RGDSS Memorandum

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	Andy Moore, P.E.	Colorado Water Conservation Board
From:	HRS Water Consultants, Inc.	
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Subject:	Hydrogeologic Mapping Review of Conejos / San Antonio Region	
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INTRODUCTION

This memorandum summarizes the results of a review of hydrogeologic layer mapping of the Conejos River / San Antonio River valleys region of the San Luis Valley modeled area. This work was done as part of HRS' participation in the peer review process to identify and implement improvements to the RGDSS. The study area for this hydrogeologic review included the subdrainages of the Conejos River, the San Antonio River, Punche Arroyo; their tributaries, and parts of the Alamosa River and La Jara Creek subdrainages within the RGDSS modeled area. The study area was defined on the north and south by the northern and southern boundaries of Conejos County; on the east by the San Luis Hills and the Rio Grande River, and on the west by the Los Mogotes volcanic highland (see Plate 1). An extension of this hydrogeologic review to the south, encompassing the valley of the San Antonio River and the Los Pinos River from approximately the Colorado – New Mexico line downstream to U.S. Highway 285 near Antonito is discussed in a separate memorandum.

Modeling results as compared to stream gain/loss and water-level observations in the study area over the past several years has shown that the valley-wide hydrogeologic mapping done in the earlier phases of the RGDSS was not sufficiently detailed to reflect the complexity of the hydrogeology in this study area. The State and the Peer Review Team (PRT) felt that a better conceptual representation of the hydrogeology was needed than currently exists in the model. Accordingly, HRS was asked to review the available hydrogeologic data and propose improvements to be incorporated in the model.

The primary objectives of this assignment were:

- Determine the depth and extent of the confining clay layer underlying the region, and determine whether or not a confining clay layer is present or absent beneath the Conejos and San Antonio Rivers within the RGDSS model area.
- Recommend any changes to the depth and thickness of the layering of the unconfined aquifer (layer 1), the uppermost confined aquifer layer (layer 2), and deeper layers (as needed) that are represented in the RGDSS model.
- Identify the extent of perched water tables in the study area, because of potential effects on the location of well pumping depletions or recharge accretions.

Other objectives included addressing the following questions, to the extent data would allow:

- What is the relationship/interaction between the surface water flow in the Conejos and San Antonio Rivers to the underlying aquifer(s)?
- What is the general gradient of the water table in the study area?
- Is there a hydrogeologic explanation for the commonly observed problem of waterlogging of soils east of Highway 285 in the Conejos River valley?
- Is the confined aquifer or the unconfined aquifer the primary source of water to McIntyre Spring?
- Does upwelling of confined aquifer water through the Manassa Fault cause the observed gain in the Conejos River between the confluence with the San Antonio River and the Rio Grande River?

No field measurements or testing were done specifically as part of this hydrogeologic evaluation. HRS has visited the study area during this work. We have reviewed published and unpublished public-record geologic and hydrologic data, including work done during previous phases of RGDSS and on our many field trips to the region.

APPROACH

The majority of the site-specific hydrogeologic interpretations made during this work were based on interpretation of lithology from driller's reports. All of the available logs were researched using the State Engineer's Office (SEO) well permit database. Other data reviewed included lithologic logs from RGDSS piezometers nos. 3, 7, 8, and 12 (see Plate 1 for locations). The Rio Grande Water Conservation District water level database was reviewed for water levels and artesian heads in the study area. U.S. Geological Survey, U.S. Bureau of Reclamation, and New Mexico Bureau of Geology and Mineral Resources geologic maps and hydrologic reports were consulted. In addition, previous recent HRS studies consulted included a hydrogeologic well data review of the San Antonio River subdrainage for the RGDSS in 2008, and a hydrogeologic data review of the Punche Arroyo subdrainage for Salazar Farms in 2009. Hydrogeologic studies by HRS personnel in this general study area have been done at various times since 1979.

Well Log Evaluations

All well logs were downloaded from the SEO's website using the site's Well Permit Search Tool http://www.dwr.state.co.us/WellPermitSearch/default.aspx. First, well permits were downloaded by Township & Range and only those with a status of Well Constructed, Well Abandoned, Well Replaced, Permit Issued, and Completion Status Unknown were selected. These permitted wells were then exported and combined into a single Excel™ spreadsheet:

(RGDSS_WellLog_PermitSearch.xlsx MostCurrentFromGIS tab).

Eight fields/columns were added to the spreadsheet in addition to the fields included from the SEO. The eight additional fields include: total clay above first rock/volcanic, depth to first clay, depth to first rock/volcanic, log comments, static water level elevation, elevation from the National Elevation Dataset (NED), NED Elevation Source, and Log Availability. Next, the actual well logs/completion reports with lithology listed were downloaded from the SEO's site and log data were added to the Excel spreadsheet.

Initially only wells within one mile of the Conejos and San Antonio Rivers were examined. Later, after discussion with the RGDSS peer review team, the scope was broadened to include the present study area. After reviewing every well log and adding the log data to the spreadsheet, the well data were imported into the project GIS (RGDSS_Conejos.mxd) using the UTM X & Y coordinates (NAD 83 meters). During this data review a total of 3,367 well permit records were examined. Of these 3,367 wells, 1,555 permit files – (46%) included a well log/completion report. The wells with well logs and completion reports are shown on Plate 1. All of those driller's reports were reviewed in this evaluation of the study area. Decreed wells without permits were not included in this evaluation, as most of these wells would not have well logs. "WCB" (i.e. CWCB; Colorado Water Conservation Board) well locations were corrected to match their latest permit number. These are cross-referenced in the well log database.

Criteria Used in the Evaluation of Well Logs

In order to evaluate the many driller's logs in the study area in a manageable time period, we identified certain criteria that could be used to isolate the depths of the rock types and layers of interest. These criteria included: the depth to water (indicative of the top of the saturated portion of layer 1, the unconfined aquifer); the top of first clay (indicative of the top of layer 2, the first confined aquifer layer); the top of the first indication of a volcanic rock layer (this can be indicative of the bottom of layer 2 and the top of layer 3 in the study area); and the total clay thickness above the first volcanic rock layer (indicative of the thickness of the confining clay in layer 2).

Specific criteria for selection and inclusion in the log database were as follows:

- Total clay above first 'rock' (Ft.) - This field of the database includes total clay above the first rock/volcanic as identified on drillers' logs (clay below first rock was not included). Clay was defined as clay-only layers, shale, and clay mixed with other rock materials (i.e. clay mixed with sand, gravel, boulders, rock, etc.). Solid rock or volcanic rock identified in the well log were used to define the first rock layer. In driller's descriptions this can be described in various terms including solid rock, malpie, lava rock, or basalts. As shown on the data-posting working maps for this review, 0 = No clay identified in the log.

- Depth to First Clay (Ft.) – This field includes the depth to the first clay or shale identified in the well log, whether it was clay-only or clay mixed with sand, gravel, boulders, or rock. It includes the depth to first clay even when the clay was below the first rock layer. As shown on the data-posting working maps: "Surface" = clay at surface. "NA" = no clay mentioned in log.

- Depth to First Rock (Ft.) – This field includes the depth to the first rock layer identified in the well log. Solid rock or volcanics in the well log were used to define the first rock layer (i.e. solid rock, malpie, lava rock, basalt, and similar terms). Mixed rock layers (i.e. rock & sand or rock and boulders) were not counted as a depth to first rock. On the data-posting maps: 'Surface' = rock at surface, 'NDE' = Not deep enough to identify rock.

- Log Comments – This field includes general notes from the log report, and occasional comments regarding the quality of the log.

- Static Water Level Elevation – This was calculated using the SWL from the well log/permit file and the NED Elevation as ground surface. Note: For well reported as flowing well at the time of drilling, SWL elevation was set to 0 on the data posting maps.

- NED GS Elevation – the USGS *Lat/Lon to Elevation* tool was used to determine elevations for each well point with a log. This ground surface elevation then was used to calculate the SWL Elevation. The tool used to perform this is no longer supported by the USGS. The successor USGS toolset is located at: http://seamless.usgs.gov/ned1.php

- NED Elevation Source – The source for all elevation points was the NED 1/3 arc second (10 meter) database.

- Log Available – This field indicates that a lithologic log was available for a particular well permit – either yes or no. If the field is blank it was assumed that no well log was available. This was most common for late-registered or older permitted wells.

San Luis Valley Well & Water-Level Database

Additional well data from the Rio Grande Water Conservation District ("SLV Well database") was used to provide supplemental water level data. Files were downloaded from the SLV well database at http://www.prinmath.com/rgwcd/dbase/data.htm

The Master.databasef and wl.databasef were used to create a single table with average depths to water (DTW). An average DTW for each well was calculated using an Excel pivot table (SLVWelldatabase_WLs.xlsx). This average DTW table was then joined with the Master database table to define a location and ground surface elevation for each well (these data points are stored in SLV_Wells_AvgWLs.shp). Static water elevation was then calculated using GS - avg. DTW. GS = ground surface used for RGDSS. Per Principia Mathematica (verbal communication, various dates), all water levels measurements in the wl.databasef have been adjusted to correspond to the GS elevation. Therefore, GS-DTW = Water Elevation.

Hydrogeologic Interpretation of Well Log Data

After the well log database was populated and error-checked, and the data posted to working maps using a USGS topographic map background, HRS hydrogeologists reviewed the working data-posting maps, continually referring to the well data, to arrive at our interpretation of the hydrogeologic features of interest to this evaluation.

Hydrostratigraphy and Aquifer Layers

This hydrogeologic review has confirmed the general stratigraphy of the aquifer layering as previously represented in the RGDSS, but has provided refinement of the depth, thickness, and aquifer materials that comprise aquifer layers 1, 2, and 3. Layer 4 was too deep to be considered in this evaluation of driller's logs from well records. No well information in the study area is sufficiently deep to determine whether Layer 5 exists in the study area. Our best estimate based on regional geophysics is that Layer 5 is unlikely to exist in this area, although at this time data is not sufficient to answer this question. Until such time as the deep well and geophysical database improves, we have chosen not to include Layer 5 in this study area.

Figure 1 shows generalized east-west and north-south cross-sectional views of the geology in the central part of the study area. These two illustrative cross sections show the geologic formations that form the aquifer layers as they are represented in the RGDSS model. These formations, and the physical characteristics of the aquifer layers in the different subwatersheds within the study area, are shown in Table 1.

Table 1 Hydrostratigraphy of the Conejos River valley and San Antonio River valley study area

		Conejos River Subwatershed	La Jara Creek / Alamosa River Subwatershed	San Antonio River Subwatershed	Punche Arroyo Subwatershed (northern Taos Plateau)
Layer 1	*Formation*	Quaternary alluvium and glacial outwash. Holocene deposits in present river bottoms. Colluvium and landslide deposits along steep hillsides.	Quaternary alluvium and glacial outwash. Holocene deposits in present river bottoms. Colluvium and landslide deposits along steep hillsides.	Quaternary alluvium and glacial outwash. Holocene deposits in present river bottoms.	Quaternary alluvium and glacial outwash. Holocene deposits in present river bottoms. Not present south of T32N - T33N line.
	Lithology	Poorly stratified silt, sand, gravel in valley bottoms. Clay lenses present in most areas.	Poorly stratified silt, sand, gravel in valley bottoms. Clay lenses present in most areas.	Poorly stratified silt, sand, gravel in valley bottoms. Clay lenses present in most areas.	Poorly stratified silt, sand, gravel in valley bottoms. Clay lenses present in most areas.
	Thickness	20 to 60 feet. Generally thinning from west to east.	20 to 60 feet. Generally thinning from west to east.	20 to 50 feet in San Antonio valley bottom.	0 to 40 feet
	Type of Aquifer	Unconfined	Unconfined	Unconfined. Perched water table generally south of T33N - T34N line.	Unconfined, perched water table where the aquifer exists. Does not exist generally south of T32N - T33N line.
Layer 2	*Formation*	Older alluvium (Pleistocene - Pliocene?) grading into Alamosa Formation confining clays to the north.	Alamosa Formation confining clay series	Older alluvium (Pleistocene - Pliocene?). Servilleta Fm. In southern part.	Servilleta Formation (Pliocene)
	Lithology	silt, sand, gravel terrace and fan deposits; poor to fair stratification; uppermost clay forms an aquitard. Some clay in discontinouous lenses deeper. Grades into Alamosa Fm. 'blue clay' series north of Manassa.	silt, sand, gravel terrace and fan deposits; poor to fair stratification; some clay in discontinouous lenses. Grades into Alamosa Fm. 'blue clay' series north of Manassa.	silt, sand, gravel terrace and fan deposits; poor to fair stratification; uppermost clay forms an aquitard. Servilleta basalt lava flows may be present beneath San Antonio River in some parts of this area.	Fractured to non-fractured olivine basalt lava flows, interlayered with sediments. Where unfractured, lava forms an aquitard along with clay layers on top of, and between, lava flows.
	Thickness	20 to 200 feet. Generally thicker in central study area; thins to east and west.	20 to 300+ feet. Generally thickens to the north; thins south, east and west.	20 to 150 feet. Thickens to the south.	20 to 200 feet. Thickens to the south.
	Type of Aquifer	Confined	Confined	Confined (N.) to Unconfined (S.)	Unconfined
Layer 3	*Formation*	Hinsdale / Los Pinos interbeds (Oligocene)	Hinsdale / Los Pinos interbeds (Oligocene)	Hinsdale / Los Pinos interbeds (Oligocene) and Servilleta Fm. (south)	Servilleta Formation (Pliocene) or Hinsdale / Los Pinos interbeds (where present)
	Lithology	Fractured to unfractured basalt lava flows sourced from vents at Los Mogotes. Enhanced permeability where fractured. Lava flows are interbedded with Los Pinos Fm sediments; thickest in central study area.	Fractured to unfractured basalt lava flows sourced from vents at Los Mogotes. Enhanced permeability where fractured. Lava flows are interbedded with Los Pinos Fm sediments; thickest in central study area.	Fractured to unfractured Hinsdale basalt lava flows sourced from vents at Los Mogotes. Interfingers with Los Pinos Fm sediments.	Fractured to non-fractured olivine basalt lava flows, interlayered with sediments. Where unfractured, lava forms an aquitard along with clay layers on top of, and between, lava flows.
	Thickness	20 to 200+ feet. Generally thicker in central study area; thins to east and west.	20 to 200+ feet. Generally thicker in central study area; thins to east and west.	20 to 200+ feet. Hinsdale pinches out to south; Servilleta thickens to south.	20 to 200 feet. Thickens to the south.
	Type of Aquifer	Confined	Confined	Confined (N.) to Unconfined (S.)	Probably unconfined; may be confined in some areas.
Layer 4	*Formation*	Conejos Formation	Conejos Formation	Conejos Formation	Conejos Formation
	Lithology	Lava flows, flow breccias, lahar, ash fall, and similar deposits interbedded with poorly-indurated mostly fine-grained volcaniclastic deposits. Layer 4 may inlcude some deeper, mostly fine-grained sandstones and mudstones of the Santa Fe Fm in this area.	Lava flows, flow breccias, lahar, ash fall, and similar deposits interbedded with poorly-indurated mostly fine-grained volcaniclastic deposits. Layer 4 may inlcude some deeper, mostly fine-grained sandstones and mudstones of the Santa Fe Fm in this area.	Lava flows, flow breccias, lahar, ash fall, and similar deposits interbedded with poorly-indurated mostly fine-grained volcaniclastic deposits. Layer 4 may inlcude some deeper, mostly fine-grained sandstones and mudstones of the Santa Fe Fm in this area.	Lava flows, flow breccias, lahar, ash fall, and similar deposits interbedded with poorly-indurated mostly fine-grained volcaniclastic deposits. Layer 4 may inlcude some deeper, mostly fine-grained sandstones and mudstones of the Santa Fe Fm in this area.
	Thickness	200 to 1,500+ feet. Generally thought to be thicker in central study area; thinner to east and west based on regional geophysics.	200 to 1,500+ feet. Generally thought to be thicker in central study area; thinner to east and west based on regional geophysics.	200 to 1,000+ feet. Little data available on this formation.	200 to 1,000+ feet. Little data available on this formation.
	Type of Aquifer	Confined	Confined	Confined	Confined

Note: Based on regional geophysics, Layer 5 is unlikely to exist in this area. No wells penetrate sufficiently deep to define this layer in the Conejos / San Antonio study area.

As described in Table 1, the hydrogeology of the aquifers in the study area is quite complex. Notable features of the aquifer layers in the study area, with respect to questions raised by the RGDSS peer review committee, are as follows:

- The unconfined aquifer (model Layer 1) in the majority of the study area generally thickens and is more gravelly to the west toward Los Mogotes, and becomes thinner and less gravelly to the east toward the Conejos River and the lower reach of the San Antonio River.
- Ground water recharges to the unconfined (and also the confined) aquifer in the western part of the study area by deep percolation from precipitation, stream losses, and ditch losses.
- Soil waterlogging due to high water table is common in the area generally east of Highway 285. It is exacerbated by the thinning of Layer 1 in a downgradient direction toward the Conejos River (generally north and east), probably in combination with irrigation return flows.
- Clay is not noted in every one of the 1,500-plus driller's logs in the study area, but the presence of clay is noted in a majority of the well logs. Clay is noted in a majority of well logs at the bottom of the near-surface Layer 1 alluvium and glacial outwash deposits distributed throughout the majority of the study area. From this, we conclude an aquitard layer exists throughout the majority of the study area with the exception of the westernmost part (i.e. upper Conejos River valley above Antonito, and a gravel-rich area at the foot of the Los Mogotes highland) where the clays described in driller's logs generally are less continuous than in the rest of the study area.
- Relatively continuous layers described as clay or clay-rich of varying thickness can be found beneath the San Antonio River and the Conejos River at nearly all locations in the study area, with the exception of the upper part of the Conejos River above Antonito, and the upper part of the San Antonio River in the vicinity of the villages of San Antonio and Ortiz. However, distinct differences between shallow (perched) and deeper (regional) water table depth and gradients indicate the likelihood of a relatively low hydraulic conductivity layer associated with near-surface streambed deposits in this area.

- Layer 2 in the majority of the study area, with the exception of part of the San Antonio River valley and the entirety of the Punche Arroyo subwatershed, is comprised of interbedded sands, gravels, and clays. The clays are of sufficient lateral continuity to form an aquitard (confining layer) in most of the study area. In the northern part of the study area, generally north of Manassa, the ‘blue clay series’ of the Alamosa Formation is present, and thickens from southwest to northeast from a feather edge south of Manassa to 300+ feet north and east of Sanford.
- Basaltic lava flows of the Hinsdale Formation, and Los Pinos Fm. sediments (part of the Santa Fe group of formations) are interbedded with the Hinsdale lava flows. These layers, together, comprise Layer 3 in the majority of the study area. Where the basalt flows are unfractured their permeability is relatively low. Where fractured, which appear to be the case in the majority of the study area, the basalt flows comprise a highly permeable aquifer. The sediment layers of the Los Pinos formation that are interbedded with the Hinsdale basalt lava flows generally are comprised of poorly indurated conglomerate and sandstone, with some thinner layers comprised of volcanic ash along with silt and clay. The Los Pinos sediments appear to be of relatively low hydraulic conductivity throughout the study area, sufficient to form an aquitard or series of aquitards creating multiple perched water tables. The Los Pinos sediments, where they are present immediately below more highly permeable younger sediments of the San Antonio, Los Pinos, and Conejos Rivers and glacial outwash or fan deposits, are believed to form an aquitard layer sufficient that in some areas, such as in the upper San Antonio River valley south of Antonito, the top of the Los Pinos forms the top of Layer 2, the uppermost confining layer.
- Flowing wells in the confined aquifer layers (generally layers 2 and 3) as reported in driller’s logs exist generally north and east of Highway 142 and Highway 285 with the exception of the La Jara / Alamosa subwatershed area, where flowing wells exist in some areas west of Highway 285 (see Plate 3).
- The reach of the San Antonio River generally located between Antonito and a few miles southeast of Manassa, and its associated water-table aquifer, are perched above a deeper regional water table that exists within or beneath Servilleta Formation basaltic lava flows and interflow sediment layers, where the Servilleta Formation is present. The Servilleta

Formation extends in the subsurface only a few miles north from New Mexico into Conejos County, generally to a point beneath the Conejos River in T33N as interpreted from driller's logs and regional geophysical surveys.

- The deeper water table seen in T32N (San Antonio River valley and Punche Arroyo subwatershed) generally coincides with, and may be a result of, the presence of the Servilleta Formation, which is not seen to extend to the north (or, if it does, it is much deeper to the north). Review of water levels in the Punche Arroyo subwatershed reveals a series of water tables, generally occurring within the Servilleta Formation lava flows and finer-grained layers and lenses of sediments that are found between the Servilleta lava flows. The regional water table in the Servilleta (model layer 2 in the Punche Arroyo subwatershed; see Table 1) is generally on the order of 100 feet deep, appears to be unconfined, and has a gradient to the south and east away from the San Antonio River.
- This is in contrast to the overlying perched water table in the near-surface alluvium of the San Antonio River, where the gradient is generally parallel to the San Antonio River, and the confined aquifer gradient in layers 2 and 3 in the area generally north of Antonito, where the gradient is north and east toward the Conejos River.
- Aquifer layer 1 does not exist in the southernmost two to three miles of the study area generally located between Highway 285 on the west and the Pinon Hills (southern part of the San Luis Hills) on the east (see Figure 1). In this area, which is part of the Punche Arroyo watershed (geologically considered a part of the northern Taos Plateau) lava flows of the Servilleta Formation exist at the ground surface or just below surface soils. Alluvium of the San Antonio River or Punche Arroyo either was never deposited in this area or was eroded away from the upper lava flow surface.

Other specific questions posed by the RGDSS peer review team are addressed in the following sections.

Clay Extent Underlying the Conejos & San Antonio Rivers

In order to address the question of the lateral extent of clay layers underlying the rivers, HRS constructed five cross sections across the Conejos River where lithologic logs existed for wells on either side of the river. HRS also constructed a sixth cross section parallel to and on their south side. The locations of the cross sections, which are attached to this report, are labeled A-A' through F-F'. The locations of the cross sections are shown on Plate 1. The wells used in the construction of each cross section are highlighted. The ground level elevations used for the sections were estimated from USGS 7 ½ minute topographic maps. Each of the first four cross sections A-A' through D-D' is approximately orthogonal to the river. Plate 2 shows the depth to first clay based upon the driller's logs.

Cross section A-A' is located just north of Saddleback Mountain in Sections 13 and 14, T35N, R10E. This cross section shows the top of the clays. In this area the clays were generally described on the driller's reports as blue to brown clay, or blue clay, at 18 to 38 feet below ground level and generally range from 12 to 32 feet thick. The elevation of the top of the clay varies from 7527 to 7548 feet based on a ground level elevation from the available digital elevation model (DEM).

Cross section B-B' is located approximately 1.5 southwest of cross section A-A', in Sections 26 and 27, T35N, R10E. This cross section shows a similar interval generally described on driller's logs as blue clay, with a depth to the top of 28 to 35 feet and an elevation of 7553 to 7556 feet.

Cross section C-C' is located approximately 3.5 miles southwest of cross section B-B' and just north of Sego Springs, in Sections 8 to 10, T34N, R10E. Three of the four wells list clay of blue color (or no color is noted) with the top at 38 to 45 feet and 20 to 35 feet thick. One well, Permit No. 1236 on the east side of the river, did not have any clay described above the first volcanic rock at 80 to 100 feet (total depth [TD] of 100 ft). It is not known whether the driller did not see any clay, did not describe clay that was present in the drill cuttings, or whether there was actually no clay present. This variation between descriptions that do not identify clay, to those that do identify clay in wells very close to each other, is not uncommon in the data set of driller's logs in the study area. The elevation of the top of clay varies from 7586 to 7602 feet.

Cross section D-D’ is located approximately 1.5 miles to the south of the confluence of the Conejos and San Antonio Rivers and southeast of Manassa in Sections 20, 29, 28 and 30, T34N, R10E. “Blue clay with sand” to “brown clay” to “clay” (with no color noted) was described in each of the five wells reviewed. The top of clay was encountered from 21 to 60 feet with an elevation of 7618 to 7653 feet. No clay was described for well Permit No. 240709, only sand and gravel above volcanic rock at 91 to 100 feet. This well is approximately 1,500 feet southwest of well Permit No. 20793-R which had “clay” (no color mentioned) described from 37 to 67 feet. These two wells are located between the two rivers.

Cross section E-E’ is located approximately two miles northeast of Antonito in Sections 10, 15, 14, 23, 25 and 36, T33N, R9E, Sections 30 and 31, T33N, R10E, Section 1, T32N R9E and Section 6, T32N, R10E. As can be seen from the cross section, there are several “clay” to “clay and sand” layers shown. These layers appear to act as an aquitard, causing the surface water and Layer 1 ground water within the Conejos and San Antonio Rivers or their alluvium in this area to be perched, as seen from the near-surface and the deeper water levels in wells in this area. Well Permit 8634 has no clay described until 126 feet. Well Permit 49593 and wells to the south show the deeper, Layer 2 unconfined water table (below the perched unconfined water table) within the volcanic rocks. Near the south end of this cross section well Permit pair 27294-A and 49594 show the layer 1 and the layer 2 water levels. A clay layer reported in well 49593 above the water table apparently is discontinuous, and does not appear to form a confining layer.

Cross section F-F’ is located approximately parallel to CR E.5 from Highway 285 eastward. From Highway 285 this cross section trends northwest approximately 2.5 miles crossing the San Antonio River and then approximately paralleling the Conejos River. The cross section traverses from west to east the following sections of land: Section 36, T33N, R8E; Sections 31 to 36, T33N; and Section 31, T33N, R10E. The west end shows the Conejos River alluvium having minor thin clay lenses. The Holocene or Quaternary alluvium overlies the older Los Pinos sedimentary deposits. Well Permit 224964 shows the deeper confined water level of Layer 2 within the basalts. The bluff on the east of the San Antonio River valley is the western edge of the Servilleta Formation volcanic rocks. Wells from this point eastward show the deeper Layer 2 water level within the volcanic rocks or within interbedded sediments of the Los Pinos

Formation. The two Rio Grande Water Conservation District monitoring wells, Permits 230639 and 23058, show the Layer 1 unconfined water table.

Based upon our review of the driller's log data and construction of cross sections A-A' through E-E', the 'blue clay series' of the Alamosa Formation extends underneath the Conejos River to the edge of the volcanic rocks or a talus / rubble zone at the western edge of the San Luis Hills. The clay layer forms an aquitard that defines the top of Layer 2 of the confined aquifer. From these cross sections, the clay aquitard appears to be continuous beneath the Conejos River and the San Antonio River in the areas encompassed by these cross sections. The top of the clay generally dips to the northeast, toward the Closed Basin.

Well logs are few in the San Luis Hills, and we cannot conclusively determine whether a talus zone exists in the subsurface along the western edge of the San Luis Hills. If present, a talus or rubble zone might allow enhancement of vertical permeability in local areas such as Sego Springs and McIntyre Spring.

From the cross sections developed as part of this study, and from our review of the driller's logs in the study area, we believe earlier conceptual models of the upper 100+ feet of sediments in the Conejos River valley depicted as largely consisting of sand and gravel, with clay only notable by its absence, are in error[1]. Certainly much sand and gravel does exist in Layer 1; however, clay is present in the majority of the study area with sufficient lateral continuity in Layers 1 and 2 that it becomes an important component of the hydrogeologic conceptual model of the area.

Extent of Alamosa Formation 'Blue Clay' Series

The southwestern extent of the 'blue clay series' of lacustrine (i.e. lakebed) deposits of the Alamosa Formation was tracked by determining the approximate elevation of the first blue clay described in Section 1, T34N, R10E. This elevation was then used to estimate the approximate depth that blue clay would be expected, progressing southwest in the study area. To the southwest the ground level elevation rises upstream on alluvial fan of the Conejos River.

[1] Williams, R. S., Jr.; Hammond, S. E., 1989. Selected water-quality characteristics and flow of ground water in the San Luis basin, including the Conejos River subbasin, Colorado and New Mexico. U.S. Geological Survey ; U.S. Geological Survey, Water-Resources Investigations Report 89-4040, 43 p.

Progressing southwest from Section 1, T34N, R10E there are fewer wells drilled deep enough to have penetrated to the estimated elevation of the top of the blue clay. Yellow clay was described in a few wells in the expected interval of the first blue clay. This description is indicative of an oxidized zone of clay, perhaps due to weathering and chemical alteration near the top of the series of lakebed deposits. From the driller's logs reviewed, the blue clay series extends to a point approximately 2 miles southwest of Manassa. We interpret this to indicate the southernmost point of deposition of the Alamosa Formation lakebed clays. Southwest of the blue clay extent, brown clay layers were described in the same approximate depth interval as the blue clay would be expected. The yellow and brown clay layers reported in driller's logs are interpreted to be part of the depositional system of the Conejos River alluvial fan including overbank deposits from local flooding of the rivers, or from slow moving streams deposited near the southernmost extent of the lake in which the Alamosa lakebed clays were deposited, when Lake Alamosa represented a local base level for the ancestral Conejos River and San Antonio River.

Extent of Flowing Wells

The general southwestern extent of flowing wells can be identified from the database of driller's reports used in this hydrogeologic review. However, the driller's logs represent a time span of approximately 50 years and therefore do not allow us to define the extent of flowing wells as of any particular date. Based on the driller' logs reviewed, the southwestern extent of flowing wells is approximately coincident with the town of Manassa. This is shown by the dashed orange line on the depth to water map, Plate 3. Records of flowing wells can be found in the areas of the San Antonio River and the Conejos River from approximately Manassa downstream to the confluence with the Rio Grande.

San Antonio River from Highway 285 South of Antonito to the Confluence with the Conejos River

In the area south of Antonito the San Antonio River flows directly on volcanic rock in Section 32, T33N, R9E. To the east of this location, driller's logs describe the depth to first clay as being less than 35 feet and in some areas as being less than 10 feet. The depth to the first volcanic rock is also quite shallow, generally less than 80 feet (see Plate 4). Also in this area there are two distinct water tables: a shallow one associated with the river and near surface alluvial deposits in which the gradient is approximately parallel with the river, and a deeper water table within the interbedded Servilleta Formation basalt lava flows and interbedded sediments, in which the gradient is toward the southeast. The first "confined" aquifer (Layer 2) appears actually to be unconfined in the area southeast of Antonito, but transitions to confined aquifer conditions as one progresses downstream toward Manassa and the confluence of the San Antonio River with the Conejos River. The water in the San Antonio River and the near-surface alluvium is perched on top of shallow clay layers or, in some areas, on top of the shallow-lying Servilleta Formation volcanic rock. The available driller's logs indicate that this perched aquifer system probably persists downstream along the San Antonio River approximately as far as the T33N – T34N township line, which is about two to three miles southeast of Manassa. This is approximately coincident with the southern limit of flowing wells in this area. The two water tables are separated by an unsaturated zone in an area that appears, in the southern half of T33N, to coincide with the presence of relatively shallow basalt lava rock layers of the Servilleta Formation in the subsurface.

As an example in the vicinity of cross section D-D', Well Construction and Test Report form for well Permit No. 187335 (Sec. 33, T34N, R10E) shows this well to be 92 feet deep and perforated (open to the formation) from 70 to 90 feet. The static water level for the Layer 1 "unconfined" aquifer (gravel above the brown clay from 21 to 35 feet) is listed as 3.5 feet. The completed well is listed as flowing: i.e. the static water level is above ground level an undefined height. This well is located approximately 1,500 feet southeast of the San Antonio River. This shows the perched water table and the unsaturated zone between the near-surface water table and the confined aquifer, probably is not present at this location.

Another example, showing perched water table conditions, is well Permit No. 5930-R (Sec. 28, T33N, R9E). This well is 305 feet deep. The driller's log reported shallow water at 21 feet within the alluvial sand and gravel interval (Layer 1) above the "sand and streaks of clay" layer from 45 to 50 feet, and above the volcanic rock described at 180 feet. The water level in the completed well was at 157 feet within the volcanic alluvial sand and gravel interval. Streaks of clay were reported from 45 to 50 feet and 105 to 120 feet with the first volcanic rock at 180 feet.

Conejos River Downstream of Highway 285

From its crossing under Highway 285 about one mile north of Antonito, downstream to its confluence with the Rio Grande River, the depth to first clay beneath the Conejos River is generally less than 30 feet. In most areas along its course, there are multiple clay layers below river level, as described in the driller's reports. There are two distinct water tables beneath the Conejos River in the vicinity of Antonito: a shallow water table associated with the river and near-surface alluvial material (Layer 1), and a deeper water table within the interbedded volcanic and alluvial material (Layer 2). The first "confined" aquifer (layer 2) appears to be unconfined for a distance of approximately four miles east of Antonito. Layer 2 appears to transition from unconfined to confined conditions approximately two to three miles south of Manassa, based on the available well data. The Layer 1 water table and the river appear to be perched due to the presence of relatively low-permeability shallow clay or clay-rich layers in the reach between Highway 285 and a point approximately four miles downstream.

Conejos River Upstream of Highway 285

Progressing upstream (southwest) along the Conejos River from its crossing of Highway 285 north of Antonito, the depth to first clay is quite variable according to driller's reports. There does not appear to be a consistent clay interval underlying the river in this reach. The water level in any given well is dependent upon the depth to which the well was drilled. Shallower wells generally have a shallower depth to water while deeper wells generally have a deeper depth to water. This indicates a downward gradient of ground water movement, i.e. the river is recharging the unconfined aquifer as well as the confined aquifer in this reach.

An example of a downward gradient is found in well Permits 53580-A and 242347-A whose reported locations are approximately 250 feet apart in Section 33, T33N, R8E. Well 53580-A is completed from 310 to 330 feet with a reported water level of 280 feet. No volcanic rock layers were described in this well. A clay and sand layer was described from 60 to 120 feet. Well 242347-A is completed from 100 to 120 feet with a reported water level of 60 feet. No clay or volcanic layers were described in this well. The lithologic descriptions of these two wells in close proximity also show the variability in formation descriptions between drillers.

Depth to Top of Volcanic Rocks

Contour mapping of the depth to the first layer described as "volcanic" or "rock" from the driller's reports (see Plate 4) shows that the depth to the volcanic rocks generally increase to the northeast. There is a trough-like zone of deeper depth to the top of the volcanic rocks that trends south-southeast approximately through Sanford and Manassa, possibly extending to a point near Antonito. There are several features that appear as 'lobes' that are identifiable at the top of the mapped volcanic rocks. We believe the most likely interpretation is that these lobes are relatively narrow Hinsdale Formation basalt lava flows whose source was the Los Mogotes volcanic highland to the west and south of the lower Conejos River valley. The variability in driller's descriptions from well to well make it difficult to map individual faults or lava flows. Also, it is likely that a number of different lava flows represent the uppermost volcanic layer at different locations and at different elevations. The first volcanic layer encountered during the drilling of one well is likely to be from a different volcanic eruption than a volcanic layer described in a well at a different location.

This mapping indicates that the northernmost subsurface extent of the Servilleta Formation basalts underlies the Conejos River at approximately the 100 foot contour line. At this point the depth to the top of first volcanic/rock deepens abruptly to the north, and Servilleta lava flows are no longer identifiable.

Based upon processed (horizontal gradient, reduced to the pole) aeromagnetic geophysical contour maps supplied to HRS by Dr. V.J.S. (Tien) Grauch, USGS, in combination with our review of the driller's logs, the deepening of the 'first volcanic rock' depth may be a fault-bounded geologic feature trending NE-SW approximately through Sanford and Manassa. This feature may reflect the location of the Manassa Fault zone, a northeast-trending fault zone that has been described by previous investigators.[2][3][4]

Depth to Water Trends in the Unconfined Aquifer

The depth to water data shown on Plate 3 is from multiple years and different times of year. The data is also from wells of varying depths. Contouring of this data is very general, and was smoothed to represent an average of the depth to water in any given area. In general Plate 3 shows that the depth to water in the unconfined aquifer, layer 1, becomes progressively shallower from the west (50 ft +/-) toward the northeast part of the study area, where the depth to water generally is 20 feet or less. This is partly due to the topographic slope becoming flatter from southwest to northeast. It is also due to an overall decrease in depth to first clay from southwest to northeast.

Unconfined Aquifer Water Table Elevation

Plate 5 is a contour map of the unconfined aquifer water table elevation based upon the data shown on Plate 3 and digital elevation data for each well. Contouring of this data is very general, and was smoothed to represent an average of the water level elevation in any given area. The contouring shows that the water table gradient is relatively consistent in the majority of the study area, sloping to the northeast.

McIntyre Spring

Questions have been raised as to whether the flow of McIntyre Spring is an indicator of the piezometric head in the confined aquifer. In our experience and reading of the literature, McIntyre Spring has been thought of as an indicator of the confined aquifer at least since the Rio

[2] Tweto, Ogden, 1979, Geologic Map of Colorado. 1:500,000. U.S. Geological Survey special map.
[3] Burroughs, R., 1972, Geologic Map of the San Luis Hills, South-Central Colorado.
[4] Drenth, B., 2009, Potential field studies of the central San Luis Basin and San Juan Mountains, Colorado and New Mexico, and southern and western Afghanistan. Ph.D. Thesis, The University of Oklahoma, 165 pages.

Grande Joint Investigation (1937) or W. J. Powell's U. S. Geological Survey study of 1946-1953[5], and probably before. Powell stated:

> The [McIntyre] springs, which discharge at the base of the San Luis Hills near the contact of Alamosa formation and the volcanic rocks of the San Luis Hills, are believed to be sustained by artesian water rising to the surface along a fault plane."[6]

McIntyre Spring was referenced by C.E. Siebenthal (1910, USGS Water Supply Paper 240) as follows:

> "These springs rise in the bottom just at the foot of one of the San Luis Hills, and some of the springs appear to come up through crevices in the lava." (WSP-240, p. 101).

McIntyre Spring was referenced in the Rio Grande Joint Investigation (1936-1937) [7]as follows:

> "Among the largest springs in the valley are the McIntire Springs, on the south side of the Conejos River… They rise along the Conejos River at the base of the San Luis Hills at the contact between the Alamosa formation and the volcanics of the San Luis Hills. According to Siebenthal this is probably a fault contact. Confined water moving southeastward in the Alamosa formation comes up along the contact and through the volcanics and escapes at the surface as the McIntire Springs." - Rio Grande Joint Investigation, Volume 1, p. 262.

McIntyre Spring and its relationship to the confined aquifer were referenced by Emery and others in 1973[8]:

> "Increased withdrawal of water from the confined aquifer has caused a decrease in the flow of most artesian springs [in the SLV]. For example, McIntire Springs near Lasauses had an average flow of 21 ft3/sec in 1904 but the average flow between 1966 and 1970 was only 13.5 ft3/sec." (CWCB Circular 18, p. 24.)

A comparison of field water quality measurements of McIntyre Springs and a nearby 'cold' spring, as compared to RGDSS Piezometer no. 3, and the adjacent irrigation well 3080-F, yields the result shown in Table 2.

[5] Powell, W.J., 1958, Ground-Water Resources of the San Luis Valley, Colorado. U.S. Geological Survey Water-Supply Paper 1379, 284 pages.
[6] Ibid., p. 37.
[7] Robinson, T.W., and Waite, H.A., 1937, Ground water in the San Luis Valley, Colorado; a contribution to the Rio Grande Joint Investigation.
[8] Emery, P.A., R.J. Snipes, J.M. Dumeyer, J.M. Klein, 1973, Water in the San Luis Valley, South-Central Colorado. U.S. Geological Survey in cooperation with the Colorado Water Conservation Board. Colorado Water Resources Circular 18. 26 pages and 10 plates.

Table 2 Water Quality Field Parameters McIntyre Spring					
Source	**Date Sampled**	**Temperature deg C**	**pH**	**Specific Conductance (uS/cm at 25C)**	**Comments**
RGDSS P-3 / 3080-F (production zone 372' – 720' depth)	Oct. 2000	15.2	7.6	124	By HRS during RGDSS aquifer testing. Approx 1.5 miles NW of McIntyre Spring
McIntyre Warm Spring	1976/04/19 1984/05-04 0930 1984/05-04 0945 Circa 1903	14.0 16.0 16.0 15.6	6.9 7.7 7.8 --	265 165 215 --	1970's – 80's: NWIS no. 371648105483400 1903: as reported by Siebenthal, sampled by Headdon
Pikes Stockade Cold Spring	1976/08/22	12.0	6.5	260	NWIS no. 371737105483400

A more complete comparison is made by plotting McIntyre Spring major-ion data on a Piper trilinear diagram. We have done this, and compared McIntyre Spring major-ion component data from the U.S. Geological Survey[9] with major-ion data from Dexter Warm Spring and from well 3080-F, which is adjacent to RGDSS Piezometer no. 3 (P-3). This Piper diagram (see Figure 2) shows that the major-ion concentrations of water from McIntyre Spring and from 3080-F are very similar. Well 3080-F is screened from 372' to 696' and open hole from 696' to 720 in Los Pinos / Santa Fe sediments and lava flows of Hinsdale Formation as shown by the lithologic log of RGDSS P-3. The three McIntyre water samples and the 3080-F water sample all show water of the Calcium-Bicarbonate type, which we have found to be common in the confined aquifer of the San Luis Valley. The McIntyre sample showed slightly lower Sulfate concentrations than did well 3080-F, but otherwise the major-ion chemistry is virtually identical.

[9] Williams, R.S., Jr., and Hammond, S.E., 1989, Ground-water quality in the San Luis Basin, Colorado and New Mexico, with emphasis on the Conejos River Subbasin: U.S. Geological Survey Water-Resources Investigations Report 89-4040, 43 p.

McIntyre Springs water was sampled by the U.S. Geological Survey for Tritium, a naturally occurring isotope of Hydrogen in May, 1984[10]. The sample showed a concentration of 5.75 Tritium units, a low value indicating that the water discharging at McIntyre Springs is almost certainly dominated by confined aquifer water. "Young" ground water, recharged in 1952 or later, shows Tritium concentrations much larger than is seen at McIntyre due to the relatively high Tritium concentrations in precipitation between 1952 and 1969, during the era of atmospheric thermonuclear bomb testing.[11]

A comparison of the flow of McIntyre Spring over its known period of record (provided to us in March, 2011 by the Division 3 Engineer's Office); (see Figure 3), shows very close correlation between McIntyre Spring discharge and artesian head in a nearby confined aquifer monitoring well that has a good period of record (CON-2, located approximately two miles due north of McIntyre Spring).

Overall, based on water quality similarity, Tritium measurements, and the strong correlation between McIntyre Spring discharge and confined aquifer head in this local area, we conclude McIntyre Spring discharge is a good indicator of the confined aquifer head in this area. From this study, we hypothesize that McIntyre Spring is not directly fed by upwelling ground water through the Manassa Fault only, but instead through a combination of enhanced vertical hydraulic conductivity (Kv) in the area of the Manassa Fault zone and also enhanced Kv in a rubble or talus zone eroded from the San Luis Hills. The close similarity to Layer 3 water chemistry from Well 3080-F, located approximately 1 ½ miles upgradient (northwest) of McIntyre Spring, leads us to conclude that McIntyre Spring discharge is predominantly Layer 3 confined aquifer ground water.

Manassa Fault and the Conejos River

Emery et al (1973) reference the Manassa Fault and its supposed relationship to observed gain in flow in the Conejos River:

[10] Ibid., p. 21.
[11] Ibid.

> “The Conejos River is apparently in hydraulic connection with both the unconfined and the confined aquifers. In the reach between Manassa and Lasauses the Conjeos River flows along the fault and(or) depositional contact of the valley fill and the volcanic San Luis Hills. Geologic and hydrologic data indicate that in this reach, the confined aquifer, as well as the unconfined aquifer, discharges water into the Conejos River.” .” (CWCB Circular 18, p. 22.)

Recent geophysical work conducted by the U.S. Geological Survey[12] indicates that the Manassa Fault, shown on some maps as existing only along the western edge of the San Luis Hills, may instead be a zone of more than one fault, with vertical offsets (down to the west) in a stepwise fashion (see Figure 4). Some of the faulted areas that form the Manassa Fault zone do appear to define the western edge of the San Luis Hills, and at least one part of the Manassa Fault zone is coincident with the Conejos River. There also appear to be buried portions of this fault zone that do not directly underlie the exposed western escarpment of the San Luis Hills or the Conejos River, but instead are west of, but approximately parallel to, the river. Holocene or late Pleistocene sediments under the Conejos River, including a relatively continuous clay-rich zone, do not appear to be offset by the Manassa Fault zone. From our cross-sections of the shallow sediments across the Conejos River, it appears the sediments in Layer 1 contain clay in sufficient amount and continuity that a significant portion of the gain in the Conejos River is due to ground water discharge from the unconfined aquifer upgradient (west and south), as well as from overland flow and surface drainage. Some amount of the gain most likely is due to discharge from the confined aquifer upward into the unconfined and then into the Conejos River.

We agree with the Emery conclusion in the sense that the Conejos River is apparently in hydraulic connection with both the confined aquifer and the unconfined aquifer between Manassa and Lasauses. However, the work discussed in this document strongly suggest that the presence and apparent lateral continuity of clay-rich sediments under the river in the uppermost 50 to 100 feet indicate that the Manassa Fault should not be represented as a very high hydraulic conductivity feature that provides a “conduit” for ground water to flow from the confined aquifer directly to the Conejos River.

[12] Grauch, V.J.S, 2009-2012, personal communications.

Conclusions

1. Clay exists with sufficient lateral continuity beneath the Conejos River and the San Antonio River in the majority of the study area that the clay acts as an aquitard, impeding the vertical movement of water. The exceptions in this study area are the Conejos River valley upstream of Highway 285, and the area of the Conejos valley just east of the Los Mogotes volcanic escarpment. In these areas, water seeping from the river and from ditches apparently recharges the aquifer layers. The clay aquitard appears to form the uppermost surface of the confined aquifer (layer 2) in much of the study area.
2. Due to the presence of the nearly continuous aquitard layer beneath the Conejos River, we conclude that a significant amount of the gain observed in the Conejos River between its confluence with the San Antonio River and the Rio Grande River is from Layer 1 ground water discharge and from overland flow and surface drainage. Part of the gain is thought to be a result of upward leakage from the confined aquifer. Most of this upward leakage apparently moves through the near-surface aquitard layer to reach the river
3. Because well logs are few in the San Luis Hills and along their western edge, we cannot conclusively determine whether a talus zone exists in the subsurface along the western edge of the San Luis Hills. If a talus zone is present, which is likely based on the geologic history of the area, such a talus or rubble zone might allow enhancement of vertical permeability in local areas such as Sego Springs and McIntyre Spring.
4. Recent geophysical work conducted by the U.S. Geological Survey indicates that the Manassa Fault, formerly mapped as a single fault along the western edge of the San Luis Hills, instead is best represented as a zone of more than one fault, with vertical offsets (down to the west) in a stepwise fashion. Some fault steps do not directly underlie the Conejos River, but instead are further west.
5. From available water quality data, and from good correlation between discharge at McIntyre Spring and artesian head in the confined aquifer nearby, we conclude that the majority of the water discharged at McIntyre Spring is from the confined aquifer (predominantly Layer 3). This is most likely due to enhanced hydraulic conductivity through the Manassa Fault zone and also due to a rubble or talus zone adjacent to the nearby San Luis Hills.

Recommendations

From this review of hydrogeologic data in the Conejos River / San Antonio River study area, we make the following recommendations to the RGDSS for modeling revisions.

1. We recommend that the unconfined aquifer (layer 1) and the uppermost confined aquifer (layer 2) be revised in the RGDSS model to approximate their depth and thickness as shown on Plates 6 and 7.
2. The reaches of the Conejos River and the San Antonio River where water-table perching is observed should be represented in the RGDSS model as a relatively low Kv between layer 1 and layer 2, and a relatively high Kh in layer 2, so that the unsaturated zone between these layers will be represented in the model.
3. Layer 1 should be omitted from the model altogether in the southernmost area of the model in Conejos County where the Servilleta Formation basalts exist at the surface, and there is no alluvium present.

The Manassa Fault should be represented in the model as a zone of elevated hydraulic conductivity in Layers 2, 3, and 4, between 1 and 1 ½ miles wide. Such a zone is reasonable, because from geologic and geophysical evidence the Manassa Fault zone appears to crosscut volcanic rocks and sediments that comprise Layers 2 and 3. The evidence from driller's logs shows that the Manassa Fault zone does not offset or cut across the uppermost confining clay layer that is present beneath the Conejos River at a depth generally between 20 and 50 feet, located at and generally downstream of cross section D-D'.

Comments and Concerns

As discussed previously, HRS has researched and reviewed over 1,500 well driller's lithologic logs from the SEO well database to determine depths to water table, first reported clay, first reported volcanic rock, and total clay above first reported volcanic rock. The quality of the lithologic descriptions varied greatly from quite detailed to very general. Some logs were unreadable because the copy was too light to read. Most logs were of sufficient quality for the purposes of this investigation.

There is a noticeable variation in lithologic descriptions between drillers, even in wells that are close together. This was especially true between deeper wells and shallower wells in close proximity. One example can be seen in the following three wells in Section 20, T35N, R10E:

- Permit No. 18751-F (SE NW) is 1,000 feet deep and has no clay noted until 350 feet.
- Permit No. 41525 (NW SE) is 110 feet deep has blue clay described from 70 to 90 feet.
- Permit No. 219102 (SE NE) is 85 feet deep and has several clay to sand and clay layers described.

As shown by this example, it was not possible in this data review to reflect the exact values for depth to clay, depth to first volcanic rock, etc., for every data point. Due to the variations between well driller's descriptions we have interpreted aquifer layer depths and thicknesses on using our judgment and experience as to which logs appeared to best describe a particular locality, and also on the basis of general agreement between logs as to representative depths to clay, volcanic rocks, and water table for any particular area.

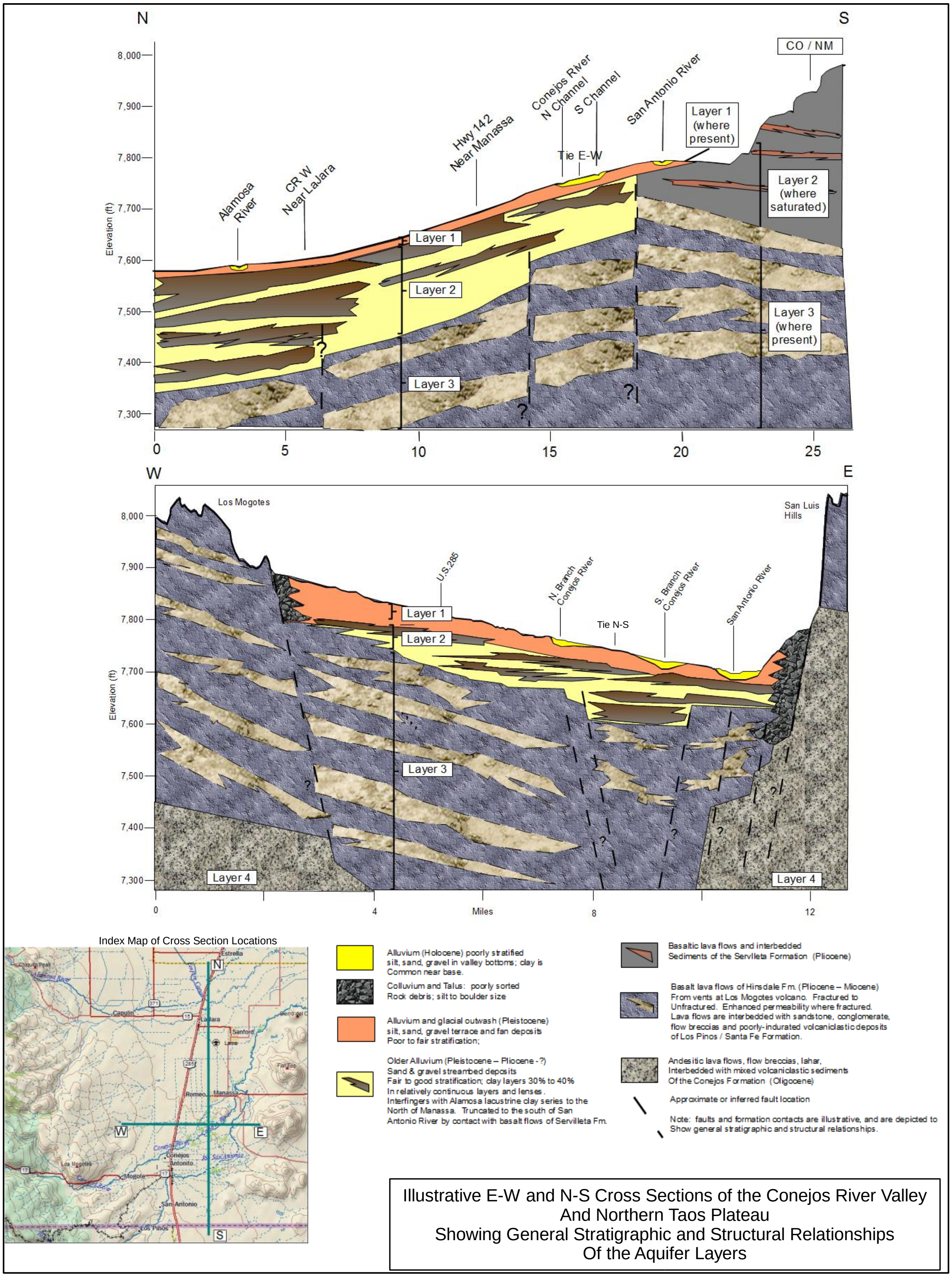

Figure 1: Illustrative East-West and North-South Geologic Cross Sections, Conejos River Valley and Punche Valley / Northern Taos Plateau.

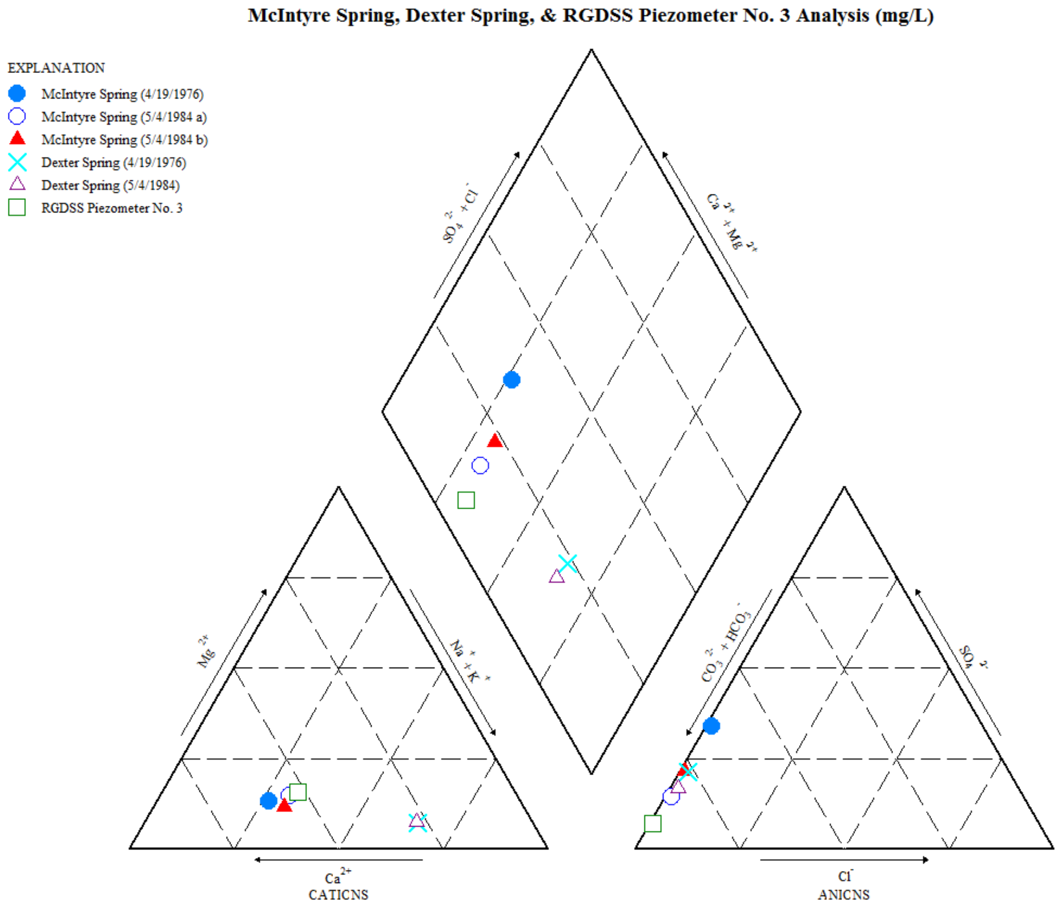

Figure 2: Piper trilinear diagram of major-ion water chemistry analysis for McIntyre Spring, Dexter Warm Spring, and RGDSS Piezometer no. 3.

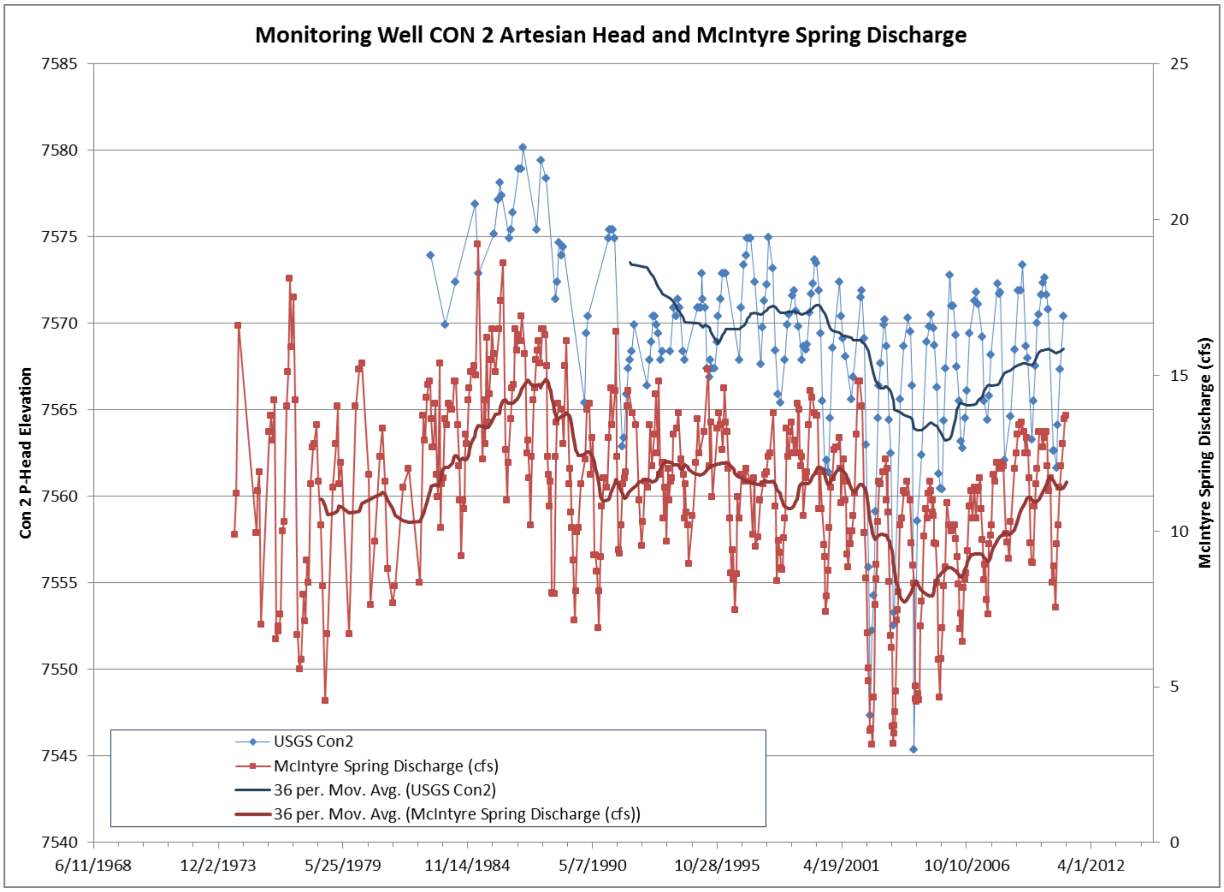

Figure 3: Comparison of McIntyre Spring discharge and artesian head in well CON 2.

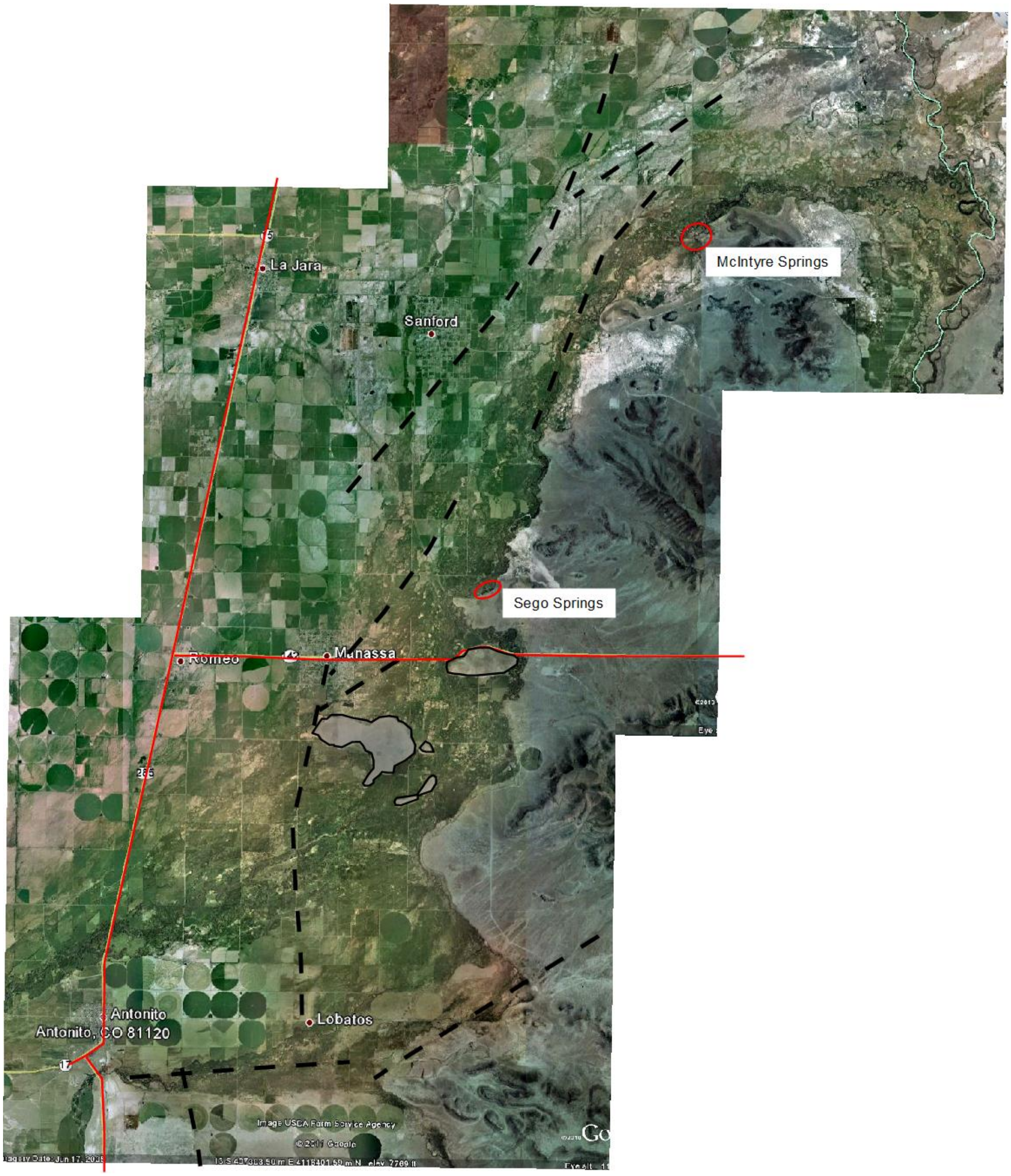

Figure 4: Interpreted location of fault segments showing the zonation of the Manassa Fault based on interpretation of U.S. Geological Survey aeromagnetic survey maps.