RGDSS Memorandum
FINAL

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Cc:		
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Subject: RGDSS Peer Review: Review of wells and areas of high model residuals

Date: June 22, 2015

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1 Introduction

Based on direction by the RGDSS Peer Review Team (PRT) and the State's authorization, HRS has reviewed geographic areas within the San Luis Valley (SLV), and particular wells within those areas, that show persistently high residual values in the active area of the RGDSS ground water flow model. Dr. Willem Schreuder, Principia Mathematica, provided HRS a list of 268 wells with high residuals (greater than 100 ft). A positive residual means the modeled value of water level elevation in a well is higher than the observed value. A negative residual means the modeled value of water level elevation in a well is lower than the observed value. Of the 268 wells, 61 wells (21%) have positive residuals and 225 wells (79%) have negative residuals.

The objectives of this review are:

- Identify the likely causes of the high residuals.
- Recommend changes to calibration weighting, omission from weighting, change of well layer assignment, or other actions as appropriate.
- Recommend future investigations suggested by this review.
- Recommend future modeling and Sustainable Water Supply metric enhancements.

2 Approach

2.1 Background

Principia provided HRS UTM coordinates (UTM zone 13 NAD 83) for each high-residual well. From these coordinates, HRS plotted the locations of each well. A large majority of the wells are grouped in certain relatively localized areas of the SLV (see Figure 1). The strongly localized grouping of the high-residual wells led us to suspect that wells in local groups may show similar reasons for the high residuals. This was because through our work on the RGDSS PRT in recent years, we have found that the conceptual aquifer layering represented in the regional model, in some smaller local areas of the SLV, may not be sufficiently detailed to reflect the complex hydrogeology that exists in those areas. Our previous work also has shown that review of local areas, based on review of individual well records and local geologic information from maps, aerial photographs, and site visits, can be beneficial in improving the conceptual model and, in turn, improve model calibration.

2.2 Approach to High-Residual Well Review

At the outset of our review work, we felt it may be possible that review of a relatively small number of wells in each localized area of high residual wells would be sufficient to identify hydrogeologic factors common to the entire local group of wells, such that individual well record review would not be necessary. That turned out not to be the case in most areas. Accordingly, HRS has reviewed and has made recommendations for the majority, approximately 174, of the 268 high-residual wells individually as well as by local grouping.

Our approach was to assign HRS hydrogeologists first to review the well records, focusing primarily on the driller's completion reports and pump installer's reports (from the State Engineer's Office online well permit database), for a representative sampling of wells in each local grouping. If a common reason for the high residuals in that group was identified, a recommendation could be made for the group. Some local areas required further division into subgroups of wells. If, in our judgment, little commonality was seen in the probable reasons for the high residuals from well to well, then we proceeded with a detailed review of the well completion reports for all of the wells within a particular grouping or subgrouping. HRS has done a detailed review of well records for approximately 174 (about 65%) of the 268 wells in the high-residual well list provided by Principia. The first check was to try to verify the water level (WL) and total well depth (TD) shown on Principia's list. If this could be verified, we then reviewed the reported lithology and screened interval(s), and made a judgment as to whether, based on our present knowledge of the area, we believe the well should be assigned to a different model layer or omitted from the calibration set. In addition, HRS reviewed geologic maps and satellite imagery for each area, and in some instances we have reviewed recent articles in the professional geologic literature that pertain to certain local areas.

A small number of wells (9 of the 268 total wells) are not closely grouped geographically (see Figure 1). Records of these 9 wells were reviewed individually. Following well record review by HRS hydrogeologists, the HRS project manager reviewed the recommendations by well group, sub-group, or individual well, to provide consistency among the interpretations. The recommendations by well were entered into an Excel™ spreadsheet, which was used to generate a preliminary tabulations of wells and recommendations.

HRS then submitted the preliminary Excel tabulation, with recommendations, to the State for review. There were approximately 10 wells for which HRS could not find well records in the SEO well permit database, or for which records did not agree with the receipt number, WDID, or the well permit number. The State, including Division 3 personnel, then reviewed and found records for the missing or contradictory records. In a few instances, Division 3 personnel contacted a well contractor or well owner to query them about missing or contradictory data. The State then sent the missing information, including weblinks to well records, to HRS. HRS then revised our draft tabulation and recommendations, and provided it to the State and Principia. Appendix A contains copies of the spreadsheet well tabulations and recommendations for wells that were reviewed.

Nearly all high-residual wells reported by Principia are located in areas along the rim of the SLV. The exception is the South-Central SLV group.

- South-Central SLV: nine widely dispersed wells generally located in the Alamosa / LaSauses, Trinchera, and San Luis Hills areas (see Figure 1). (all wells were reviewed).

In order proceeding counterclockwise around the SLV, beginning with the Mt. Blanca area, the identified well groups and subgroups are as follows (see Figure 1). The local well groups and sub-groups of high-residual wells we identified are as follows:

- Mt. Blanca Alluvial Fan area
  - Mt. Blanca alluvial fan south area (all wells reviewed)
  - Zapata Subdivision & Urraca Canyon area (sampling of deeper wells reviewed)

- Baca / Crestone area
  - Outside Crestone (all wells reviewed)
  - In Crestone or immediate area (sampling of wells reviewed)

- San Luis Creek / NE Sangre Mtn Front area (all wells reviewed)
  - San Luis Creek area
  - NE Sangre Mtn Front area

- Upper San Luis Creek / Poncha Pass area (all wells reviewed)
- Kerber Creek & alluvial fan area (sampling of deeper wells reviewed)
- Mineral Hot Springs / NW Alluvial Fan Area (sampling of wells reviewed)
- Carnero Creek alluvial fan area (all wells reviewed)
- LaGarita Creek alluvial fan area (all wells reviewed)
- Upper Alamosa / La Jara alluvial fan area (all wells reviewed)
  - Upper Alamosa River area, well currently assigned to Layer 1
  - Upper Alamosa / La Jara fan area, currently assigned to Layer 2 or deeper
- Upper Conejos River: Fox Creek / Mogote area (all wells reviewed)
  - Conejos River Valley
  - Bluffs & slopes south of Conejos River
- San Antonio area (all wells reviewed)
- Costilla Plain area (all wells reviewed)
  - Wells North of Mesita
  - Wells South of Mesita

- Culebra Graben & Rito Seco Area (all wells reviewed)
  - Southern Culebra Graben area
  - San Luis / Rito Seco area

- Ft. Garland / Sangre de Cristo Creek area (all wells reviewed)
  - Garland South area
  - Sangre de Cristo Creek area

The well records review, probable reasons for the high residuals, and well by well recommendations, are discussed in subsequent sections of this report, and are shown in the accompanying tabulations for each local grouping of high-residual wells.

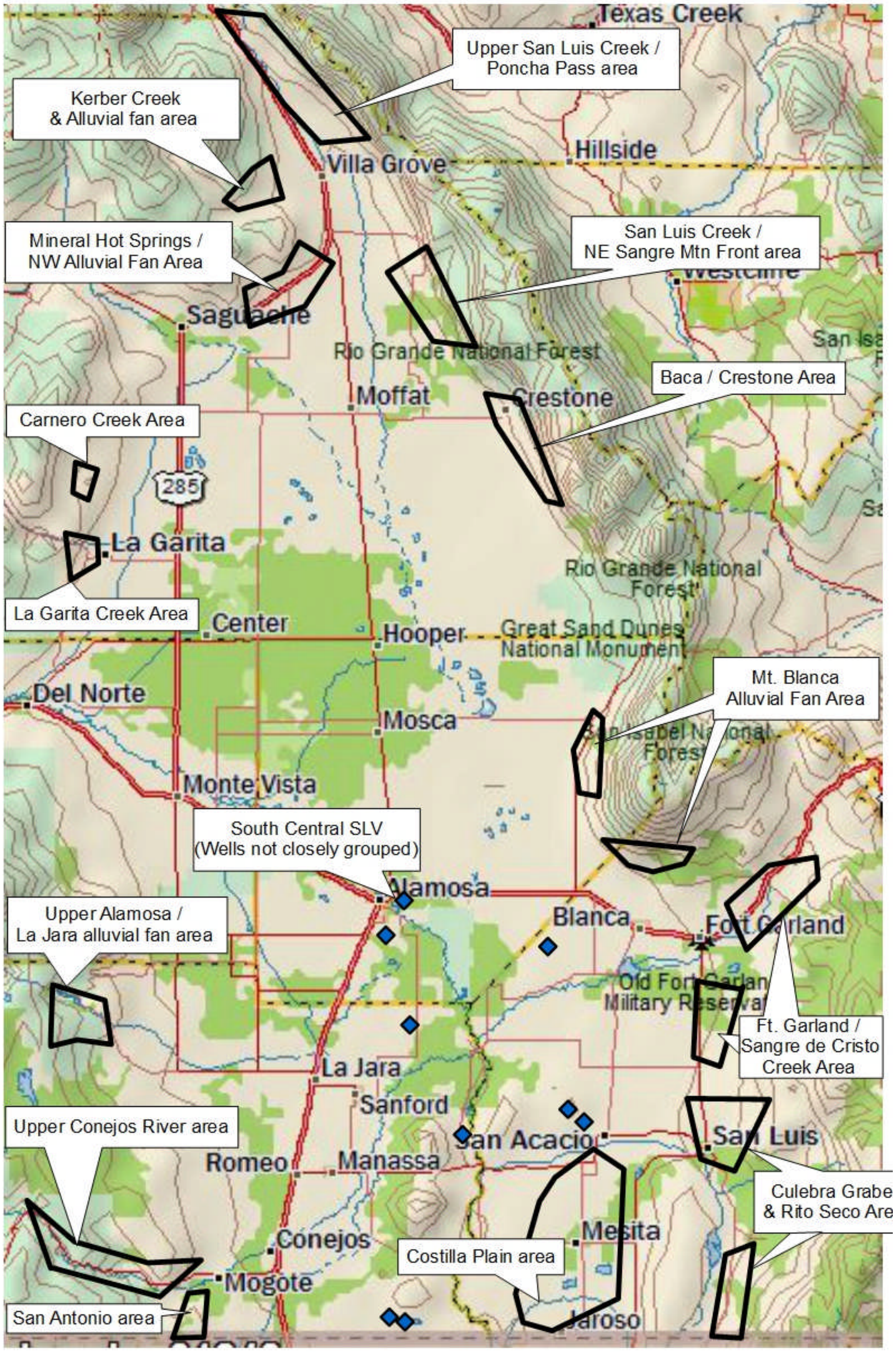

Figure 1: Map of San Luis Valley showing high residual wells individually (blue diamonds) and in groups (black polygons).

3 High-Residual Review by Locality

This section discusses the observed conditions of high residual wells, organized by well group locality. At the outset of this review, it was suspected that a primary reason for high negative residuals, particularly in alluvial fan areas, was localized perching of the water levels above the regional water table. This is suspected as the probable cause of high residuals in certain local areas, but was not generally observed. There are several reasons why it is probable that high model residuals occur in the wells reviewed, including the following (listed in decreasing order of occurrence in the wells reviewed):

- Error in assignment of the aquifer layer to which a particular well observation is assigned.
- Perching of the local water table above the regional water table.
- Wells in bedrock formations not represented in the RGDSS aquifer layering.
- Wells that may be located in mis-mapped or unmapped geologic fault blocks that, to some degree, may hydrogeologically isolate certain areas of water table.
- Wells screened or slotted across more than one aquifer layer.
- Erroneous water level, well depth, or screened interval due to an error in transcription from well record to database.
- Erroneous water level, well depth, or screened interval due to an error in reporting by the well contractor.
- Error in location of the well.

Not all of the wells reviewed were recommended to be re-assigned to a different model layer. In some areas, high model residuals appear to be mostly unrelated to discrepancies in layer assignment or local hydrogeology. In the following subsections of this memorandum we provide recommendations that particular wells and sub-groups of wells should be omitted from the calibration set, or should be assigned a reduced weighting in the calibration set, until our understanding of the hydrogeology is advanced beyond its current level in those areas.

On all of the figures shown in the following sections the well index number shown is the UTM X coordinate for the given well. Blue diamonds denote wells currently assigned to L2, L3, or L4. Gold triangles denote wells currently assigned to L1. The heavy red line the figures denotes the edge of the active model area in the RGDSS model.

3.1 South-Central San Luis Valley: (widely dispersed wells)

This series of wells is the only high-residual set in which the wells are not grouped in a common locality. The location of this set of wells is shown on Figures 2 and 3.

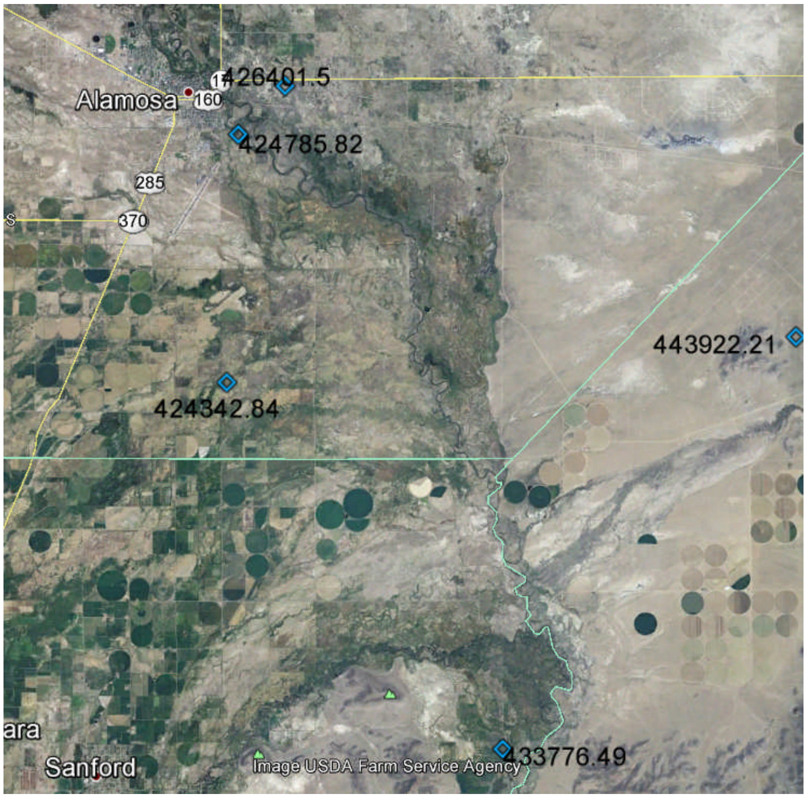

Figure 2: widely dispersed wells in south central SLV.

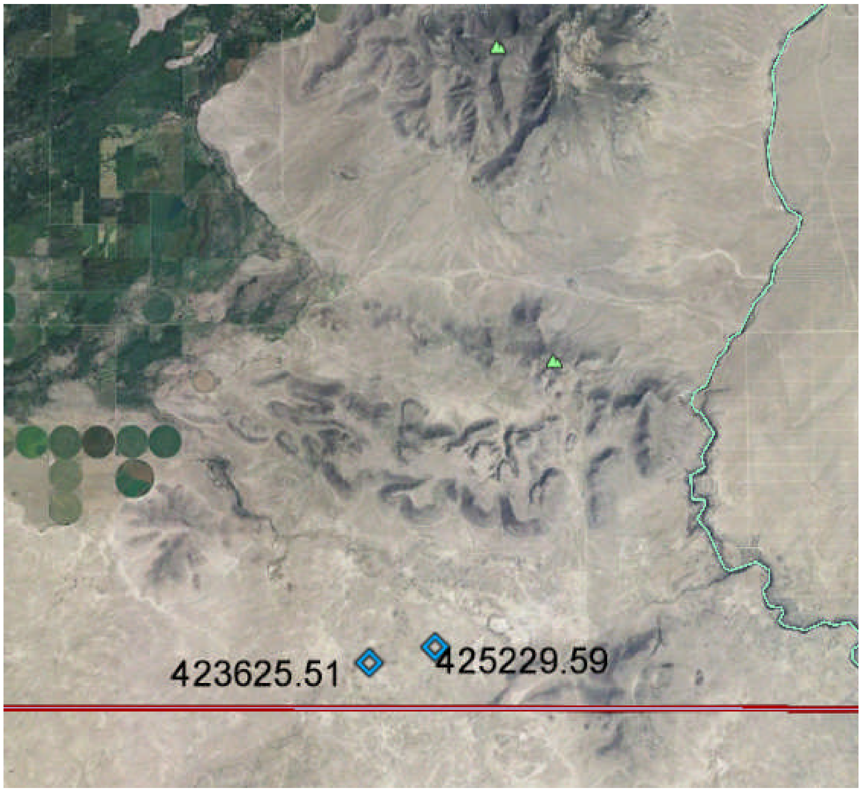

Figure 3: Wells in Punche Arroyo, new CO / NM state line.

Of these nine wells, we recommend that 7 be omitted from the calibration data set. Three confined aquifer wells have shown anomalously deep water levels (permit no. 32092, 33063, 30630) in areas where confined aquifer potentiometric head is high, and wells in aquifer layers L3 and L4 commonly flow. All three of these showed errors in the driller's well completion report: all three wells reportedly flowed at the time of completion, but the driller erroneously reported the depth where ground water flow first was encountered (600', 600', 750' respectively). Several wells are completed in low-permeability Conejos Formation near the edge of the San Luis Hills, and should not be used to represent confined aquifer conditions in the productive layers L3 and L4. Two wells are located in Punche valley, and in our opinion are correctly assigned to L3 (see Figure 3).

Recommended calibration weighting changes: Reduce weighting of Punche valley wells due to relative isolation from SLV aquifer layers due to low hydraulic conductivity (K) in the San Luis Hills.

Recommended future investigations: none.

Recommended future modeling and sustainability metrics enhancements: None of the wells in this group are recommended for inclusion in future enhancement of sustainability metrics.

3.2 Mt. Blanca Alluvial Fan area

This geographic locality contains two subgroups, representing two different local areas. These are discussed below.

3.2.1 Mt. Blanca alluvial fan south area

Nine wells used in the model calibration data set are located along the southern flank of Mt. Blanca (see Figure 4). Records of all nine of these wells were reviewed.

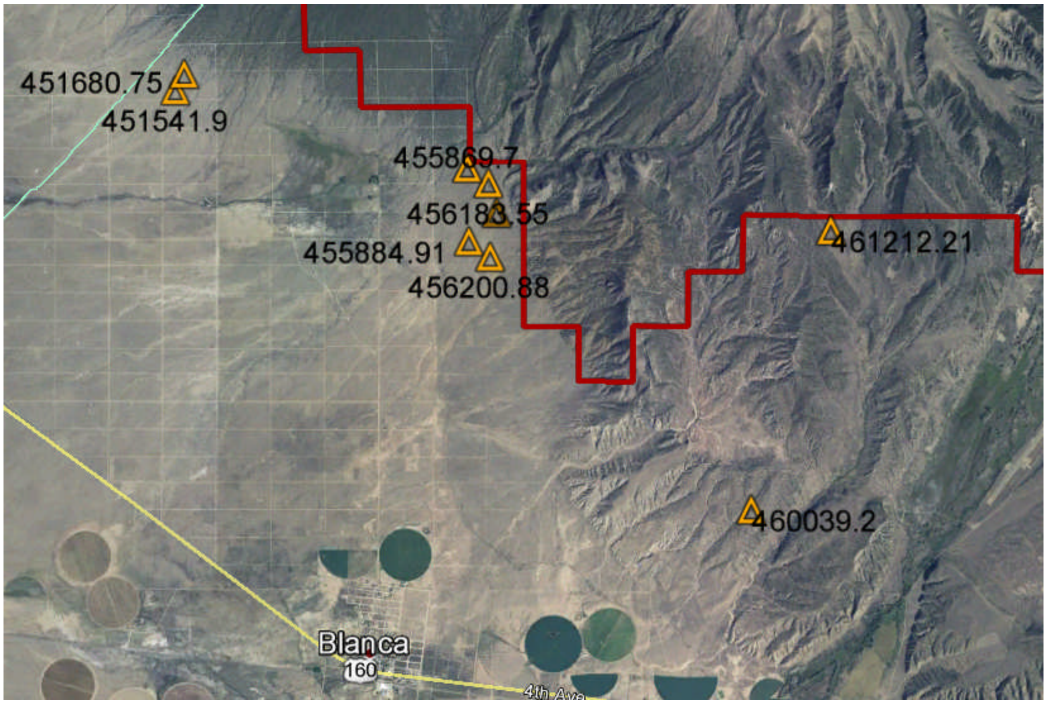

Figure 4: Wells near the southern flank of Mt. Blanca.

Two wells in this locality are recommended to be omitted from the calibration set. One is probably in an isolated zone of bedrock, and the other is approximately 600 feet in elevation above the adjacent valley floor, and is unlikely to represent the regional water table. Although the majority of the wells in this zone are correctly assigned to model layer 1 (L1), the large negative residuals suggest that there may be a hydrogeologic reason for the high residual – possibly a perched water table due to stratification not seen in driller's logs, or possibly an isolated fault block (the area is very near mapped splays of the Sangre de Cristo fault.

Recommended calibration weighting changes: Reduce weighting of L1 wells in this group due to high potential for perched water table or fault block isolation from SLV aquifer layers due to close proximity to mapped faults.

Recommended future investigations: Check to see whether USGS aeromagnetic coverage suggests fault isolation for any of these wells.

Recommended future modeling and sustainability metrics enhancements: None of the wells in this group are recommended for inclusion in future enhancement of sustainability metrics. These wells are generally high on the alluvial fan, and may reflect local recharge conditions but are unlikely to reflect long term regional water table or potentiometric head changes due to SLV well pumping.

3.2.2 Zapata Subdivision & Urraca Canyon area

A large number of small-capacity residential wells exist in this area, which is along the western flank of the Mt. Blanca mountain front (see Figure 5). HRS has reviewed two of the three wells located in Urraca Canyon, and a sampling of 5 the 87 Zapata Subdivision wells that are noted to have high residuals.

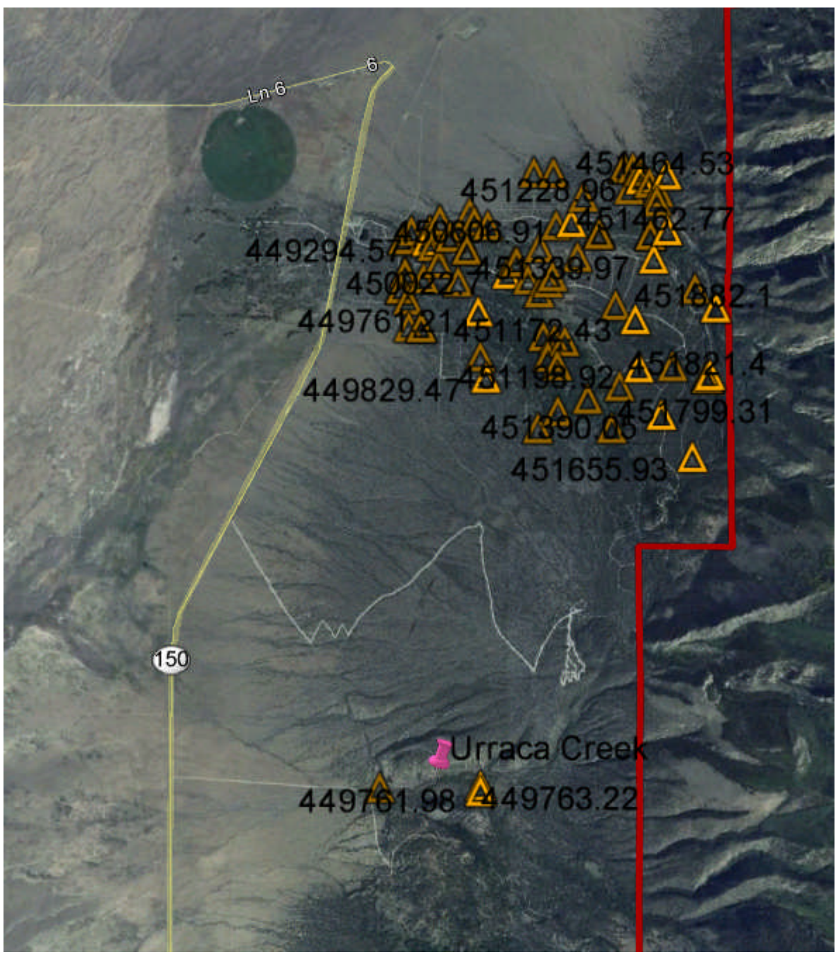

Figure 5: Urraca Canyon and Zapata Subdivision high residual wells.

All of the wells in this group (which are all currently assigned to L1) have high negative residuals ranging between approximately 100 and 1,000 feet. The driller's reports for several of the wells checked in this area show typical alluvial fan material – sand and gravel – overlying what appears to be hard, cemented sedimentary rock ranging from red to green and gray. This strongly suggested to us that there may be an elevated block of older, pre-rift bedrock formations that underlies the unconsolidated alluvial fan deposits this area. A check with U.S. Geological Survey researchers showed that there is a recently-published tentative interpretation of a fault block in this area[1], covered by the alluvial fan, that may indeed isolate this area from the SLV regional water table, and cause locally elevated water levels, particularly in the Zapata Subdivision wells. This interpreted faulting is shown on Figure 6.

[1] Grauch, V.J.S., 2014, email communication with E. Harmon.

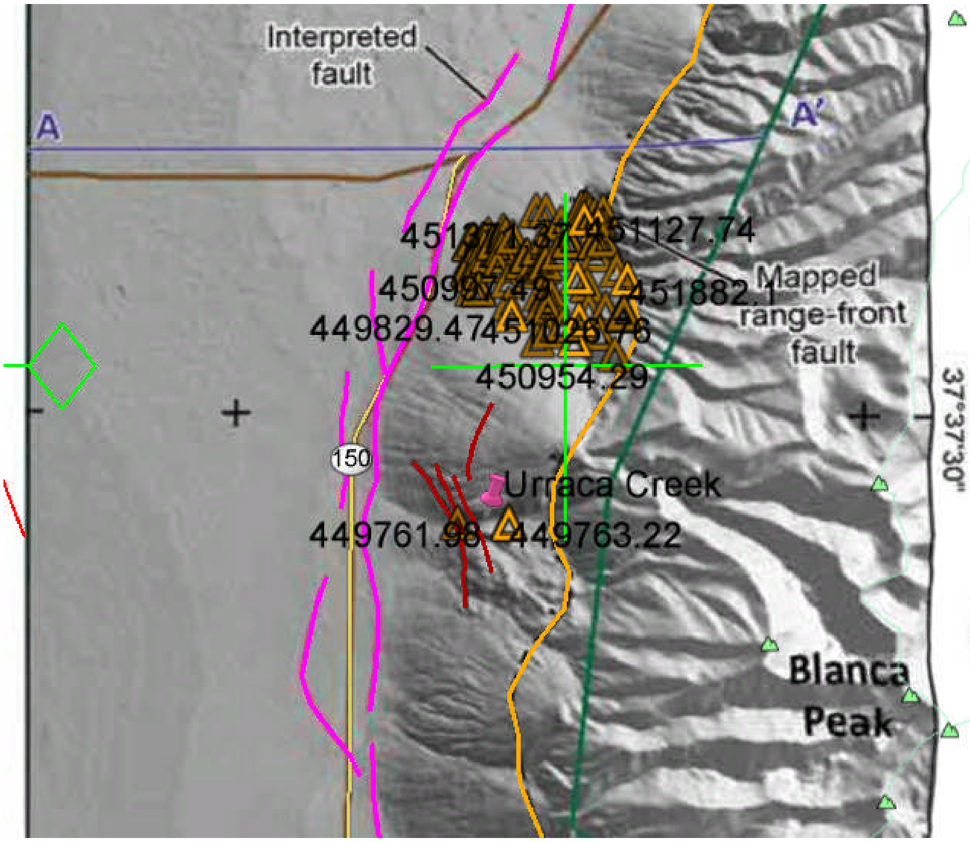

Figure 6: Tentative interpretation of Blanca Piedmont Fault zone (Grauch et al, 2013) with high residual wells in the Zapata and Urraca areas. Fault and shaded relief mapping from *Grauch et al, 2013, U.S. Geological Survey, Advancements in understanding the aeromagnetic expressions of basin-margin faults—An example from San Luis Basin, Colorado. The Leading Edge, August 2013, pp. 882-891.*

Recommended calibration weighting changes: Defer the use of wells in this group for the present time. There is a high potential for these wells to represent a perched water table or fault block isolated from SLV aquifer layers due to close proximity to mapped faults and a potential high elevation bedrock block in the subsurface. There are 87 high-residual wells in the Zapata Subdivision – approximately 1/3 of the total number of wells in the list of 268 high-residual provided by Principia. Due to the potential for fault isolation and/or perching, it is possible that very few if any of these wells are representative of the SLV sedimentary aquifer layers.

Recommended future investigations: Follow up with USGS researchers, and use the new information to develop revised aquifer mapping along the Mt. Blanca reach of the Sangre de Cristo mountain front.

Recommended future modeling and sustainability metrics enhancements: All wells in this group should be deferred from inclusion in sustainability metrics until completion of revised mapping, a revised estimation of whether or not any of these wells are reflective of the SLV aquifer layering, and revised model calibration.

3.3 Baca / Crestone area

This geographic locality contains 32 high-residual wells concentrated in and around the town of Crestone (28 wells), and 4 wells located south of Crestone in or near the Baca Grande subdivision south of Crestone (see Figure 7). All 32 are currently assigned to L1. HRS has reviewed the records of all 4 wells south of Crestone, and a sampling of 5 of the 28 wells located in and around Crestone.

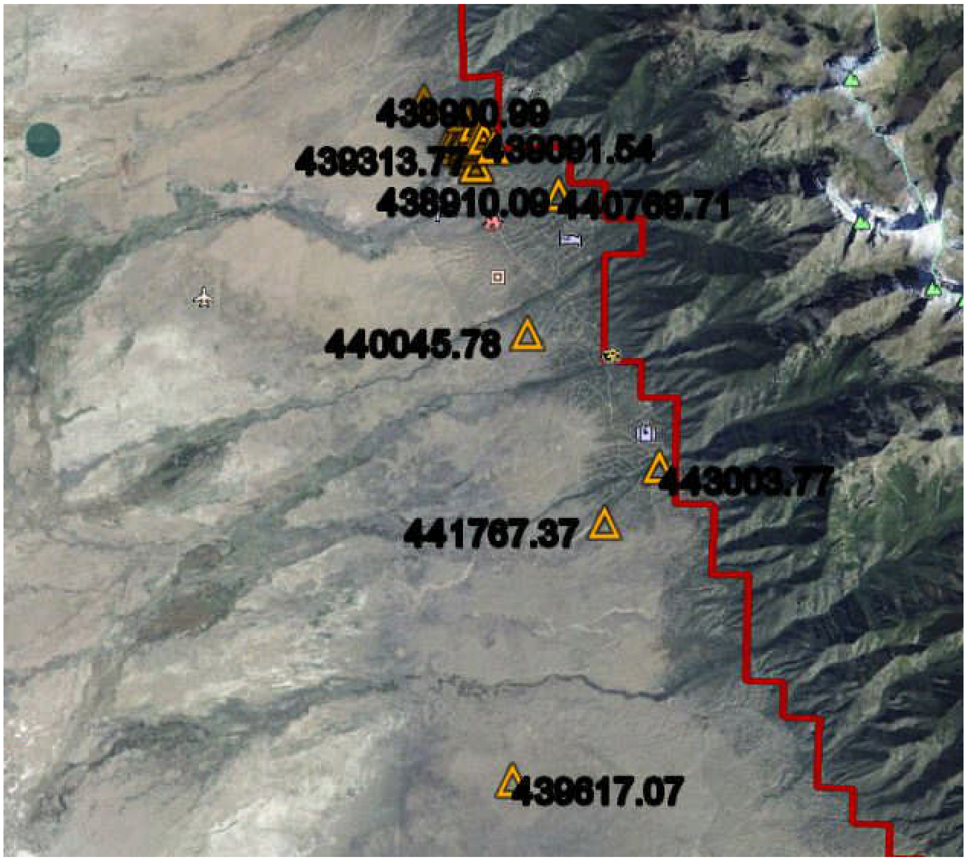

Figure 7: Wells in Crestone and vicinity.

3.3.1 South of Crestone

The four wells in this area all are assigned to L1. One of these (permit no. 221139) is more likely reflective of L2, as it appears to be confined by a series of thin clay layers. Two wells are recommended for omission, as we suspect they may be located on a bedrock bench with overlying alluvial fan materials. The fourth well appears to be properly assigned to L1

3.3.2 In Crestone or immediate area

All 28 of the high-residual wells in or near the town of Crestone currently are assigned to L1. We recommend that all 28 be deferred from inclusion in the calibration set at present, because we suspect the presence of a buried bedrock 'bench' beneath near-surface fan alluvium. All of the five wells in this sampling that we reviewed showed typical high-energy alluvial near-apex fan material: cobbles, boulders, gravel, sand, with minimal clay and silt. However, all water levels are relatively shallow – generally less than 100 feet – which would probably not be the case if there were no low-permeability layers extent at a relatively shallow depth beneath the coarse-grained alluvium.

Recommended calibration weighting changes: Defer the use of wells in the Crestone area for the present time. There is a high potential for these wells to represent a perched water table due to a potential high elevation bedrock block buried beneath the coarse alluvium in the subsurface. There are 28 high-residual wells in the Crestone area – approximately 10% of the total of 268 high-residual wells in the list provided by Principia. Due to the potential presence of buried bedrock step causing locally elevated water levels, it is possible that few of these wells are representative of water levels in the SLV sedimentary aquifer layers.

Recommended future investigations: Follow up with USGS researchers regarding the northern extension of recent high-resolution aeromagnetic geophysical surveys, and use the new information to develop revised aquifer mapping along the Crestone / Baca reach of the Sangre de Cristo mountain front.

Recommended future modeling and sustainability metrics enhancements: All wells in the Crestone subgroup, and all but two in the area just south of Crestone, should be deferred from inclusion in sustainability metrics until completion of revised mapping and a revised estimation of whether or not any of these wells are reflective of the SLV aquifer layering, and revised model calibration.

3.4 San Luis Creek & NE Sangre de Cristo Mtn. Front area

This area encompasses high-residual wells located along the Sangre de Cristo mountain front generally north of Crestone, and also several wells in the valley of San Luis Creek (see Figure 8).

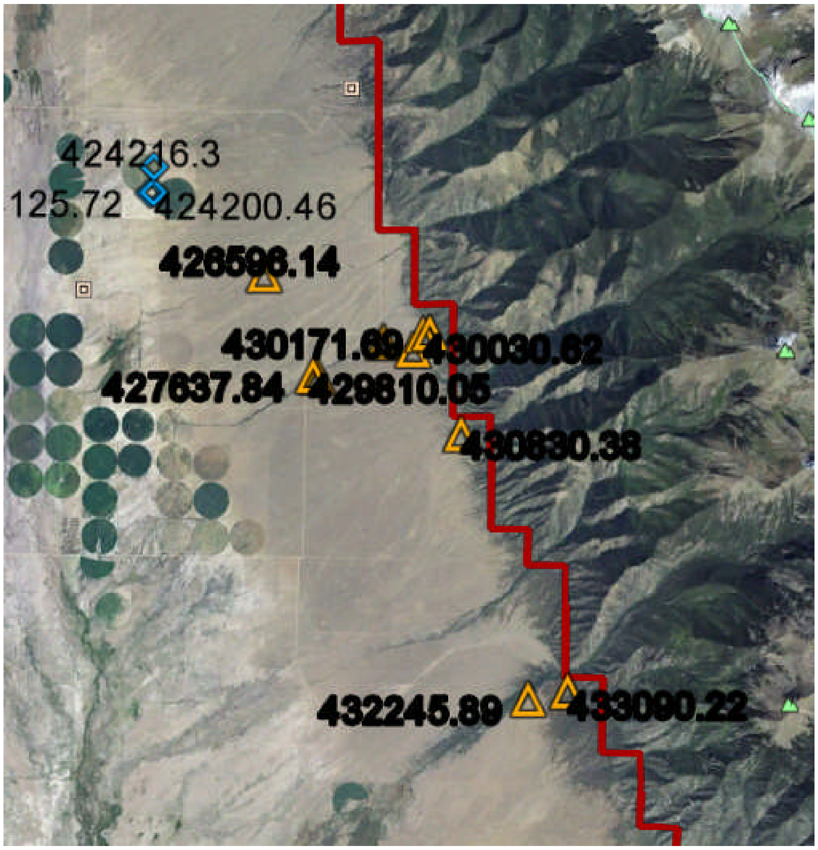

Figure 8: High residual wells in the San Luis Creek and NE Sangre de Cristo mountain front area.

3.4.1 San Luis Creek sub-area

The four high-residual wells in this sub-area generally show an alluvial sequence of sand/gravel, with some clay layers noted. One well is a duplicate, and is recommended for omission so as not to inordinately weight this point in the calibration. Two of the wells are suspected to be currently assigned to the wrong model layer.

3.4.2 NE Sangre de Cristo Mtn. Front sub-area

The nine wells in this sub-area all are currently assigned to L1, but range in depth from 120 to 775 feet, and eight wells show some clay layers interbedded with coarser alluvial fan material. The two wells in the Rito Alto Creek area (southernmost wells on Figure 8) are recommended to be omitted due to either possible perching on a bedrock fault block or possible recharge from the creek. We suspect that all the wells are more reflective of L3 water levels than L1, and we recommend layer reassignment.

Recommended calibration weighting changes: One of the wells in the San Luis Creek sub-area is recommended for omission, as it is duplicative, and if honored, it would inordinately weight this data point. Two of the well in the NE Sangre de Cristo Mtn. Front sub-area are recommended to be omitted as the static water levels are not reflective of the regional water levels in any of the model layers.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: The commonality of current L1 layer assignments to wells on the alluvial fan ranging from approximately 120 to 700+ feet deep, coupled with the presence of clay in these wells, suggests to us that it may be advisable to review the Sangre de Cristo fan area to see whether there is sufficient data, and sufficient hydrogeologic justification, to warrant revising aquifer mapping near the Sangre de Cristo mountain front in this vicinity. No sustainability metrics enhancements are recommended at this time.

3.5 Upper San Luis Creek / Poncha Pass area

There are four wells in this area (see Figure 9). Of these four, only one was found from well records as likely to be reflective of SLV aquifer layering. The other three are recommended for omission from the calibration set: one is reportedly completed entirely in granite, and two are high up on an alluvial fan NE of San Luis Creek. These latter two both show relatively shallow water table, but are between 300 and 400 feet in elevation above the adjacent stream valley. We therefore suspect that these are probably perched water levels, or are otherwise not reflective of the regional water table in the SLV aquifer layers.

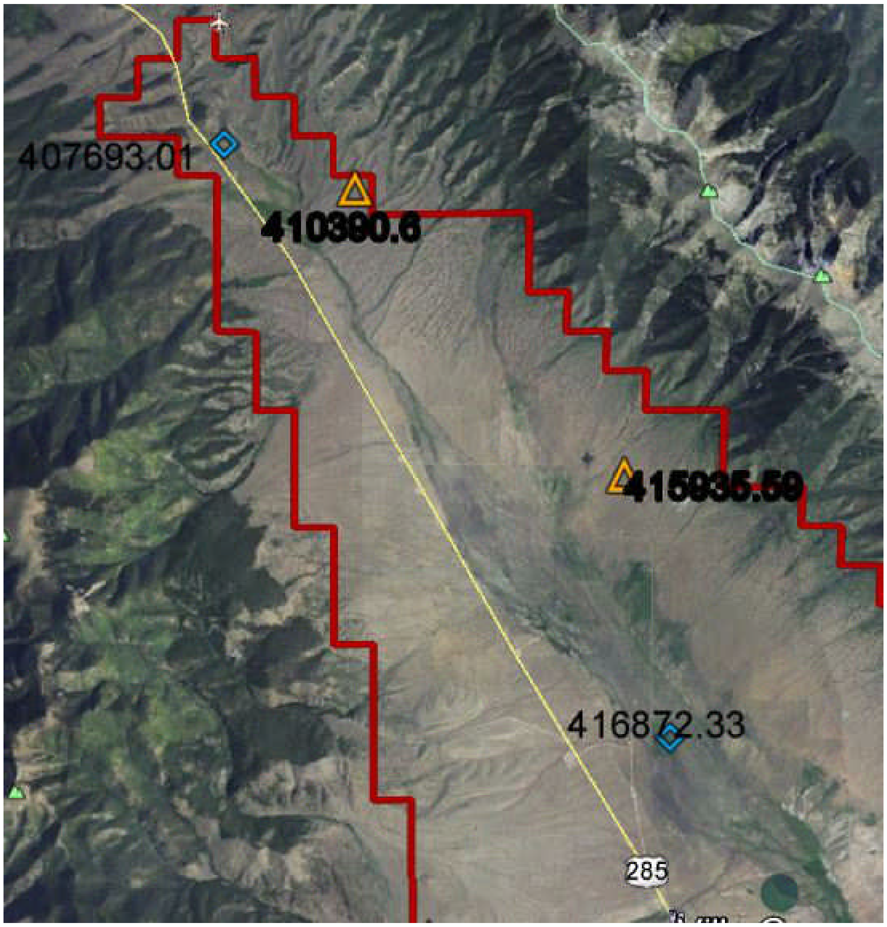

Figure 9: upper San Luis / Poncha Pass area

Recommended calibration weighting changes: Three of the four wells in the Poncha Pass area are recommended for omission, as discussed previously. The fourth is recommended for layer re-assignment to L2 instead of L4, as it is currently assigned.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: No sustainability metrics enhancements are recommended at this time.

3.6 Upper Kerber Creek area

There are seven wells in this area (see Figure 10), of which HRS reviewed records from three. Of these three, none were found from well records as being reflective of SLV aquifer layering. The wells in this area, based on geologic mapping, are located in an isolated fault block, and the well records reflect bedrock formations such as the Hermosa and Belden, which are not part of the SLV aquifer layering. From this, we recommend omission of all wells in this area from the calibration set.

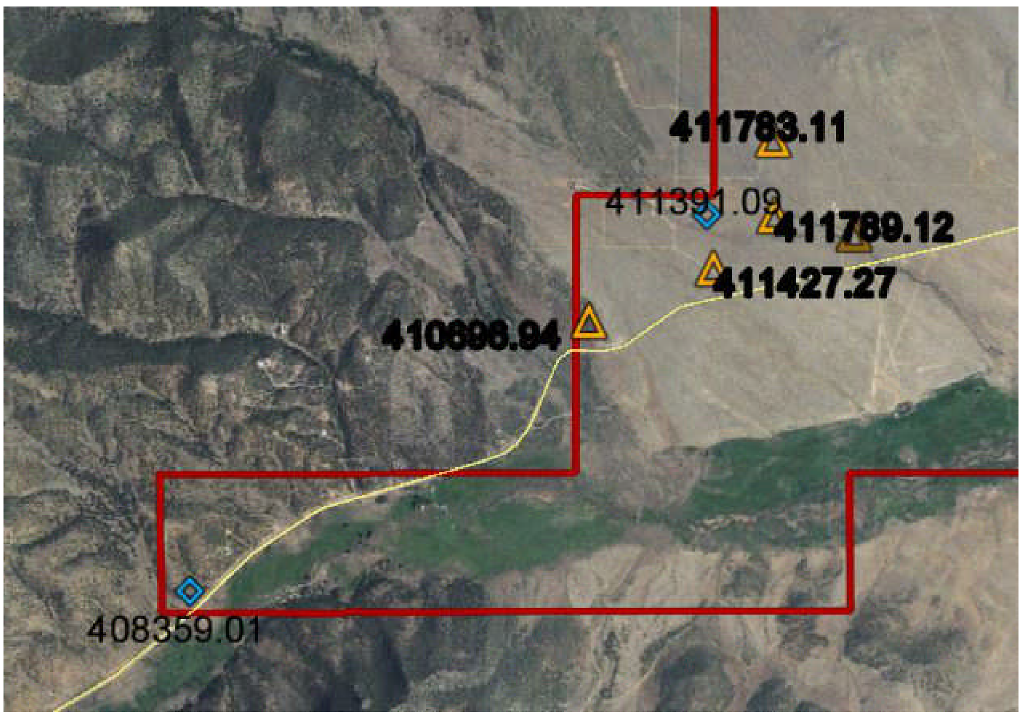

Figure 10: upper Kerber Creek area.

<u>Recommended calibration weighting changes:</u> All wells in the upper Kerber Creek area are recommended for omission, as discussed previously.

<u>Recommended future investigations:</u> None.

Recommended future modeling and sustainability metrics enhancements: None of the wells in the upper Kerber Creek area should be included in sustainability metrics, as wells in this area do not appear to be reflective of water levels in the SLV aquifer layers represented in the RGDSS model.

3.7 Mineral Hot Springs / NW Alluvial Fan Area

There are 12 wells in this area (see Figure 11), of which HRS reviewed records from seven. Of these seven, only one was found from well records to be reflective of SLV aquifer layering. The majority of the high-residual wells in this area, based on well records, are completed in what is described as "granite", "gray granite", or "gray volcanic rock". From this, we recommend omission of all wells in this area from the calibration set, with one exception (well permit no. 239601), which appears to be completed in L3. This is a recommended re-assignment from L4, the current layer assignment for this well.

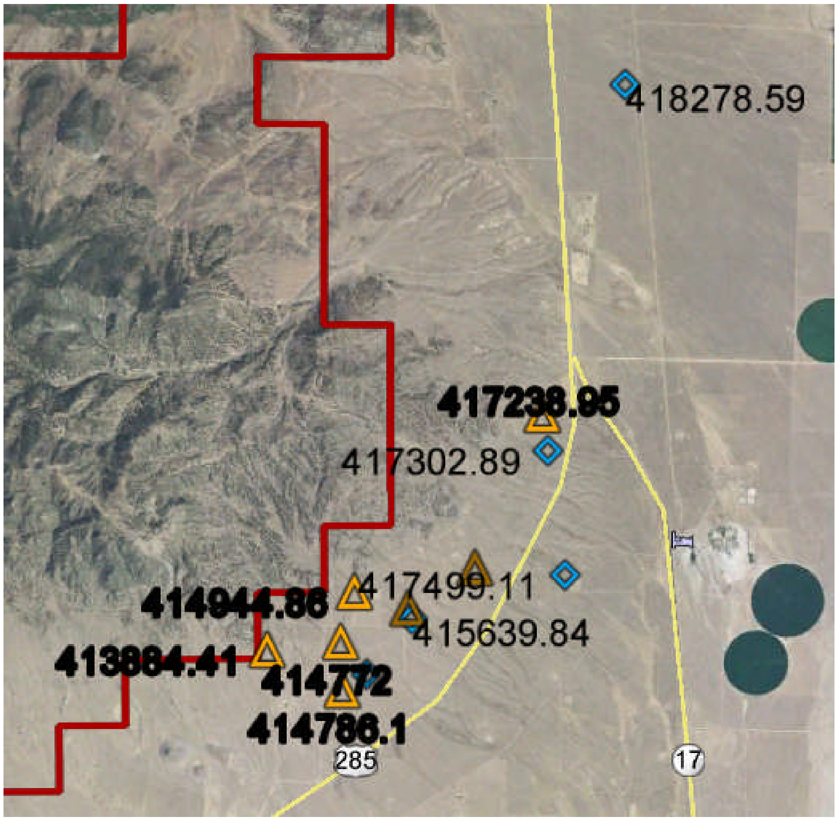

Figure 11: Mineral Hot Springs / NW alluvial fan area.

Recommended calibration weighting changes: With one exception, all wells in the Mineral Hot Springs / NW alluvial fan area are recommended for omission, as discussed previously.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: With the exception of Well permit no. 239601, we recommend that none of the wells in the Mineral Hot Springs / NW alluvial fan area should be included in sustainability metrics, as wells in this area do not appear to be reflective of water levels in the SLV aquifer layers represented in the RGDSS model.

3.8 Carnero Creek Alluvial Fan Area

There are 6 wells in this area (see Figure 12), of which HRS reviewed records from all six. Of these six, two are recommended for omission from the calibration set: one due to a suspected perched water level, and one is completed in the Conejos Formation, and is not reflective of the SLV aquifer layers represented at this location. Of the remaining 4 wells, only one layer reassignment has been recommended.

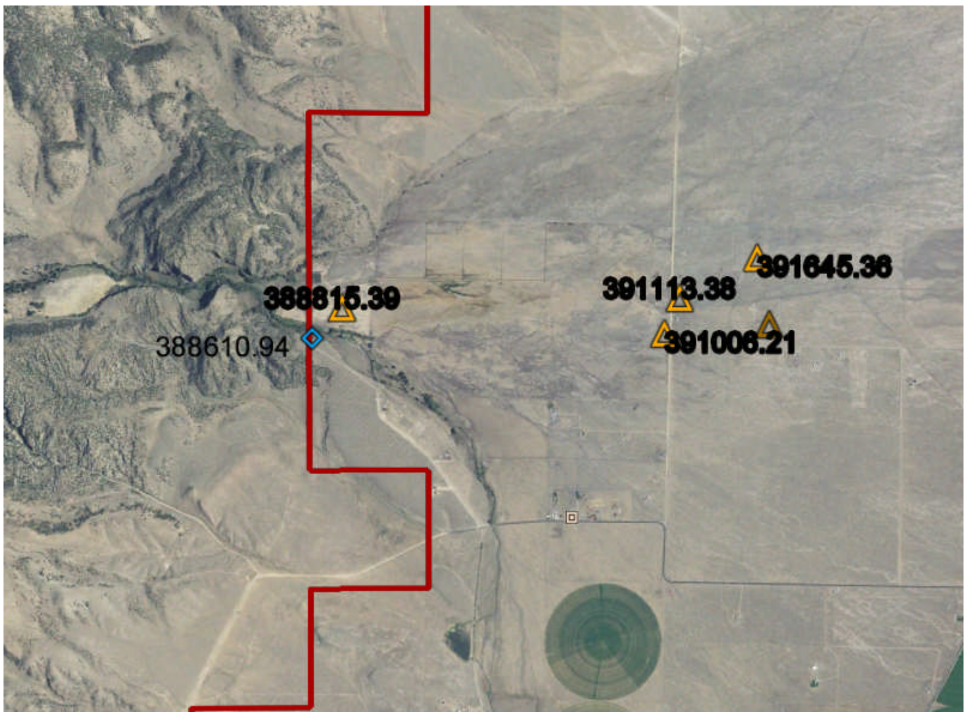

Figure 12: Carnero Creek alluvial fan area.

Recommended calibration weighting changes: Two of the six wells in this are recommended for omission, as discussed previously. One is recommended for layer reassignment.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: With the exception of the two recommended omissions, the other wells in this area, in our opinion, would be suitable for inclusion in future sustainability metrics.

3.9 La Garita Creek Alluvial Fan Area

There are 11 wells in this area (see Figure 13), of which HRS reviewed records from all 11. Of these 11, only 2 are recommended for retention in the calibration set, and those two are recommended to be reassigned to L3 instead of L2, their current layer assignment. The other 8 are recommended for omission, because the well records show that they are completed in bedrock formations: either the Fish Canyon Tuff or the Carpenter Ridge Tuff. These formations are not reflective of the SLV aquifer layering intended to be represented at these locations.

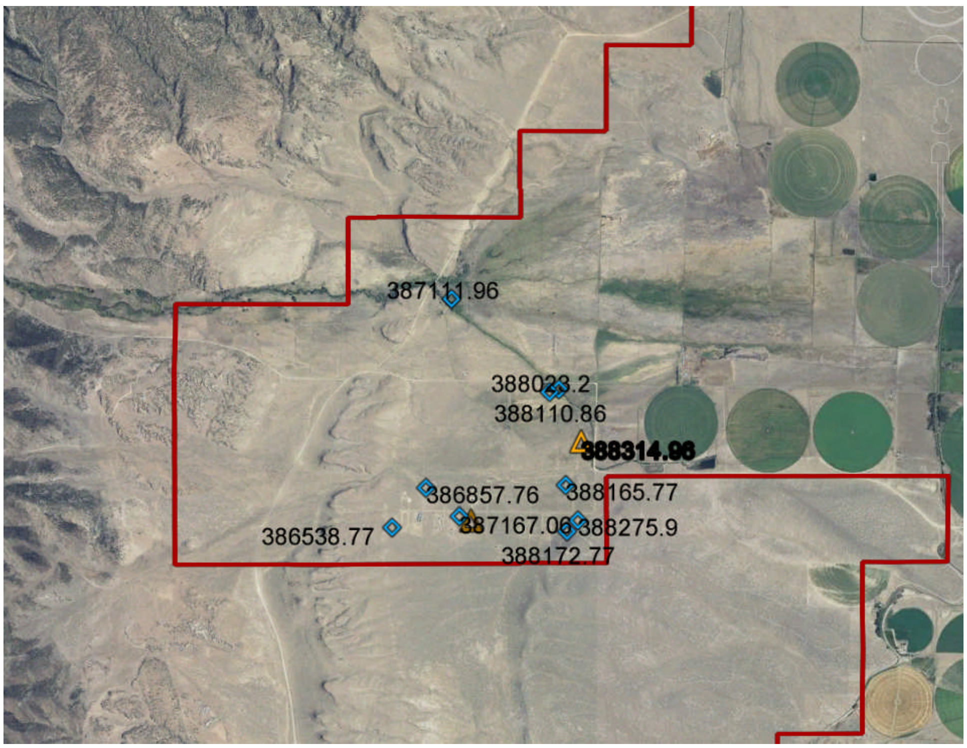

Figure 13: La Garita Creek alluvial fan area.

Recommended calibration weighting changes: Of the 10 high residual wells in this group, only 2 are recommended for retention in the calibration set, and those two are recommended to be reassigned to L3 instead of L2, as discussed previously.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: With the exception of the two wells recommended for retention (with layer reassignment) the other wells in this area, in our opinion, would not be suitable for inclusion in future sustainability metrics and should be omitted.

3.10 Upper Alamosa / La Jara Creek Alluvial Fan Area

There are 19 wells in this area (see Figure 14), of which HRS reviewed records from all 19. One subset of 8 of these wells is currently assigned to L1. All of these wells are located along the Alamosa River. A second subset, comprised of the remaining 11 wells, are currently assigned to deeper layers. These generally are located further downstream along the Alamosa River, or are closer to La Jara Creek (see Figure 14).

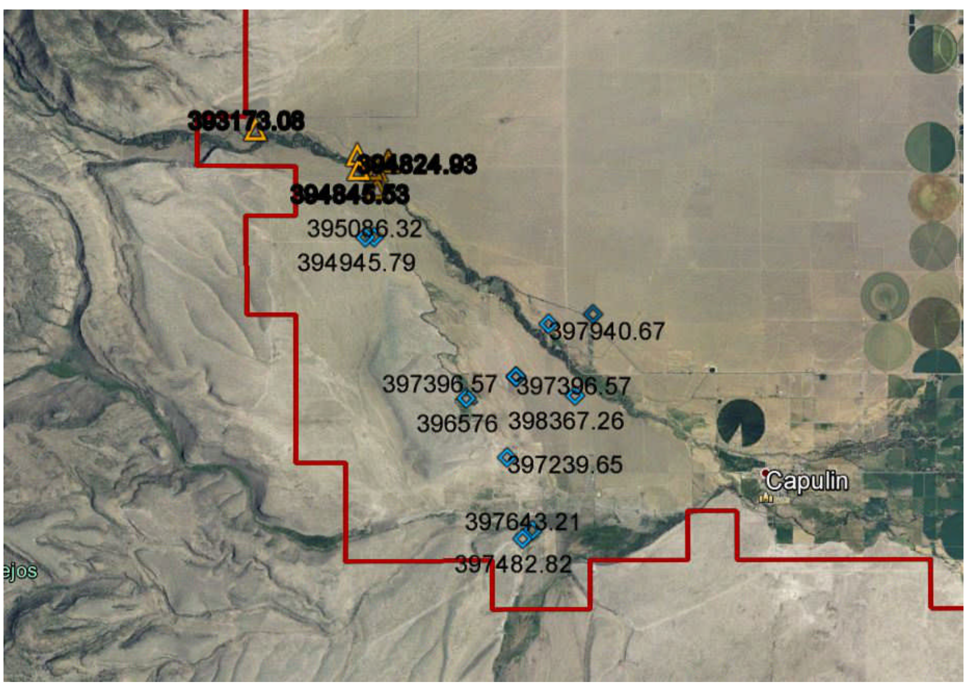

Figure 14: Upper Alamosa /La Jara Creek alluvial fan area.

Of the 8 wells in the L1 subset (all of which have negative residuals), we recommend deferral of 6 wells at this time due to a high likelihood of perched water table in this area, and layer reassignment to the remaining two. Well records in this area show a shallow water table a few tens of feet deep, probably associated with the Alamosa River and its shallow alluvium, and a deeper water level, generally at least 100 feet deep, with an intervening unsaturated zone.

Of the deeper subset of 11 wells, 5 are recommended for omission from the calibration set for several reasons, chief of which is our inability, based on the available well records, to determine with confidence which aquifer layer a well represents. Three wells of this subset are recommended for layer reassignment, and we recommend that the remaining 3 wells be retained in their current layer assignments.

<u>Recommended calibration weighting changes:</u> Several wells in this group are recommended for omission or layer reassignment. None are recommended for calibration weighting changes.

<u>Recommended future investigations:</u> Verify presence of unsaturated zone below near-surface alluvium in upper Alamosa River area.

<u>Recommended future modeling and sustainability metrics enhancements:</u> For future phases of modeling, we recommend assigning a lower vertical conductance between L1 and L2, to allow shallow water table to remain perched, thus representing the observed condition. Perched wells are not likely to be suitable candidates for future sustainability enhancements. Other wells in this group most likely would be suitable for inclusion in future sustainability metrics, as they probably represent SLV regional head changes in the aquifer layers represented in the RGDSS model.

3.11 Upper Conejos River Area

There are 14 wells in this area (see Figure 15), of which HRS reviewed records from all 14. Wells in this group are of two types: wells located in the Conejos River valley, and wells located on bluff and upland slopes above the valley. The majority of the wells located in the Conejos River valley (8 wells), in our opinion, reflect the water table at their respective locations, and are appropriately assigned by layer. We have made specific layer recommendations on a well by well basis for a few wells. The majority of the wells in this set in the Conejos River valley show positive residuals between 100 and approximately 240 feet. In our opinion this consistency in positive residuals indicates a need to revisit the hydrostratigraphy of this area to see whether there is more subtle layering than appears in driller's reports, or other hydrogeologic factors, that may be causing the consistently high residuals.

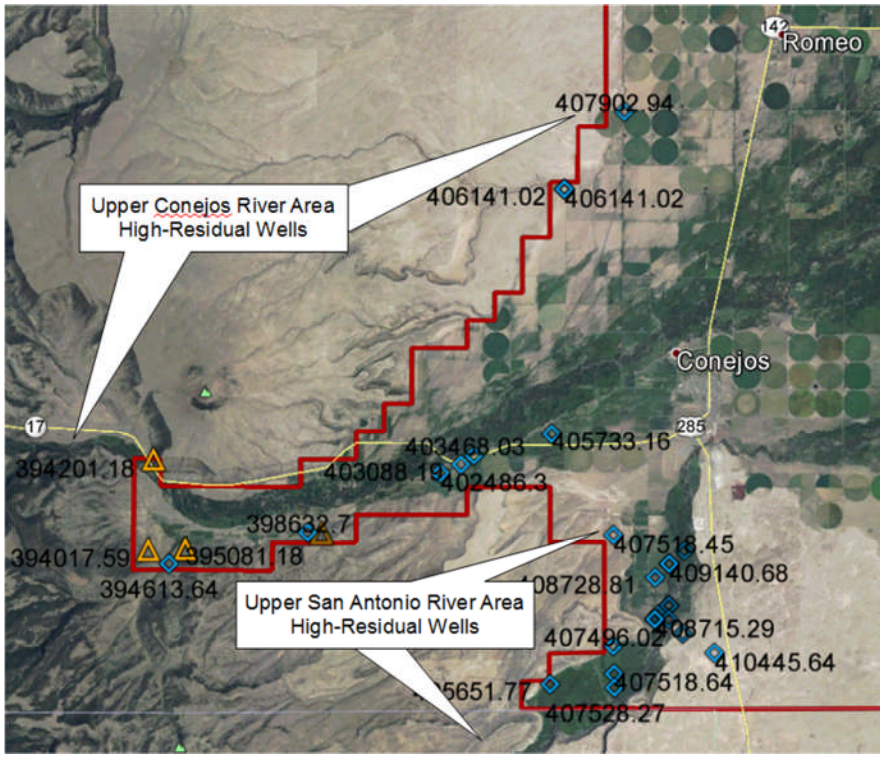

Figure 15: Upper Conejos River and San Antonio River areas.

There are 6 wells of the 14 in this area that are located on bluffs or upland slopes above the river valley. With one exception, these wells show negative residuals of between 100 and 220 feet. One well is recommended for omission because it is duplicative of another well in the set. For the others, we have recommended well-specific layer reassignments.

<u>Recommended calibration weighting changes:</u> Several wells in this group are recommended for omission or layer reassignment. None are recommended for calibration weighting changes.

<u>Recommended future investigations:</u> As discussed previously, in our opinion there is a need to revisit the hydrostratigraphy of this area to see whether there is more subtle layering than appears in driller's reports, or other hydrogeologic factors, that may be causing the consistently high residuals in the wells located in the Conejos River valley.

Recommended future modeling and sustainability metrics enhancements: We recommend deferring wells in this group from inclusion in sustainability metrics for the present, until the hydrostratigraphy can be revisited and the model layering revised in this area, if needed.

3.12 Upper San Antonio River Area

There are 17 wells in this area (see Figure 15), of which HRS reviewed records for all wells. There are three sets of two wells each that have the same UTM coordinates but separate / different permit numbers. This is due to how the UTMs were selected: based on footages from section lines or by quarter quarter. All of the wells in this group are currently assigned in layers 2, 3, or 4; none are in L1. With one exception (well permit no. 22783-A, with a positive residual of 312 feet) the wells reviewed show negative residuals between approximately120 and 215 feet. Sevens wells in this group have been recommended for omission from the calibration set, as they appear to be dual completed in L1 and L2 or L2 and L3, thus the water level does not represent a single aquifer layer. Seven wells are recommended for reassignment from L3 to L1 and one from L2 to L4.

Recommended calibration weighting changes: Seven wells are recommended for omission from the calibration set due to dual completion in L1and L2 or L2 and L3. Eight wells in this group are recommended layer reassignment with two wells in tis group remaining the same. None are recommended for calibration weighting changes.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: This area was studied in some detail by HRS at the request of the State and the PRT[2]. At that time HRS made specific recommendations for model enhancements, which have been implemented. The wells in this group for which the aquifer layer has been checked, most likely would be suitable for inclusion

[2] HRS Water Consultants, Inc., Sept. 6, 2012, Hydrogeologic Mapping Review of San Antonio - Ortiz Region. RGDSS final memorandum, 12p.

in future sustainability metrics, as they probably represent SLV regional head changes in the aquifer layers represented in the RGDSS model.

3.13 Costilla Plain Area

There are 17 wells in this area (see Figure 16), of which HRS reviewed records from all 17. For purposes of our review, wells in this group were divided into two sub-areas: wells located north of the village of Mesita, and wells located south of Mesita.

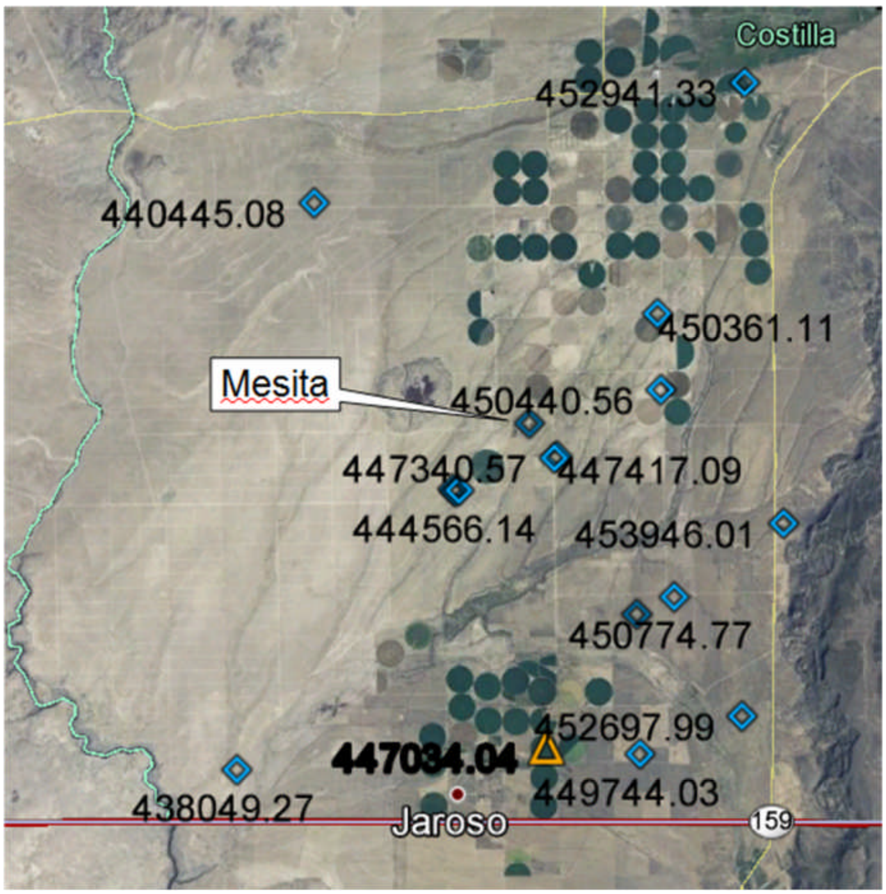

Figure 16: High residual wells in the Costilla Plain area.

Five of the high residual wells are located generally north (and either NW or NE) of Mesita. Two of these are recommended to be omitted from the calibration set: Permit no. 5825-R is suspected to have influence from L2, in addition to L3 and L4 in which the well is screened. The multiple layers leads to the measured water level not being identifiable as representative of one aquifer layer, and should be omitted. Well permit no. 56692-F is recommended to be omitted unless further work shows that this well is not located in an isolated fault block of Servilleta formation, as we suspect from its location and the aeromagnetic geophysical survey coverage in the area. The other three wells in this subgroup all appear to appropriately assigned.

The remaining 12 of the 17 high residual wells in the Costilla Plain are generally located south (and either SE or SW) of Mesita. Of these 12, two are recommended for omission because no log could be found to enable us to verify the hydrogeology. Three wells are appropriately assigned to L3. The remaining wells are recommended for layer reassignment; most from L2 (current assignment) to L3. These wells all appear from the records to reflect water levels in the Servilleta formation aquifer, which represents L3 in the RGDSS model in this area.

Recommended calibration weighting changes: Several wells are recommended for omission from the calibration set due to lack of logs. Several wells in this group are recommended for layer reassignment. None are recommended for calibration weighting changes.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: The wells in this group for which the aquifer layer has been checked and verified most likely would be suitable for inclusion in future sustainability metrics.

3.14 Culebra Graben and Rito Seco Area

There are 19 wells in this area (see Figure 17), of which HRS reviewed records from all 19. For purposes of our review, wells in this group were divided into two sub-areas: wells located south of San Luis in the Culebra Graben, and wells located generally north of San Luis in the Rito Seco area.

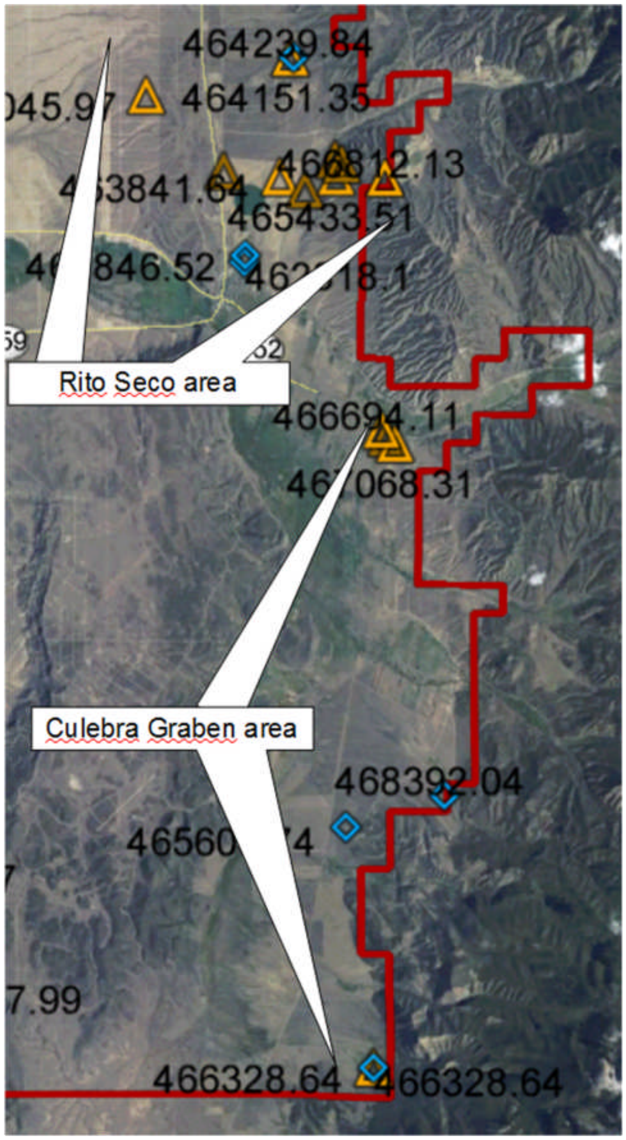

Figure 17: High residual wells in the Culebra Graben and Rito Seco areas.

Of the seven wells located in the Culebra Graben area south of San Luis, two are recommended for omission from the calibration set. Permit no. 246273 has a poor driller's log so that the layer represented by the water level cannot be verified, and also is located closely adjacent to the mapped location of one branch of the Sangre de Cristo fault in this area. Permit no. 31587 has no screened interval documented, and so the aquifer layer could not be verified. HRS was able to verify appropriate layer assignment for two wells, and the remaining 3 wells are recommended for layer reassignment based on the driller's logs and well completion reports.

The remaining 12 wells in this group are all located generally NE to NW of San Luis, in the Rito Seco area. Of these 12, three are recommended for omission from the calibration set due to duplicative wells also in the high-residual well list. The majority of the remaining 10 wells are recommended for reassignment from L1 (current assignment) to L2 or L3, depending on the well depth and the stratigraphy reflected on the well logs. Most of these are not in L1 (alluvium) but instead reflect either shallow Santa Fe formation (L2) or deeper Santa Fe formation (L3).

Recommended calibration weighting changes: Several wells are recommended for omission from the calibration set due to duplicative entries in the high-residual well list. Several wells in this group are recommended for layer reassignment from L1 to either L2 or L3. None are recommended for calibration weighting changes.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: The wells in this group for which the aquifer layer has been checked and verified most likely would be suitable for inclusion in future sustainability metrics.

3.15 Fort Garland / Sangre de Cristo Creek Area

There are 10 wells in this area on the high residual list (see Figure 18), of which HRS reviewed records from all 10. For purposes of our review, wells in this group were divided into two sub-areas: wells located south of the town of Fort Garland, and wells located north (one well) or generally east of Fort Garland, in or near the valley of Sangre de Cristo Creek.

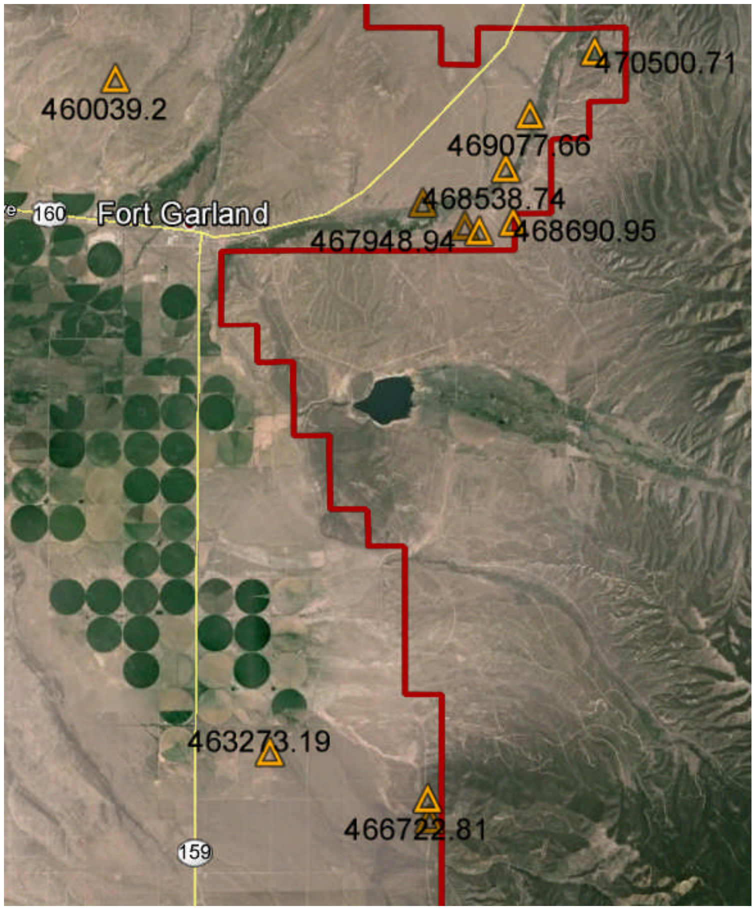

Figure 18: High residual wells in the Fort Garland / Sangre de Cristo Creek area.

Three wells are located south of Fort Garland. Of these, two are recommended for omission from the calibration set. One (permit no. 67007-F) showed inconsistent and contradictory water levels, logs, and total depths between records. Another (51506-F) appears to be mislocated, as the written record shows that it is located in the Zapata Subdivision, which is approximately 20 miles NW of the permitted location. The third well in this subarea (permit no. 47016-FR) is recommended for layer reassignment from L1 to L3, as the log indicates the well is completed in Santa Fe formation, which is L2 and L3 in this area.

The remaining 7 wells are located generally east of Fort Garland, in or near the valley of Sangre de Cristo Creek (see Figure 18). Two of these 7 are recommended for omission from the calibration set. Well permit no. 85414 appears to be dual-completed in L1 and L2, so that the water level is probably not reflective of one aquifer layer. The driller's report for Well permit no. 65009 is of poor quality and unreadable on the best copy available, and no screened interval is reported. Of the remaining 5 wells, all are recommended for reassignment from L1 to L2, as the logs for all 5 show that the wells are completed in the upper Santa Fe formation, which is L2 in this area.

Recommended calibration weighting changes: Several wells are recommended for omission from the calibration set for various reasons as discussed previously. Several wells in this group are recommended for layer reassignment from L1 to L2. None are recommended for calibration weighting changes.

Recommended future investigations: None.

Recommended future modeling and sustainability metrics enhancements: The wells in this group for which the aquifer layer has been checked and verified most likely would be suitable for inclusion in future sustainability metrics.

4 Conclusions and Recommendations

The high residual wells were placed into 15 well groups with a number of the well groups having two subgroups. Within each well group or subgroup all of the wells or a representative sample were reviewed to determine the reason for the high residual values. There are several reasons why it is probable that high model residuals occur in the wells reviewed, including the following (listed in decreasing order of occurrence in the wells reviewed):

- Error in assignment of the aquifer layer to which a particular well observation is assigned.
- Perching of the local water table above the regional water table.
- Wells in bedrock formations not represented in the RGDSS aquifer layering.
- Wells that may be located in mis-mapped or unmapped geologic fault blocks that, to some degree, may hydrogeologically isolate certain areas of water table.
- Wells screened or slotted across more than one aquifer layer.
- Erroneous water level, well depth, or screened interval due to an error in transcription from well record to database.
- Erroneous water level, well depth, or screened interval due to an error in reporting by the well contractor.
- Error in location of the well.

Within each well group or subgroup recommendations were made as to how to resolve the high residual problems. These recommendations included the following:

- Reassign to new layer, generally from shallower to deeper layer.
- Omission from calibration set due to completion in more than one layer, poor well logs, discrepancy in water level, lack of completion interval, duplicative wells, water table perching, mislocated well, and others.
- Reduce weighting of wells within a group due to perching of water table above regional water table.

- Defer the use of wells within given area for now due to a high potential for these wells to represent a perched water table or fault block isolation from SLV aquifer layers due to close proximity to mapped faults and a potential high elevation bedrock block in the subsurface.
- Deferral from inclusion in sustainability metrics until completion of revised mapping and a revised estimation of whether or not any of these wells are reflective of the SLV aquifer layering, and revised model calibration.

Follow up with USGS researchers regarding recent high-resolution aeromagnetic geophysical surveys, and use the new information to develop revised aquifer mapping.

Within certain groups none of the wells are recommended for inclusion in future enhancement of sustainability metrics.

It may be advisable to review the Sangre de Cristo fan area to see whether there is sufficient data, and sufficient hydrogeologic justification, to warrant revising aquifer mapping near the Sangre de Cristo mountain front in the San Luis Creek and Crestone vicinity.

5 Comments and Concerns

None

Appendix A

Spreadsheet Tabulations and Recommendations of All Wells Reviewed