Attachment 3
Part II

Development of the T17sup.M7 Superposition Version of the Taos Area Groundwater Model and Water Rights Administration under the Taos (Abeyta) Settlement,
April 16, 2012,
by Peggy Barroll, PhD, NM OSE.
17 pages, plus Appendices A, B, C, D and E.

Development of the T17sup.M7 Superposition Version of the OSE Taos Area Groundwater Model and Water Rights Administration under the Taos (Abeyta) Settlement

April 16, 2012

by
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Prepared by the
New Mexico Office of the State Engineer
Water Resource Allocation Program
Hydrology Bureau

Overview

The T17 Taos Groundwater Model is a calibrated groundwater model that was developed by a Technical Committee as part of the Taos Adjudication Settlement process[1]. The model was finalized in 2006, and this model was accepted as the Settlement Model, for use in water rights administration under the 2006 Draft Taos Settlement (i.e.: Draft Settlement Agreement Among The United States Of America, Taos Pueblo, The State Of New Mexico, The Taos Valley Acequia Association And Its 55 Member Acequias, The Town Of Taos, El Prado Water And Sanitation District, and the 12 Taos Area Mutual Domestic Water Consumers' Associations.) The T17 model (or Settlement Model) is documented in Part 1 of Attachment 3 of the to the 2006 Draft Taos Settlement Agreement.

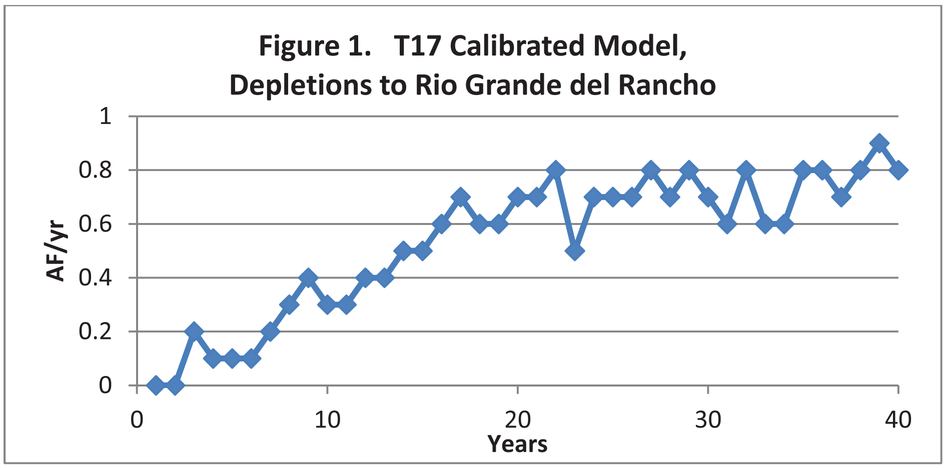
. This memo describes the development of the T17sup.M7 Taos superposition version of the Settlement Model for administrative purposes. Also presented are comparisons of results from the two different model versions: the T17 calibrated model version, and the T17sup.M7 superposition model version. Results for hypothetical future pumping scenarios as simulated by the two model versions, are compared; and also individual response functions. In addition, this memo outlines the application of this superposition version to water rights administration under the final Taos Settlement Agreement agreed to by the parties in 2012.

General Discussion of Groundwater Models in Administration

The Office of the State Engineer (OSE) commonly uses groundwater models to calculate stream depletions associated with groundwater pumping. In some cases a fully calibrated model is developed for a basin, and the OSE may want to use results from this model for administration. However, there are a number of issues that arise in the direct use of a calibrated model for calculating stream impacts. Firstly, there are practical concerns in that to determine the incremental effect of a stress, it is necessary to run the model twice (with and without the stress of interest) and take the difference between the two runs. Each step introduces

[1] Peggy Barroll and Peter Burck, 2006. Documentation of OSE Taos Area Calibrated Groundwater Flow Model T17.0, NMOSE Hydrology Bureau Report 06-04.

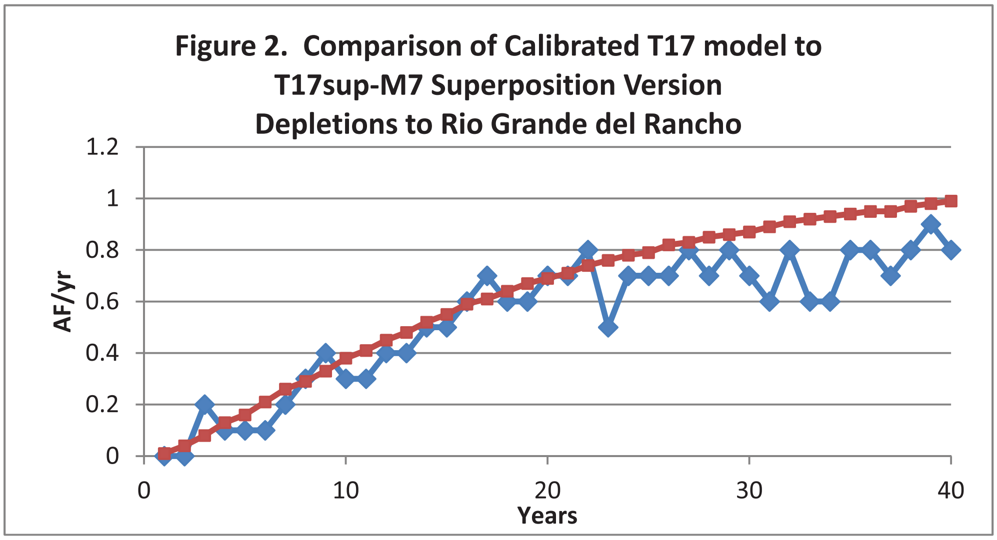
more opportunity for error, or for disagreement in exactly how to perform the model runs. Secondly, model results may vary depending on what background stresses are applied. Thirdly, results may be irregular due to model artifacts associated with the boundary conditions used to simulate streams, or because small stresses may fall within the "noise level" of the water budget terms of the fully calibrated model.[2] Figure 1 (below) illustrates this problem. The graph shows the depletions calculated to the STR cells in the calibrated model version representing Rio Grande del Rancho caused by a test well pumping 10 AF/yr stress.



This problem has frequently been encountered in water resource modeling at the OSE, and one resolution of this problem has been to develop a superposition version of the model that eliminates background stresses (such as recharge and groundwater diversions, which are eliminated from a superposition model unless the effect of those stresses is being specifically tested). Figure 2 (below) shows in red the stream depletions calculated for the same stress using a superposition

[2] For additional discussion of the advantages of superposition models for water resource modeling, see Leake, S. A. (2011), Capture—Rates and Directions of Groundwater Flow Don't Matter!. Ground Water, 49: 456–458. Additional discussion of groundwater modeling, and the use calibrated and superposition models can be found in Reilly, T.E. and Harbaugh, A.W. (2004) Guidelines for Evaluating Ground-Water Flow Models. U.S. Geological Survey Scientific Investigations Report 2004-5038.

version of T17 (which will be more fully described in the following sections).



The superposition version of the model yields comparable, but much more stable stream depletions.

An additional issue associated with the calibrated version of the Settlement Model is the simulation of changes in evapotranspiration (ET). In effect, the calibrated model simulates some of the impacts of pumping as reductions in ET. Such model predictions of salvaged ET are highly uncertain, and it is contrary to conservation to administer water rights based upon the possibility of salvaged ET. The superposition version of a model can eliminate these effects, thus resulting in a calculation in which all pumping impacts are eventually felt on the streams. Such a calculation is conservative with respect to protecting water resources, because it reduces the chance that we have underestimated the magnitude of stream depletions.

The Taos Technical Committee has agreed to the use of a Superposition Application of the Settlement Model, which includes the condition that part of the depletions simulated by the superposition model version on the Rio Lucero and Rio Pueblo de Taos shall be mitigated by means of the Buffalo Pasture Recharge Project.

Theory of Superposition

The theory of superposition is founded on model linearity. For a completely linear model, the presence or absence of background recharge or background pumping would not influence or change the drawdowns or surface water effects that are calculated to result from a proposed pumping stress. While not absolutely linear, the Taos groundwater system behaves linearly to a large extent because the water table drawdowns that have been historically observed, or simulated in future scenarios, are small compared to the saturated thicknesses of the aquifers. No significant change in relative aquifer thickness and corresponding transmissivity is anticipated to occur in typical pumping stresses expected to occur as a result of implementation of the Taos Settlement. However, there are some non-linear features of the model, such as the Stream (STR), River (RIV) and Evapotranspiration (ET) packages, which are "piece-wise" linear[3]. Hydrologic effects to these features change in character after the water table drops below a certain point. This conversion to superposition attempts to address these piece-wise linear features in a reasonable yet conservative fashion as described below.

Conversion of Calibrated Model Version to Superposition: Development of the T17sup.M7 Superposition Version

In conversion to superposition, modeled hydraulic conductivities, transmissivities and aquifer storage from the calibrated model version are maintained and fixed, all "background" recharges and pumping are removed, all observation packages are removed, ET is removed, STR and RIV packages are converted to General Head Boundary (GHB) package, and initial heads and boundary condition heads are set to 0.0.

The GHB package replaces the STR and RIV package in the simulation of the Rio Grande and its tributaries, including Buffalo Pasture. GHB, like RIV and STR, is a head dependent boundary, in which changes in stream seepage are calculated based on changes in groundwater levels. The GHB package is simpler,

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[3] Piece-wise linear boundary conditions in a groundwater model provide linear results over discrete intervals of groundwater level, not over the entire possible range of groundwater levels.

avoiding problems related to background stream seepage (GHB does not require a river stage to be specified), and is completely linear, avoiding the problem of piece-wise linearity producing variable results. When converting the STR cells into GHB cells, those STR cells that the calibrated model simulated as "disconnected" from the groundwater were eliminated (that is, cells for which the simulated water table is sufficiently deep so that groundwater pumping would not influence stream leakage from those cells, or for which the surface flow was zero). Some cells that represent frequently dry reaches of Rio Seco (or Arroyo Seco) are given reduced conductances to represent the fact that stream impact to the cells is limited by the availability of surface water. In addition, the conductances of other GHB cells were also reduced in order to better match the spatial distribution of tributary depletions simulated by the calibrated model version.

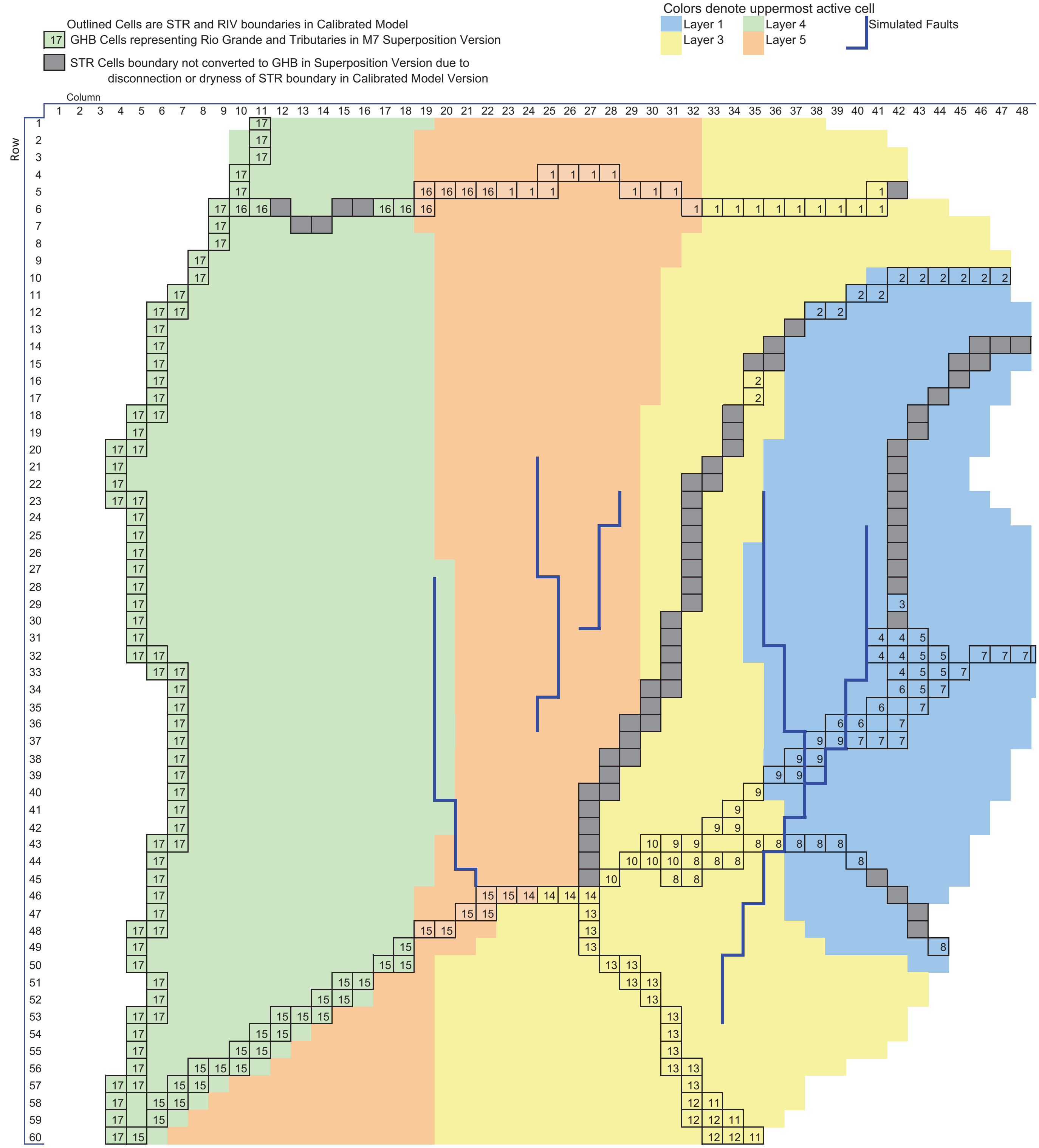
Since ET has been removed, the effects of aquifer stresses that resulted in changes in ET in the calibrated model version will now show up as changes to the GHB fluxes in the superposition version, predominantly as additional depletions on the tributaries.

Summary Description of Model Conversion

Steps of Conversion Process:

1) Compare calibrated model simulated water table elevation with streambed elevation in STR package. If water table is significantly deeper than streambed over more than three adjacent cells, assume disconnection and eliminate these from incorporation into the GHB package (see Figure 3 for resulting GHB distribution). Take the rest of the STR cells, and put in GHB package with a Bhead elevation of 0.0, maintaining conductance values. Put reach numbers in "comment" column.
2) Take cells from RIV package and convert to GHB, Boundary Head elevation = 0.0, append to bottom of GHB cells created from STR cells, give them reach number 17.
3) Eliminate ET package
4) Basic (BAS) package: Hinit=0

Figure 3: Diagram of Rio Grande and Tributaries in Taos Settlement Model Calibrated and M7 Superposition Version



Segment Number	Segment Name	Mitigation System
1	Upper Rio Hondo	Mitigation Well A
2	Rio Seco	ASR well acting as Mitigation well
3	Upper Rio Lucero	Mitigation Well B
4	Buffalo Pasture West	Buffalo Pastures Recharge Project
5	Buffalo Pasture East	Buffalo Pastures Recharge Project
6	Lower Rio Lucero	Mitigation Well B
7	Rio Pueblo de Taos A	Mitigation Well B
8	Rio Fernando	Mitigation Well C
9	Rio Pueblo de Taos B	Mitigation Well B
10	Rio Pueblo de Taos C	Mitigation Well B
11	Rio Chiquito	Mitigation Well E
12	Upper Rio Grande del Rancho	Mitigation Well D
13	Lower Rio Grande del Rancho	Mitigation Well D
14	Rio Pueblo de Taos D	Mitigation Well B
15	Rio Pueblo de Taos E	No Mitigation, Offset on Rio Grande
16	Lower Rio Hondo	No Mitigation, Offset on Rio Grande
17	Rio Grande	No Mitigation, Offset on Rio Grande

5) DIS package: reassign layer top and bottom elevations :[top 1 = 0.0], [bot 1 = 0.0 - thick1], etc.
6) Layer Property Flow (LPF) package: no change
7) Zone (ZON) and Multiplier (MUL) packages: no change
8) Omit observation packages
9) Omit Recharge (RCH) package
10) Well (WEL) package: wells eliminated representing mountain front recharge, and background groundwater diversions. WEL package now used only for test stresses.
11) Make comparable runs of calibrated model version and superposition model, and adjust GHB conductances from cells representing parts of the Rio Fernando, Rio Lucero and Rio Seco to better match the spatial distribution of tributary depletions calculated by the calibrated model version.

The resulting superposition version is referred to as the T17sup.M7. Printouts of key model files are provided in Appendix D.

Testing of Superposition Version

Results from the T17sup.M7 were compared with results from the calibrated version (T17.0), to ensure that the superposition version of the model provides comparable results. Two tests are documented here, which are referred to in this document as the Settlement Pumping Scenarios[4] for El Prado and for the Town of Taos. These scenarios simulate the “Future Groundwater Diversions” described in the Taos Settlement, increasing the diversions with time from current levels, and were developed for demonstrative purposes only. These Settlement Scenarios do not define or restrict how the Town of Taos or El Prado will actually develop their water rights and pumping schedules. These runs are more fully documented in Appendix A and Appendix B.

[4] Settlement Pumping Scenario is not a defined term in the Settlement, it used in this Attachment in order to designate specific model runs that were done for demonstrative purposes.

For the calibrated model version, numerous background stresses (natural recharge, irrigation return flow, municipal pumping, etc.) were still present, and the model was run twice: 1) with only background stresses (including current groundwater pumping levels), and 2) with the same background stresses and the addition of Settlement pumping. The net effect of the test stress was determined by subtracting the results of those two runs.

Comparisons were made using depletion results from the superposition and calibrated model versions calculated at 40 years time, which are shown in Tables 1 and 2 below. (Note: no administrative adjustments to the depletions for Rio Lucero or Rio Pueblo de Taos have been applied to the results in these Tables). The depletions calculated to the Rio Grande mainstem in the superposition version were extremely close to those calculated for the calibrated model version: within 1%.

Table 1. El Prado Settlement Pumping Scenario
Simulated Depletions in acre-feet per year, at 40 years
See Appendix A for more details

40 years	Superposition	Calibrated
1 Upper Rio Hondo	4.43	3.50
2 Rio Seco	0.89	1.50
3 Upper Rio Lucero	1.94	3.20
4 Buffalo Pasture West	8.93	4.70
5 Buffalo Pasture East	5.85	4.50
6 Lower Rio Lucero	8.19	5.80
7 R P de Taos A	10.16	6.20
8 Rio Fernando	5.75	6.60
9 R P de Taos B	16.85	8.50
10 R P de Taos C	1.77	0.70
11 Rio Chiquito	0.57	0.50
12 Upper R G del Rancho	0.47	0.40
13 Lower R G del Rancho	3.77	2.60
14 R P de Taos D	0.34	0.20
15 R P de Taos E	1.95	1.90
16 Lower Rio Hondo	7.84	6.30
Rio Grande Mainstem	82.62	83.00

Table 2. Town of Taos Settlement Pumping Scenario Simulated Depletions in acre-feet per year, at 40 years See Appendix B for more details		
40 years	Superposition	Calibrated
1 Upper Rio Hondo	2.99	2.4
2 Rio Seco	0.39	1.5
3 Upper Rio Lucero	0.9	1.5
4 Buffalo Pasture West	4.02	2.4
5 Buffalo Pasture East	3.17	1.2
6 Lower Rio Lucero	5.18	5.5
7 R P de Taos A	13.76	8.4
8 Rio Fernando	22.44	27.1
9 R P de Taos B	24.02	12.2
10 R P de Taos C	5.4	2.2
11 Rio Chiquito	7.33	7.8
12 Upper R G del Rancho	8.6	8.5
13 Lower R G del Rancho	49.35	41.4
14 R P de Taos D	2.93	2
15 R P de Taos E	57.09	55.4
16 Lower Rio Hondo	6.6	5.4
Rio Grande Mainstem	169.4	169.8

The simulated depletions to surface water flows in the tributaries in the superposition version were, on the whole, systematically greater than those calculated by the calibrated model version. This was the anticipated result of eliminating ET from the superposition model. Salvaged ET calculated by the calibrated model largely came from changes in the water budget near the tributaries, and appears in superposition results as an increase in the surface water depletions to those tributaries.

A comparison of the simulated stream depletions is shown in Figures 4 through 7, below.

FIgure 4. Calibrated Model Version T17: Surface Water Depletions and "Salvaged ET"
El Prado Settlement Scenario

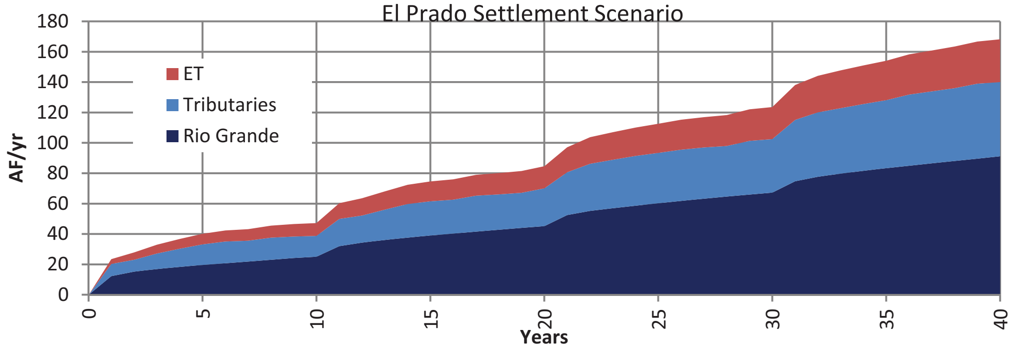


Figure 5. Superposition Version T17sup.M7: Surface Water Depletions
El Prado Settlement Scenario

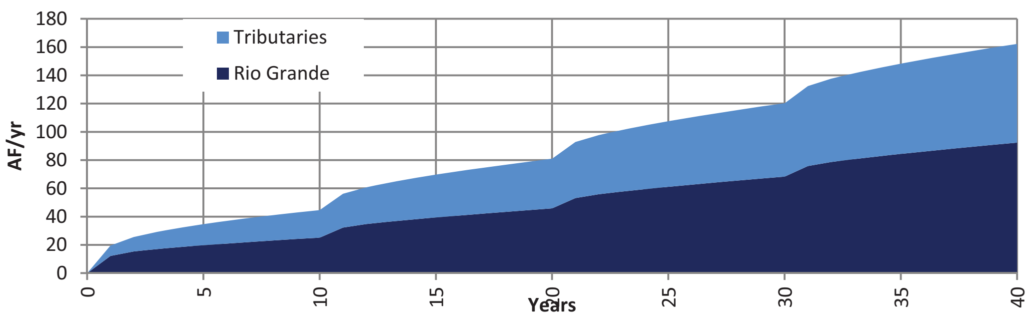


Figure 6. Calibrated Model Version T17: Depletions to Surface Water and "Salvaged ET"
Town of Taos Settlement Scenario

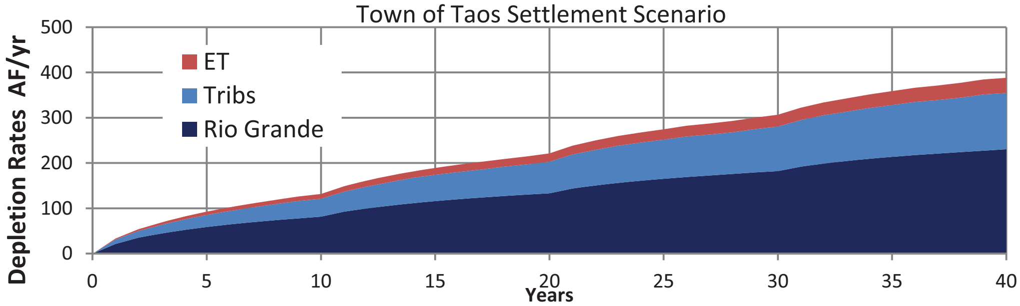
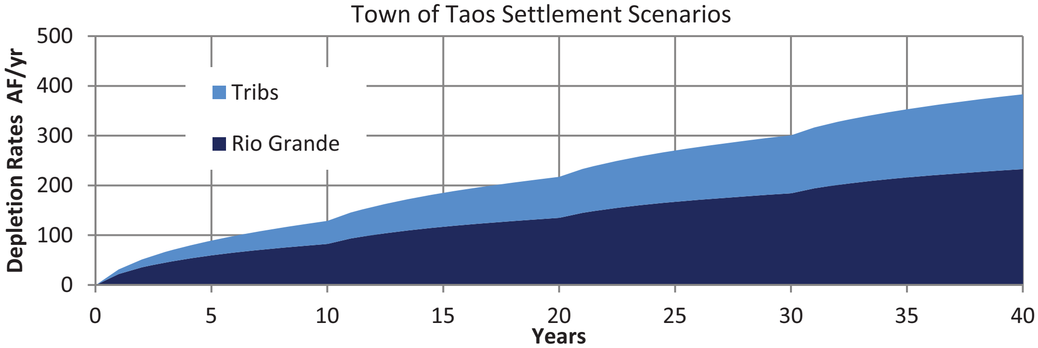


Figure 7. Superposition Version T17sup.M7: Surface Water Depletions
Town of Taos Settlement Scenarios



The surface water depletions in the superposition version were approximately equal to the sum of the surface water depletions and the salvaged ET simulated by the calibrated version. At 40 years time, the difference between surface water depletions calculated by the superposition version of the model and the combined surface water and salvaged ET calculated by the calibrated version was 3% for the El Prado run and 1% for the Town of Taos run.

The groundwater drawdowns simulated by the superposition version were also comparable to those calculated using the calibrated model version. Discrepancies were generally much less than 1 foot, except in layer 7 (the layer in which the pumping stress was situated). In layer 7 the maximum discrepancy was about 2 feet out of about 50 feet of simulated drawdown. In general, the superposition version tended to simulate slightly higher drawdowns than the calibrated model. Other spot tests of the superposition version produced similar results.

Mitigation System Administration under the Taos Settlement

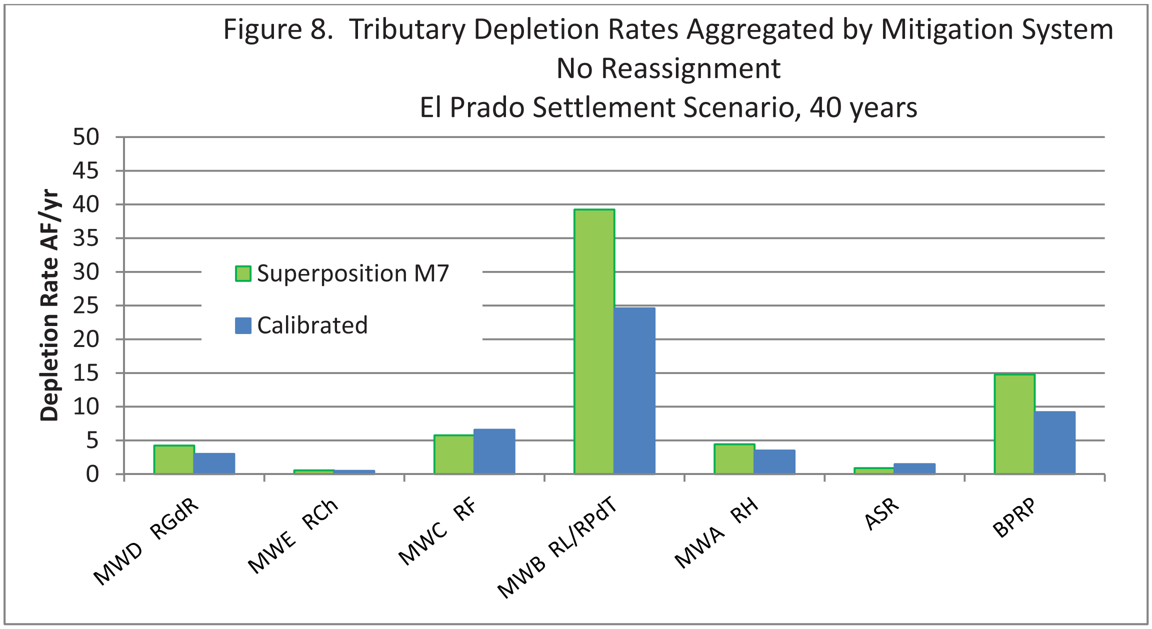
Under the Taos Settlement, tributary depletions caused by groundwater pumping may be offset using mainstem Rio Grande water rights, provided that the tributary depletions are addressed through mitigation systems (for more detail, see Article 7 of the Taos Settlement). Mitigation systems include 5 Mitigation Wells (MWA, MWB, MWC, MWD and MWE), an aquifer storage and recovery (ASR) well that will also be used as a Mitigation Well, and the Buffalo Pastures Recharge Project (BPRP). Model simulated tributary depletions will be used to calculate constraints for mitigation system operations, and the Rio Grande offsets associated with mitigation system operation.

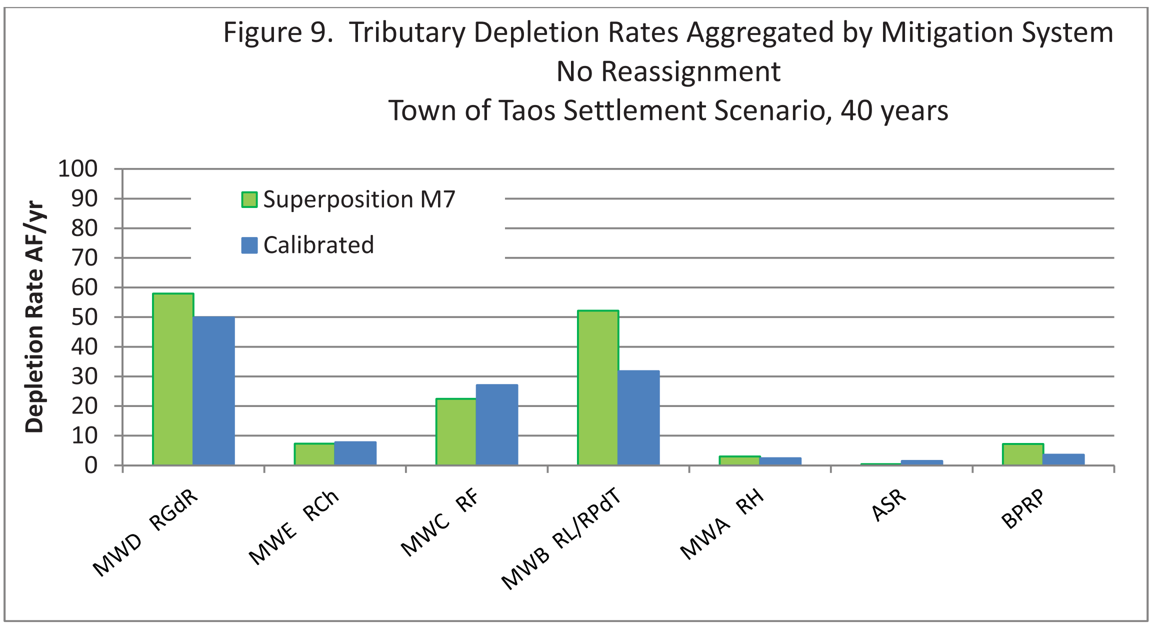
The model simulated depletions for tributary stream segments will be lumped according to the mitigation system associated with those segments as defined in the Taos Settlement and described below in Table 4. Note that under the Taos Settlement, depletions simulated on segments Lower Rio Hondo and the Rio Pueblo de Taos E, downstream of current irrigation diversions, are to be offset with mainstem Rio Grande water rights, and further mitigation is not required.

Table 4. Taos Tributary Segments Associated with Each Mitigation System

	Mitigation System	Location	Segments Aggregated
1	Mitigation Well A (MWA)	Rio Hondo	Upper Rio Hondo
2	Mitigation Well B (MWB)	Rio Pueblo de Taos/Rio Lucero	Rio Pueblo de Taos A, B, C and D; Upper Rio Lucero and Lower Rio Lucero
3	Mitigation Well C (MWC)	Rio Fernando	Rio Fernando
4	Mitigation Well D (MWD)	Rio Grande del Rancho	Upper Rio Grande Del Rancho and Lower Rio Grande del Rancho
5	Mitigation Well E (MWE)	Rio Chiquito	Rio Chiquito
6	ASR Well	Rio Seco	Rio Seco
7	Buffalo Pastures Recharge Project (BPRP)	Buffalo Pastures	Buffalo Pastures East and West

Tributary depletion rates calculated using the calibrated and superposition versions of the model at 40 years time have been aggregated by mitigation system in Figures 8 and 9 below, for the El Prado and Town of Taos Settlement Pumping.

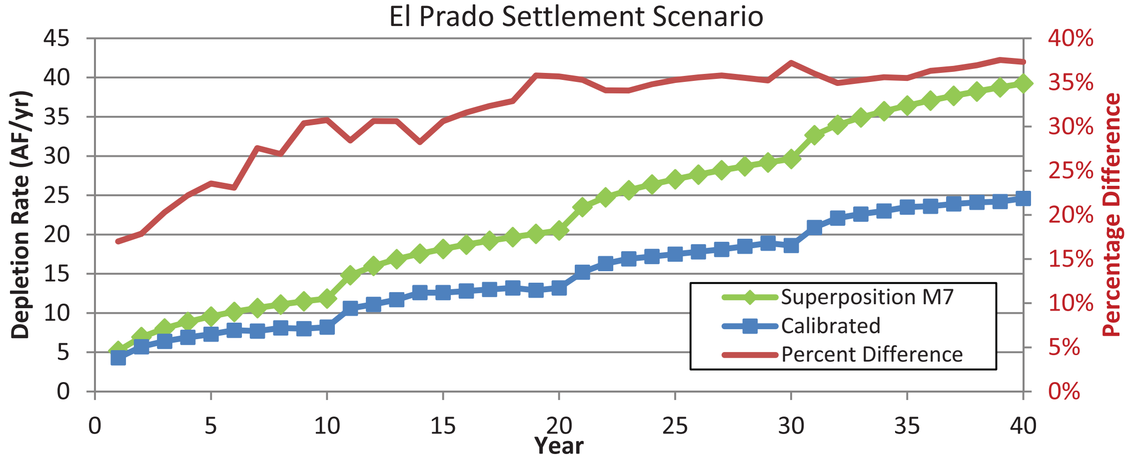




In both cases, the largest difference between depletions simulated by the calibrated model and the superposition version are for Mitigation Well B (MWB) - Rio Pueblo de Taos/Rio Lucero. This difference corresponds to “salvaged” ET in the calibrated model runs occurring in the vicinity of the Rio Lucero and Rio Pueblo de Taos. The Taos Technical Committee has agreed that the additional amount of depletions requiring mitigation on the Rio Pueblo de Taos and Rio Lucero (i.e., those associated with MWB) that are simulated by superposition version shall be reassigned for mitigation by means of the Buffalo Pasture Recharge Project. (By "additional", the Technical Committee means the amount by which the depletions calculated by the superposition version exceed those of the calibrated version.)

The amount by which the MWB depletions from superposition version exceed those from the calibrated version varies with time. Figure 10 and 11 below show this variation, along with the percentage difference relative to the superposition depletions. In general, the depletions simulated for MWB by the calibrated model version are about 30 to 40 % lower than those simulated by the superposition version.

Figure 10. Simulated Depletion Rates Associated with MWB and Percentage Difference between Model Version Results
El Prado Settlement Scenario



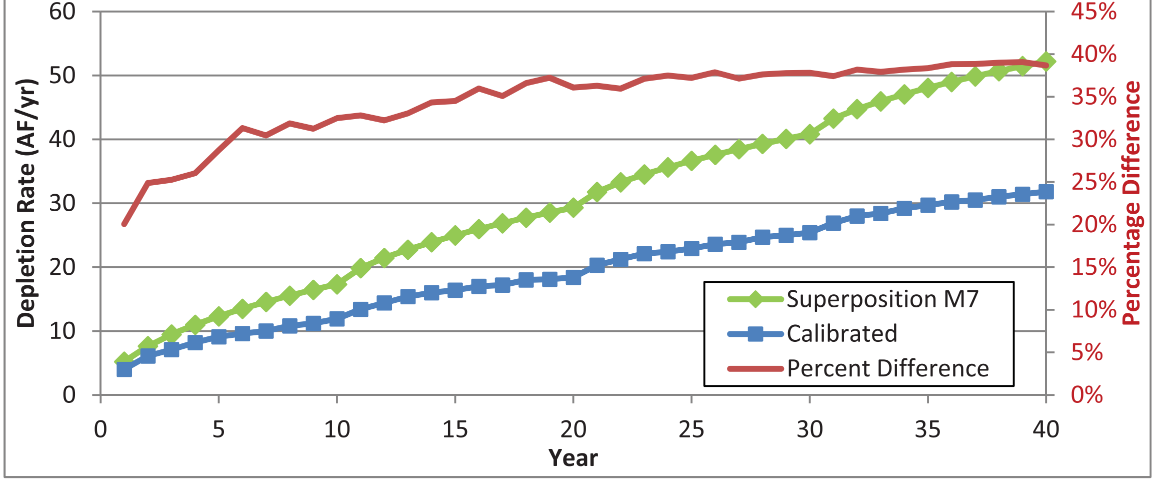


Figure 11. Simulated Depletion Rates Associated with MWB and Percentage Difference between Model Version Results Town of Taos Settlement Scenario

These results indicate that it would be reasonable to reassign 35% of the depletions simulated to occur on the Rio Pueblo de Taos and Rio Lucero to mitigation using the Buffalo Pastures Recharge Project. Figures 12 and 13 show the resulting depletion rates by mitigation system after application of this 35% reassignment factor.

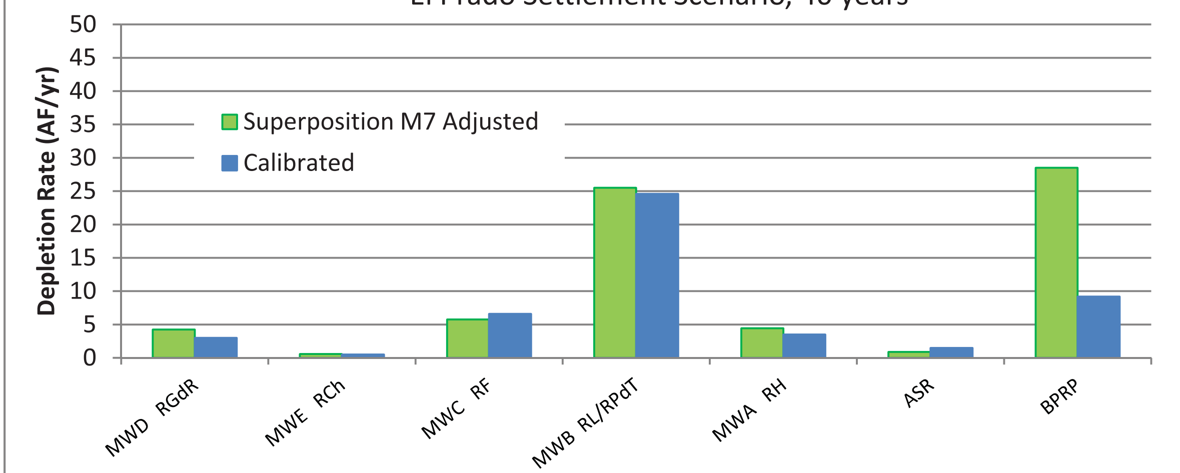
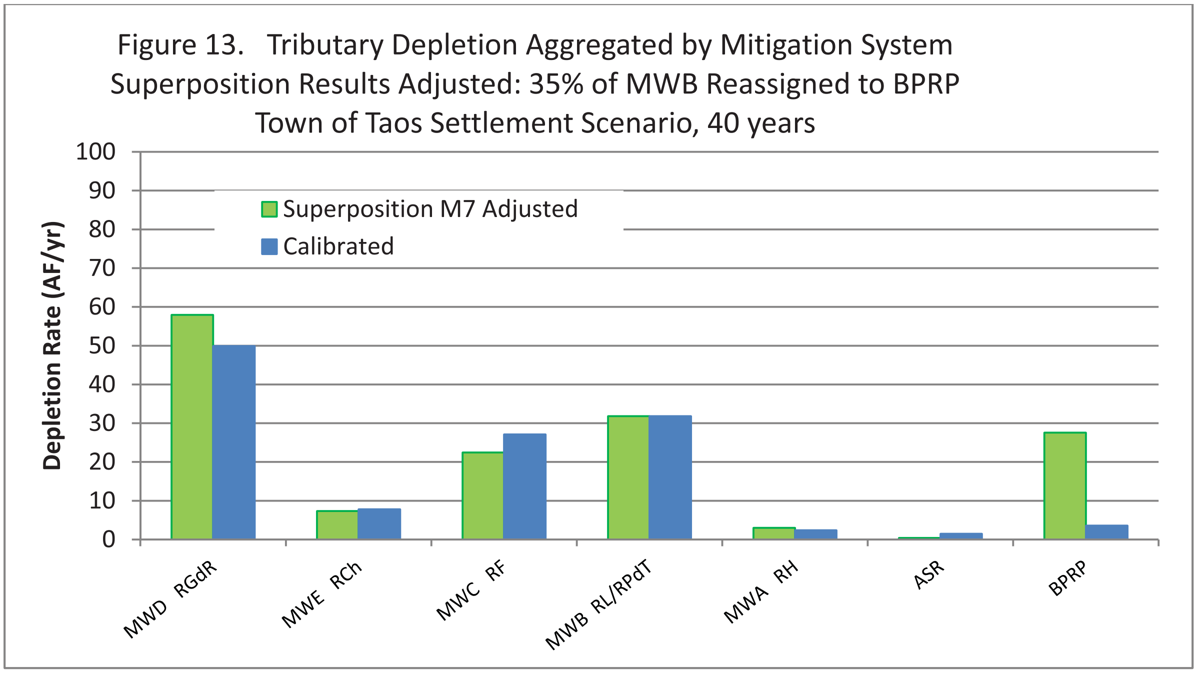


Figure 12. Tributary Depletions Aggregated by Mitigation System Superposition Results Adjusted: 35% of MWB Reassigned to BPRP El Prado Settlement Scenario, 40 years



Response Functions

Administration of offsets and mitigation under the Taos Settlement involves annual model calculations made using actual pumping amounts. To facilitate this process, and reduce the opportunity for error and for variable results, the Taos Technical Committee has agreed that the OSE will calculate depletions using response functions created using the T17sup.M7 superposition version of the Settlement Model (with 35% reassignment from MWB to BPRP as described above).

Response functions have been calculated using the T17sup.M7 Taos superposition version for a number of the existing and proposed Settlement well locations for El Prado and the Town of Taos. This process is described in Appendix C.

In order to use response functions for administration, a response function, R(t), will be calculated for each well using a test stress of 100 AF/yr. The depletions resulting from pumping a well Q acre feet per year can be calculated by scaling (multiplying) R(t) by Q/100. The depletions resulting from pumping that well at rates that vary from year to year can be determined by adding and subtracting scaled versions of R(t), incorporating time lags.

Appendix C describes the development of such response functions for Settlement wells given the locations, depths and construction described by the Taos Settlement, with additional detail provided by El Prado and the Town of Taos. Some of these wells have not yet been drilled. In actual administration, response functions must be determined by runs of the T17sup.M7 model based on the actual location, depth and construction of each well.

Offset of Mitigation System Operations

Under the Taos Settlement, the hydrologic effects of the operations of the Mitigation Systems will require offsets on the Rio Grande. The methodology for determining - those offsets has been agreed to in the Taos Settlement. Pumping of Mitigation Wells for mitigation purposes requires offset on the Rio Grande equal to 33.3% of the mitigation pumping. Operations of the Buffalo Pasture Recharge Project to mitigate depletions on Buffalo Pastures shall require offset on the Rio Grande equal to 11.1% of those depletions (this will include the depletions reassigned from MW B to Buffalo Pastures Recharge Project, described above.) Responsibility for these offsets shall rest with the Party or Parties whose groundwater development is being mitigated. This accounting is discussed in detail in Appendix E.

Conclusion

The T17sup.M7 superposition version of the Settlement Model is a reasonable and useful representation of the Settlement Model. The superposition version produces stable results that are comparable to the results of the calibrated model version. The reduction in ET simulated by the calibrated model version appears as additional tributary depletions in the superposition version.

The Taos Technical Committee has agreed that Superposition Application of the Settlement Model, in which response functions generated from the T17sup.M7 Taos Superposition Version, with a 35% administrative adjustment of depletions associated with Mitigation Well B, which are reassigned to the BPRP, should be used for administration of water rights under the Taos Settlement.

Appendix A

El Prado Settlement Scenario: Description of Taos Model Test Runs

Calibrated model difference run compared with Superposition T17sup.M7 version

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February 2012

Purpose: To show the difference between Calibrated Model results and Superposition model version results.

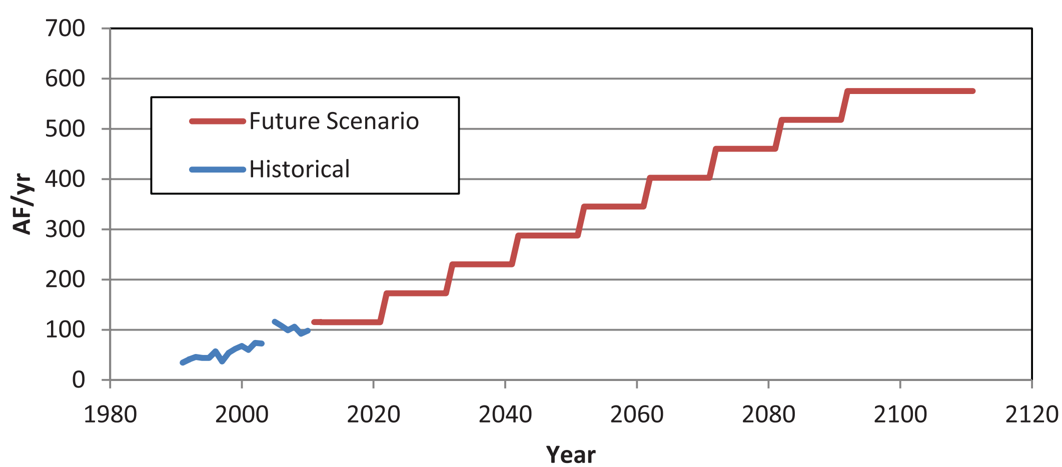
These runs have been made with the T17sup.M7 version of the Superposition model, in which the distribution of tributary depletions is generally consistent with the distribution of stream depletions and salvaged ET in the Calibrated model.

Note: Surface water depletions are split so that “Rio Grande Mainstem Depletions” include the depletions to the Lower Rio Hondo and Rio Pueblo de Taos E, while depletions to these segments are not included in “Tributary Depletions.”

Pumping Scenario

The simulation ramps up El Prado pumping from 115 AF/yr to 575 AF/yr over 80 years (El Prado currently diverts about 100 AF/yr). This level of pumping increase is generally consistent with the historical increase in El Prado diversions (Figure 1). The future pumping distribution for El Prado shown in red in Figure 1 shall herein be referred to as the El Prado Settlement Scenario. This Scenario was developed for demonstrative purposes only, and does not define or restrict how El Prado will actually develop their water rights and pumping schedules.

Figure 1. El Prado Historical Pumping and Settlement Scenario Pumping



The Superposition T17sup.M7 version was run with the pumping for El Prado shown in Figure 1, starting in year 0. Depletions were extracted for the Rio Grande mainstem segments, and tributary and Buffalo Pasture segments.

The Calibrated model was run twice for a difference calculation. The runs were:

1) A Baseline run
2) An Action run

Both runs start at predevelopment and include the calibration period. At the end of the calibration period, the model runs diverge to simulate different futures. The Baseline run keeps pumping constant into the future set equal to the pumping in the last stress period of the calibration. The Action run has the same future pumping as the Baseline run, with the addition of the El Prado Settlement Scenario pumping, as shown in Figure 1. Stream package outputs from the Baseline and Action runs were subtracted to calculate the net effect of the El Prado Settlement Scenario.

Results from the Superposition run were compared with the difference results from the future period of the Calibrated model runs. Since the calibration period is 40 years in length, results from year 40 of the Superposition run are comparable to year 80 of the Calibrated model runs.

Model Results at 40 year

Under the Settlement Scenario, at 40 years time, El Prado's diversion has increased to 288 AF/yr.

Calibrated Model Difference Run results:

Depletions to Stream and RIV cells total 140 AF/yr

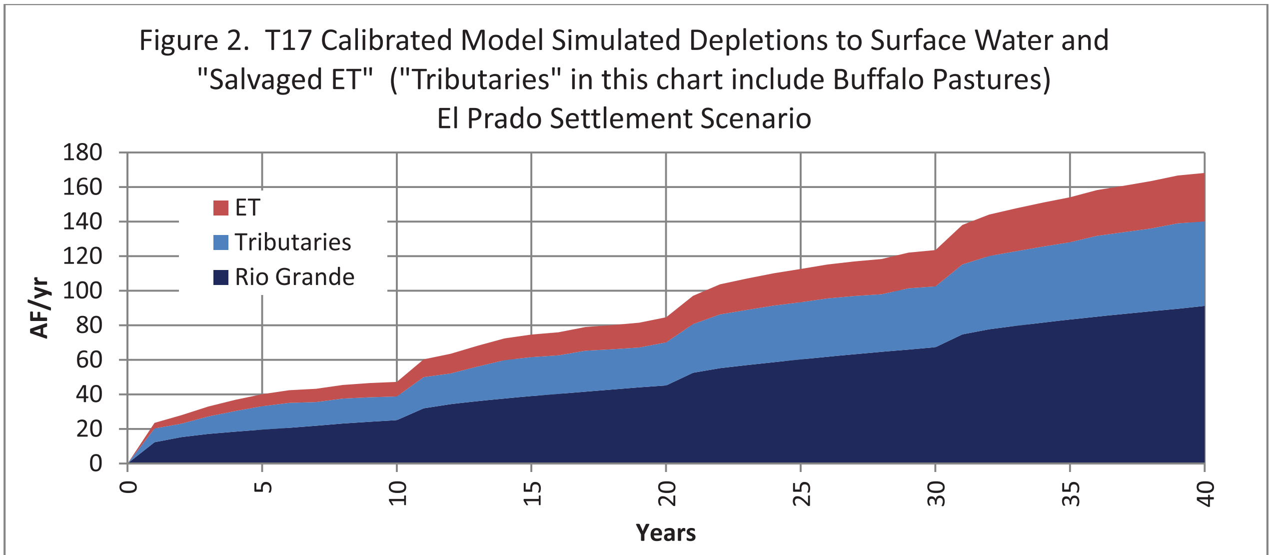
91 AF/yr from the Rio Grande Mainstem

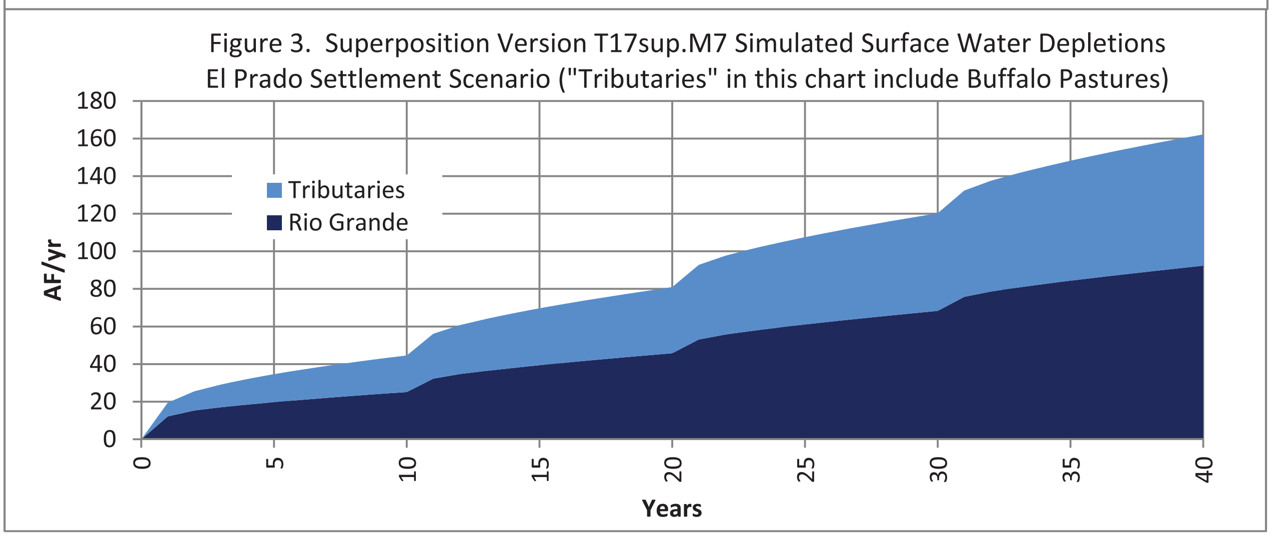
49 AF/yr total from the Tributaries and Buffalo Pastures.

In addition 28 AF/yr of "salvaged ET" are simulated.

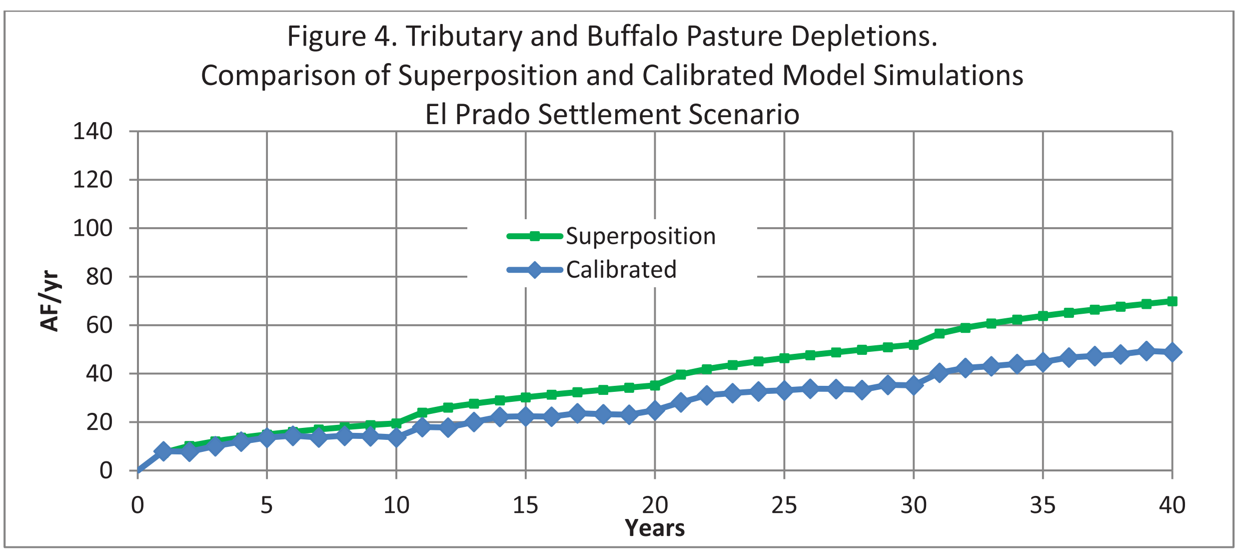
Superposition Version Total Surface Water depletions calculated using the Superposition depletions total 162 AF/yr. Of this total 91 AF/yr are from the Rio Grande Mainstem, 70 AF total from Tributaries and Buffalo Pastures.

More comprehensive results are shown below. Figure 2 shows the depletions and "Salvaged ET" from the Calibrated Difference run. Figure 3 shows the depletions calculated by the Superposition version. Figure 4 compares the depletions to the tributary and Buffalo Pasture stream cells (in all reaches above the last diversions) from the Calibrated Difference run and Superposition run.



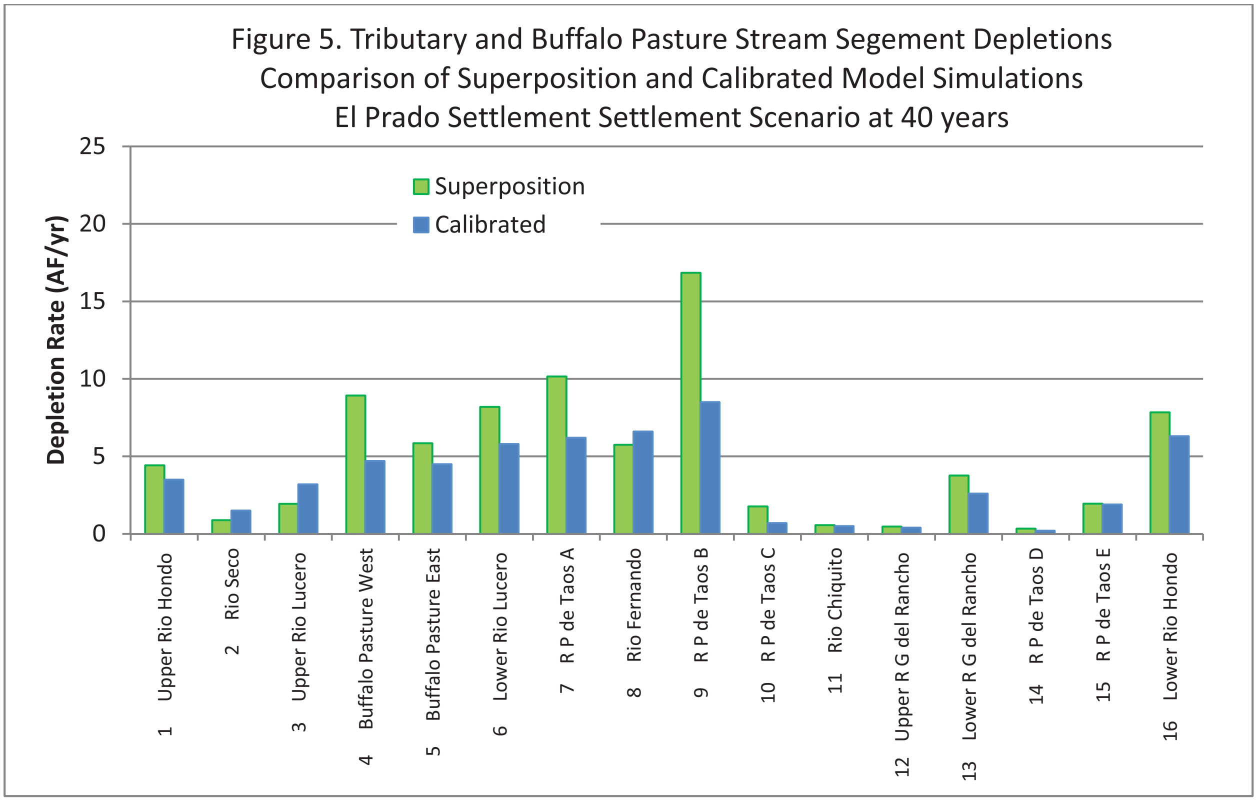


Rio Grande Mainstem depletions are almost identical between the two model versions, but Tributary depletions are higher in the Superposition version: 21 AF/yr higher at 40 years time.



The Calibration model run, however, predicts 28 AF/yr of "Salvaged ET", which effectively dampens and reduces the tributary and Buffalo Pasture depletions simulated by the Calibrated model.

The distribution of depletions among the tributary and Buffalo Pasture stream segments by both model versions is shown below in Figure 5



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Appendix B

Town of Taos Settlement Scenario: Description of Taos Model Test Runs

Calibrated Model Difference run compared with Superposition T17sup.M7 version

Peggy Barroll, NMOSE, Hydrology Bureau

February 2012

Purpose: To show the difference between Calibrated Model results and Superposition model version results.

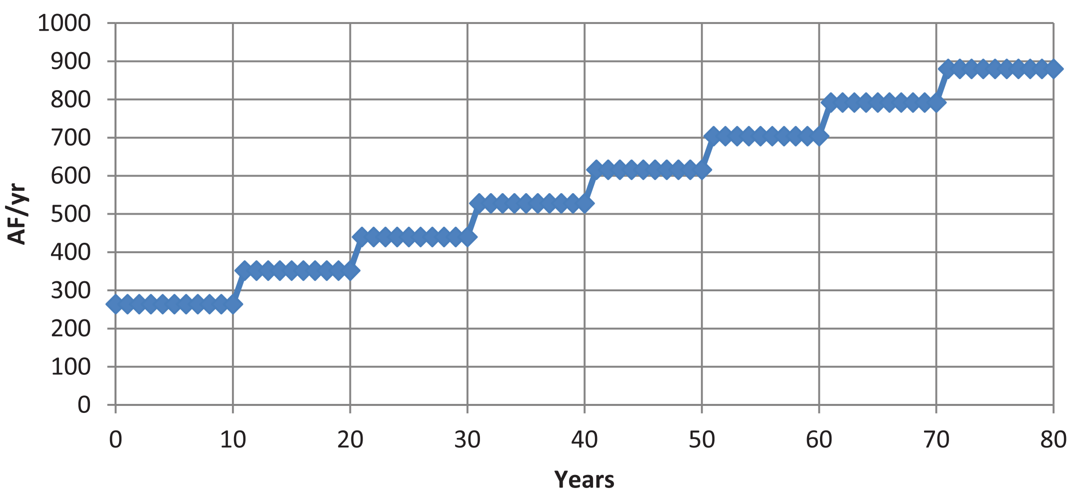
These runs have been made with the T17sup.M7 version of the Superposition model, in which the distribution of tributary and Buffalo Pasture depletions is generally consistent with the distribution of stream depletions and salvaged ET in the Calibrated model.

Note: Surface water depletions are split so that "Rio Grande Mainstem Depletions" include depletions to the Lower Rio Hondo and Rio Pueblo de Taos E, while depletions to these segments are not included in "Tributary Depletions".

Pumping Scenario

The scenario simulates the Town of Taos pumping from the Future Water Supply Well field and the Bataan well described in the Taos Settlement. The well locations and spatial pumping distribution used is the same that was simulated in the test runs for the Taos Settlement negotiations. The pumping in this analysis is ramped up as shown in Figure 1, starting at 264 AF/yr in the first year to 880 AF/yr over 70 years, and this is herein referred to as the Town of Taos Settlement Scenario. The effects of pumping from existing Town well field are not analyzed here. This Scenario was developed for demonstrative purposes only, and does not define or restrict how the Town of Taos will actually develop their water rights and pumping schedules.

Figure 1. Town of Taos Settlement Scenario: Estimated Town of Taos Pumping from New Wells under Taos Settlement



The Superposition T17sup.M7 Version was run with the Town of Taos Settlement Scenario, starting in year 0. Depletions were extracted for the Rio Grande mainstem segments, and tributary and Buffalo Pasture segments.

The Calibrated model was run twice for a difference calculation. The runs were:

1) A Baseline run
2) An Action run

Both runs start at predevelopment and include the calibration period. At the end of the calibration period, the model runs diverge to simulate different futures. The Baseline run keeps pumping constant into the future set equal to the pumping in the last stress period of the calibration. The Action run has the same future pumping as the Baseline run, with the addition of the Town of Taos new well pumping ramped, as shown in Figure 1. Stream package outputs from the Baseline and Action runs were subtracted to calculate the net effect of the Town of Taos Settlement Scenario.

Results from the Superposition run were compared with the difference results from the future period of the Calibrated model runs. Since the calibration period is 40 years in length, results from year 40 of the Superposition run are comparable to year 80 of the Calibrated model runs.

Model Results at 40 year

At 40 years time, the Town of Taos' diversion from the new proposed wells is simulated to be 600 AF/yr.

Calibrated Model Difference Run results:

- Depletions to Stream and RIV cells total 355 AF/yr
  - 231 AF/yr from the Rio Grande Mainstem
  - 124 AF/yr total from the Tributaries and Buffalo Pastures.
- In addition 34 AF/yr of "salvaged ET" are simulated.

Superposition Version Total Surface Water depletions calculated using the Superposition depletions total 384 AF/yr. Of this total 233 AF/yr are from the Rio Grande Mainstem, 151 AF total from Tributaries and Buffalo Pasture.

More comprehensive results are shown below. Figure 2 shows the depletions and "Salvaged ET" from the Calibrated Difference run. Figure 3 shows the depletions calculated by the Superposition version. Figure 4 compares the depletions to the tributary and Buffalo Pasture stream cells (in all reaches above the last diversions) from the Calibrated Difference run and Superposition run.

FIgure 2. Calibrated Model Simulated Depletions to Surface Water and "Salvaged ET" ("Tribs" include Buffalo Pastures)
Town of Taos Settlement Scenario

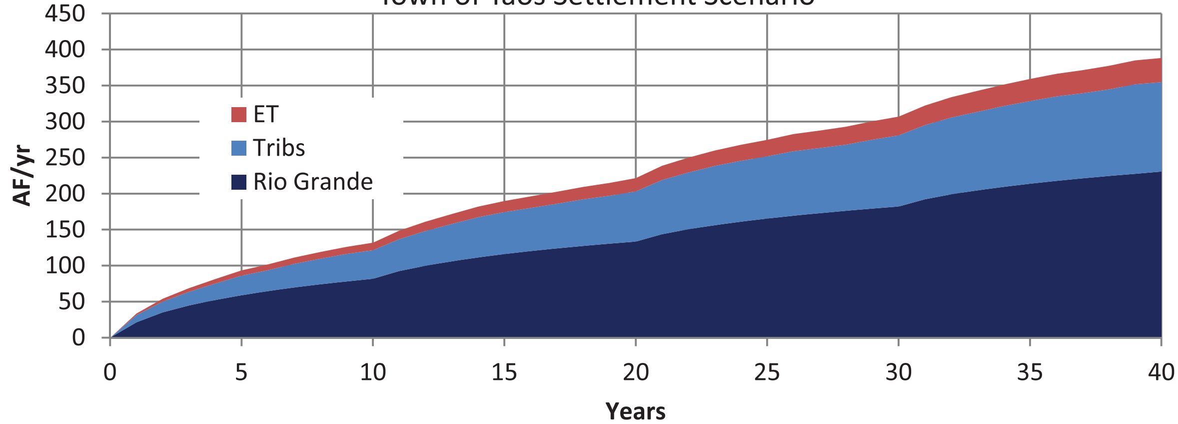
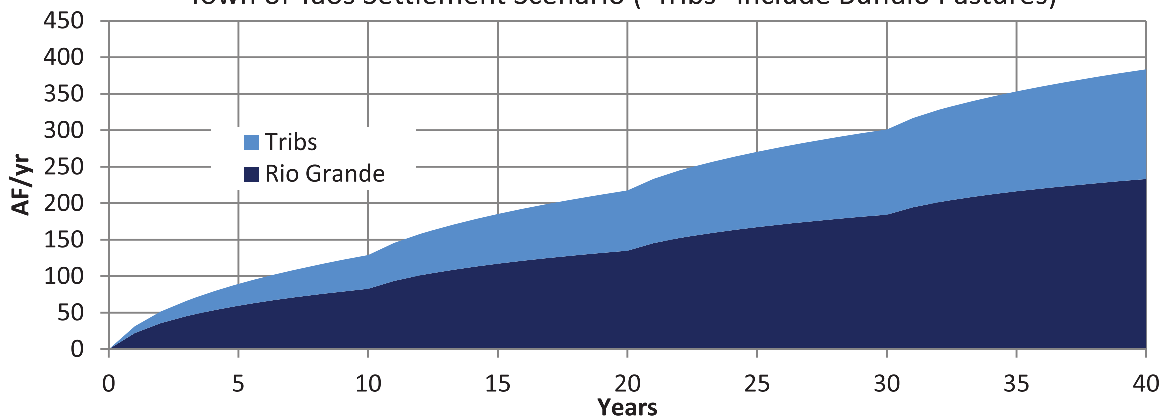
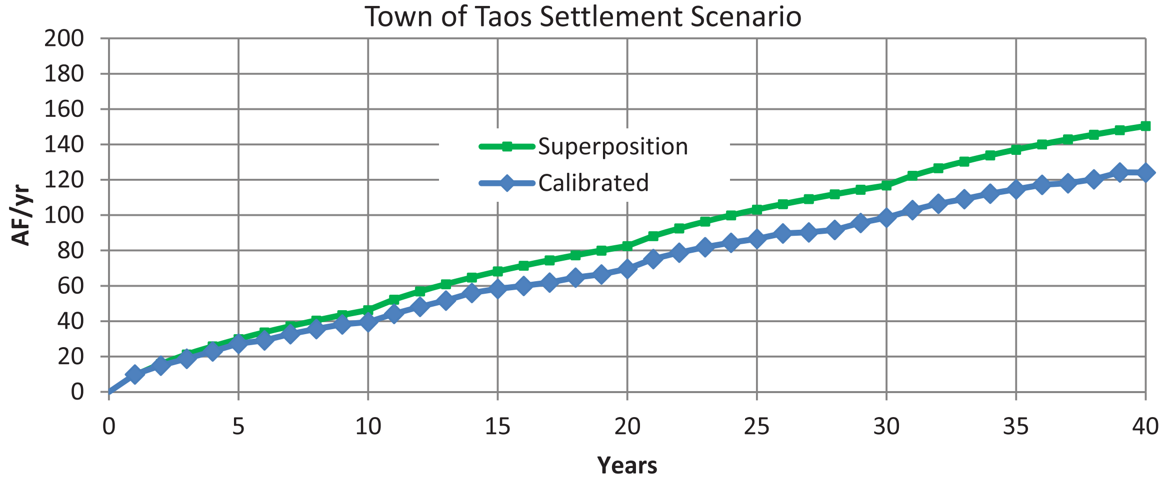


Figure 3. Superposition Version T17sup.M7 Surface Water Depletions
Town of Taos Settlement Scenario ("Tribs" include Buffalo Pastures)



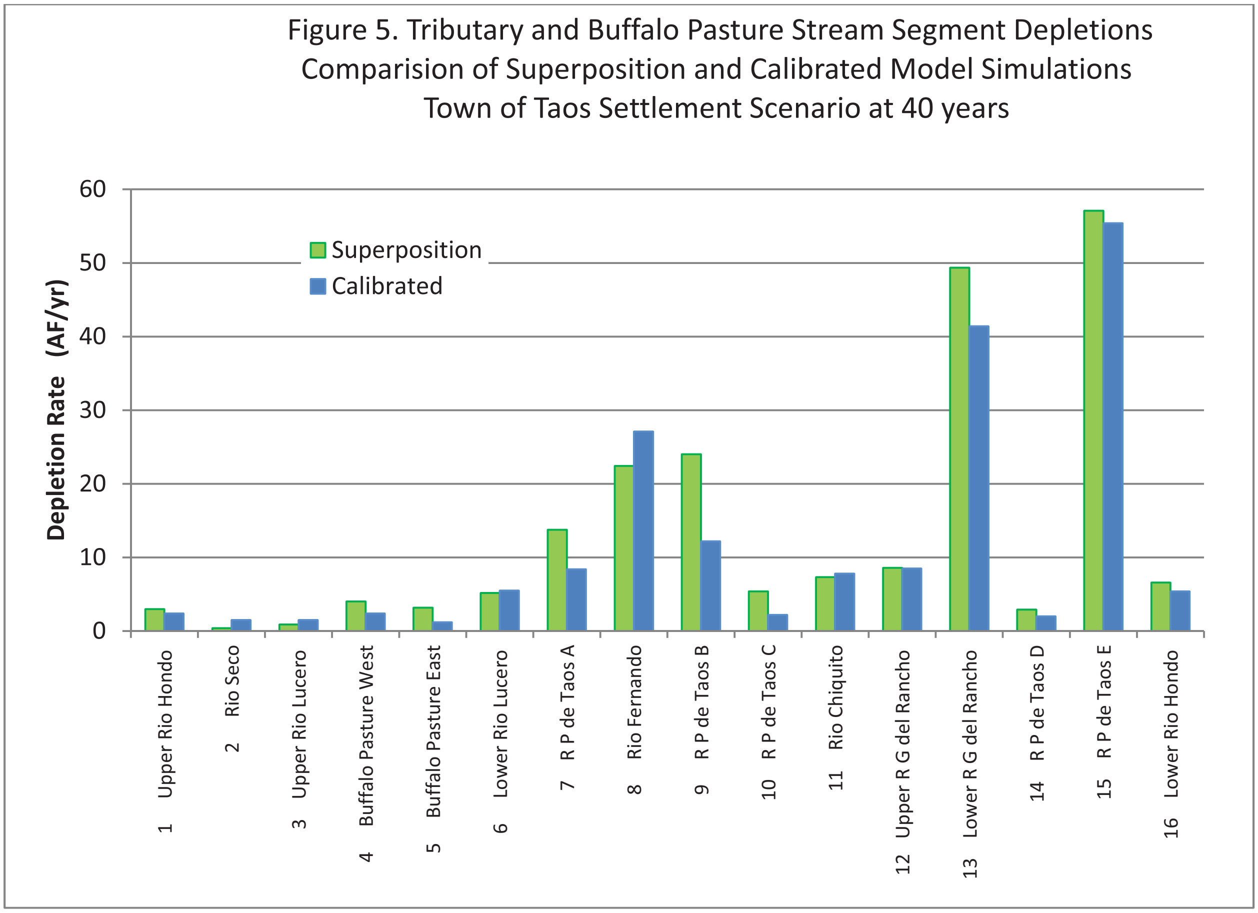
Rio Grande Mainstem depletions are almost identical between the two model versions, but tributary and Buffalo Pasture depletions are higher in the Superposition version: 26 AF/yr higher at 40 years time.

Figure 4. Tributary and Buffalo Pature Depletions.
Comparison of Superpostion and Calibrated Model Simulations
Town of Taos Settlement Scenario



The Calibrated model run, however, predicts 34 AF/yr of "Salvaged ET", which effectively dampens and reduces the tributary and Buffalo Pasture depletions simulated by the Calibrated model.

The distribution of depletions among the tributary and Buffalo Pasture stream segments by both model versions is shown below in Figure 5



Appendix C

Development of Trial Response Functions for the Taos Settlement Model, T17sup.M7 Superposition Version

Peggy Barroll, NMOSE, Hydrology Bureau

3/2012

This document describes response functions developed by OSE Staff for well sites associated with the Taos Settlement for El Prado and the Town of Taos. Response functions developed using the T17sup.M7 Superposition version of the T17 Taos groundwater model were generated, and these are compared with model runs using the fully calibrated version of the T17 model.

The development of response functions for Settlement wells was based on the locations, depths and construction described by the Taos Settlement, with additional detail provided by El Prado and the Town of Taos. Some of these wells have not yet been drilled. In actual administration, response functions must be determined by runs of the T17sup.M7 model based on the actual location, depth and construction of each well. The response functions in this report were developed for illustrative purposes only.

Each response function was generated for a 100 AF/yr stress at each well site. If a well is anticipated to produce water from more than one model layer, the 100 AF/yr was distributed among the layers as shown below in Tables 1 and 2. The layer distribution for El Prado wells is based on information provided by El Prado in 2004. The layer distribution for the Town of Taos wells was provided by DBS&A.

Table 1. Town of Taos Well Test Sites for Response Function Generation
Locations and Layer Distribution Provided by DBS&A 1/23/2012

Layer	Row	Column	Pumping Distribution by Layer	Well ID	Response Function ID
7	49	19	100%	Rio Pueblo (RP3000)	ToT-RF1r
6	57	24	3%	National Guard (Taos NG DOM)	ToT -RF2r
7	57	24	97%		
7	47	34	100%	Camino del Medio (BOR3)	ToT -RF3r
4	40	41	68%	Bataan Well	ToT -RF5
5	40	41	32%		
6	57	20	1.7%	Taos No 3 Deep –Klauer	ToT –RF6r
7	57	20	98.3%		
4	43	38	78.4%	Mitigation Well C, Rio F,	ToT –RF7
5	43	38	21.6%		

Table 2. El Prado Well Test Sites for Response Function Generation Locations and Layer Distribution based on 2004 Technical Analysis of Full Settlement					
Layer	Row	Column	Pumping Distribution by Layer	Well ID	Response Function ID
4	35	40	59.5%	El Torreon	ELP-RF1
5	35	40	40.2%		
6	35	40	0.3%		
3	27	32	20%	Las Colonias	ELP-RF2
4	27	32	80%		
6	24	15	100%	Rio Grande	ELP-RF3
5	25	21	60%	Midway	ELP-RF4
6	25	21	40%		

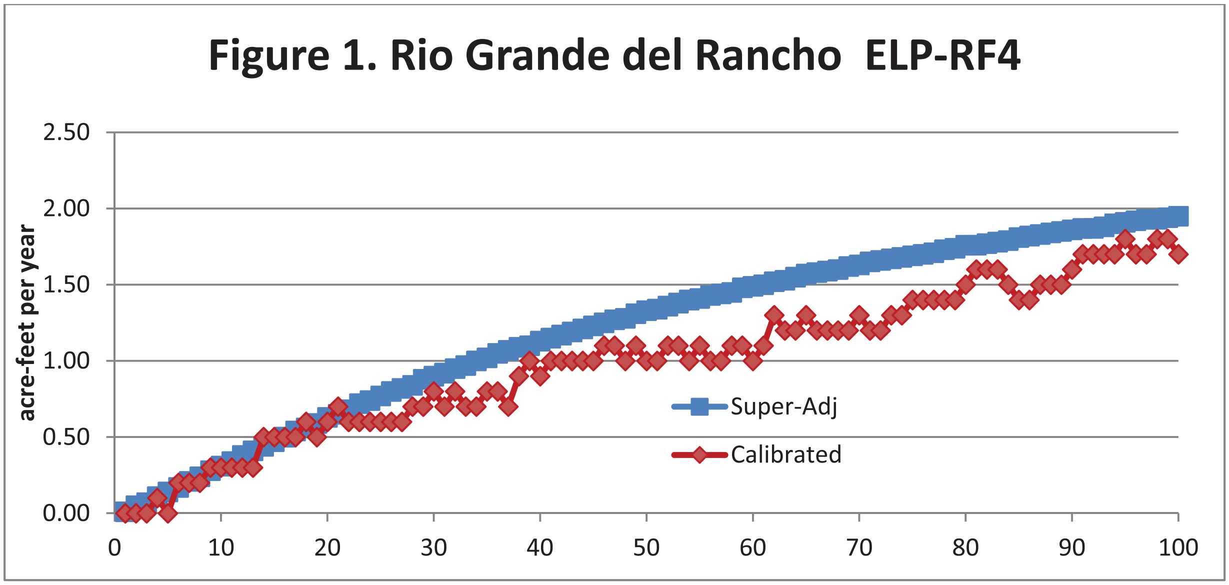
The Superposition model runs were 100 years long, with the test stress simulated as beginning at time zero, and held constant at 100 AF/yr. Depletions were extracted from the model output file for the Rio Grande mainstem and for the tributary reaches, including Buffalo Pastures.

A Baseline Run
An Action Run for each test well site.

Both calibrated model runs start with predevelopment conditions and include the calibration period. At the end of the calibration period, the model runs diverge to simulate different futures. The Baseline Run keeps pumping constant into the future, set equal to the pumping in the last stress period of the calibration. The Action Run has the same future pumping as the Baseline run, with the addition of the test well pumping at 100 AF/yr. Stream package outputs from the Baseline and Action runs were subtracted to calculate the net effect of the test well pumping.

Response Function Results:

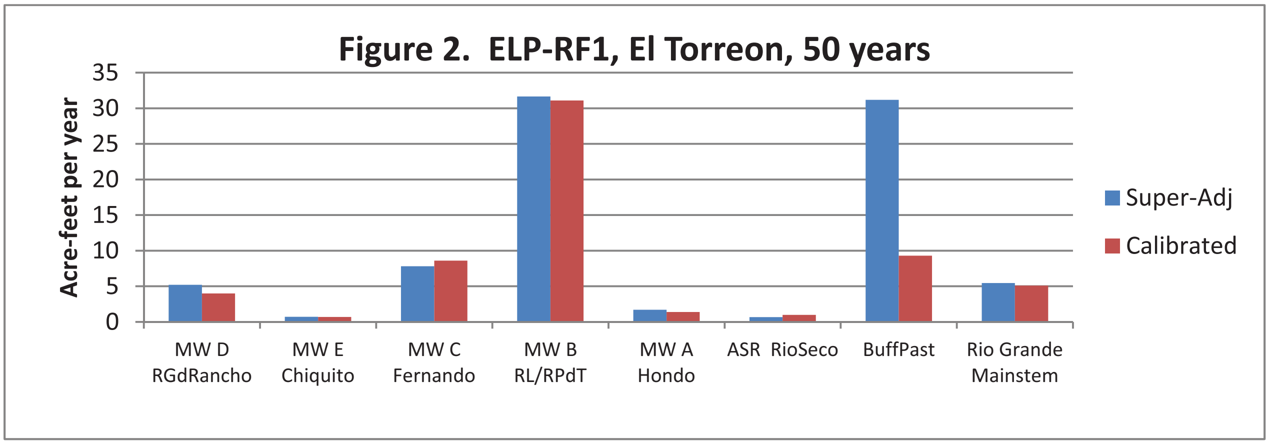
The result of these model runs is a number of curves for each test well site; one curve for each tributary reach of interested. In this case, the MODFLOW tributary segments have been lumped by Mitigation Well or Mitigation System. Figure 1, below, is a sample response function showing the effect that El Prado's Midway well has on the Rio Grande del Rancho.

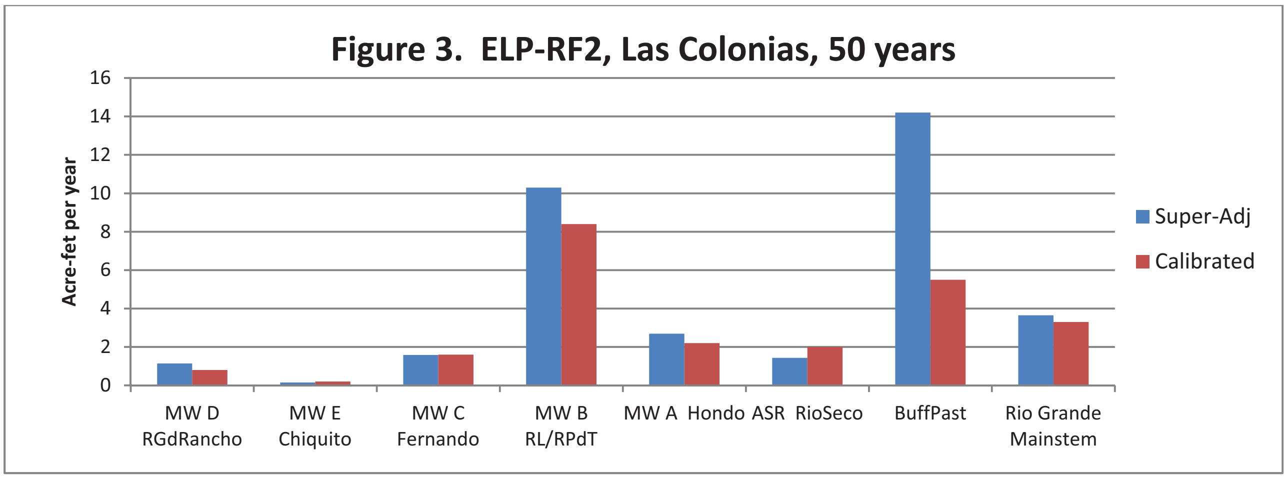


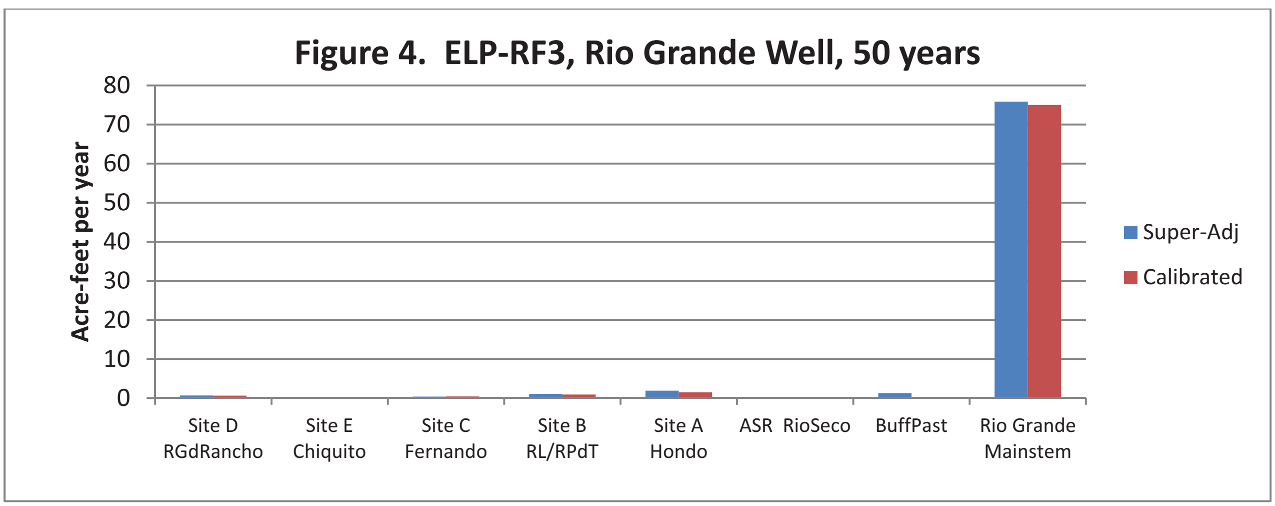
Summary of Response Function Magnitudes at 50 years.

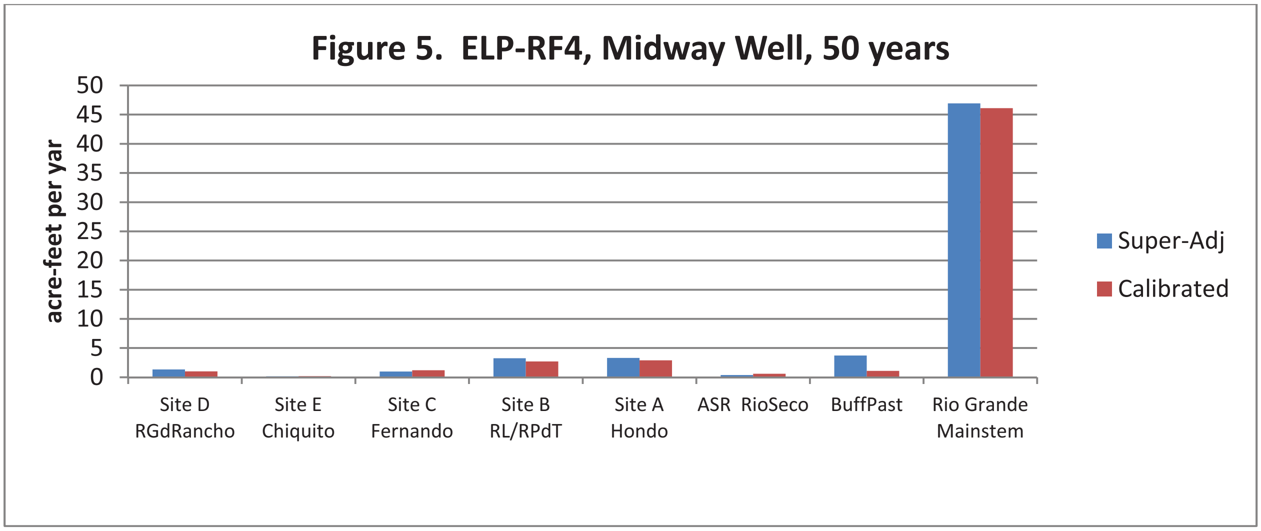
The next 4 plots show the 50 year response for each El Prado pumping site, as simulated by the Calibrated model version and the Superposition model T17sup.M7 version. Depletions have been summed by Mitigation well or Mitigation System. The results of the Superposition version have also been adjusted so that the depletions simulated to the Rio Lucero/Rio Pueblo de Taos site (B) have been reduced by 35%, and that that amount of depletion has been reassigned to the Buffalo Pastures site.

El Prado Pumping Well Sites:

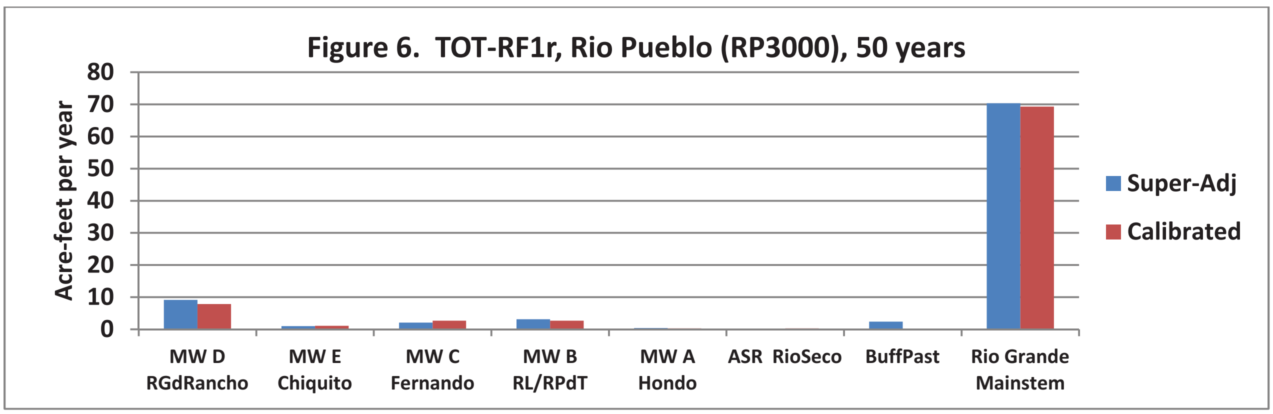


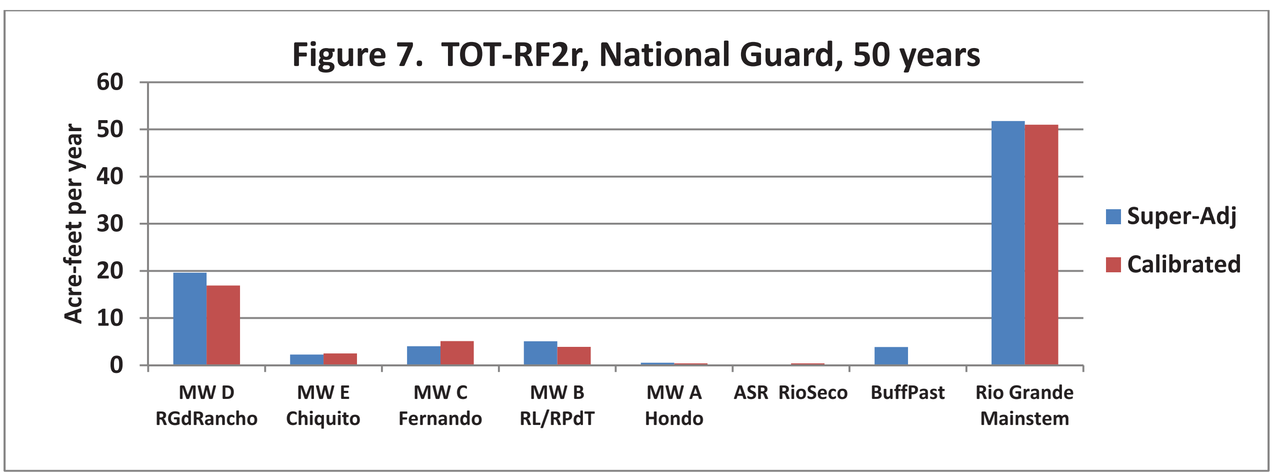






Town of Taos Well Sites





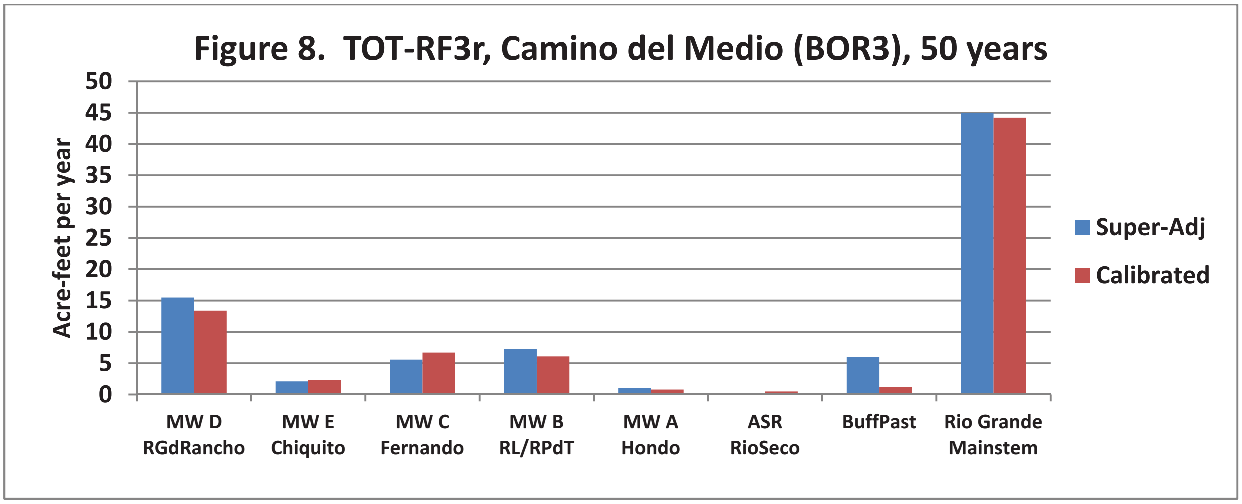


Figure 8. TOT-RF3r, Camino del Medio (BOR3), 50 years
Acre-feet per year
50
45
40
35
30
25
20
15
10
5
0
MW D RGdRancho
MW E Chiquito
MW C Fernando
MW B RL/RPdT
MW A Hondo
ASR RioSeco
BuffPast
Rio Grande Mainstem
Super-Adj
Calibrated

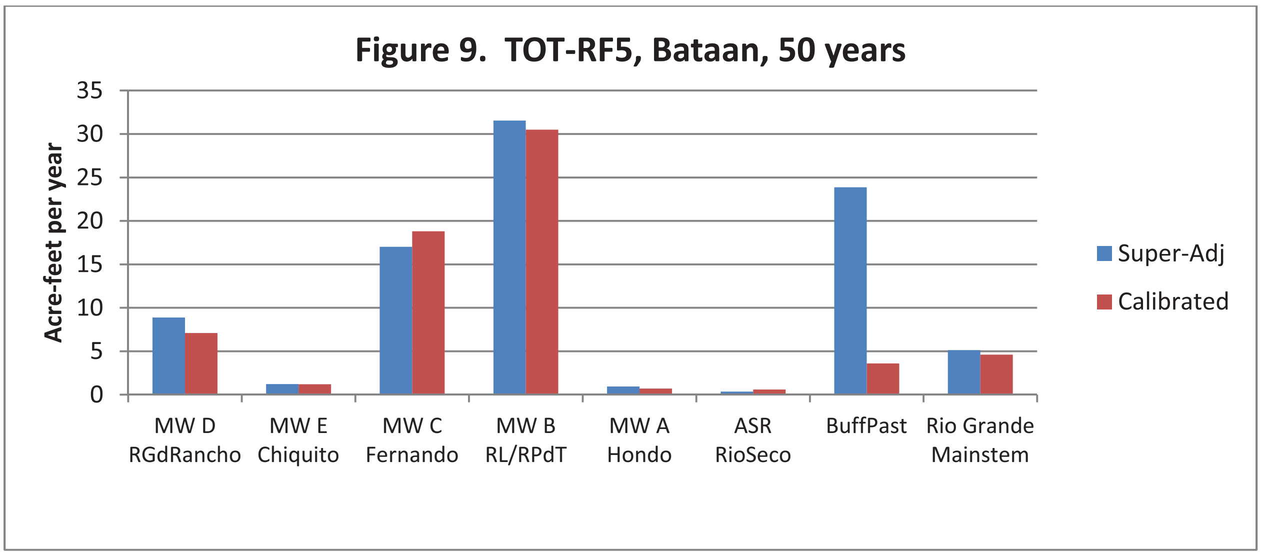


Figure 9. TOT-RF5, Bataan, 50 years
Acre-feet per year
35
30
25
20
15
10
5
0
MW D RGdRancho
MW E Chiquito
MW C Fernando
MW B RL/RPdT
MW A Hondo
ASR RioSeco
BuffPast
Rio Grande Mainstem
Super-Adj
Calibrated

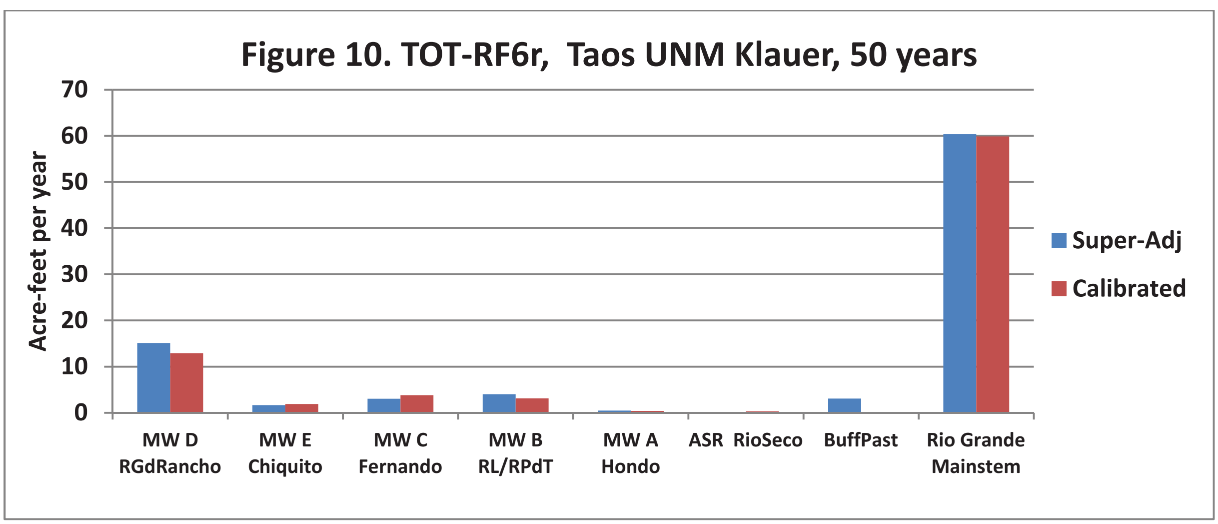
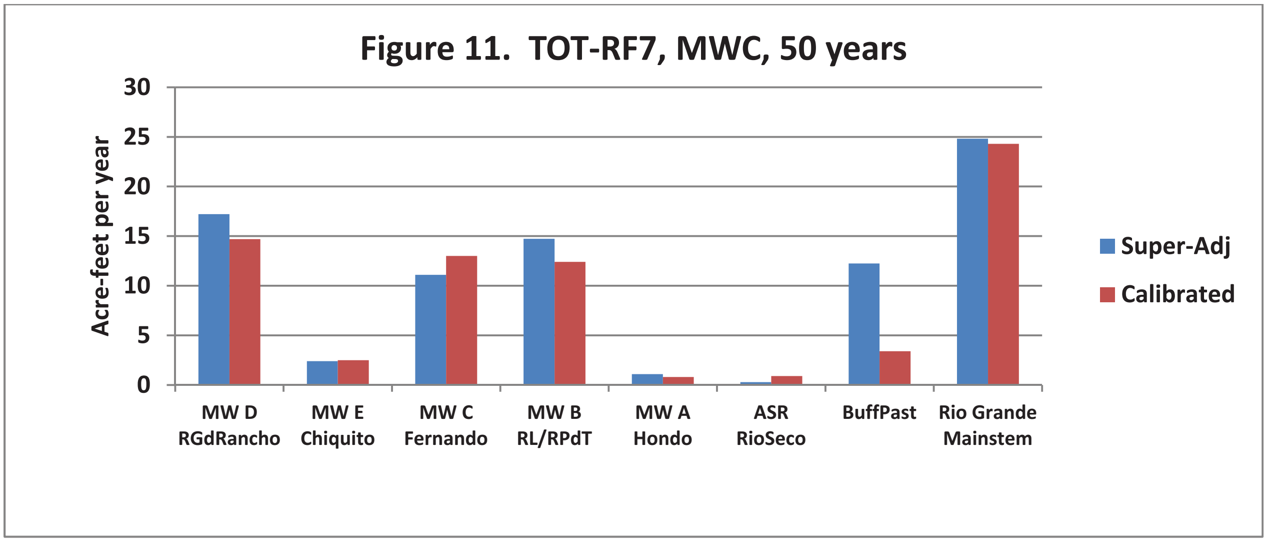
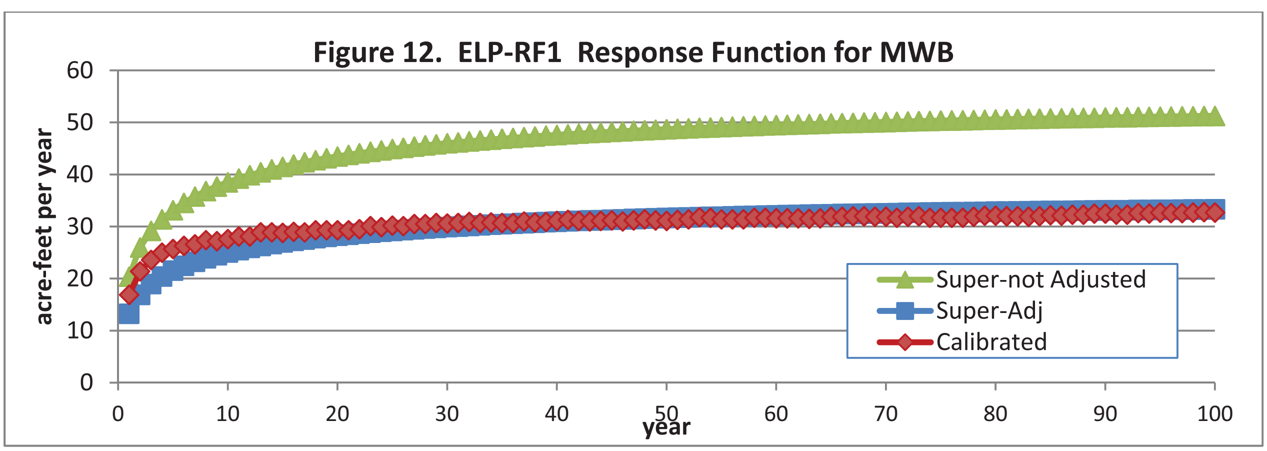


Figure 10. TOT-RF6r, Taos UNM Klauer, 50 years
Acre-feet per year
70
60
50
40
30
20
10
0
MW D RGdRancho
MW E Chiquito
MW C Fernando
MW B RL/RPdT
MW A Hondo
ASR RioSeco
BuffPast
Rio Grande Mainstem
Super-Adj
Calibrated



Each column in these plots is the 50 year point on a corresponding response function curve.

Under the reassignment procedure for Rio Lucero/Rio Pueblo de Taos depletions that is to be used administratively under the Taos Settlement, then the individual response functions for MW B and Buffalo Pasture need to be adjusted. The following figures show some examples of how this works for some of the El Prado and Town of Taos well sites. The first two charts below show the response function for the effect of pumping the El Torreon well on the Rio Pueblo de Taos/Rio Lucero system and on Buffalo Pastures. The red curve shows the calibrated model results, the green curve shows the unadjusted Superposition model results, and the blue curve is the adjusted superposition model result, in which the approximate portion of the depletion which relates to salvaged ET is reassigned from the Rio Pueblo de Taos/Rio Lucero system to Buffalo Pasture.



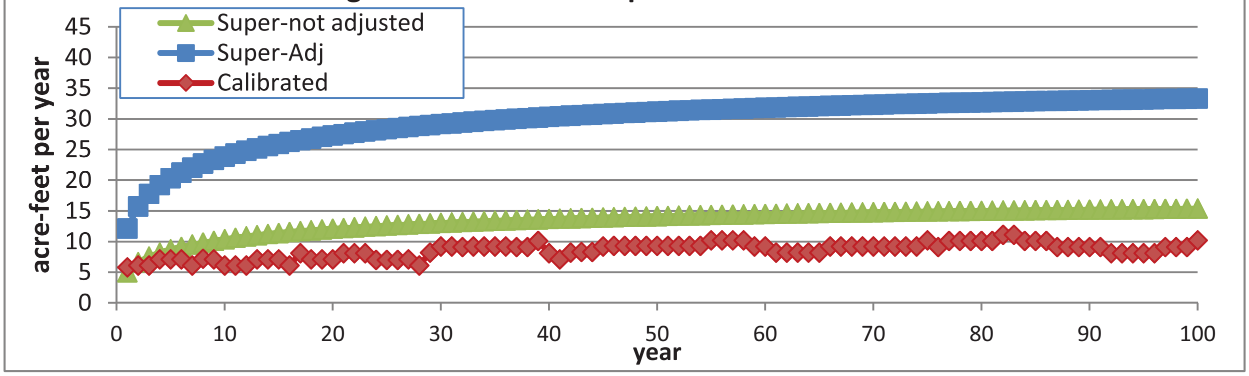


Figure 13. ELP-RF1 Response Function for BPRP

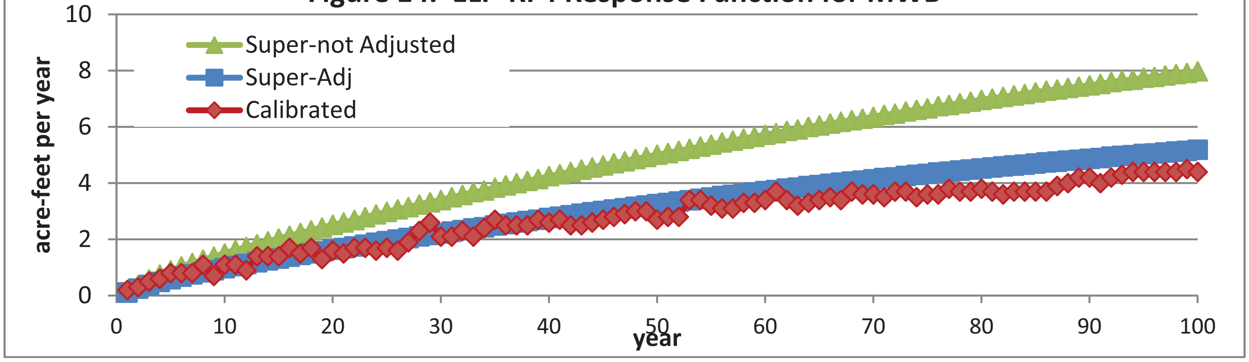


Figure 14. ELP-RF4 Response Function for MWB

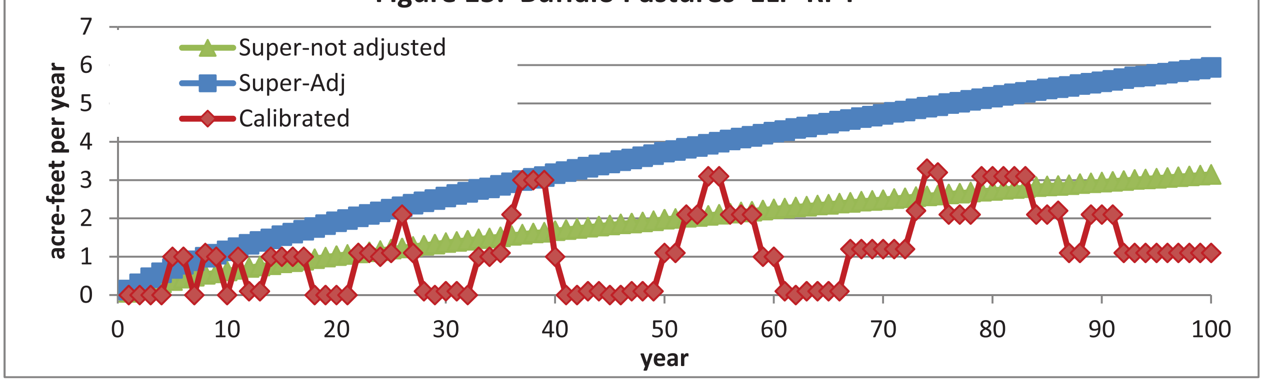


Figure 15. Buffalo Pastures ELP-RF4

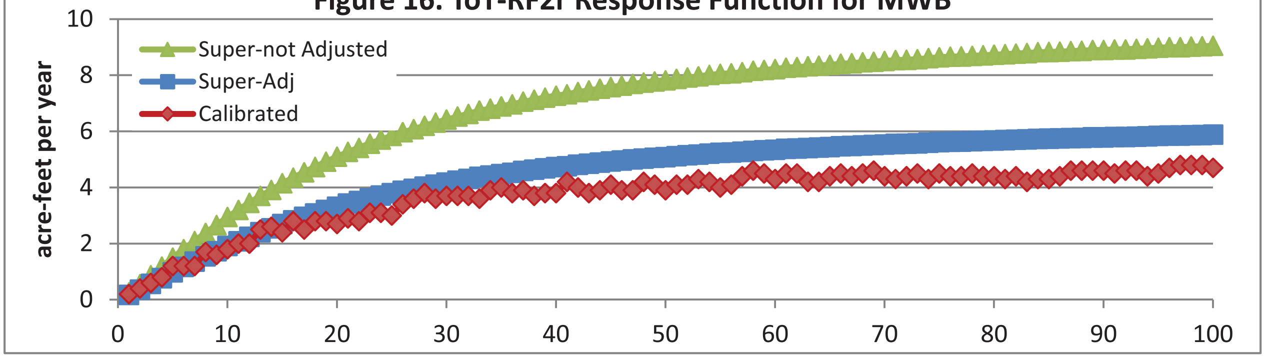


Figure 16. ToT-RF2r Response Function for MWB

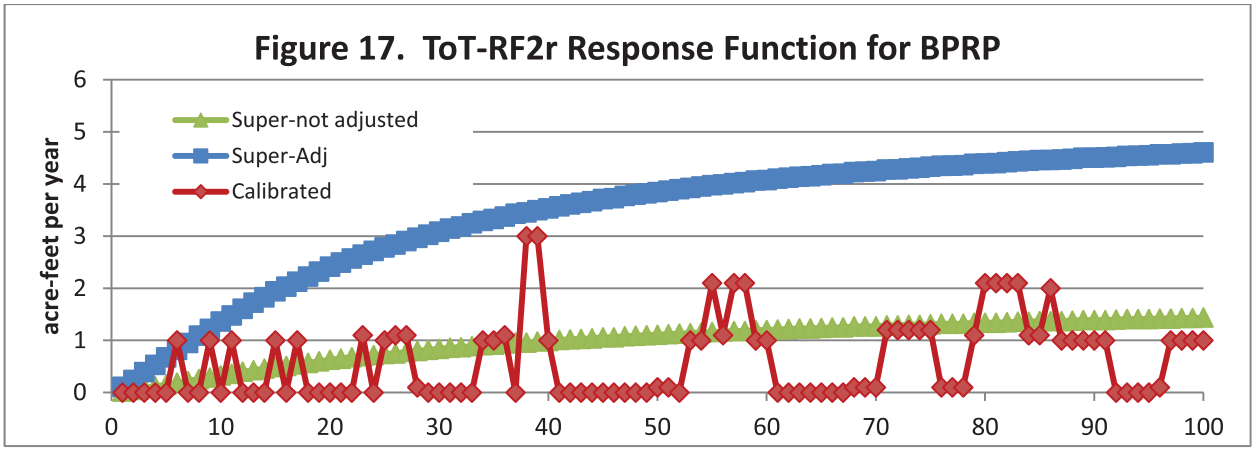


Figure 17. ToT-RF2r Response Function for BPRP
acre-feet per year
Super-not adjusted
Super-Adj
Calibrated
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70
80
90
100

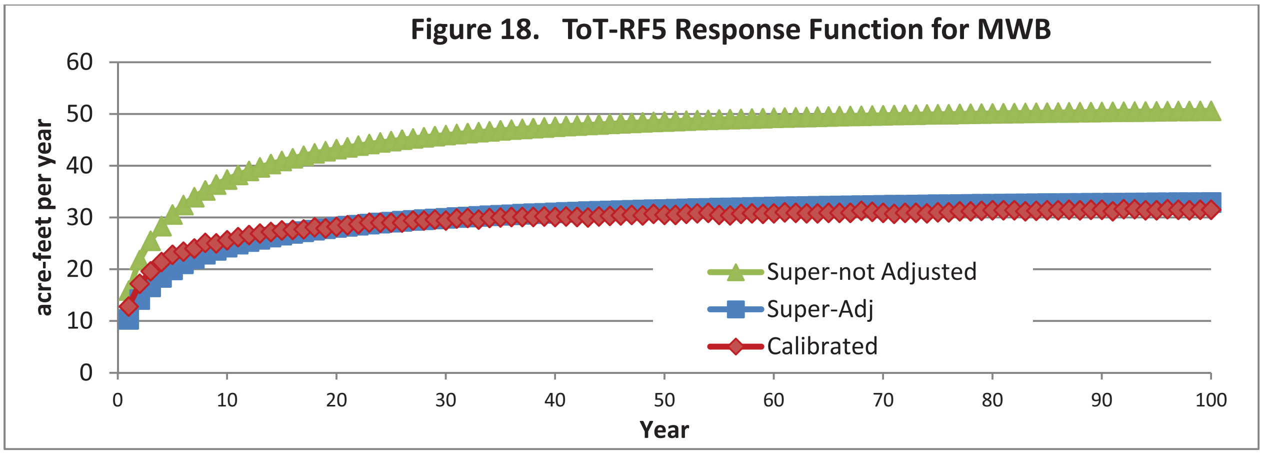


Figure 18. ToT-RF5 Response Function for MWB
acre-feet per year
Super-not Adjusted
Super-Adj
Calibrated
Year
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
90
100

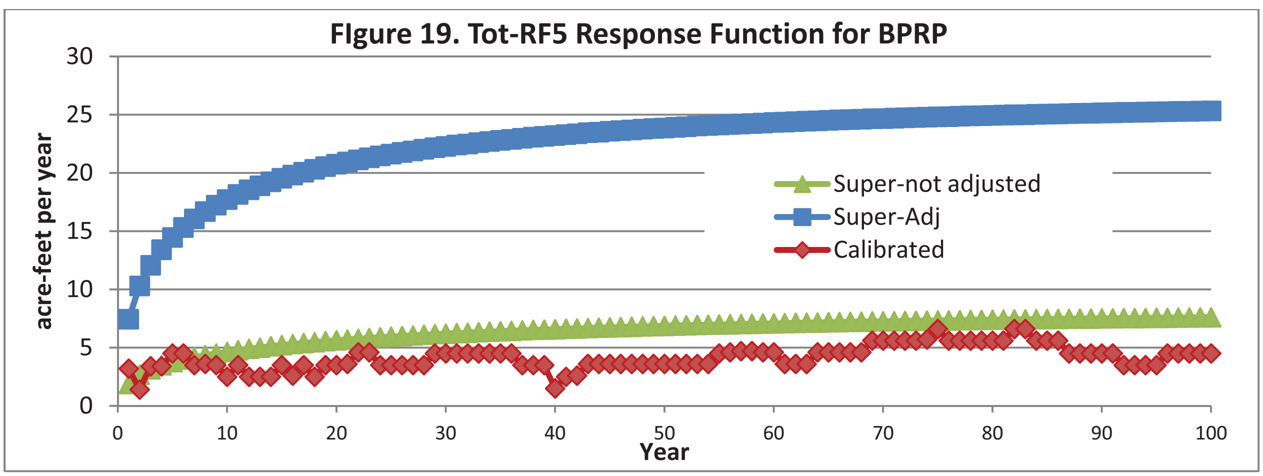


FIgure 19. Tot-RF5 Response Function for BPRP
acre-feet per year
Super-not adjusted
Super-Adj
Calibrated
Year
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100

Appendix D

Selected Input Files for T17sup.M7 Superposition Version of Taos Area Calibrated Model T17.0

1) BS6 Package
2) DIS Package
3) GHB Package
4) LPF Package

T17sup.bs6   M7 Taos Superposition Version

```
#TAOS 7/15/03 Modflow 2000

open/close  arrays/ibo1.prn   1  (60i3)   4    #ibound arrays
open/close  arrays/ibo2.prn   1  (60i3)   4
open/close  arrays/ibo3.prn   1  (60i3)   4
open/close  arrays/ibo4.prn   1  (60i3)   4
open/close  arrays/ibo5.prn   1  (60i3)   4
open/close  arrays/ibo6.prn   1  (60i3)   4
open/close  arrays/ibo6.prn   1  (60i3)   4
0.00
constant 0.0
constant 0.0
constant 0.0
constant 0.0
constant 0.0
constant 0.0
constant 0.0
```

T17sup.dis

```
#MODFLOW2000 DIS file for taos model   7 layers
         7        60        60        10         4         1         0
0  0  0  0  0  0  0  0
CONSTANT  1320.000
CONSTANT  1320.000
constant  0.0
OPEN/CLOSE arrays/supbot1.arr  1.0  (60F8.2)   3
OPEN/CLOSE arrays/supbot2.arr  1.0  (60F8.2)   3
OPEN/CLOSE arrays/supbot3.arr  1.0  (60F8.2)   3
OPEN/CLOSE arrays/supbot4.arr  1.0  (60F8.2)   3
OPEN/CLOSE arrays/supbot5.arr  1.0  (60F8.2)   3
OPEN/CLOSE arrays/supbot6.arr  1.0  (60F8.2)   3
OPEN/CLOSE arrays/supbot7.arr  1.0  (60F8.2)   3
 3652.5000        10    1.0000        TR         !first 10 years
 3652.5000        10    1.0000        TR         !10-20 years
 3652.5000        10    1.0000        TR         !20-30 years
 3652.5000        10    1.0000        TR         !30-40 years
 3652.5000        10    1.0000        TR         !40-50 years
 3652.5000        10    1.0000        TR         !50-60 years
 3652.5000        10    1.0000        TR         !60-70 years
 3652.5000        10    1.0000        TR         !70-80 years
 3652.5000        10    1.0000        TR         !80-90 years
 3652.5000        10    1.0000        TR         !90-100 years
```

T17sup.ghb M7 Taos Superposition Version

```
# M7 version GHB file representing tributaries in superposition version of Taos T17 model
       224        -1
       224                                              Mitig.#   STR Reach  Segment Name
         3         5         42          0   30000.0         1         1     Upper Rio Hondo
         3         5         41          0   30000.0         1         1     Upper Rio Hondo
         3         6         41          0   30000.0         1         1     Upper Rio Hondo
         3         6         40          0   30000.0         1         1     Upper Rio Hondo
         3         6         39          0   30000.0         1         1     Upper Rio Hondo
         3         6         38          0   30000.0         1         1     Upper Rio Hondo
         3         6         37          0   30000.0         1         1     Upper Rio Hondo
         3         6         36          0   30000.0         1         1     Upper Rio Hondo
         3         6         35          0   30000.0         1         1     Upper Rio Hondo
         3         6         34          0   30000.0         1         1     Upper Rio Hondo
         3         6         33          0   30000.0         1         1     Upper Rio Hondo
         4         6         32          0   20000.0         1         1     Upper Rio Hondo
         4         5         31          0   20000.0         1         1     Upper Rio Hondo
         4         5         30          0   20000.0         1         1     Upper Rio Hondo
         4         5         29          0   20000.0         1         1     Upper Rio Hondo
         4         4         28          0   20000.0         1         1     Upper Rio Hondo
         4         4         27          0   20000.0         1         1     Upper Rio Hondo
         4         4         26          0   20000.0         1         1     Upper Rio Hondo
         4         4         25          0   20000.0         1         1     Upper Rio Hondo
         4         5         25          0   20000.0         1         1     Upper Rio Hondo
         4         5         24          0   20000.0         1         1     Upper Rio Hondo
         4         5         23          0   20000.0         1         1     Upper Rio Hondo
         4         5         22          0   20000.0         8        16     Lower Rio Hondo
         4         5         21          0   20000.0         8        16     Lower Rio Hondo
         4         5         20          0   20000.0         8        16     Lower Rio Hondo
         4         5         19          0   20000.0         8        16     Lower Rio Hondo
         4         6         19          0   20000.0         8        16     Lower Rio Hondo
         5         6         18          0   20000.0         8        16     Lower Rio Hondo
         5         6         17          0   20000.0         8        16     Lower Rio Hondo
         5         6         11          0   20000.0         8        16     Lower Rio Hondo
         5         6         10          0   20000.0         8        16     Lower Rio Hondo
         1        10         47          0     200.0         6         2      Rio Seco
         1        10         46          0     200.0         6         2      Rio Seco
         1        10         45          0     200.0         6         2      Rio Seco
         1        10         44          0     200.0         6         2      Rio Seco
         1        10         43          0     200.0         6         2      Rio Seco
         1        10         42          0     200.0         6         2      Rio Seco
         1        11         41          0     200.0         6         2      Rio Seco
         1        11         40          0     200.0         6         2      Rio Seco
         1        12         39          0     200.0         6         2      Rio Seco
         1        12         38          0     200.0         6         2      Rio Seco
         3        16         35          0     200.0         6         2      Rio Seco
         3        17         35          0     100.0         6         2      Rio Seco
         1        29         42          0    3000.0         7         3      Upper Rio Lucero
         1        31         42          0  500000.0         7         4      Buffalo Pastures West
         1        31         41          0  500000.0         7         4      Buffalo Pastures West
         1        32         42          0   10000.0         7         4      Buffalo Pastures West
         1        32         41          0   10000.0         7         4      Buffalo Pastures West
         1        33         42          0   10000.0         7         4      Buffalo Pastures West
         1        31         43          0  500000.0         7         5      Buffalo Pastures East
         1        32         44          0  500000.0         7         5      Buffalo Pastures East
         1        32         43          0   10000.0         7         5      Buffalo Pastures East
         1        33         44          0  500000.0         7         5      Buffalo Pastures East
         1        33         43          0   10000.0         7         5      Buffalo Pastures East
         1        34         43          0   10000.0         7         5      Buffalo Pastures East
         1        34         42          0   10000.0         2         6       Lower Rio Lucero
         1        35         41          0   50000.0         2         6       Lower Rio Lucero
         1        36         40          0   50000.0         2         6       Lower Rio Lucero
         1        36         39          0   50000.0         2         6       Lower Rio Lucero
         1        32         49          0   50000.0         2         7      Rio Pueblo de Taos A
```

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1	32	48	0	50000.0	2	7	Rio Pueblo de Taos A
1	32	47	0	50000.0	2	7	Rio Pueblo de Taos A
1	32	46	0	50000.0	2	7	Rio Pueblo de Taos A
1	33	45	0	50000.0	2	7	Rio Pueblo de Taos A
1	34	44	0	20000.0	2	7	Rio Pueblo de Taos A
1	35	43	0	20000.0	2	7	Rio Pueblo de Taos A
1	36	42	0	20000.0	2	7	Rio Pueblo de Taos A
1	37	42	0	20000.0	2	7	Rio Pueblo de Taos A
1	37	41	0	20000.0	2	7	Rio Pueblo de Taos A
1	37	40	0	20000.0	2	7	Rio Pueblo de Taos A
1	49	44	0	1000.0	3	8	Rio Fernando
1	44	40	0	1000.0	3	8	Rio Fernando
1	43	39	0	1000.0	3	8	Rio Fernando
1	43	38	0	1000.0	3	8	Rio Fernando
1	43	37	0	1000.0	3	8	Rio Fernando
3	43	36	0	1000.0	3	8	Rio Fernando
3	43	35	0	1000.0	3	8	Rio Fernando
3	44	34	0	1000.0	3	8	Rio Fernando
3	44	33	0	1000.0	3	8	Rio Fernando
3	44	32	0	1000.0	3	8	Rio Fernando
3	45	32	0	1000.0	3	8	Rio Fernando
3	45	31	0	1000.0	3	8	Rio Fernando
1	37	39	0	20000.0	2	9	Rio Pueblo de Taos B
1	37	38	0	20000.0	2	9	Rio Pueblo de Taos B
1	38	38	0	20000.0	2	9	Rio Pueblo de Taos B
1	38	37	0	20000.0	2	9	Rio Pueblo de Taos B
1	39	37	0	20000.0	2	9	Rio Pueblo de Taos B
1	39	36	0	20000.0	2	9	Rio Pueblo de Taos B
3	40	35	0	20000.0	2	9	Rio Pueblo de Taos B
3	41	34	0	20000.0	2	9	Rio Pueblo de Taos B
3	42	34	0	20000.0	2	9	Rio Pueblo de Taos B
3	42	33	0	20000.0	2	9	Rio Pueblo de Taos B
3	43	32	0	20000.0	2	9	Rio Pueblo de Taos B
3	43	31	0	20000.0	2	9	Rio Pueblo de Taos B
3	44	31	0	20000.0	2	10	Rio Pueblo de Taos C
3	43	30	0	20000.0	2	10	Rio Pueblo de Taos C
3	44	30	0	20000.0	2	10	Rio Pueblo de Taos C
3	44	29	0	20000.0	2	10	Rio Pueblo de Taos C
3	45	28	0	20000.0	2	10	Rio Pueblo de Taos C
3	60	35	0	30000.0	5	11	Rio Chiquito
3	59	34	0	30000.0	5	11	Rio Chiquito
3	58	33	0	30000.0	5	11	Rio Chiquito
3	60	34	0	30000.0	4	12	Upper Rio Grande del Rancho
3	60	33	0	30000.0	4	12	Upper Rio Grande del Rancho
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3	51	30	0	20000.0	4	13	Lower Rio Grande del Rancho
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3	50	29	0	20000.0	4	13	Lower Rio Grande del Rancho
3	50	28	0	20000.0	4	13	Lower Rio Grande del Rancho
3	49	27	0	20000.0	4	13	Lower Rio Grande del Rancho
3	48	27	0	20000.0	4	13	Lower Rio Grande del Rancho
3	47	27	0	20000.0	4	13	Lower Rio Grande del Rancho
3	46	27	0	20000.0	2	14	Rio Pueblo de Taos D
3	46	26	0	20000.0	2	14	Rio Pueblo de Taos D

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3	46	25	0	20000.0	2	14	Rio Pueblo de Taos D
3	46	24	0	20000.0	2	14	Rio Pueblo de Taos D
4	46	23	0	20000.0	2	14	Rio Pueblo de Taos D
4	46	22	0	20000.0	8	15	Rio Pueblo de Taos E
4	47	22	0	20000.0	8	15	Rio Pueblo de Taos E
4	47	21	0	20000.0	8	15	Rio Pueblo de Taos E
4	48	20	0	20000.0	8	15	Rio Pueblo de Taos E
4	48	19	0	20000.0	8	15	Rio Pueblo de Taos E
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5	59	6	0	20000.0	8	15	Rio Pueblo de Taos E
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5	2	11	0	550000.0	8	20	Rio Grande
5	3	11	0	550000.0	8	20	Rio Grande
5	4	10	0	550000.0	8	20	Rio Grande
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6	22	4	0	550000.0	8	20	Rio Grande
6	23	4	0	550000.0	8	20	Rio Grande
6	23	5	0	550000.0	8	20	Rio Grande
6	24	5	0	550000.0	8	20	Rio Grande
6	25	5	0	550000.0	8	20	Rio Grande
6	26	5	0	550000.0	8	20	Rio Grande
6	27	5	0	550000.0	8	20	Rio Grande
6	28	5	0	550000.0	8	20	Rio Grande

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6	29	5	0	550000.0	8	20	Rio Grande
6	30	5	0	550000.0	8	20	Rio Grande
6	31	5	0	550000.0	8	20	Rio Grande
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-1							
-1							
-1							
-1							
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-1							
-1							
-1							
-1							
-1							

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  0  0  0  0  0  0  0               harmonic mean
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  1  1  1  1  1  1  1          LAYVKA  vert anisotropy = Kv/Kh (not
vcont)
  0  0  0  0  0  0  0        laywet: no rewetting
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T1b     HK       1.0       1
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T1c     HK       10.0      1
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T1f     HK       5.0       1
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T6c     HK       0.2      1
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T7c     HK       0.2     1
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T7d     HK       0.5     1
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T7e     HK       0.1     1
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aniv3s   VANI    100.    1
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aniv4   VANI    500.     1
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aniv4s   VANI    400.    1
  4     NONE    anz3     3
aniv5   VANI    1400.    1
  5     NONE    anz6     1    2    4
aniv5nb  VANI   400.     1
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aniv6   VANI    300.     1
  6     NONE    anz6     1    4
aniv6a  VANI    400.     1
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aniv6nb  VANI  100.      1
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3       SMULT3    S3ZONE   3
4       SMULT4    S4ZONE   4
5       SMULT5    S5ZONE   5
6       SMULT6    S6ZONE   6
SSconf   SS     2E-6   6
2       NONE     ALL
3       NONE     S3ZONE     1
4       NONE     S4ZONE     3  1
5       NONE     S5ZONE     4  3  1
6       NONE     S6ZONE     5  4  3  1
7       NONE     ALL
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 3           only print codes - Horiz anisotropy
 3           only print codes -  Kh/Kv
 0           only print codes -  Ss
 3           only print codes - Ks                 LAYER 2
 3           only print codes - Horiz anisotropy
 3           only print codes -  Kh/Kv
 0           only print codes -  Ss
 3           only print codes - Ks                 LAYER 3
 3           only print codes - Horiz anisotropy
 3           only print codes -  Kh/Kv
 0           only print codes -  Ss
 3           only print codes - Ks                 LAYER 4
 3           only print codes - Horiz anisotropy
 3           only print codes -  Kh/Kv
 0           only print codes -  Ss
 3           only print codes - Ks                 LAYER 5
 3           only print codes - Horiz anisotropy
 3           only print codes -  Kh/Kv
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 0           only print codes -  Ss
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 3           only print codes - Horiz anisotropy
 3           only print codes -  Kh/Kv
 0           only print codes -  Ss
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Appendix E

Treatment of Tributary Depletions, Buffalo Pasture Depletions, and Rio Grande Depletions under the Taos Settlement Agreement

The Settlement Agreement provides for different approaches to offset the three types of surface water depletions projected to result from future groundwater diversions of the Parties.

1. Tributary Depletions will occur on the streams of the Taos Valley which are relied upon by the Pueblo and Acequias. The Mitigation Well system will help to reduce the need for the acquisition and retirement of water rights from the Acequias and, as stated in Section 3.5.1 of the Settlement Agreement, the Parties recognize the mutual benefits to be achieved by use of the Mitigation Well System.
2. The Buffalo Pasture, an important Pueblo cultural resource, will experience depletions from groundwater pumping. As stated in Section 7.3.1 of the Settlement Agreement, "due to the nature of the Buffalo Pasture, existing State Engineer permitting requirements cannot offset effectively the Buffalo Pasture Depletions" and further "the Mitigation Well System is neither designed nor intended to deliver waters to the Buffalo Pasture". The Buffalo Pasture Recharge Project will provide a means of protecting this cultural resource.
3. Depletions on the Rio Grande can be offset, at least in part, by San Juan Chama Project Water provided for in the Settlement. SJCP contracts are characterized as a consideration for actions by the Parties. Mainstem offsets (including new and prior SJCP contracts, retirement of Rio Grande water rights, or discharge of return flows) are the preferred means of offset because they do not reduce availability or use of water in the Taos Valley.

One effect of allowing the Parties to mitigate Tributary Depletions by Mitigation Wells and Buffalo Pasture Depletions by the Buffalo Pasture Recharge Project is to shift the offset requirements on tributaries and the pasture to the Rio Grande. In addition, a portion of certain Tributary Depletions can be reassigned to the Buffalo Pasture for mitigation there. Whether by Mitigation Wells or the Recharge Project, this has the practical effect of shifting the depletions and the offset requirements to the Rio Grande. In addition, there are Rio Grande impacts from the operation of the mitigation projects themselves that also must be offset. The result is several components of Rio Grande offsets.

1) Offsets for the depletions from future diversions that occur directly on the Rio Grande and on the Lower Rio Hondo and Rio Pueblo de Taos E, as calculated by the Settlement Model (Article 7.3.2.1).
2) Offsets for the Tributary Depletions that are calculated by the Settlement Model, but then shifted to the Rio Grande (Article 7.3.2.2) if the Tributary Depletions are offset by the Mitigation Wells.
3) Offsets for the Depletions to Buffalo Pasture that are calculated by the Settlement Model, but then shifted to the Rio Grande (Article 7.3.2.2) if the Depletions to the Buffalo Pasture are offset by the Buffalo Pasture Recharge Project.
4) Offsets for the Depletions to Buffalo Pasture that result when a portion of the Tributary Depletions on Rio Lucero and Rio Pueblo de Taos are reassigned to the Buffalo Pasture if the reassigned Depletions to the Buffalo Pasture are then offset by the Buffalo Pasture Recharge Project.

5) Extra offsets for those depletions that result from the operation of the Mitigation Wells (equal to an additional 33% of a party's share of Mitigation pumping, see Article 7.3.3.1.12) and Buffalo Pasture Recharge Project (equal to an additional 11.1% of its portion of Buffalo Pasture Depletions that is offset by the Buffalo Pasture Recharge Project, see 7.3.1.4).

In effect, item 5 means that a party must provide offsets on the Rio Grande equal to 133% of its Mitigation Well pumping and 111% of its Buffalo Pasture depletions. For Rio Pueblo de Taos and Rio Lucero the Mitigation Well pumping is required to mitigate 65% of the Tributary Depletion and the Buffalo Pasture Recharge Project provides the remaining 35%. This is in addition to offsets for the direct depletions on the Rio Grande, Lower Rio Hondo and Rio Pueblo de Taos E.

The discussion below aims to illustrate how offsets are shifted to the Rio Grande by means of the mitigation projects. They reflect hypothetical scenarios that do not define or restrict how any Party will actually develop and implement their water rights and pumping scenarios. The results discussed below have not been adopted for administrative purposes and no example should be considered binding on any party. Calculations of actual depletions and corresponding offset requirements will be conducted at such time as permit applications are subject to administrative review.

<u>Calculations of depletions</u>

The calibrated version of the settlement model produces a water balance in which the amount of water pumped in a future diversion is balanced by a combination of three sources: lowering of the water table (reduction of water in storage), reduction in streamflow (less groundwater seeping to streams or discharging at springs), and reduction in water lost through evapotranspiration or ET (wetlands shrink).

In the superposition version of the model, the reduction in streamflow and the reduction in ET are effectively combined into a single water depletion quantity. The table below illustrates the difference between the two models. The illustration is provided for EPWSD and the Town of Taos because model runs have been made specific to a ramped up pumping schedule for these parties; future diversions by the Pueblo will have similar impacts but these have not been simulated as part of a particular scenario. The illustration is provided for Rio Lucero and Rio Pueblo de Taos because these are the streams where depletions can be reassigned to the Buffalo Pasture. The illustration is provided for Rio Hondo as just one example of the many other tributaries. All quantities below are in acre-feet per year.

Table 1. Difference in Tributary Depletions Calculated by Calibrated and Superposition Versions of Taos Groundwater Model for hypothetical pumping scenarios

Entity that pumps	Tributary	Calibrated Model Tributary Depletion	Superposition Model Tributary Depletion	Difference
EPWSD	Rio Hondo	3.5	4.4	0.9
EPWSD	Rio Pueblo de Taos and Rio Lucero	24.6	39.3	14.7
Town	Rio Hondo	2.4	3.0	0.6
Town	Rio Pueblo de Taos and Rio Lucero	31.8	52.2	20.4

Note on table. These model results are presented for illustrative purposes and for such purposes assume pumping as described in Attachment 3, Part II, Appendix A, in which the El Prado's future diversions in 40 years reach 288 AFY; and in Attachment 3, Part II, Appendix B, in which the Town of Taos's future diversions in 40 years reach 528 AFY. The increased depletion number in the last column above is approximately the amount of ET salvage calculated in the calibrated model. Note that in addition to the effects above, for this example the Superposition model simulates 82.6 AFY of direct impacts to the Rio Grande for EPWSD, and 169.4 AFY for the Town, both of which would need to be offset.

Effect of providing tributary offsets using mitigation wells

Tributary Depletions decrease the supply of water available to acequias and the amount of non-irrigation season flows to the Rio Grande. Offset of Tributary Depletions can be shifted to the Rio Grande, provided that the lost supply to the acequias is provided through mitigation well pumping. Pumping of mitigation wells will cause additional depletions on the Rio Grande. The Settlement Agreement specifies these depletions will be calculated as 33% of Mitigation well pumping. The table below illustrates the offsets that result if all Tributary Depletions are made up by mitigation wells (no transfer of water rights). These offsets are in addition to the offsets to the direct Rio Grande depletions quantified in the note to Table 1.

Table 2. Rio Grande Offsets required for Tributary Depletions and Mitigation Well Pumping for hypothetical pumping scenarios

Entity that pumps	Tributary	Mitigation Well	Tributary depletions shifted to Rio Grande	33% additional mitigation-related offset required on Rio Grande	Total Rio Grande offset requirement (sum of 2 columns to left)
EPWSD	Rio Hondo	Well A	4.4	1.4	5.8
EPWSD	Rio Pueblo de Taos and Rio Lucero	Well B	39.3	13.0	52.3
Town	Rio Hondo	Well A	3.0	1.0	4.0
Town	Rio Pueblo de Taos and Rio Lucero	Well B	52.2	17.2	69.5

Note on table. For the Rio Pueblo de Taos and Rio Lucero, there is a further adjustment discussed below, e.g. assignment of some of the Tributary Depletions to the Buffalo Pasture.

Effects of providing direct Buffalo Pasture offsets through the Buffalo Pasture Recharge Project

Response functions provided in Attachment 3, Part II, Appendix C, have been developed to show the amount of Buffalo Pasture depletions that are the direct result of future groundwater diversions. The agreement provides that the Pueblo will offset these impacts through the Buffalo Pasture Recharge Project, and that the Project itself will cause an additional depletion of the Rio Grande equal to 11.1% of the depletions thus offset. Use of the Buffalo Pasture Recharge Project for mitigation effectively shifts the Buffalo Pasture depletions to the Rio Grande. Each party is responsible for providing the Rio Grande offsets that equal their depletions on the Buffalo Pasture, plus an additional 11.1% that results from operation of the Buffalo Pasture Recharge Project. For the scenarios used in Tables 1 and 2, those requirements are as follows.

Table 3. Rio Grande offsets required for Buffalo Pasture Depletions for hypothetical pumping scenarios					
Entity that pumps	Tributary	Calculated depletion of Buffalo Pasture	Buffalo Pasture depletions shifted to Rio Grande	11.1% additional mitigation-related offset required on Rio Grande	Total Rio Grande offset requirement (sum of 2 columns to left)
EPWSD	Rio Pueblo de Taos and Rio Lucero	14.8	14.8	1.6	16.4
Town	Rio Pueblo de Taos and Rio Lucero	7.2	7.2	0.8	8.0

Note on table. This assumes the Buffalo Pasture Recharge Project is successful.

Effects of providing tributary offsets through the Buffalo Pasture Recharge Project

Under the administrative system established by the Abeyta Settlement Agreement, the stream depletions on the Rio Lucero and Rio Pueblo de Taos would be treated differently, compared to all other tributaries. For the latter (Rio Hondo, Arroyo Seco, Rio Fernando, Rio Chiquito, Rio Grande del Rancho), mitigation-related offsets on the Rio Grande would still be equal to the shift of 100% of the depletions plus the extra 33% related to operation of the Mitigation Wells.

For depletions calculated on the Rio Lucero and Rio Pueblo de Taos, there would be reassignment of 35% of such depletions to the Buffalo Pasture. These reassigned depletions then become Buffalo Pasture Depletions which would be mitigated by the Buffalo Pasture Recharge Project. The remaining 65% of the depletions on Rio Lucero and Rio Pueblo de Taos would need to be made up by the Mitigation Wells, and the Mitigation Well pumping would still be subject to a mitigation-related offset requirement of 33% on the Rio Grande. The Party responsible for the reassigned impact would have an obligation to provide Rio Grande mitigation-related offsets equal to 11.1% of that reassigned depletions. The table below illustrates the effect of reassignment.

Table 4. Rio Grande Mitigation Offsets Required as Calculated by Superposition Model Version with Reassignment of 35% of Depletions for Rio Pueblo de Taos and Rio Lucero, for hypothetical pumping scenarios						
Entity that pumps	Stream	Table 2 Total Tributary Depletion	Table 2 Depletion reassigned to Buffalo Pasture (35%)	Revised Rio Grande Mitigation-related offset after reassignment	New Rio Grande offset required due to Buffalo Pasture Recharge Project	Total Rio Grande offset (Shifted Tributary and Buffalo Pasture depletions plus Mitigation-related offset terms)
EPWSD	Rio Pueblo de Taos/Rio Lucero (Mitigation Well B)	39.3 (original) 25.5 (after reassignment)	13.8	8.5 (33% of 25.5)	1.5 (11.1% of 13.8 AFY)	(=25.5+8.5+13.8+1.5) 49.3
Town	Rio Pueblo de Taos/Rio Lucero (Mitigation Well B)	52.2 (original) 33.9 (after reassignment)	18.3	11.2 (33% of 33.9)	2.0 (11.1% of 18.3 AFY)	(=33.9+11.2+18.3+2.0) 65.4

Summary of shifts and reassignments

Table 5 shows all components of the total Rio Grande offsets required for Tributary Depletions and Buffalo Pasture Depletions, assuming 35% of Rio Lucero and Rio Pueblo de Taos Tributary Depletions are reassigned to the Buffalo Pasture, that the remaining 65% of Rio Lucero and Rio Pueblo de Taos Tributary Depletions are mitigated by the Mitigation Wells, and 100% of depletions on all other tributaries are mitigated by Mitigation Wells.

Table 5. Tributary and Buffalo Pasture Depletions, Reassignment, and Mitigation-Related Offsets for hypothetical pumping scenarios

Entity that pumps	Stream	Rio Grande offset from shift of Tributary depletions (after reassignment)	Rio Grande offset from operation of mitigation wells	Offset from shift of Buffalo Pasture Depletions	Offset from operation of Buffalo Pasture Project	Total Rio Grande offset (sum of all 4 terms to the left)
EPWSD	Rio Hondo	4.4	1.5			5.9
EPWSD	Arroyo Seco	0.9	0.3			1.2
EPWSD	Rio Lucero	6.6	2.2	3.5	0.4	12.7
EPWSD	Rio Pueblo	18.9	6.2	10.2	1.1	36.5
EPWSD	Rio Fernando	5.8	1.9			7.6
EPWSD	Rio Chiquito	0.6	0.2			0.8
EPWSD	Rio Grande del Rancho	4.2	1.4			5.6
EPWSD	Buffalo Pasture			14.8	1.6	16.4
Town	Rio Hondo	3.0	1.0			4.0
Town	Arroyo Seco	0.4	0.1			0.5
Town	Rio Lucero	4.0	1.3	2.1	0.2	7.6
Town	Rio Pueblo	30.0	9.9	16.1	1.8	57.8
Town	Rio Fernando	22.4	7.4			29.8
Town	Rio Chiquito	7.3	2.4			9.7
Town	Rio Grande del Rancho	58.0	19.1			77.1
Town	Buffalo Pasture			7.2	0.8	8.0

Note to Table. These values are specific to the assumed pumping schedules described in the Note to Table 1. The sum of the Rio Grande offsets related to Tributary and Buffalo Pasture depletions is 86.7 acre-feet for EPWSD, and 194.5 acre-feet for the Town.

Total Rio Grande offsets

For EPWSD, assuming the specified hypothetical pumping schedule, the illustrative Rio Grande Offset requirement would be:

- Direct effect on Rio Grande (note to Table 1): 82.6
- Sum of shifts and reassignments (Table 5): 86.7
- TOTAL: 169.4

For the Town, assuming the specified hypothetical pumping schedule, the illustrative Rio Grande Offset requirement would be:

- Direct effect on Rio Grande (note to Table 1): 169.4
- Sum of shifts and reassignments (Table 5): 194.5
- TOTAL: 365.0