigation water and for which adequate information is available, these data should be included in the overall salinity loading calculation.

Task 4: Estimate Benefits of Salinity Reduction Alternatives

For each study subarea, implement the analytical model developed for the PEIA using avoided costs and avoided damages, allowing for limited changes in cropping pattern. All evaluations described below would be repeated as needed for each salinity reduction alternative, subarea, and point in time.

Task 4.1: Evaluate Potential Cropping Changes

First, assess whether irrigation water salinity appears to be a significant limit on crop selection within each subarea. This would be done through a combination of agronomic assessment of irrigation practices, water quality, and crop yields, as well as interviews with local growers, extension experts, and others.

Second, survey local crop market experts to develop an estimate of the market effect of increased acreage of alfalfa, chile, corn, onions, and other crops that could increase in currently salinity-impaired portions of the study area. Contacts should include university and extension experts, USDA staff, and local commodity market representatives. The purpose would be to assess how the market for these crops is expected to expand over time as a result of population and other demand pattern changes. From this information, determine an upper limit on expansion of the crops. If no reasonable limit can be determined, then consider only changes to acreage of basic crops defined in the P&G such as alfalfa and corn.

Third, for subareas determined to be limited in crop selection, evaluate the effect of the change in irrigation water salinity on basic crops (as defined by the P&G) that could come into production. For those crops that could profitably increase in acreage, allow their proportion of subarea acreage to increase only up to the proportion of the least-salinity-impaired subarea. Estimate the increase in net revenue using the method developed in the PEIA Addendum.

Task 4.2: Evaluate Avoided Cost and Damages from Salinity Reduction

For acreage not affected by cropping changes estimated in Task 4.1, use the recommended methodology to evaluate the change in delivered water salinity estimated in Task 3. The methodology determines the least-cost combination of avoided leaching and yield decrement for each crop given the irrigation water salinity.

Task 4.3: Calculate Present Value of Benefits

Interpolate results of the point-in-time estimates to create a hypothetical time trend of benefits for each alternative. As a reasonable approximation, the interpolation of benefits between results at each point in time could be based on the trend in flow in the lower Rio Grande, or on another agreed-upon hydrologic projection. Discount the time trend of benefits to the base year. Display results for ultimate comparison to project costs.

Task 5: Draft Report

Prepare a draft report that describes the alternatives evaluated, methodology used, data gathered or updated, hydrologic and salinity model results used, and results.

Optional Task: Scenario Analysis of Climate Change

An optional analysis of benefits in the context of climate change is suggested that would use the economics methodology to assess benefits at up to two future points in time. Flow and salinity results from the ISC model (or other appropriate analysis) would be used to estimate benefits of alternatives under existing or near-term conditions and at future points in time, with and without climate change. The selection of future time periods and appropriate climate change models and assumptions for flow and salinity analysis would be outside the scope of the economics analysis. But after those decisions have been made and analyzed, the economic assessment would be applied using the following steps:

1. Evaluate the benefits of each alternative (or a subset of alternatives) by comparing avoided costs, damages, and net revenue changes with the proposed salinity reduction alternative to the without-project results at up to two future points in time consistent with the climate change analysis of flow and salinity.
2. Calculate and display the economic benefits (or range of benefits if more than one climate change scenario is evaluated) at each point in time using baseline estimates of water use per acre, yields, prices, and costs. Crop yields and consumptive use rates could also be projected if an acceptable analytical approach is identified and agreed upon; however, estimation of those potential effects of climate change is outside this scope.
3. Interpolate results of the point-in-time estimates to create a hypothetical time trend of benefits for each alternative. As a reasonable approximation, the interpolation of benefits between results at each point in time could be based on the trend in flow in the lower Rio Grande, or on another agreed-upon hydrologic projection. Discount the time trend of benefits to the base year. Display results for ultimate comparison to project costs.

Deliverables

1. Notes summarizing topics and key findings or decisions of all interviews, meetings, and telephone contacts with growers and other local experts.
2. Technical memorandum regarding Task 1 that summarizes current and future study area agricultural production without a project, and provides justification for assumptions and calculations used to project future conditions.
3. Draft report that describes the alternatives evaluated, methodology used, data gathered or updated, hydrologic and salinity model results used, and results.

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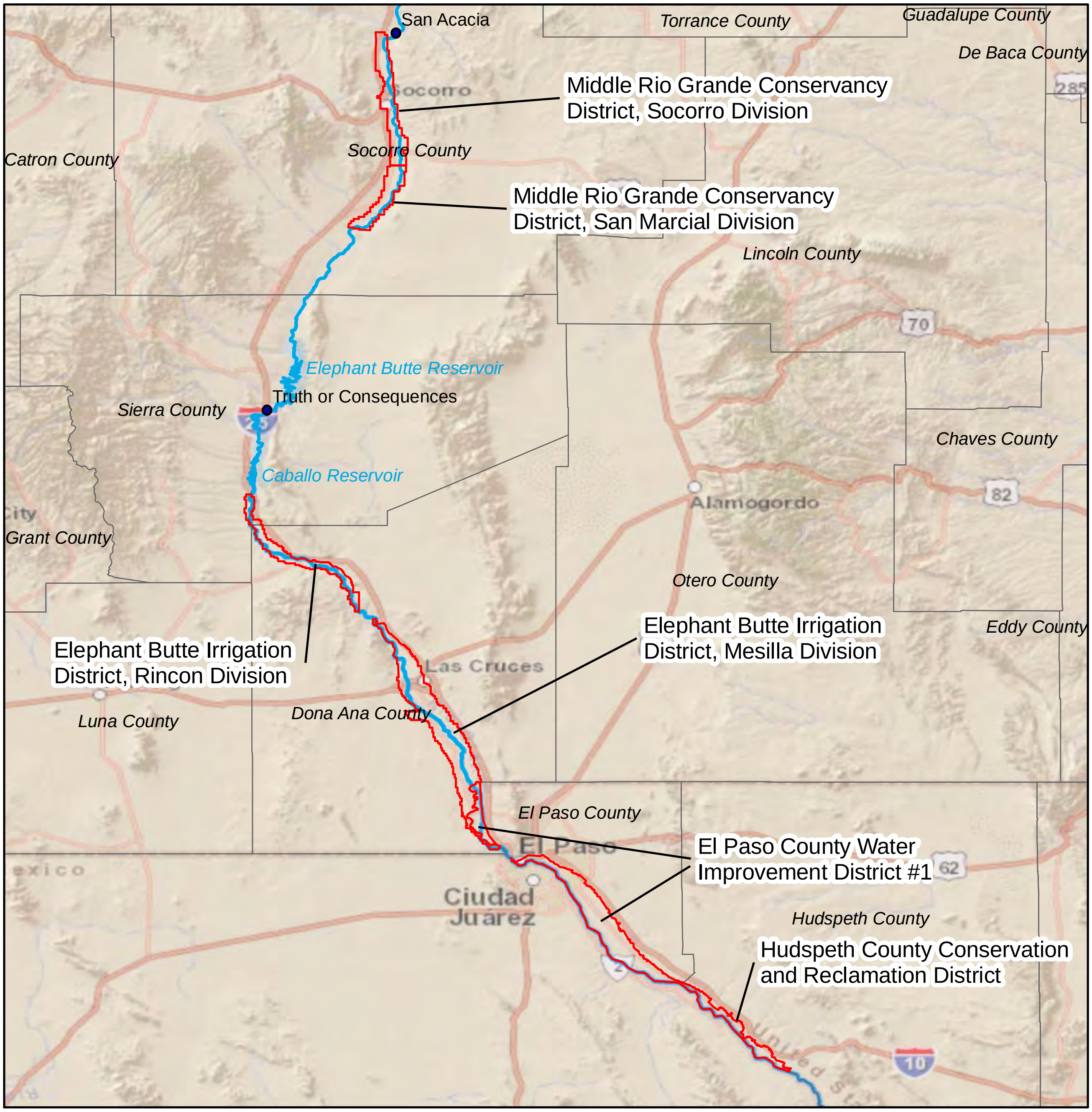
Figures



VICINITY MAP

LEGEND

- Irrigation District Boundaries
- Rio Grande
- Counties

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FIGURE 1
Study Area
Review Findings of PEIA and Recc. for Ag. Econ. Assessment
Rio Grande Salinity Management Program

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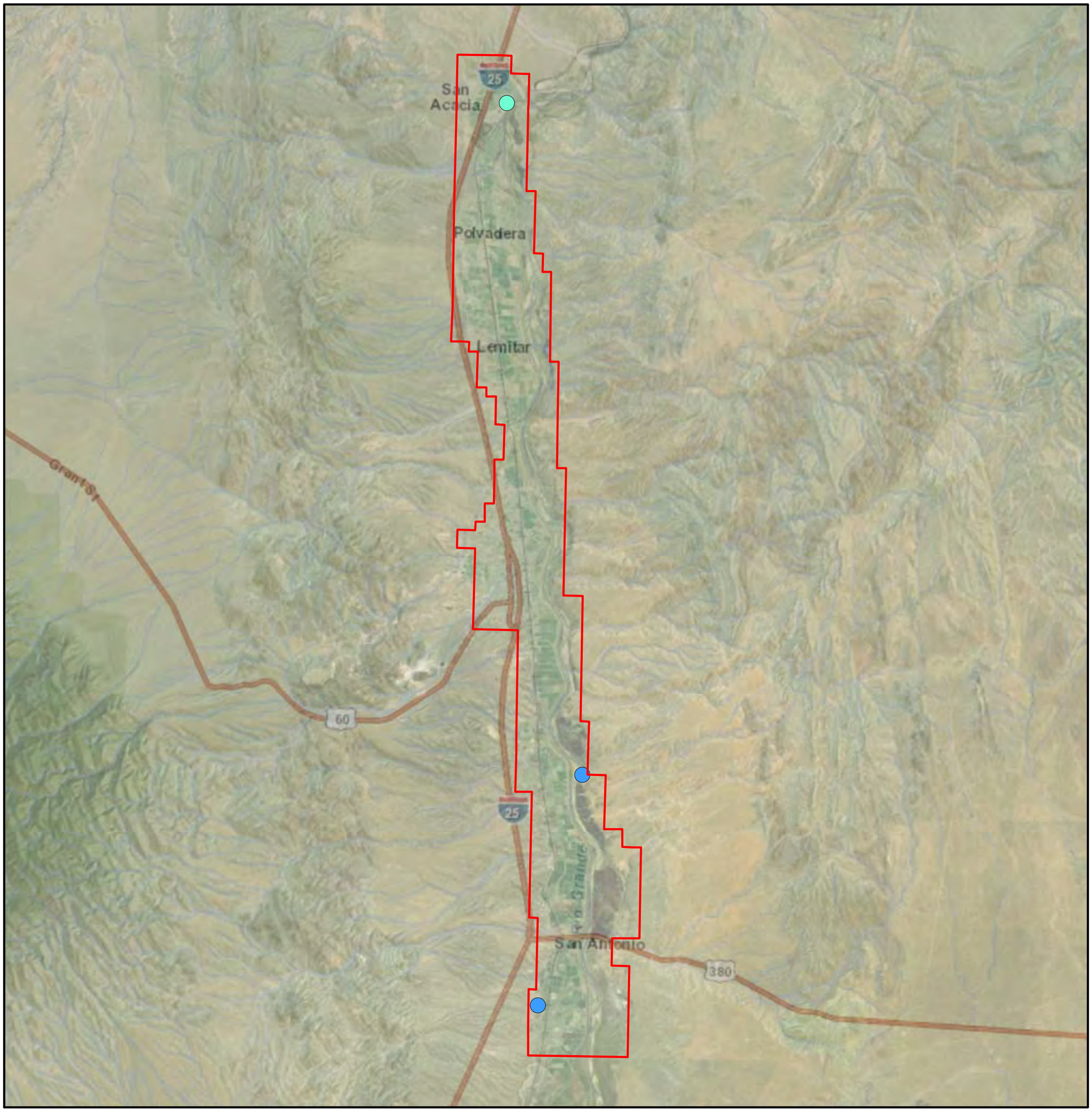

LEGEND

Socorro Division Boundary

Average TDS (mg/L) in groundwater

- < 200.0
- 200.1 - 500.0
- 500.1 - 1,000.0
- 1,000.1 - 2,000.0
- 2,000.1 - 5,000.0
- > 5,000.0

Data Source:
USGS-NMISC database compendium

VICINITY MAP

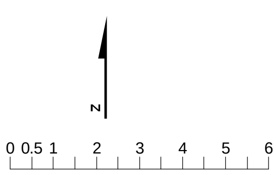

FIGURE 2
Average TDS, Middle Rio Grande Conservancy District, Socorro Division

Review Findings of PEIA and Recc. for Ag. Econ. Assessment

Rio Grande Salinity Management Program

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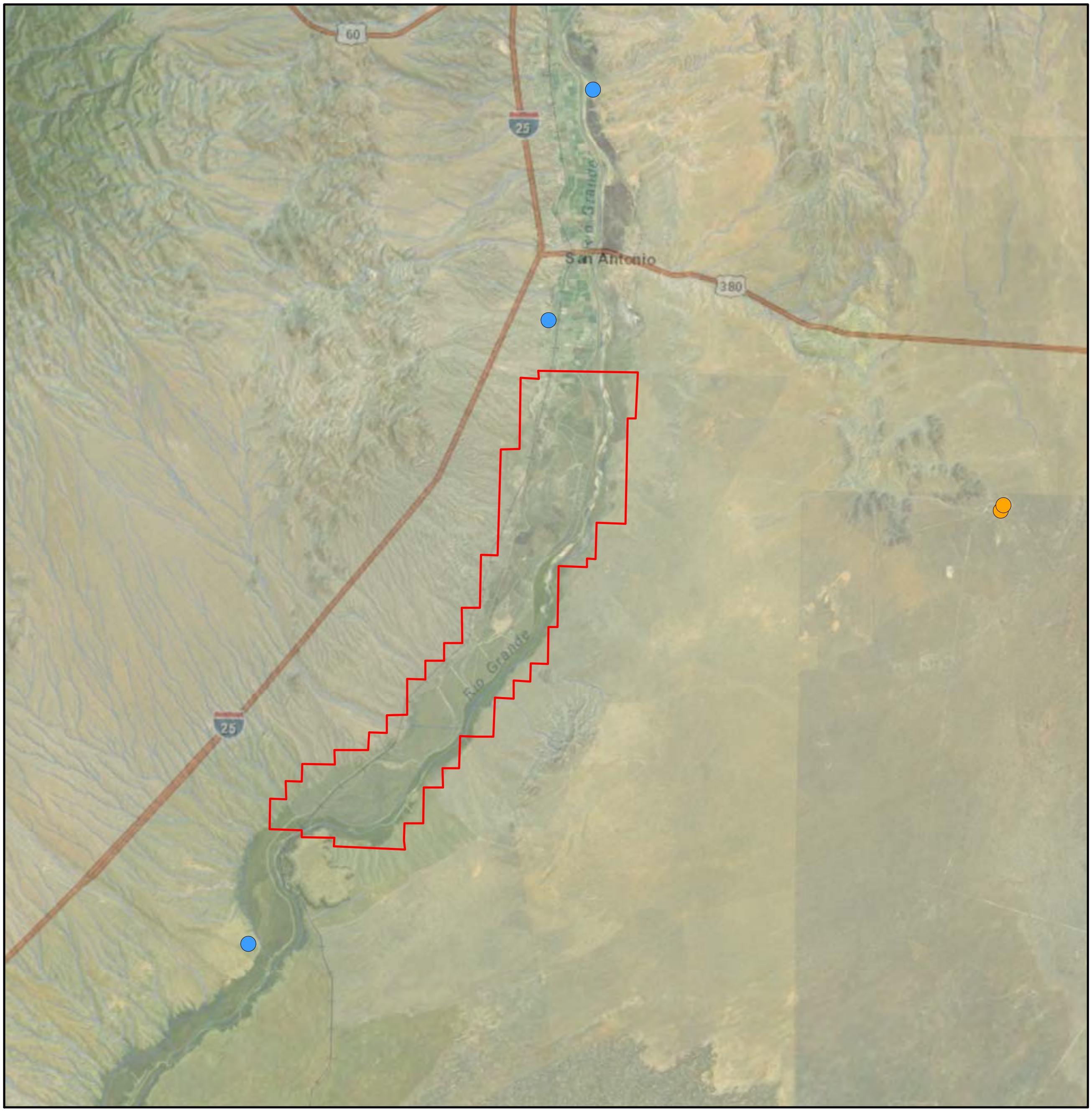


LEGEND

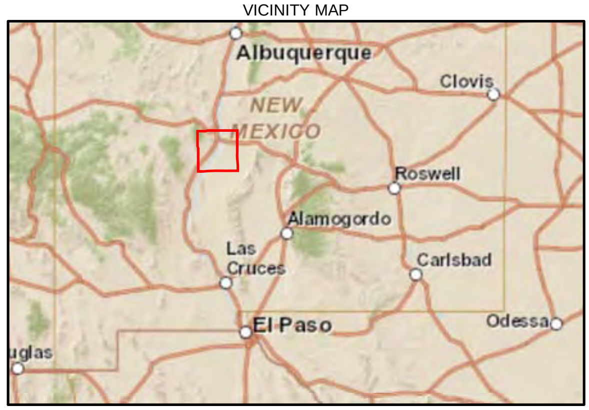
San Marcial Division Boundary

Average TDS (mg/L) in groundwater

- < 200.0
- 200.1 - 500.0
- 500.1 - 1,000.0
- 1,000.1 - 2,000.0
- 2,000.1 - 5,000.0
- > 5,000.0

Data Source:
USGS-NMISC database compendium

VICINITY MAP



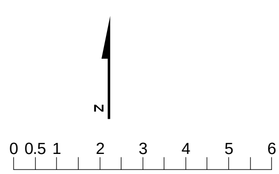
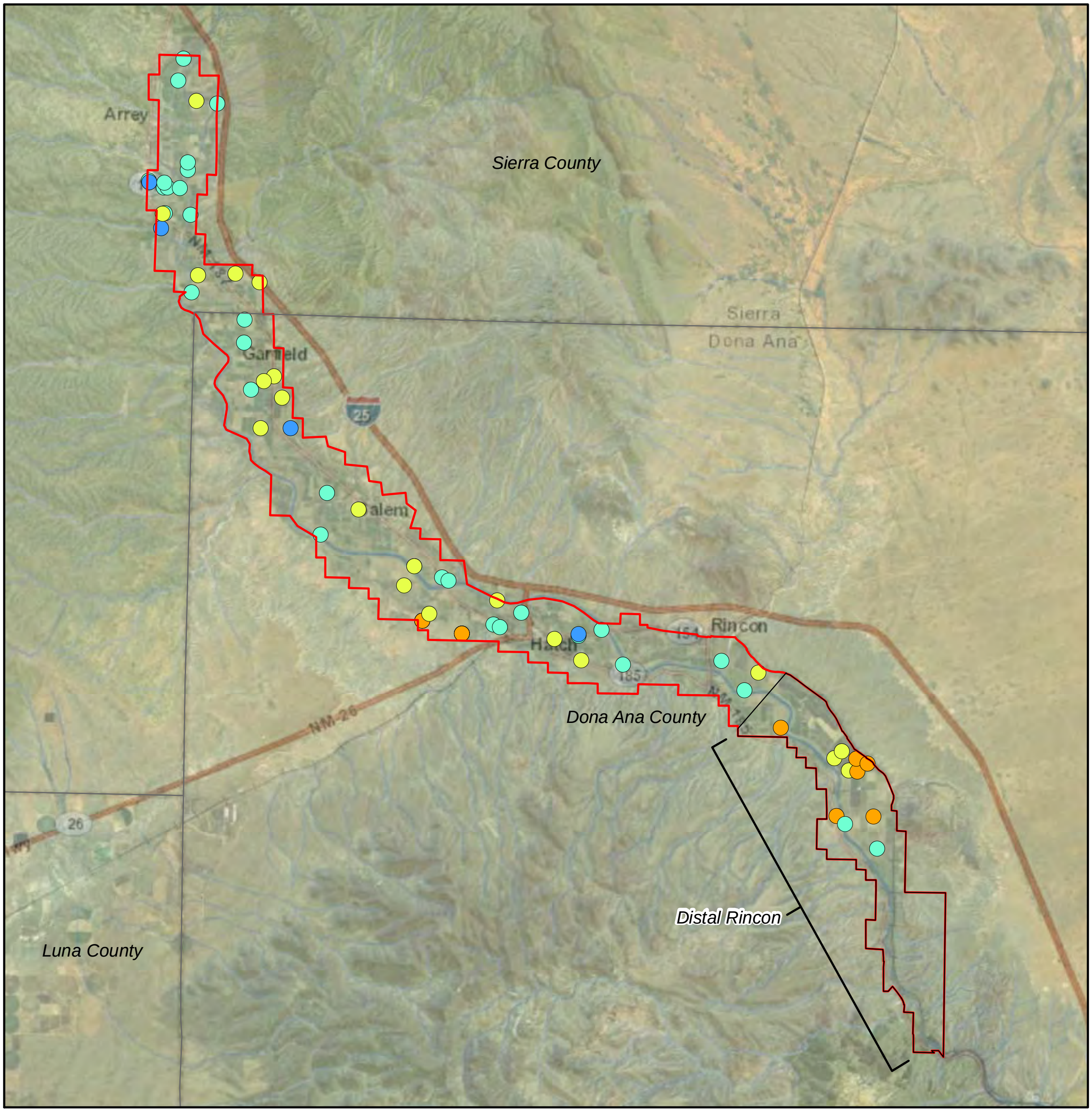


FIGURE 3
Average TDS, Middle Rio Grande Conservancy District, San Marcial Division
Review Findings of PEIA and Recc. for Ag. Econ. Assessment
Rio Grande Salinity Management Program



LEGEND

- Counties
- Rincon Division Boundary
- Water Quality Sub-Areas

Average TDS (mg/L) in groundwater

- < 200.0
- 200.1 - 500.0
- 500.1 - 1,000.0
- 1,000.1 - 2,000.0
- 2,000.1 - 5,000.0
- > 5,000.0

Data Source:
USGS-NMISC database compendium

N

0 0.5 1 2 3 4 5
Miles

VICINITY MAP

FIGURE 4
Average TDS, Elephant Butte Irrigation District, Rincon Division

Review Findings of PEIA and Recc. for Ag. Econ. Assessment

Rio Grande Salinity Management Program

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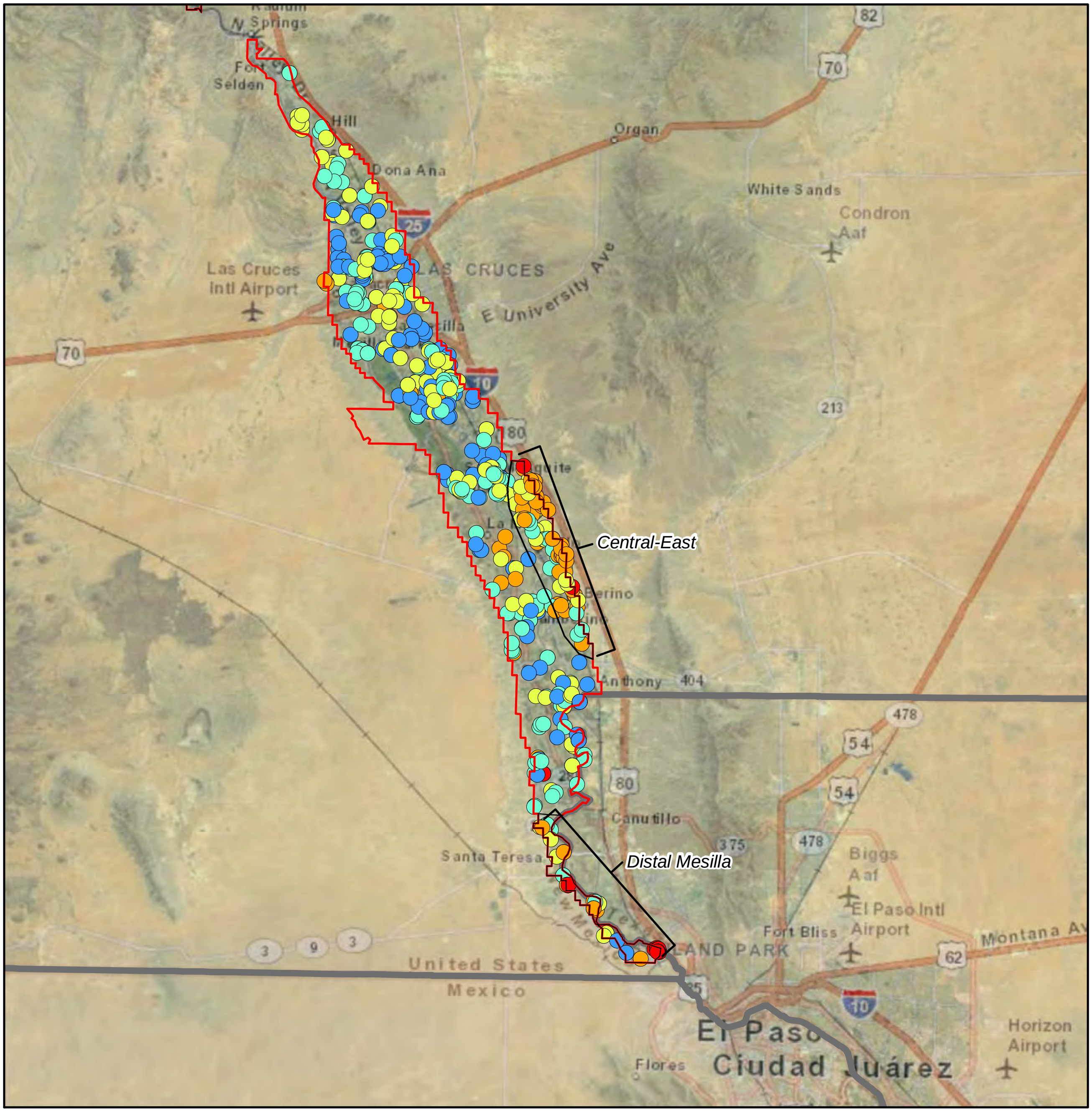

LEGEND

Mesilla Division Boundary

Water Quality Sub-Areas

Average TDS (mg/L) in groundwater

- < 200.0
- 200.1 - 500.0
- 500.1 - 1,000.0
- 1,000.1 - 2,000.0
- 2,000.1 - 5,000.0
- > 5,000.0

State Boundary

Data Source:
USGS-NMISC database compendium

VICINITY MAP

N

0 0.5 1 2 3 4 5 6 7 8 9 10
Miles

FIGURE 5
Average TDS, Elephant Butte Irrigation District, Mesilla Division

Review Findings of PEIA and Recc. for Ag. Econ. Assessment
Rio Grande Salinity Management Program

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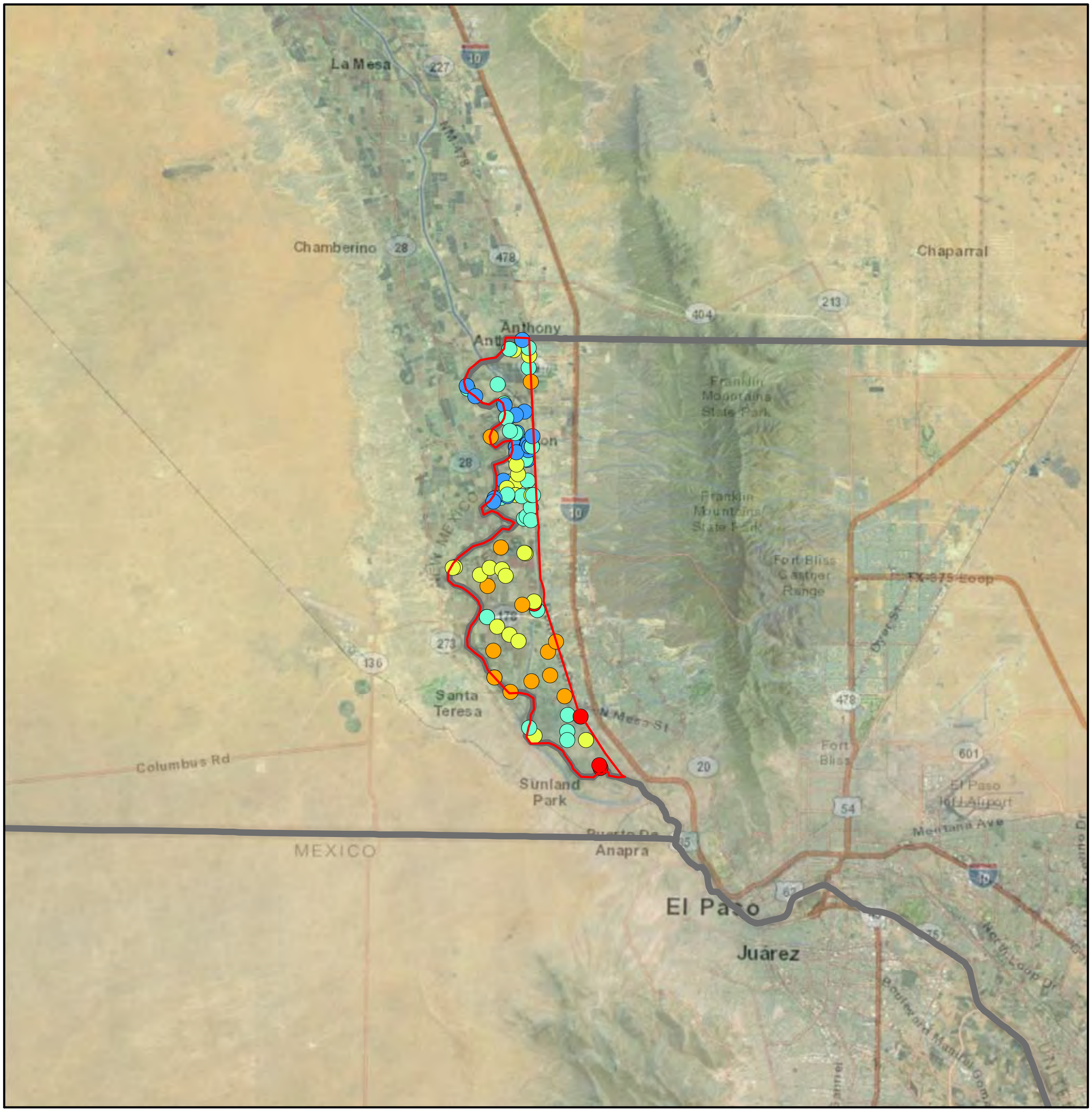

LEGEND

El Paso County Water Improvement District #1 Boundary

State Boundary

Average TDS (mg/L) in groundwater

- < 200.0
- 200.1 - 500.0
- 500.1 - 1,000.0
- 1,000.1 - 2,000.0
- 2,000.1 - 5,000.0
- > 5,000.0

Data Source:
USGS-NMISC database compendium

0 0.5 1 2 3 4
Miles

VICINITY MAP

FIGURE 6
Average TDS, El Paso County Water Improvement District #1 (North)

Review Findings of PEIA and Recc. for Ag. Econ. Assessment
Rio Grande Salinity Management Program

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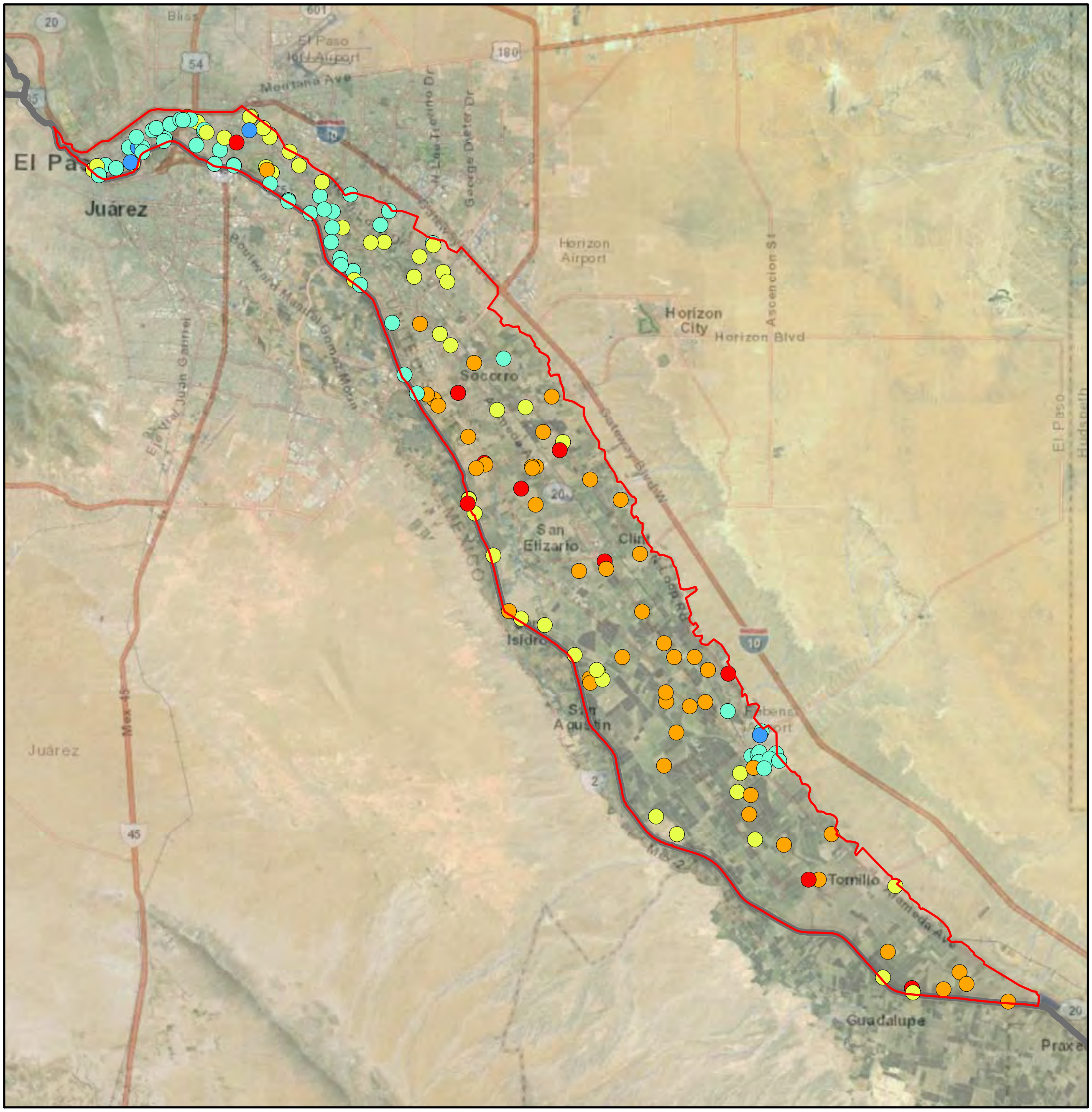


LEGEND

El Paso County Water Improvement District #1 Boundary

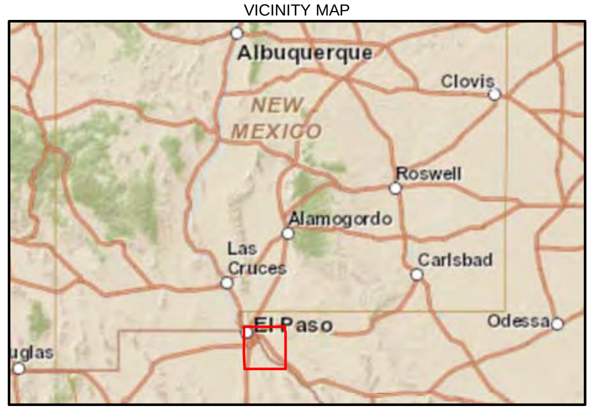
State Boundary

Average TDS (mg/L) in groundwater

- < 200.0
- 200.1 - 500.0
- 500.1 - 1,000.0
- 1,000.1 - 2,000.0
- 2,000.1 - 5,000.0
- > 5,000.0

Data Source:
USGS-NMISC database compendium

VICINITY MAP



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0 0.5 1 2 3 4 5 6
Miles

FIGURE 7
Average TDS, El Paso County Water Improvement District #1 (South)

Review Findings of PEIA and Recc. for Ag. Econ. Assessment
Rio Grande Salinity Management Program

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LEGEND

Hudspeth County Conservation & Reclamation District Boundary

State Boundary

Average TDS (mg/L) in groundwater

- < 200.0
- 200.1 - 500.0
- 500.1 - 1,000.0
- 1,000.1 - 2,000.0
- 2,000.1 - 5,000.0
- > 5,000.0

Data Source:
USGS-NMISC database compendium

N

0 0.5 1 2 3 4
Miles

VICINITY MAP

FIGURE 8
Average TDS, Hudspeth County Conservation And Reclamation District

Review Findings of PEIA and Recc. for Ag. Econ. Assessment

Rio Grande Salinity Management Program

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Attachment A
Photo Log

MRGCD, Socorro Division—Typical Flood-irrigated Alfalfa and Pasture

MRGCD, Socorro Division—Irrigation/Drain Canal

MRGCD, Socorro Division—Poor Alfalfa Stand

EBID, Rincon Division—Flood-irrigated Alfalfa

EBID, Rincon Division—Flood-irrigated Vegetable Beds

EBID, Rincon Division—Harvesting Cotton

EBID, Rincon—Calf Pens for Large Dairy

EBID, Rincon Division, Hatch, New Mexico— Shop Highlighting Economic and Cultural Importance of Chile

EBID, Rincon Division—Field of Red Chile Peppers

EBID, Rincon Division, Near Rincon—New Pecan Plantation

EBID, Mesilla Division—Lettuce in foreground, Pecans in background

EBID, Mesilla Division—Stressed Pecans Near El Paso

EBID, Mesilla—Flood-irrigated Alfalfa

EP1 (South)—Stressed Young Pecan Plantation

EP1 (South)—Tilled Field, with Pecans in Background

Hudspeth County—County Line Lakes

Hudspeth County—Cotton Production

Hudspeth County—Irrigation Ditch

Hudspeth County—Ridged Field

Hudspeth County—Hay Crop (Johnsongrass or another Sorghum sp.)

Attachment B
Response to Comments

ATTACHMENT B-1

Summary of Review Comments on RGSS Preliminary Draft report for CSM, Criteria and Draft Econ

Reviewer	Task/Report Section	Comment	Addressed By	Notes
NMED / ISC / OSE*	Option 2/ Economic Analysis	The economic assessment only contains review and comments for agricultural economic assessment. Why were urban economic damages not considered – especially since this is the largest damages?	Steve Hatchett	The contractor was not tasked with developing a scope for assessing urban economic damages. The COE believes it has in-house expertise to develop and implement a scope of work for urban damages.
NMED / ISC / OSE*	Option 2/ Economic Analysis	The review of the preliminary economic analysis suggests improvements/ refinements but basically says the preliminary assessment was a sound starting point. It would be helpful to know if these refinements are likely to increase or decrease estimates compared to the preliminary assessment.	Steve Hatchett	The comment is accurate regarding the conclusions of the review and the recommended scope of work. It is unclear whether the refinements would increase or decrease the agricultural economic damage estimates, or how large the magnitude of change might be.