RGDSS Memorandum
Final

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Subject: Hydrogeologic Investigation of Upper San Luis Creek, Saguache County CO

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1 Introduction

This memorandum summarizes the results of a study of the hydrogeology of upper San Luis Creek, which is part of the San Luis Valley modeled area. This work was done as part of HRS' participation in the Peer Review Team (PRT) process to identify and implement improvements to the RGDSS. The study area for this investigation included the San Luis Creek valley from Saguache County Road AA on the south, to approximately two miles north of Villa Grove within the RGDSS modeled area, on the north. The investigation area for new data collection was confined to accessible creek crossings within the present floodplain of San Luis Creek. Review of published and unpublished data extended several miles east and west of the location of the San Luis Creek channel within that North – South reach (see Figure 1).

Comparison during RGDSS Phase 6 peer review of modeling results with water-level and streamflow observations in the study area has shown differences between the model results and observed streamflow and water table. Specifically, discussions within the RGDSS Peer Review Team revealed that there may be an area of localized near-surface water saturation in the San Luis Creek bottom that may be "perched"[1], and thus would not be reflective of the regional unconfined aquifer water table elevation.

Valley-wide hydrogeologic mapping done in the earlier phases of the RGDSS, and an earlier study of San Luis Creek further to the south[2], were not sufficiently detailed to reflect the relatively small-scale features of the near-surface hydrogeology of San Luis Creek 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, collect new data in the form of shallow (30 feet or less) drill samples and water levels, and propose improvements to be incorporated into the model.

The primary objectives of this assignment were:

[1] Perched water table: a water table that is separated from the regional water table by an unsaturated zone.
[2] HRS Water Consultants, Inc., 2012, Hydrogeologic Review of the San Luis Creek Area, Saguache County CO. Unpublished consultant's report, 14p.

- Determine, if possible, the reason for the waterlogged/wet areas along upper San Luis Creek near Villa Grove, and whether there is a perched water table separate from the unconfined aquifer in the near-surface soils and sediments along San Luis Creek in the vicinity of Villa Grove south to Peachwood Farms and CR AA.
- Recommend any changes to the depth, thickness, and hydrologic characteristics of the unconfined aquifer (Layer 1) and the uppermost confined aquifer layer (Layer 2) as represented in the RGDSS model.

Other objectives included:

- Identify the gradient of the regional water table in the study area from CR LL-57 south to the vicinity of Peachwood Farms and CR AA.

- Identify whether any perched water tables or geology-related or soils-related water table discontinuities are present along San Luis Creek in this same area.

On July 25, 2013 the Board of Directors of the Rio Grande Water Conservation District (RGWCD) authorized funds for HRS to perform this investigation according to a Scope of Work developed by HRS. During the planning and implementation of this investigation, contact was maintained with members of the PRT, whose suggestions were helpful in guiding and expediting the investigation. HRS would like to acknowledge the help of Mr. Jack Uhlenbrock, who aided HRS in locating accessible test hole sites and in obtaining permission for drilling rig access on Peachwood Farms and on private land owned by Mr. Dick Blumenhein, adjacent to CR GG.

2 Approach

New data collection was an important part of this investigation. Four E-W transects of 3 to 4 test holes each were placed (in order from north to south) along Saguache County Road (CR) LL-57 (aka Hayden Pass road), CR DD.2, CR GG, and a private farm lane in the Peachwood Farms as part of this hydrogeologic evaluation (see Figure 1). The lithologic and water level data were analyzed in combination with one transect of three 20-foot deep direct-push test holes that were placed along Saguache County Road AA in May, 2012, as part of an earlier task of hydrogeologic evaluation. In addition to the new test hole data, HRS has relied on published and unpublished public-record geologic and hydrologic data. These sources included driller's reports of water wells in the study area, geologic and geophysical maps and studies covering the area, and work done by HRS and others during previous phases of the RGDSS.

The majority of the site-specific hydrogeologic interpretations made as a result of this work were based on interpretation of lithology from the core samples obtained from the direct-push test holes for the uppermost 15 to 30 feet depth in the San Luis Creek floodplain, and from driller's reports of water wells for deeper lithology. Hydrogeologic studies by HRS personnel in this general study area have been done at various times since approximately 1979.

2.1 General Site Observations in the San Luis Creek Study Area

At the time of HRS' visit to the study area to locate and GPS the test holes, we made general observations of the soils, vegetation cover, presence / absence of streamflow, and other characteristics. This section discusses our general observations from the CR 57 crossing of San Luis Creek located approximately three miles NW, upstream, of CR LL-57 east of Villa Grove, to CR AA, about 11 miles South, downstream, of CR LL-57.

At Saguache County Road 57, approximately three miles north of Villa Grove, at the time of our site visit on August 6, 2013, there was no flow in San Luis Creek, and less than 0.25 cubic feet per second (cfs) (estimated) in its tributary Rock Creek. The channels of San Luis Creek and Rock Creek are nearly parallel in this reach, and the hay meadows at CR 57 were dry. From review of satellite imagery between 1999 and 2011 (Google Earth™) this dominantly dry condition appears to persist to a point approximately one mile upstream of CR LL-57 (Hayden Pass Road) east of Villa Grove. From that point to approximately ½ mile downstream of CR LL-57, springs and seeps are common, soils become waterlogged, and peat is common, particularly near Rock Creek. Extensive peat deposits and wetland (hydric[3]) soils have been

[3] Hydric soil: a soil that is water saturated a high percentage of the time, so that anaerobic (oxygen poor) conditions develop.

documented in this area by Cooper & Severn (1992)[4]. Poorly draining humus-rich clay loam soils along the creek bottoms in this area have been documented by the SCS (now NRCS) soil survey of Saguache County.[5]

[4] Cooper, D. J., and Severn, C., January, 1992, Wetlands of the San Luis Valley, Colorado: An Ecological Study and Analysis of the Hydrologic Regime, Soil Chemistry, Vegetation, and the Potential Effects of a Water Table Drawdown. Unpublished consultants' report prepared for Colorado Division of Wildlife, U.S. Fish & Wildlife Service, and RGWCD.

[5] Yenter, J. M., 1984, Soil Survey of the Saguache County Area, Colorado. USDA Soil Conservation Service. 203 pages, plus maps.

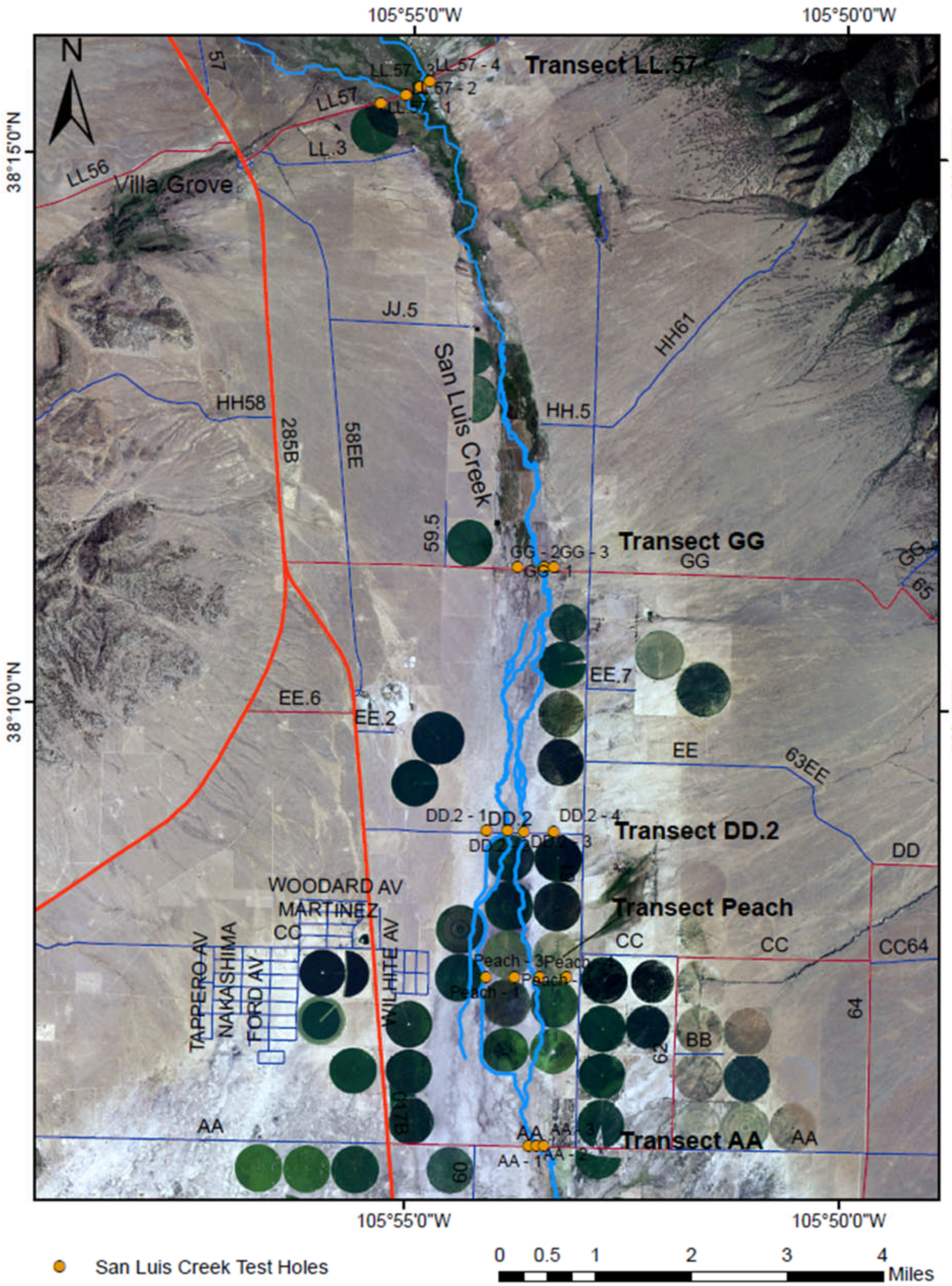

Figure 1: San Luis Creek Location Map

At the time of our site visit on August 6, Kerber Creek had no flow at Villa Grove or downstream. Only a few isolated puddles were present, apparently from a recent rain. At CR LL-57, San Luis Creek (interpreted to be the westernmost of the two active stream channels) was flowing an estimated 1 to 2 cfs. About ¼ mile to the east of San Luis Creek, Rock Creek at CR LL-57 was flowing at an estimated rate of between 1 and 3 cfs, although estimation was difficult due to slow flow through wetland vegetation. Rock Creek joins San Luis Creek about ¼ mile downstream of CR LL-57.

At a point approximately 1 ½ miles downstream of CR LL-57, peat was no longer observed, and hydric soil conditions become sparse and localized, generally along irrigation ditches on the east and west sides of the San Luis Creek bottom. The soils in the San Luis Creek bottom in this area are described by the SCS soil survey as poorly-draining clay loam. On the date of our site visit on August 6, all of the available surface water was being diverted.

Downstream at CR GG, approximately five miles downstream from CR LL-57, although a recent scour and point-bar channel of San Luis Creek was observed, the stream channel was dry.

2.2 Test Hole Transects: Location and Data Collection

2.2.1 County Road ROW and Private Property Access

HRS coordinated with Saguache County Road & Bridge Department with respect to traffic safety and County ROW access for CR LL-57 and CR DD.2. Note that the test hole drilling along a transect near Road GG actually was done just north of CR GG on private land (with permission) owned by Mr. Dick Blumenhein of Boulder, CO. One week before drilling was scheduled to begin, HRS (Harmon) visited the proposed drilling sites accompanied by Mr. Jack Uhlenbrock. During that visit, HRS selected, staked, and recorded the GPS locations of the test holes, and permission was obtained from the landowner of the GG transect and the Peachwood transect from the owner, Mr. Dick Blumenhein. Table 1 lists the locations and other pertinent data on the test holes drilled in each of the four E-W transects.

2.2.2 Safety Considerations: Utility Location and Road Signage

Once the sites were staked and measured with a handheld GPS unit, and ROW and private property access were secured, utility locate requests were called in to the Utility Notification Center of Colorado. All of the test hole drilling sites were clear of underground utilities. A buried fiber optic line in the north ROW of CR GG was avoided by drilling the test holes on the adjacent private property just to the north of the CR GG ROW.

Prior to drilling, HRS contacted Saguache County Road & Bridge Department (Mr. Elvie Samora, Asst. Superintendent) to inform them of our planned drilling locations on CR LL-57 and CR DD.2 rights of way, and to make sure we were in compliance with recommended safety

Table 1, San Luis Creek Test Hole Locations

Test Hole Name	Land Owner	Latitude	Longitude	Elevation (ft.)	Total Depth of Test Hole Below Ground Level (ft.)	Depth to Water Below Ground Level (ft.)	Macro (M) or Dual Tube (DT) Sampling	Date Drilled
LL-57 - 1	Saguache County	-105.92309	38.257074	7894	30	1.0	DT	8/14/2013
LL-57 - 2	Saguache County	-105.92311	38.259323	7894	30	0.8	DT	8/14/2013
LL-57 - 3	Saguache County	-105.91554	38.260543	7894	30	0.6	DT	8/14/2013
LL-57 - 4	Saguache County	-105.9138	38.261367	7894	30	1.4	DT	8/14/2013
GG - 1	Dick Blumenhein	-105.89594	38.187996	7763	20	-	DT	8/14/2013
GG - 2	Dick Blumenhein	-105.8909	38.187884	7760	35	-	DT	8/14/2013
GG - 3	Dick Blumenhein	-105.88908	38.187828	7767	30	21.1	DT	8/15/2013
DD.2 - 1	Saguache County	-105.90138	38.147967	7697	10	-	DT	8/15/2013
DD.2 - 2	Saguache County	-105.89739	38.147967	7696	25	-	DT	8/15/2013
DD.2 - 3	Saguache County	-105.89424	38.147948	7698	12	-	DT	8/15/2013
DD.2 - 4	Saguache County	-105.88858	38.147911	7704	15	-	DT	8/15/2013
Peach - 1	Dick Blumenhein	-105.90126	38.125831	7665	15	-	DT	8/15/2013
Peach - 2	Dick Blumenhein	-105.89574	38.125887	7662	15	-	DT	8/15/2013
Peach - 3	Dick Blumenhein	-105.89107	38.125943	7662	15	-	DT	8/15/2013
Peach - 4	Dick Blumenhein	-105.88574	38.125887	7670	30	-	DT	8/15/2013

signage. Saguache County loaned HRS sufficient signs and traffic cones to give traffic on the county roads notice of our work on the county roads. There were no traffic incidents during this investigation.

2.2.3 Direct-Push Drilling and Sampling Procedure

Site Services Inc. of Golden, Colorado was contracted to do the test hole drilling using its Geo-Probe direct push track-mounted drilling rig. This rig uses a hydraulic operated hammer to push/hammer hollow steel tubes into the ground. There is no drillstem rotation with this method. Soil samples were recovered in plastic tubes of 1.4-inch outside diameter using the dual tube sample collection method. In the dual tube method the sample tube is attached to an inner rod and after penetrating depth increments of five feet, the inner drill rods and the plastic core-collection tube are removed from the outer steel drill tubes, leaving the outer steel drill tubes in the borehole.

As each sample tube was removed from the drill tubes, flexible plastic end caps were placed on the sample tube ends with a red cap at the top and a black cap at the bottom for later reference. The sample tubes were marked with the name of the test hole and depth interval. Each sample tube was briefly described in the field. Due to the smearing of the samples along the inside wall of the tube, the view of the samples when pulled from the drill tubes generally was obscured. A more detailed lithologic description was performed later, in the office, by cutting open the tubes to get an unobscured view at the samples. After the material in each tube was described, selected material from each tube was placed into a labeled plastic bag. The lithologic sample descriptions can be found in Appendix A.

2.2.4 Test Drilling Chronology

HRS (James W. Schloss, EIT, then employed by HRS) mobilized to the field site on August 13, 2013, acquired road construction signs from Saguache County Road & Bridge Department, and inspected previously-staked test hole locations. Site Services also mobilized to the field site on August 13, 2013. However, Site Services experienced transport difficulties in repairing a trailer tire which delayed drilling activities until August 14, 2013.

HRS sampled and logged the geological materials collected through test hole drilling in addition to making water level measurements from test holes and temporary piezometers. See Tables 1, A.1 – A.15, and 2 for documentation of test hole locations, observed lithology, and piezometer data, respectively.

A total of six test holes and five piezometers were completed on August 14, 2013. Test holes LL-57 – 1, LL-57 – 2, LL-57 – 3, and LL-57 – 4 were completed along County Road LL-57. All of these were completed to a total depth of 30 ft. Shallow and deep temporary piezometers were installed at both LL-57 – 2 and LL-57 – 3. Drilling continued along County Road GG where test holes GG – 2 and GG – 3 were completed to a total depth of 35 ft. and 30 ft., respectively. Lastly a deep piezometer was installed at GG – 3.

Drilling activities continued on August 15, 2013 along County Roads GG, DD.2, and Peachwood Farms where all of the remaining test holes in this project were finished. First, test hole GG – 1 was completed to a total depth of 20 ft. Next, test holes DD.2 – 1, DD.2 – 2, DD.2 – 3, and DD.2 – 4 were completed to total depths of 10 ft., 25 ft., 12 ft., and 15 ft., respectively. Deep piezometers also were installed at DD.2 – 2 and DD.2 – 3. In addition, Test holes Peach – 1, Peach – 2, Peach – 3, and Peach – 4 were completed to total depths of 15 ft., 15 ft., 15 ft., and 30 ft., respectively. Finally, a single deep piezometer was installed at Peach – 3.

Both Site Services and HRS left the field site on August 16, 2013, but at different times. Site Services departed in the early morning while HRS departed around noon after making final water level measurements before removing all piezometers, and returning road construction signs to Saguache County offices.

2.2.5 Test Hole Lithology and Water Level Data Analysis

The four test hole transects completed in this investigation were selected for access and to allow identification and documentation of any significant hydrogeologic changes in a downstream direction from the Kerber Creek / Villa Grove area to the Peachwood and CR AA vicinity, and also to identify and document changes with depth and in an east-west direction across the estimated location of the "historical" channel and the "new" channel of San Luis Creek as estimated by CDWR based on aerial imagery[6] (see Figure 5).

2.2.6 Test Hole Lithology

HRS initially logged all geologic core samples collected from the subsurface in the field, but also more closely examined all materials contained within the core sampler tubes, upon return to the HRS office.

In general, the subsurface geology encountered in these test hole transects can be characterized as an upper soil layer containing black to gray silts and clays containing variable percentages of sands and gravels, and a lower layer containing light brown sands, gravels, and sandy clays. All of the sands and gravels examined were derived from sources from two different igneous compositions of both volcanic rocks and igneous rocks from the surrounding Sangre de Cristo and Bonanza Caldera/San Juan Mountains. In general, rock materials whose source is the Sangre de Cristo Mountains are mostly granitic rocks (and some sedimentary rocks of Paleozoic age), whereas rock materials whose source is the San Juan Mountains and the Bonanza Caldera area, are mostly volcanic.[7] Fan and fluvial material derived from the Kerber Creek area also can include some granitic rocks and Paleozoic sedimentary rocks.

Transect LL-57

Upper Soils: The uppermost soils along transect LL-57 were composed of very moist to saturated gray to black clays containing medium to coarse grained sand, gravel, plant roots and other organic woody matter such as peat (Table A.1). Peat was observed in a test pit dug by HRS at LL-57 – 3 and is at least 6 in. thickness at that location (Table A.3). Although the thickness of the uppermost soils in transect LL-57 is not definitely known based on partial sample recovery in the organic rich / peat zone, the uppermost soils appear to be approximately 3 ft. – 5 ft. thick, with the greatest layer thickness occurring at LL-57 – 3.

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[6] Thompson, K., July 30-31, 2013 email communications to PRT.

[7] McCalpin, J. P., 1996, General geology of the northern San Luis Valley, Colorado, *in* Thompson, R. A., Hudson, M. R., and Pillmore, C. L., eds., Geologic Excursions to the Rocky Mountains and Beyond: Field Trip Guide for the 1996 Annual Meeting, Geological Society of America, Denver, CO, 11p.

Lower Soils: The lower soils and geologic materials encountered along Transect LL-57 are comprised of saturated sub-angular to sub-rounded very poorly sorted fine to coarse grained sands and gravels. The majority of sands and gravels (> 50 % composition) were of volcanic rock origin, indicating provenance in the Bonanza Caldera area. In addition, sandy clay lenses and interbedded sandy clays also were encountered at each test hole location. The thickness of the sandy clays varied, ranging from 1 in. to 2 ft. The poorly sorted and interbedded nature of these geologic materials are indicative of fan alluvium or reworked fan materials in stream deposits.

Transect GG

Upper soils: The uppermost soils along transect GG were dry, gray to black, and composed dominantly of silt and clay, but also contained interbedded medium to coarse grained sand, and some gravels. These uppermost soils also contained plant roots and other decaying organic matter, although no peat deposits were observed in Transect GG (or at DD.2 or Peachwood, further south) as they were in transect LL-57.

Lower Soils: Lower soils and geologic materials encountered along Transect GG also were comprised of light brown sub-angular to sub-rounded very poorly sorted fine to coarse grained sand and gravel. Moist inter-bedded sandy clays were also encountered. These were generally thin clay lenses ranging from 1 in. to 6 in. thick (Tables A.5 – A.7). These very poorly sorted sands and gravels, in addition to sandy clay lenses, are indicative of fan alluvium or alternating fan and streambed deposits.

One note of importance was that drilling was limited to 20 ft. at test hole GG – 1 because the direct push could not advance past this depth. One possible explanation is encountering boulders or cobbles that the 2.25 in. diameter direct push sampler could not penetrate.

Transect DD.2

Upper soils: The uppermost soils along transect DD.2 were very similar to those at Transect GG. These soils were dry, gray to black, and composed dominantly of silt and clay, but also contained interbedded medium to coarse grained sand, and some gravels. These uppermost soils also contained plant roots and other decaying organic matter. The estimated thickness of the upper soil layer along Transect DD.2 is approximately 3 ft.

Lower Soils: Lower soils and geologic materials encountered along Transect DD.2 also were comprised of light brown sub-angular to sub-rounded very poorly sorted fine to coarse grained sand and gravel. Once again, moist inter-bedded sandy clays were also encountered. These were thin clay lenses ranging from 1 in. to 6 in. thick (Tables A.8 – A.10). Again, these geologic materials are representative of stream and fan alluvium, and were of relatively constant composition and grain size distribution to the total depth of each test hole.

Similar drilling difficulties to those at GG were also encountered at DD.2. It is noteworthy to mention that each test hole along Transect DD.2 was able to be completed to approximately 15 ft. before drilling refusal was reached. However, DD.2 – 2 was completed to 25 ft. before reaching drilling refusal. Refusal likely was encountered at or near the top of a coarser layer with some large gravel or cobble, and most likely indicates a streambed deposit of coarser composition than the shallower materials.

Transect Peach

Upper soils: The uppermost soils along Transect Peach were very similar to those at Transects GG and DD.2. Dry, gray to black, silts and clays were encountered containing a small percentage of sands and gravels. The uppermost soils also contained plant roots and other decaying organic matter. One observable difference at Transect Peach was that the thickness of the silts appeared to increase beyond the average 3 ft. seen in transects further north, and were observed to extend to the 5 ft. to 10 ft. range. This was observed in test holes Peach – 1, Peach – 2, and Peach – 4. An additional noteworthy observation was that moderately well sorted fine to medium grained sands were encountered at Peach – 4 (Tables A.12 – A.15). The presence of silt at greater depths interbedded with streambed and fan alluvium, in addition to the presence of a more uniform sand deposition, probably indicates an eolian (i.e. wind-deposited) depositional environment.

Lower Soils: Sub-angular to sub-rounded, very poorly sorted fine to coarse grained sands and gravels in addition to interbedded sandy clays were also encountered in the Peach Transect.

Once again, drilling refusal was encountered at approximately 15 ft. for all test holes with the exception of Peach – 4. The total depth of Peach – 4 was 30 ft. and no drilling refusal was noted (Tables A.12 – A.15).

2.2.7 Soil Moisture and Ground Water Conditions

Detailed observations on soil moisture and ground water levels were noted in the field. Soil moisture content was examined primarily by inspection in the field. Ground water levels were measured during drilling, and also through the use of temporary piezometers. These were installed where moisture was noted during the test drilling program. Table 2 summarizes the details of ground water levels, piezometer construction, and test hole locations.

Table 2, Moisture Content and Piezometer Data

Piezometer Name S = Shallow D = Deep	Elevation of Ground Level (ft.)	PVC Stick Up Above Ground Level (ft.)	Depth of Piezometer Below Ground Level (ft.)	Screened Interval Below Ground Level (ft.)		Water Levels (ft.) 8/14/2013			Water Levels (ft.) 8/15/2013			Water Levels (ft.) 8/16/2013			Comments
				Base	Top	PVC	BGL	P. Head	PVC	BGL	P. Head	PVC	BGL	P. Head	
LL.57 - 2, S	7894	2.85	2	2	1.5	-		-	-		-	-	0.80	7893.20	Slotted interval blocked?
LL.57 - 2, D	7894	2.1	30	30	25	3.10	1.00	7893.00	-		-	3.10	1.00	7893.00	No measurements, 8/15/2013
LL.57 - 3, S	7894.5	1.85	3.15	3.15	1	4.11	2.26	7892.24	-		-	2.26	0.41	7894.09	No measurements, 8/15/2013
LL.57 - 3, D	7894	2.6	30	30	20	3.20	0.60	7893.40	-		-	3.04	0.44	7893.56	No measurements, 8/15/2013
GG - 3, D	7763	0.52	25	25	20	21.62	21.10	7741.90	21.52	21.00	7742.00	21.54	21.02	7741.98	-
DD.2 - 2, D	7696	1.4	25	25	15	-		-	-		-	-		-	No ground water
DD.2 - 3, D	7698	1.4	14	14	9	-		-	-		-	-		-	No ground water
Peach - 3, D	7662	0.7	14.3	14.3	9.3	-		-	-		-	-		-	No ground water

Transect LL-57

The uppermost clay and peat deposits encountered along Transect LL-57 were observed to be moist to water saturated. Below an average of 2 to 3 feet, ground water was encountered in saturated alluvium at all test hole locations along Transect LL-57. We believe this continuous saturation, and indications of upward gradient, are reflective of the regional groundwater table.

Temporary piezometers were installed along Transect LL-57. Shallow piezometers were installed at test hole locations LL-57 – 2 and LL-57 – 3. The shallow piezometer at LL-57 – 2 was initially only screened at the bottom 6 in. and no ground water was noted in the piezometer. This lack of groundwater within the piezometer was most likely due to the slots in the PVC being plugged by the formation material. However, after the shallow piezometer pipe was removed, ground water was measured at 0.2 ft. below ground level. In terms of potential head, the shallow piezometer indicated 7893.2 ft., whereas the deep piezometer at LL-57 – 2 indicated a potential head of 7893.0 ft.[8] This could suggest a downward gradient, but there is a definite presence of shallow groundwater at this location. A shallow and deep piezometer pair also was installed at LL-57 – 3. Ground water measurements from 8/16/2013 indicate a potential head of 7894.09 ft. at the shallow piezometer and 7893.56 ft. at the deep piezometer, also suggesting a downward gradient. However, when the piezometers were first installed on 8/14/2013, the data from the piezometers initially indicated an upward flow gradient (Table 2).

Transect GG

Soil moisture and groundwater conditions were very different along Transect GG as compared to Transect LL-57. First, soil moisture was low. The soils appeared to be dry to slightly moist, particularly for the uppermost soils. The sandy clays encountered in the fan and stream alluvium, however, did appear to be moist, but the sands and gravels above and below the sandy clay lenses were not moist, but rather were only slightly moist.

Ground water was encountered at GG – 3. A single deep piezometer was installed at this location. No shallow piezometer was installed, because there was no indication of a shallow water table. Core samples collected from 22 ft. to 30 ft. were fully saturated. The deep piezometer installed at GG – 3 showed a head elevation of approximately 7742 ft. This occurrence of ground water at GG – 3 is believed to the regional ground water table due to its relatively good consistency with reported water levels from wells in this local area. It should be noted that ground water was not encountered at either GG – 1 or GG – 2.

[8] These elevations are estimated from topographic maps, and do not reflect surveyed elevations.

Transects DD.2 and Peach

Soil moisture and ground water conditions at Transect DD.2 and Transect Peach are very similar. First, the uppermost soils were dry in all locations. Next, the only moisture noted in the soils was in sandy clay lenses encountered in the alluvium. The fan and stream bed alluvium above and below the sandy clay lenses was noticeably drier, and was only slightly moist. Also, no definitive ground water table was encountered at the depth of investigation down to 30 ft.

The presence of moisture especially in the sandy clays suggests that the clays retained the moisture from the last active flow in San Luis Creek at these localities, or was retained moisture from precipitation or irrigation. Clay-rich soils generally have a higher capacity to retain moisture because of capillarity which is much greater in clays as opposed to sands and gravels. Sands and gravels, absent silt or clay, generally are well drained, and do not retain ground water as well as sediments that contain some percentage of silt or clay.

Deep piezometers were installed and slotted to appropriate intervals based on field observations of lithology and moisture at test holes DD.2 – 2, DD.2 – 3, and Peach – 3. Although piezometers were installed and slotted to appropriate intervals, no ground water was encountered in the piezometers throughout the duration of the field investigation.

2.2.8 Mapped Soils in San Luis Creek Study Area

The Soil Conservation Service (SCS), currently known as the Natural Resources Conservation Service (NRCS) published The Soil Survey of the Saguache County Area (1984)[5]. This publication was used as a guideline to understand the primary upper soil types in relation to the behavior of the hydrologic system within San Luis Creek, and to compare to our test hole observations. The published map designates soil type boundaries. This coverage was overlaid in ArcGIS in relation to the test holes drilled for this project. Table B.1 correlates the test hole locations to the corresponding soil type along with a brief description of the soil characteristics. Figures B.1 to B.4 show the outline of the mapped soil boundary overlay, overlaid over the field site and drilling locations.

Soil scientists use a slightly different terminology than geologists in describing geologic materials. One term in particular used in soil science and in the Saguache County Area soil study is “loam”, which, by NRCS’ definition is a soil material that contains 40% or more of clay, 45% or more of sand, 40% or more of silt (NRCS, 2013).[9]

Transect LL-57

The upper soil descriptions by HRS generally correlate well with the NRCS soil descriptions. However, there is no peat or other organic materials noted by NRCS in these soil types, particularly with the Big Blue clay loam descriptions, as HRS observed to be present in this transect. At test hole LL-57 – 1, our upper soil description of gray clay in the upper 15 in. match the descriptions of gray clay loams followed by other gray loams to a depth of 60 in. Next, HRS identified the upper soils in LL-57 – 2 and LL-57 – 3 to be black to light gray clays with gravels containing peat. The NRCS document does not describe the black color or the presence of peat. Lastly, HRS’ upper soil descriptions of black and gray clayey soils and gray sands at approximately 5 ft. more closely correlate to the NRCS descriptions of dark loams and brownish gray loams at 60 in. within the substratum.

Transect GG

The upper soil descriptions from our observations correlate well with the NRCS soil descriptions of Asasco clay loam in this transect. Generally, the upper 9 in. to 16 in. were described by HRS as a grayish soil with average grain size of silt/clay containing sand and gravel. This correlates closely to the NRCS descriptions of gray clay and gray/brown clay loams in the same approximate depth range. The subsurface soils were described as light brown sands and gravels, which correlate closely with the NRCS description of gravelly sand to a depth of 60 in. (5 ft.).

Transect DD.2

The upper soil descriptions by HRS are generally consistent compared to the NRCS soil descriptions for the uppermost soils along Transect DD.2. The upper soils described by HRS for DD.2 – 2, DD.2 – 3, and DD – 2.4 are black to gray silts and clays with sands and gravels, much

[9] National Resources Conservation Service. Glossary of Soil Science Terms. https://www.soils.org/publications/soils-glossary/#. 22 Aug. 2013.

as the Asaco, Hagga, and Laney loams are described by NRCS; and are underlain by gray to brown loams and sandy gravels. One difference is at DD.2 – 1 where the uppermost soils by HRS are described as gray silts and clays underlain by light brown silts and sands. The NRCS describes a different color: mostly gray loams to 60 in. depth.

Peach Transect

HRS' upper soil descriptions of the upper soils at test holes Peach – 1 and Peach – 2 correlate to the NRCS soil descriptions for Acasco clay loams. This is because gray silts/clays containing sand and gravel underlain by light brown sands and gravels match closely with the gray clay loam descriptions underlain by gravelly sand. The Peach – 3 and Peach – 4 upper soil descriptions generally correlate to the grain size characteristics described by the NRCS, but the color descriptions do not match. HRS described black and light gray silty/clayey soils containing sands and gravels in the uppermost soils, which match the Hagga loam and Laney loam descriptions, but no grayish soils were observed to extend up to 60 in. as described by the NRCS.

2.3 Mapped Geology in San Luis Creek Study Area

2.3.1 Regional Geologic Mapping

Several published geologic maps cover all or part of the study area. These maps are of relatively small scale, and thus do not provide much detail of subtle differences in the geology of the study area. The maps reviewed are listed below.

Taylor, R.B., Scott, G.R., and Wobus, R.A., 1975, Reconnaissance geologic map of the Howard quadrangle, central Colorado: U.S. Geological Survey, Miscellaneous Investigations Series Map I-892, scale 1:62,500.

Scott, G.R., Taylor, R.B., Epis, R.C., and Wobus, R.A., 1976, Geologic map of the Pueblo 1 degree x 2 degrees quadrangle, south-central Colorado: U.S. Geological Survey, Miscellaneous Field Studies Map MF-775, scale 1:187,500.

Tweto, Ogden, Steven, T.A., Hail, W.J., and Moench, R.H., 1976, Preliminary geologic map of the Montrose 1 degree x 2 degrees quadrangle, northwestern Colorado: U.S. Geological Survey, Miscellaneous Field Studies Map MF-761, scale 1:250,000.

Lindsey, D.A., and Soulliere, S.J., 1987, Geologic map and sections of the Valley View Hot Springs quadrangle, Custer and Saguache Counties, Colorado: U.S. Geological Survey, Miscellaneous Field Studies Map MF-1942, scale 1:24,000.

These geologic maps generalize the alluvial fan deposits and the stream deposits that occur in the study area. Most describe all fan deposits, irrespective of provenance (whether from the Sangre de Cristo Mountains on the east, or the Bonanza Caldera / San Juan Mountains on the west, as either Qf or Qfp: “fan alluvium”. The deposits of San Luis Creek are mapped in varying widths from approximately ½ to 3 miles wide (wider with increasing distance downstream), and are lumped into Qa or Qal: “stream alluvium”, “Holocene alluvium” or “Piney Creek alluvium”. The latter term is a time-equivalent term from well-documented deposits near Parker, CO, referring to unconsolidated stream alluvium deposited during early Holocene time (beginning approximately 11,700 years before present).

In summary, the published small scale to medium scale geologic maps are not sufficiently detailed to note any differences in the types of deposits from upstream to downstream along San Luis Creek, such as we see between the test holes on the CR LL-57 transect and the CR GG transect. Even though there is no mapped difference in the type of deposits, the more detailed of these maps do show geologic structures that crosscut the area and may be of hydrologic significance.

2.3.2 Detailed Geologic Mapping and Paleotectonics

Detailed mapping of the geology of the northern San Luis Valley, including the study area, have been done[10] [11]. One of the more detailed studies in terms of the geology and the geologic structure of the younger sediments that make up the alluvial fans and streambed deposits in the eastern Sangre de Cristo Mountains area, that encompassed our study area, was done by James McCalpin.[12]

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[10] Huntley, D., 1976, Ground Water Recharge to the Aquifers of the Northern San Luis Valley, Colorado: A Remote Sensing Investigation. Colorado School of Mines Thesis no. T-1864.

[11] Huntley, D., 1979, Ground Water Recharge to the Aquifers of the Northern San Luis Valley, Colorado. Geological Society of America Bulletin, Part II, Volume 90, pp. 1196-1281.

[12] McCalpin, J. P., July 1982, Quaternary Geology and Neotectonics of the West Flank of the Northern Sangre de Cristo Mountains, South-Central Colorado. Colorado School of Mines Quarterly, Volume 77, no. 3. 97p.

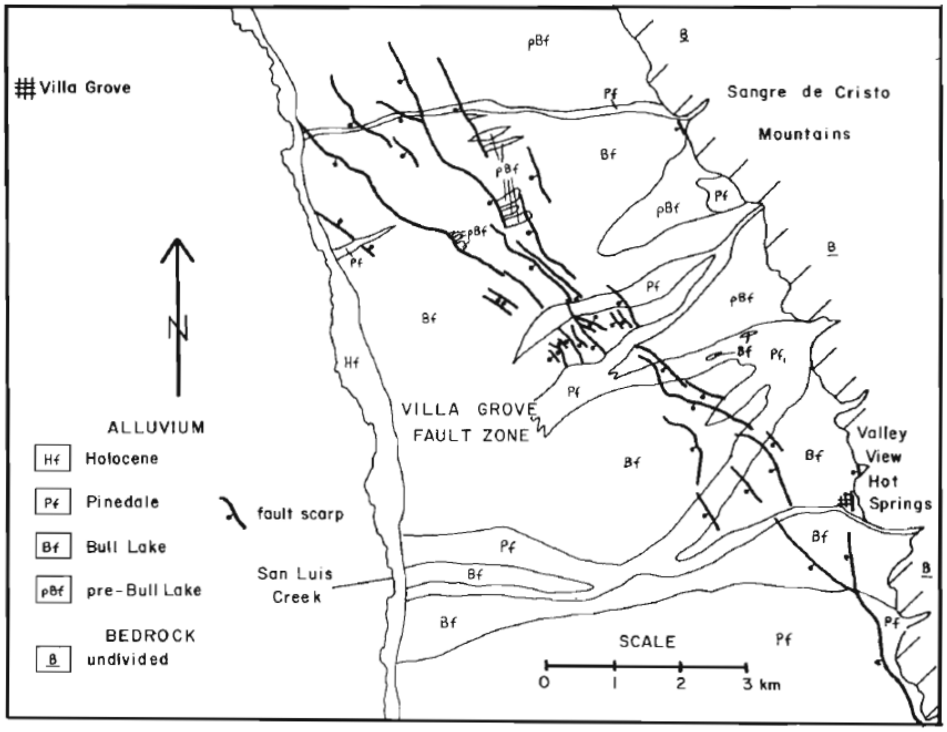

Figure 2: Generalized geologic map of the Villa Grove Fault Zone area (Figure 49 from McCalpin, 1982).

Figure 2 shows the Quaternary sediments of San Luis Creek ("Holocene alluvium") and the fans deposits east of San Luis Creek up to the Sangre de Cristo Mountains, in terms of their glacial age. Pinedale age sediments reflect younger alluvial fan deposits sourced from glaciation (approximately 30,000 to 10,000 years before present[13]). Older Bull Lake age sediments reflect glaciation approximately 200,000 to 130,000 years before present.

Also shown on the McCalpin map (see Figure 2) is the eastern portion of the Villa Grove fault zone in the alluvial fans east of San Luis Creek. McCalpin and others have mapped approximately 40 fault scarps, both east and west of San Luis Creek, that reflect different episodes of seismic activity during the late Pleistocene (approximately 2.5 million to about 11,700 years before present). As part of his investigation, McCalpin trenched several fault scarps in the Villa Grove fault zone and the related Major Creek fault zone, and performed detailed identification of the materials in the uppermost 10 to 18 feet. McCalpin's work showed the presence of fine sand and silt on the downhill side of at least one fault scarp, and sand,

[13] Ka: thousands of years before the present time.

gravel, and cobble on the uphill side.[14] This corroborates our observations that ground water tends to discharge upward on the upgradient side of these fault scarps, possibly due to reduced hydraulic conductivity of the sediments by development of fault gouge along the fault plane. As part of a hydrogeologic study of the Baca Graben area (eastern part of the Closed Basin) in preparation for the trial of AWDI's nontributary claim in 1991, HRS (Harmon) noted several locations in young, presumably late Quaternary, alluvial fans in the Villa Grove fault zone near the Sangre de Cristo mountain front where the water table was elevated significantly upgradient of the fault scarp as compared to downgradient of the fault scarp.[15] This may help explain the observed differences in water level in aquifer layers 1 and 2 north, as compared to south, of the Villa Grove vicinity.

McCalpin concluded that the youngest fan deposits offset by faulting due to seismic activity on the Villa Grove fault zone are approximately 13,000 years old[16], which is older than Holocene (the Holocene epoch began ~11,700 years ago). Based on fault scarp geometry, McCalpin also concluded that the youngest fault scarps in the Villa Grove fault zone reflected movement "less than 10,000 years ago"[17]. Thus based on McCalpin's study the San Luis Creek stream deposits that we see today (which are Holocene) and that have been drilled in this test hole drilling program, may have been offset across this fault zone, although this is not definitive from the McCalpin study.

In a later study, McCalpin concluded that there is evidence of fault scarps in the alluvial fans along the Sangre de Cristo mountain front due to major (greater than Richter Magnitude 7) earthquakes as recently as 7,600 years ago:

> "Fault scarp profiling and trenching suggest: 1) average vertical displacement per faulting event is 1.2-2.9 m, 2) long term return times for M>7 earthquakes are 10-47 kyr, and 3) the latest two M>7 paleoearthquakes occurred about 10-13 ka and 7.6 ka. Based on these data, the Sangre de Cristo fault has experienced Holocene displacement and is thus one of Colorado's few active faults by common definition."[18]

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[14] McCalpin, pp. 56-57, Figure 57, "Log of Trench, profile S2, Villa Grove Fault Zone."
[15] Harmon, E., 1991, testimony in AWDI trial.
[16] McCalpin, p. 54.
[17] Ibid., p. 50.
[18] McCalpin, J. P., 1996, General geology of the northern San Luis Valley, Colorado, *in* Thompson, R. A., Hudson, M. R., and Pillmore, C. L., eds., Geologic Excursions to the Rocky Mountains and Beyond: Field Trip Guide for the 1996 Annual Meeting, Geological Society of America, Denver, CO, 11p.

2.4 Geophysical Survey of the San Luis Creek Area

As part of its ongoing efforts to geophysically map the subsurface structure of the Rio Grande Rift, U.S. Geological Survey researchers recently published the results of a study using LIDAR (light detection and ranging) and an aeromagnetic geophysical survey of the upper San Luis Creek area.[19] The area of the LIDAR / aeromagnetic study generally was from Poncha Pass on the north to approximately CR AA on the south, and from the Sangre de Cristo range on the east to the hills west of Villa Grove on the west (see Figure 3). This makes the USGS study area generally coincident with this investigation.

As shown on Figure 3, there are mapped scarps of the Villa Grove fault zone that crosscut San Luis Creek one to two miles downstream of CR LL-57. In addition, the USGS researchers have concluded that the stream channels and Holocene floodplain deposits of San Luis Creek and Rock Creek above their confluence, and San Luis Creek below their confluence a distance of at least 6 to 7 miles (based on the mapping of Figure 4) are fault-controlled:

> "The HGM [horizontal gradient of the magnetic field] ridges from the aeromagnetic data prominently define faults that closely follow creeks in the valley (Figure 6), confirming previous speculation that steep banks along the eastern sides of Rock Creek and San Luis Creek are tectonic rather than fluvial in origin."[20]

As the authors state, a topographic escarpment such as the erosional edge of a stream terrace may cause a magnetic anomaly, this does not appear to be the origin of the observed anomaly leading to the fault interpretation along San Luis Creek:

> "…observed aeromagnetic anomalies generally have greater amplitude than reasonably produced by relief on the terrain alone. Furthermore, HGM ridges follow straighter lines than the stream bank scarps and are continuous across places where the bank has been eroded." [21]

> "Thus, we conclude that the HGM ridges along the stream bank originate from magnetic sources that underlie the terrain and the linearity of the ridges suggests a tectonic rather than fluvial origin. The HGM image for the whole study area (Figure 6) suggests that similar faults closely

[19] Grauch, V.J.S., Ruleman, C.A., 2013, Identifying Buried Segments of Active Faults in the Northern Rio Grande Rift Using Aeromagnetic, LiDAR, and Gravity Data, South-Central Colorado, USA. International Journal of Geophysics, Volume 2013, Article ID 804216, 26 pages. Hindawi Publishing Corporation, http://dx.doi.org/10.1155/2013/804216

[20] Ibid., p. 21.

[21] Ibid., p. 16.

> follow San Luis Creek and Rock Creek almost the entire axis of the valley within the study area."[22]

The USGS researchers' interpreted fault locations of the Villa Grove fault zone and the San Luis Creek fault(s) with the horizontal magnetic field, reduced to the pole anomalies shown in a color-flood format, are shown on Figure 3. Their interpreted fault locations for their entire study area are shown on Figure 4.

[22] Ibid.

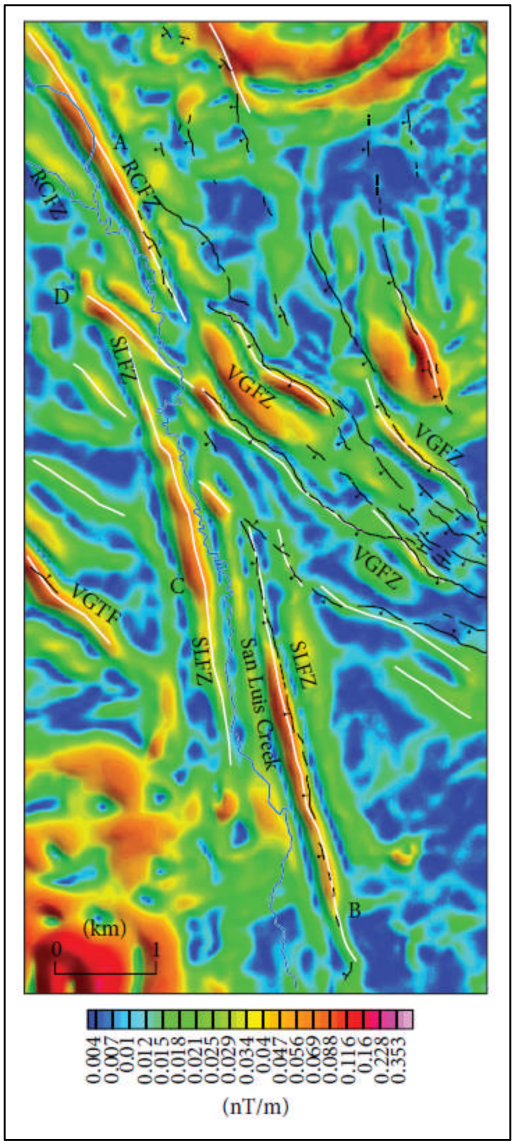

Figure 3: Reproduction of Figure 12 from Grauch and Ruleman, p. 16: "Ridges in the HGM of RTP image depicting the crossing of the Villa Grove and San Luis Creek fault zones in Area 2 (located in Figures 1–4 and 6). Letter labels are for discussion purposes. RCFZ: Rock Creek fault zone, SLFZ: San Luis Creek fault zone,VGFZ: Villa Grove fault zone, and VGTF: Villa Grove town fault."

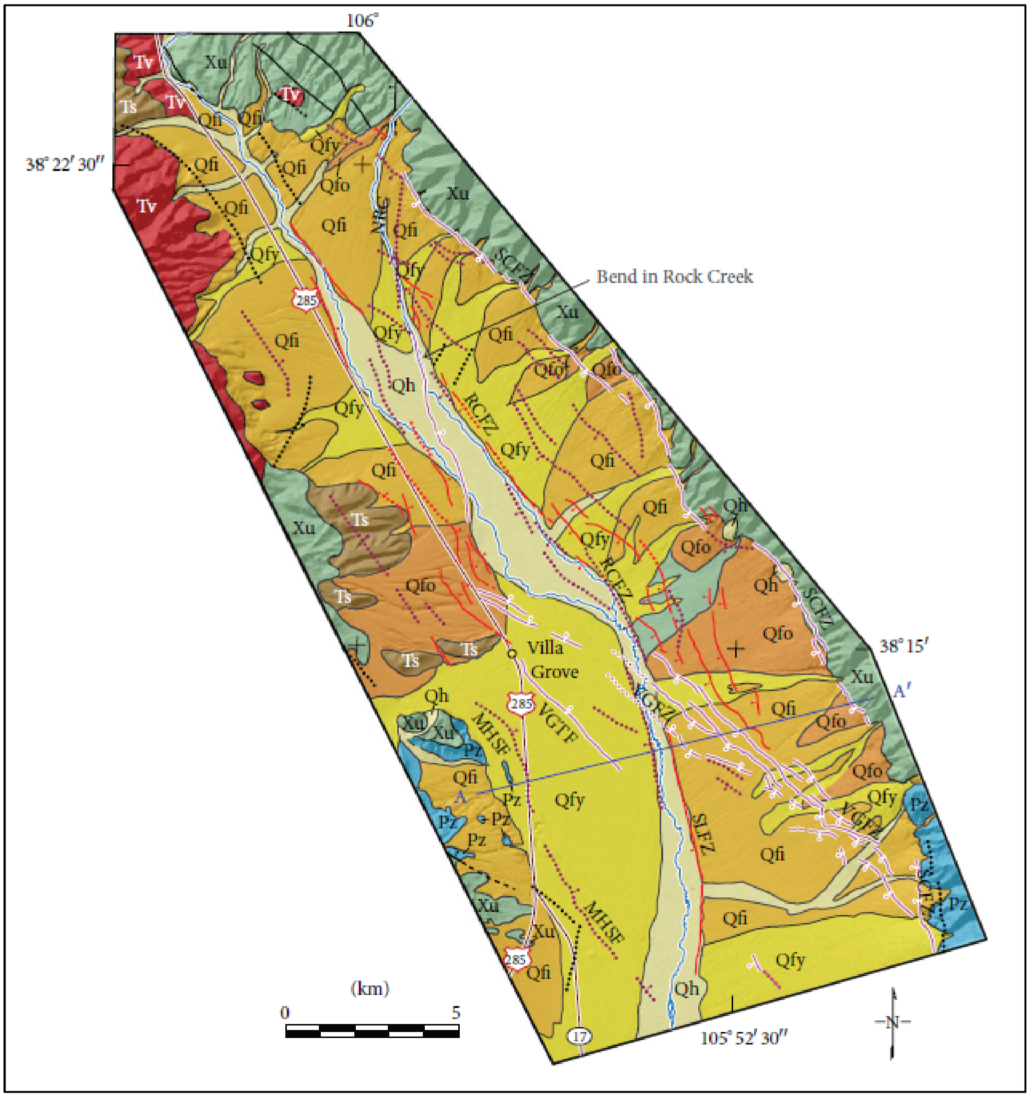

Figure 4: Study area and interpreted geology and fault locations from USGS study. This figure appears as Figure 15 in Grauch and Ruleman, 2013 (See reference footnote, this study).

2.5 Water Well Driller's Log Evaluations

Discussions with PRT members and others revealed that there may be regional differences in water level trends within the study area. Reportedly, water levels in wells in RGDSS layers 1 and 2, located from Villa Grove to the north are relatively shallow, and water levels south of Villa Grove in the San Luis Creek area in wells completed in layers 1 and 2 are deeper – an average of 20 to 30 feet in many cases.[23] An earlier task for the PRT reviewed water level elevations and driller's logs in a broader and more generalized study encompassing San Luis Creek approximately from CR GG to the town of Moffat.[24] Another more geographically limited task, which was done prior to the work documented in the main body of this memo, was to advise Principia as to the drilling evidence (if any) for a low-permeability zone in L1. That work is documented in Appendix B. For the present investigation, well permits with driller's 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.

All of the wells that appear in the CDWR well permit database within the study area were plotted on a topographic map (Figure 5). The data from wells were used to determine whether there is evidence of distinct lithologies in different areas within the study area, or whether there is any apparent correlation between reported water levels from driller's reports, and the mapped location of faults associated with the Villa Grove fault zone, or other faults as mapped by Grauch and Ruleman (2013).

For wells with a total depth greater than 100 feet, the total depth and the depth to water were listed next to the well location as reported in the SEO's water well database. As can be seen on Figure 5, the depth to water within the San Luis Creek floodplain is less than 20 feet from a point just south of CR LL-57 (aka Hayden Pass Road) extending to the north to the vicinity of CR 57. To the south of this area, the depth to water is seen to increase abruptly, and generally is reported to be deeper than 28 feet. Due to the wide differences in dates of when the wells were drilled – spanning 40 years or more - there are variations in the reported depth to water.

[23] Verbal communications with Mr. Jack Uhlenbrock and Dr. Willem Schreuder, July, 2013.
[24] HRS Water Consultants, Inc., 2012, Hydrogeologic Review of the San Luis Creek Area, Saguache County CO. Unpublished consultant's report, 14p.

One well of interest is the well listed as "517 / flowing" located in Section 17, T46N, R10 E, Permit No. 11808-F/284405 (that is, total depth 517 feet, and the well reportedly flowed at the ground surface). This well is located on an alluvial fan approximately one mile east of the San Luis Creek valley. An overlay of the mapped faults shown on Figure 5, (Grauch and Ruleman, 2013) plotted with the well locations, shows the well to be located on the upgradient side of a fault trace. This well is within a wet area, as seen on Google Earth images. HRS believes that this is an example of a normal fault acting to inhibit ground water flow within the fan material, possibly due to development of fine-grained gouge material within the fault, thus causing the upward discharge of ground water on the upgradient side of the fault.

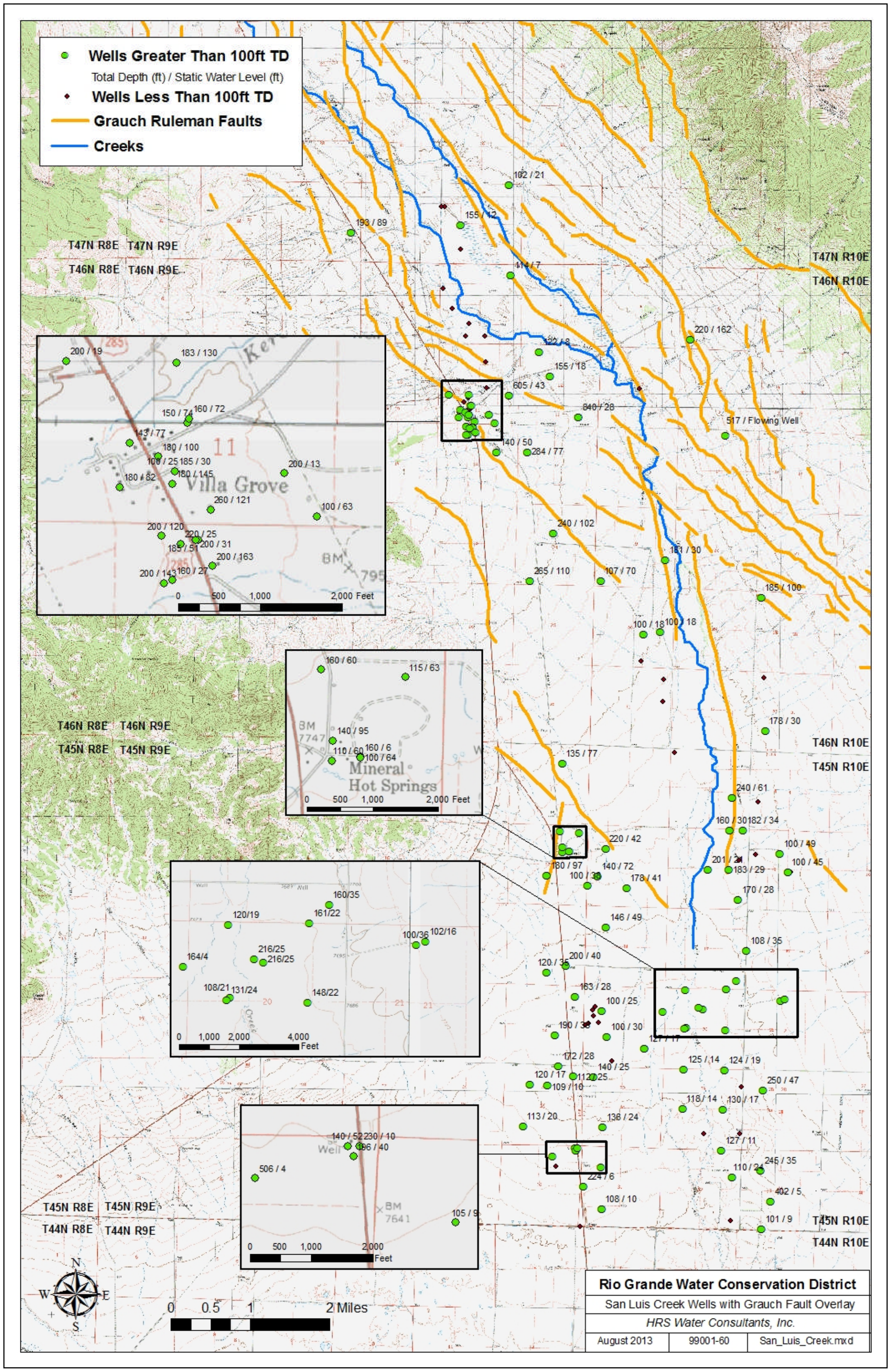

Figure 5: Wells from CDWR adjacent to San Luis Creek

The driller's logs were reviewed for lithology, as reported on the driller's well completion reports, to determine if there were any discernible trends or changes in lithology that could account for the observed changes in depth to water from north to south along San Luis Creek. The reported lithology generally consisted of sand, gravel, cobbles and clay lenses and layers as would be expected for deposition by alluvial fans and relatively high-energy fluvial environments. There were no discernible trends or changes in the reported lithology from the driller's reports that could be a contributing factor to the abrupt change in depth to water as discussed above. This may be due, at least in part, to oversimplification of the reported lithology by the drillers.

2.6 Water Table at "Historic" and "Relocated" San Luis Creek Channel

Discussions in the PRT identified what have been called "historic" and "relocated" channels of San Luis Creek approximately between CR GG and CR AA, through the Peachwood Farms area. We note that the aerial images we have reviewed lead us to the conclusion that there have been many channels of San Luis Creek that are geologically recent enough to have left subtle, but visible, traces of channels across an approximately one mile width of the stream valley in this reach. The terms "historic" and "relocated" are used here to differentiate between the most recent and obvious stream channel trace ("historic"), and what appears to be a manmade channel ("relocated") approximately ½ mile west of the "historic" channel just west of the Peachwood Farms center pivot circles, as interpreted by Mr. Kelley Thompson of the Colorado DWR[25] (see Figure 6).

The PRT discussion led to the question of whether there are any observable hydrogeologic differences between water table or the soils between the "historic" and the "relocated" channel. Based on our onsite observations and test hole drilling, we have reached the following conclusions as to these channels.

[25] Thompson, K., July 2013, email communication to PRT.

- The “historic” channel appears most closely to follow the thalweg[26] of the San Luis Creek floodplain. The “historic” channel area has been cultivated over and there is no identifiable stream channel in many places between CR GG and CR AA.
- The “relocated” channel through the Peachwood Farms area clearly is a manmade channel, and has berms on its banks that contain a relatively straight, trapezoidal channel (although much of this channel has been filled in recently with windblown silt).
- In the CR GG to CR DD.2 reach, it is unclear from our onsite observations and aerial imagery review whether the “relocated channel” originally was excavated and natural meandering followed later due to lack of channel maintenance, or whether this feature originally was an earlier natural stream channel that provided a logical low spot for later excavation of the “relocated” channel. From our observations, both may have happened in sequence.
- In the CR DD.2 to Peachwood reach, it is clear from our onsite observations that the “relocated channel” is a manmade channel intended to move San Luis Creek surface flow west of the irrigated center pivot circles. We did not find any recent trace of a natural channel in the Peachwood Farms area based on our onsite observations, although aerial imagery does show traces of earlier channels generally in this location.
- From the test drilling, we have identified no persistent or widespread perched water tables associated with either the “historic” or the “relocated” channel.
- Also from the test drilling, there is no obvious difference in the near-surface soils profile that would distinguish the “historic” and the “relocated” channel hydrogeologically, although gray sandy clay and clayey sand in the upper 10 feet does appear to be somewhat thicker and more persistent in the test holes that are near the “historic” channel as compared to the “relocated” channel.
- Overall, we have found no hydrogeologic rationale to relocate the channel of San Luis Creek from the “natural” channel to the “relocated” channel.

[26] Thalweg: a line or trace that connects points of lowest elevation along a stream valley.

Figure 6: "Historic" (blue) and "relocated" (red) channels of San Luis Creek between Saguache County Road GG (north) and AA (south). Photo interpretation by Kelley Thompson, Colorado DWR, July, 2013.

3 Conclusions

Based on the analysis of new data collected in the test hole transects, and on our analysis of published and unpublished data, HRS has arrived at the following conclusions.

1. The wet area, including the springs, seeps, and the peat-rich wetland area that exists along San Luis Creek and Rock Creek approximately 1 to 2 miles downstream of CR LL-57, primarily is due to the “damming” effect of locally reduced hydraulic conductivity (K) in Layers 1 and 2, and most likely also Layer 3, due to reduced K faulting, part of the Villa Grove fault zone, crosscutting the valley of San Luis Creek. This is the only significant discontinuity in the water table that we observed in this investigation. Evidence in support of a structural (i.e. faulting) cause for the high water table area include:
   a. We have found no significant changes in the near-surface alluvial fan or streambed material types that would indicate a stratigraphic, depositional, or erosional reason for the presence of the high water table area as compared to deeper water table further south.
   b. Trenching of some Villa Grove fault scarps by McCalpin (1982) showed finer grained materials downgradient of the faults as compared to upgradient.
   c. Water levels in wells upgradient of the Villa Grove fault zone are generally higher than water levels downgradient, and an abrupt change in reported water level is noted at approximately the location of the Villa Grove fault zone as it crosses San Luis Creek.
   d. Peat and organic-rich soil depth of up to 4 ½ feet, documented in test hole LL-57-3, coupled with estimated peat accumulation rates of 6 to 12 inches per 1,000 years by Cooper and Severn (1992)[27] leads to an estimated time period of 4,500 to 8,000 years for the observed peat layer at LL-57 to accumulate (and is still accumulating). Peat is deposited in a high water table environment, which means that high water table has been present continually in this area for an estimated

[27] Cooper, D. J., and Severn, C., January, 1992, Wetlands of the San Luis Valley, Colorado: An Ecological Study and Analysis of the Hydrologic Regime, Soil Chemistry, Vegetation, and the Potential Effects of a Water Table Drawdown. Unpublished consultants’ report prepared for Colorado Division of Wildlife, U.S. Fish & Wildlife Service, and RGWCD.

4,500 to 8,000 years. The deeper soils in the LL-57 transect have no peat, and thus it is highly probable that water table was lower when the earlier soils (pre-4,500 to 8,000 years ago) were deposited. According to McCalpin (1996)[28] there is evidence of fault scarps in the alluvial fans along the Sangre de Cristo mountain front due to major (greater than Richter Magnitude 7) earthquakes as recently as 7,600 years ago. We conclude it is likely that Holocene fault movement on the Villa Grove fault zone has locally reduced hydraulic conductivity in Layers 1 and 2.

2. No water table perching has been observed in any of the test hole transects. The high water table in the LL-57 transect is concluded to be a reflection of the regional water table. Evidence for this conclusion is:
    a. Continuous saturation from nearly ground surface, to total depth in the test holes drilled.
    b. Indications of an upward hydraulic gradient. Note that not all water levels measured by HRS in the temporary piezometers show this, but further evidence of upward movement and discharge of ground water exists in the form of springs and seep lines in, and north of, the LL-57 transect.
    c. High water tables – generally within a few tens of feet of ground surface – occur in the area upgradient (generally north) of the Villa Grove fault zone.
    d. Other than the LL-57 transect, only occasional increases in moisture, but no saturation, were observed in the GG, DD.2, and Peach transects. These were noted to be coincident with finer-grained lenses of silty or clayey sand, and probably reflect remnant moisture from earlier irrigation, or earlier creek flow.
3. We conclude there is no rationale to support moving the trace of San Luis Creek in the RGDSS model from its current location (near or coincident with the "historic" stream channel) to the "relocated" channel (see Figure __). Reasons for this are:
    a. No perched water table has been noted at either the "historic" or the "relocated" channel.

[28] McCalpin, J. P., 1996, General geology of the northern San Luis Valley, Colorado, *in* Thompson, R. A., Hudson, M. R., and Pillmore, C. L., eds., Geologic Excursions to the Rocky Mountains and Beyond: Field Trip Guide for the 1996 Annual Meeting, Geological Society of America, Denver, CO, 11p.

b. The “historic” channel is located along the thalweg of the San Luis Creek floodplain.
c. From our onsite observations, the “relocated channel” clearly is a manmade channel intended to move San Luis Creek surface flow west of the irrigated center pivot circles. We did not find any recent trace of a natural channel in the Peachwood Farms area based on our onsite observations, although aerial imagery does show traces of earlier channels generally in this location.
d. Based on the test drilling results, there is no obvious difference in the near-surface soil profile that would distinguish the “historic” and the “relocated” channel areas hydrogeologically, although gray sandy clay and clayey sand in the upper 10 feet appears to be somewhat thicker and more persistent in the test holes that are near the “historic” channel as compared to the “relocated” channel.

4 Recommendations

From this investigation of the hydrogeology of the upper San Luis Creek study area, we make the following recommendation to the RGDSS for modeling revisions.

1. The horizontal hydraulic conductivity (Kh) in model layers 1 and 2, and possibly also layer 3, should be reduced in a zone 1 to 2 model cells (i.e. ½ to 1 mile) wide that is coincident with the mapped trace of the Villa Grove fault zone as it crosses San Luis Creek. The magnitude of Kh reduction due to fault offset is not known because there are, as far as we know, no tests of the fault gouge material. As a starting point, we recommend a reduction by a factor of 2 to 4 in Kh.

5 Comments and Concerns

- A more detailed understanding of the hydrologic characteristics of the Villa Grove fault zone, and of the fault zone along San Luis Creek, could be gained by trenching one or more fault scarps, and performing a detailed geologic description of the faulted materials.
- Better elevations could be obtained by surveying the locations of the temporary piezometers. The elevations reported herein were based on estimation from topographic maps.
- The water levels and creek conditions reported in this report are a “snapshot” based on one-time observations and measurements. The water levels in the reach of San Luis Creek downstream of the Villa Grove fault zone, as discussed herein, may be subject to the long-term drought in the San Luis Valley. Review of diversion records and historic water levels would help define whether the layer 1 water levels were shallower in the past.

Appendix A

Test Hole Lithologic Descriptions

Table A.1: LL-57 – 1 Lithology

GL (ft.)	7894	Well Name	LL.57 - 1	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	30	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	3.0	very poor		clay		Top 2.0 ft.: black and light gray, gravel, plant roots, very moist
			moderately poor		sand		Bottom 1.0 ft.: fine to coarse grained, dark gray, rust, strong sulfur odor, saturated
5	10	4.2	very poor	SR/SA	sand & gravel	volcanic	medium to coarse grained, gravel, light brown, saturated
10	15	4.0	very poor	SR/SA	sand & gravel	volcanic	medium to coarse grained, gravel, light brown, interbedded sandy clays, light brown, saturated
15	20	4.0	very poor	SR/SA	sand & gravel	volcanic	Top 2.0 ft.: medium to coarse grained, gravel, light brown, saturated
			moderately well		sandy clay		Bottom 2.0 ft.: sandy clays, light brown/yellowish orange
20	25	3.5	very poor		sandy clay		Top 2.5 ft.: medium to coarse grained, gravel, light brown, saturated
			moderately well				Bottom 1.0 ft.: sandy clays, light brown/yellowish orange
25	30	3.2	very poor	SR/SA	sand & gravel	volcanic	medium to coarse grained, gravel, light brown, saturated

Table A.2: LL-57 – 2 Lithology

GL (ft.)	7894	Well Name	LL.57 - 2	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	30	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	3.0	very poor		silt/clay		Top 1.5 ft.: black and light gray, gravel, plant roots, w oody organic material, moist/saturated
			moderately w ell	SR/SA	sand		Bottom 1.5 ft.: medium to coarse grained, clayey, light brow n
5	10	3.0	very poor	SR/SA	sand & gravel	volcanic	fine to coarse grained, gravel, light brow n, saturated
10	15	0.0	*NO RECOVERY*				
15	20	3.8	very poor	SR/SA	sand & gravel	volcanic	Top 2.8 ft.: fine to coarse grained, gravel, light brow n, saturated
					sandy clay		Bottom 1.0 ft.: sandy clay, light brow n, saturated
20	25	3.8	very poor	SR/SA	sand & gravel	volcanic	fine to coarse grained, gravel, interbedded clayey sands, light brow n, saturated
25	30	4.2	moderately w ell	SR/SA	sand		medium to coarse grained sand, light brow n, saturated

Table A.3: LL-57 – 3 Lithology

GL (ft.)	7894		Well Name	LL.57 - 3				Date	8/14/13	page
Datum	ground level		Owner					by	JWS	1
TD (ft.)	30		Location					job no.	13-15	of
BH Dia.	2.25		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
							0.0 ft. - 2.5 ft.: From Test Hole
0	5	0.5	w ell		clay		0.0 - 2.0 ft: black, plant roots, w oody orgranic matter, strong sulfur odor, moist/saturated
					peat		2.0 - 2.5 ft.: light brow n, w oody organic matter, sulfur smell, saturated (peat)
							* Based on poor recovery, layer could be up to 4.5 ft. thick
5	10	2.5	moderately w ell		sand & silt		Top 2.0 ft.: silt to fine sand, light brow n, saturated
			very poor	SR/SA	sand & gravel	volcanic	Bottom 0.5 ft.: fine to coarse grained, gravel, light brow n, saturated
10	15	3.7	very poor	SR/SA	sand & gravel	volcanic	Top 2.0 ft.: fine to coarse grained, gravel, light brow n, saturated
			very poor	SR/SA	clayey sand	volcanic	Bottom 1.7ft.: fine to coarse grained, gravel, clayey, light brow n/yellow ish orange, saturated
15	20	3.8	moderately w ell	SR/SA	clayey sand	volcanic	clayey sand, interbedded fine to medium sand, light brow n/yellow ish orange, saturated
20	25	4.7	very poor	SR/SA	sand & gravel	volcanic	fine to coarse grained, gravel, some thin sandy clay lenses, light brow n, saturated
25	30	2.5	very poor	SR/SA	sand & gravel	volcanic	fine to coarse grained, gravel, some thin sandy clay lenses, light brow n, saturated

Table A.4: LL-57 – 4 Lithology

GL (ft.)	7894	Well Name	LL.57 - 4	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	30	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	2.3	well		Clay		Black, light gray at 2.3 ft. Contains plant roots and woody organic matter. Moist to very moist.
5	10	3.0	moderately well		sand & silt		Top 1.0 ft.:silt to fine sand, light gray, saturated
			very poor	SR/SA	sand & gravel	volcanic	Bottom 2.0 ft.: fine to coarse grained, gravel, light brown, saturated
10	15	3.4	moderately well		sandy clay	volcanic	Top 2.0 ft.: clay, silt to fine grained sand, light brown, gray, iron staining
			very poor	SR/SA	sand & gravel	volcanic	Bottom 1.4 ft.: fine to coarse grained, saturated
15	20	5.0	very poor	SR/SA	sand & gravel	volcanic	fine to coarse grained, gravel, light brown, saturated
20	25	4.5	moderately well		sandy clay		clay and interbedded sandy clays, light brown/yellowish orange, saturated
25	30	3.0	very poor	SR/SA	sand & gravel	volcanic	fine to coarse grained, some interbedded sandy clay lenses, light brown, saturated

Table A.5: GG – 1 Lithology

GL (ft.)	7763	Well Name	GG - 1	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	20	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	3.0	well		silt/clay		Top 0.8 ft.: black & light gray, gravel, plant roots, dry
			very poor		sand & gravel		Bottom: 2.2 ft.: fine to coarse grained sand, gravel, light brown, dry
5	10	3.4	very poor	SR/SA	sand & gravel		Top 3 ft.: fine to coarse grained, gravel, light brown, slightly moist
					sandy clay		Bottom 0.4 ft.: fine grained, yellowish orange & brown, moist
10	15	2.8	very poor		clayey sand		Top 1.0 ft.: fine grained sand, light brown & yellowish orange, moist
			very poor	SR/SA	sand & gravel		Bottom 1.8 ft.: fine to coarse grained, gravel, light brown, slightly moist
15	20	0.0	*NO RECOVERY*				Driller noted drastic decrease in R.O.P. at 19 ft., hit refusal

Table A.6: GG – 2 Lithology

GL (ft.)	7760	Well Name	GG - 2	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	35	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description
From	To						
0	5	3.0	well		silt/clay		Top 1.4 ft.: black & dark gray, med. sand, plant roots, dry
			very poor		sand & gravel	volcanics	Bottom: 1.6 ft.: fine to coarse grained sand, gravel, light brown, dry
5	10	3.5	very poor	SR/SA	sand & gravel	volcanics	Top 2.0 ft.: fine to coarse grained sand, gravel, light brown, dry
			moderately well		sandy clay		Middle 2.0 - 2.5 ft.: sandy clay, light brown/yellowish orange, moist
			very poor	SR/SA	sand & gravel	volcanics	Bottom 2.5 - 3.5 ft.: fine to coarse grained sand, gravel, light brown, slightly moist
10	15	2.8	very poor		clayey sand		Top 2.5 ft.: fine to coarse grained sand, gravel, light brown, moist
			moderately well	SR/SA	sand & gravel	volcanics	Bottom 0.5 ft.: sandy clay, light brown/yellowish orange, slightly moist
15	20	3.3	very poor	SR/SA	sand & gravel	volcanics	fine to coarse grained sand, gravel, light brown, slightly moist
20	25	5.0	very poor	SR/SA	sand & gravel	volcanics	fine to coarse sand, gravel, clayey, interbedded clays, light brown, rusty, calcaerous, appears weathered, slightly moist
25	30	5.0	very poor	SR/SA	sand & gravel	volcanics	As above
30	35	5.0	very poor	SR/SA	sand & gravel	volcanics	As above

Table A.7: GG – 3 Lithology

GL (ft.)	7767	Well Name	GG - 3	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	30	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description
From	To						
0	5	3.0	very poor		silt/clay		Top 1.3 ft.: light gray, coarse sand, plant roots, dry
			very poor		sand & gravel	volcanics	Bottom: 1.7 ft.: fine to coarse grained sand, gravel, tan, dry
5	10	3.2	very poor	SR/SA	sand & gravel	volcanics	fine to coarse grained sand, gravel, light brow n, slightly moist
10	15	2.8	very poor		clayey sand		fine to coarse grained sand, gravel, light brow n, rusty, slightly moist
15	20	3.3	very poor	SR/SA	sand & gravel	volcanics	as above
20	25	3.7	very poor	SR/SA	sand & gravel	volcanics	As above - Water at 21.1 ft.
25	30	4.6	very poor	SR/SA	sand & gravel	volcanics	As above
							* Test hole drilled to 30 ft., infilled to 25 ft.

Table A.8: DD.2 – 1 Lithology

GL (ft.)	7697		Well Name	DD.2 - 1				Date	8/14/13	page
Datum	ground level		Owner					by	JWS	1
TD (ft.)	10		Location					job no.	13-15	of
BH Dia.	2.25		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1
Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description			
From	To									
0	5	3.4	well		silt/clay		Top 1.5 ft.: light gray, plant roots, organic detritus, dry			
			moderately well		silt & sand		Bottom: 1.9 ft.: silt, fine grained, light brown/yellowish orange, dry			
5	10	3.2	very poor	SR/SA	sand & gravel	volcanics	very fine to coarse grained sand, gravel, tan, light brown, dry			
							* Driller hit refusal at 11 ft.			

Table A.9: DD.2 – 2 Lithology

GL (ft.)	7696	Well Name	DD.2 - 2	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	25	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description
From	To						
0	5	3.2	moderately well		silt, sand		fine to medium grained sand, silt, black to light gray, plant roots, dry
5	10	3.3	very poor	SR	sand & gravel	volcanics	very fine to coarse grained, gravel, light brown, slightly moist
10	15	3.4	very poor	SR	sand & gravel		very fine to coarse grained, gravel, light brown, slightly moist. Some interbedded sandy clay, light brown, moist.
15	20	3.4	very poor	SR	sand & gravel	volcanics	as above
20	25	3.2	very poor	SR	sand & gravel	volcanics	Top 1.2 ft: fine to coarse grained, gravel, light brown, slightly moist
							Bottom 2 ft.: sandy clay, light brown, rusty, moist
							* Driller hit refusal at 25 ft.

Table A.10: DD.2 – 3 Lithology

GL (ft.)	7698	Well Name	DD.2 - 3	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	12	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description
From	To						
0	5	2.3	very poor		silt, sand, gravel		Top 1.8 ft.: silt, sand, gravel, dark gray, plant roots, organic detritus, dry
				SR	sand & gravel	volcanics	Bottom 0.5 ft.: fine to coarse grained, gravel, light brow n, dry
5	10	3.1	very poor	SR	sand & gravel	volcanics	Top 2.1 ft.: fine to coarse grained, gravel, light brow n, dry
			moderately w ell		sand		Bottom 1 ft.: fine to medium grained, light brow n, dry
10	15	2.0	very poor	SR	sand & gravel		mostly fine grained, some gravel, light brow n & gray, slightly moist
							* Driller hit refusal at 12 ft.

Table A.11: DD.2 – 4 Lithology

GL (ft.)	7704	Well Name	DD.2 - 4	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	15	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description
From	To						
0	5	2.8	very poor		silt, gravel		Top 2 ft.: silt, light gray, some gravel, plant roots, dry
			moderately w ell		silt, clay		Bottom 1 ft.: light gray and rusty, dry
5	10	3.1	very poor		silt, sand		Top 2.5 ft.: silt to fine sand, light brow n & yellow ish orange, slightly moist
			moderately w ell	SR	sand & gravel	volcanics	Bottom 0.6 ft.: fine to coarse grained, gravel, light brow n, slightly moist
10	15	3.5	very poor	SR	sand & gravel	volcanics	fine to coarse sand, gravel, light brow n, slightly moist
							* Driller hit refusal at 15 ft.

Table A.12: Peach – 1 Lithology

GL (ft.)	7665		Well Name	Peach - 1					Date	8/14/13	page
Datum	ground level		Owner						by	JWS	1
TD (ft.)	15		Location						job no.	13-15	of
BH Dia.	2.25		Rig/Bit/Mud	Site Services Direct Push					permit	N/A	1
Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description				
From	To										
0	5	2.8	very poor		silt, sand		Top 1.9 ft.: silt to coarse sand black and dark gray, some gravel, plant roots, dry				
			very poor		silt, sand		Bottom 1.3 ft.: silt to coarse sand, tan, dry				
5	10	2.9	very poor	SR	sand & gravel	volcanics	silt to coarse sand, gravel, light brow n & tan, dry				
10	15	3.0	very poor	SR	sand & gravel	volcanics	very fine to coarse sand, gravel, light brow n & yellow ish orange, slightly moist				
							* Driller hit refusal at 15 ft.				

Table A.13: Peach – 2 Lithology

GL (ft.)	7662	Well Name	Peach - 2	Date	8/14/13	page
Datum	ground level	Owner		by	JWS	1
TD (ft.)	15	Location		job no.	13-15	of
BH Dia.	2.25	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval (ft) From	Depth Interval (ft) To	Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description
0	5	2.8	very poor		silt, sand		Top 2.2 ft.: silt to gravel, black and dark gray, some gravel, plant roots, dry
			very poor	SR	sand, gravel		Bottom 1.5 ft.: silt to coarse sand, gravel, light brow n & tan, dry
5	10	3.5	very poor	SR	silt, gravel	volcanics	Top 2.5 ft.: silt to coarse sand, gravel, light brow n & tan, dry
					sand, gravel	volcanics	Bottom 1 ft.: fine to coarse grained sand, gravel, dry/slightly moist
10	15	2.8	very poor	SR	sand & gravel	volcanics	fine to coarse grained, gravel, light brow n, some interbedded sandy clays, light brow n, slightly moist
							* Driller hit refusal at 12ft.

Table A.14: Peach – 3 Lithology

GL (ft.)	7662		Well Name	Peach - 3			Date	8/14/13	page
Datum	ground level		Owner				by	JWS	1
TD (ft.)	15		Location				job no.	13-15	of
BH Dia.	2.25		Rig/Bit/Mud	Site Services Direct Push			permit	N/A	1

Depth Interval (ft)		Direct Push recovery (ft)	Sorting	Rounding	Avg Gr Size	Primary Lithology (> 50% Composition)	Lithologic Description
From	To						
0	5	3.0	very poor		silt, sand		Top 1.4 ft.: silt to med. sand, black and dark gray, plant roots, dry
			very poor	SR	sand, gravel		Bottom 1.6 ft.: silt to coase sand, gravel, light brown, dry
5	10	2.8	very poor	SR/SA	sand, gravel	volcanics	fine to coarse grained, gravel, light brown & yellowish orange, dry
10	15	3.0	very poor	SR	sand & gravel	volcanics	as above, slightly moist to dry
							* Driller hit refusal at 14ft.