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Big Plains Aquifer Evaluation

A study produced by Ensign Engineering in cooperation with Big Plains Water and Sewer Special Service District and Utah Division of Drinking Water

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EXECUTIVE SUMMARY

Big Plains Water and Sewer Special Service District (BPWSSSD) services water to residents and commercial entities in the Town of Apple Valley UT. This arid area of Washington County receives little precipitation each year. This study was performed to determine the status of the aquifer underlying Apple Valley, and determine the feasibility of drilling new wells to bolster the supply to BPWSSSD.

A three-dimensional model was created using well log data to model of the subsurface lithology, boreholes, and the potentiometric surface. This model was created using Geographic Information Systems (GIS) techniques and software and is an interactive and live model showing the general thickness and orientation of the different strata throughout the valley. This model is very helpful in visualizing the subsurface geology, and is crucial in identifying potential well sites and performing mass balance and flow rate calculations.

In terms of subsurface geology, generally throughout Apple Valley the Moenkopi formation is the confining layer and is made up of hard siltstone and sandstone. The Shinarump member sits directly above the Moenkopi member and is a sandstone and conglomerate member which is typically the water bearing member in the aquifer. This member varies in thickness from 50 to 150 feet throughout the Valley. Above the Shinarump there is a thin layer of alluvial sediments followed by a clay layer. The ability for the aquifer to produce water seems directly related to the thickness of the Shinarump member.

The estimated annual withdrawal from the aquifer is estimated to be 10,334 acre-feet, while the estimated recharge is estimated to be 10,651 acre-feet annually which would result in an overdraft of 317 acre-feet. Several assumptions were made in calculating these figures, (including water rights being fully used, hydraulic conductivities in parts of the basin etc.) and in actuality the recharge and discharge figures might vary slightly. However, it is reasonable to assume that the aquifer is at best case in balance, but likely could be slightly over-drafted.

Potential well sites which may produce the best water are identified and outlined in the report, but drilling any well in the Valley is likely not the best solution. The low recharge of the aquifer makes it difficult for large wells to be sustainable. Other sources should be explored. Purchasing existing rights to wells or springs may bolster supply, if BPWSSSD is able to find a willing seller. If possible purchasing Canaan Springs could greatly benefit the residents of Apple Valley and provide source enough for further development. Canaan Springs is located about 2 miles from the Cedar Point system and is reported to have good water quality. This should be the overall strategy for BPWSSSD, to buy existing water rights throughout the Valley as they become available. Additionally as development continues BPWSSSD should look at converting agriculture water to municipal and industrial water. This strategy of buying existing water rights to springs, and wells in the valley would promote safe aquifer management. This will help prevent the aquifer from being overdrawn while still providing water to a growing community.

Besides purchasing private wells or springs, another alternative for water source could be the Lake Powell Pipeline. The pipeline which is expected to be conveying water by 2030 is planned to pass just south of Apple Valley. Purchasing rights from Washington County Water Conservancy District (WCWCD) to this pipeline and installing a water treatment plant might be an option which would be largely more sustainable than drilling wells in Apple Valley.

INTRODUCTION

Background

Apple Valley is located in South East Washington County. This valley is generally surrounded by Gooseberry Mesa to the north, Little Creek Mountain to the south and west, and Smithsonian Butte and Canaan Mountain to the west. This arid area receives little precipitation each year and is dependent on underground wells to provide culinary and irrigation water. The public water supplier in the area Big Plains Water and Sewer Special Service District (BPWSSSD) owns seven wells, although all are not active. The two main development areas in the Town of Apple Valley are both located along Highway 59. The first is near the Little Plain area, west of Smithsonian Butte and South of Gooseberry Mesa. The other area known as Cedar Point, is located east of Big Plain Junction, and west of Canaan Mountain, primarily in sections 14, 15, and 23 of Township 43 South, Range 11 West, Salt Lake Meridian. There are also many private wells throughout the valley that provide both culinary water for homes and irrigation for some center pivot sprinklers.

Purpose of Study

The purpose of this study is to help to determine potential water sources which can be efficiently incorporated into the BPWSSSD system. Evaluating the aquifer, its safe yield, and potential drill sites are key aspects to this study. Additionally water rights will be discussed, as well as other potential water sources in the area, other than the Big Plains aquifer.

Previous Studies

The understanding of the geology in the Apple Valley area has improved over the past 15 years, largely due to work done by the Utah Geological Survey (UGS). Although this area has not been studied in depth, several quadrangle maps are now available which helps give some indications to subsurface geology and areas for possible aquifer mapping. In 2004 Utah Geological Survey (UGS) released a geologic map of the Little Creek Mountain Quadrangle (Hayden). In 2008 Hayden and Sable completed a geological map of the Virgin quadrangle (Hayden and Sable). In 2002 an interim geological map of the Springdale West Quadrangle was released (Doelling et al). Additionally, in 2010 these maps, along with additional studies were compiled into a St. George 30’ x 60’ quadrangle (Biek et al). This map and associated booklet are good geological references, but they discusss groundwater very little.

Previous to these studies very little of this area was geologically mapped. The Virgin NE, NW, and SW Quadrangles were photogeologically mapped by Marshall in 1956 (Marshall) at a 1:24,000 scale. Further East the Smithsonian Butte quadrangle was geologically mapped in 1992 by Moore and Sable

(Moore and Sable) at a 1:24,000 scale, which covers the Big Plains area. Although these studies are valuable in showing geological formations, they do not directly address aquifers in the Apple Valley area. Very little has been studied on the aquifers in the Apple Valley area.

BPWSSSD Water System

Apple Valley System

The Apple Valley Town system consists of two water wells (Well #1 and Well #2), two tanks, and approximately ten miles of pipeline (see EX-001). The pipeline is currently being upgraded to allow additional capacity for fire flow. The two tanks hold a combined volume of 46,000 gallons. Well #1 is currently producing 180 gallons per minute (gpm), while Well #2 is producing around 380 gpm. According to records from the Division of Water Rights, both of these wells used to be higher producing wells (240, and 440 gpm respectively). Currently there are 300 connections in the Apple Valley town system.

Cedar Point System

The Cedar Point system consists of a storage tank of 1,000,000 gallons, and approximately five miles of pipeline (see EX-002). There are five well sites included with the system, however only two wells are currently equipped and producing. Jessop 1 well is currently producing 45 gpm, but recent reports indicate that this well is starting to fail. Cook well was rehabilitated with pumping and chemical treatment in July of 2015 and is currently producing approximately 25 gpm. The 59 well was recently rehabilitated, but piping to add it to the system has not been completed yet. The other 2 wells (Well No. 5 and Well No. 4) are currently not in production. There are 40 connections in the Cedar Point System.

Required Source Capacity

Water use data from October 2014 thru September 2015 was analyzed to determine the required source needed in both the Apple Valley and Cedar Point Systems. Through this analysis it was determined that currently the Apple Valley system has 282 Equivalent Residential Connections (ERC's) while the Cedar point system has 58 (ERC's). Following Utah Administrative Code R309-510-7 Source Sizing, the required peak day demand for source was determined. Currently the majority of homes in Apple Valley do not have lawns and thus require very little irrigation. However, some homes do have lawns and over time people may begin to add landscaping to their properties. Through aerial mapping it was determined that currently approximately 0.02 acres of landscape is being irrigated per ERC. Should more residents begin to add irrigable landscaping, or as new development occurs and adds irrigable landscaping the required source will increase from what is shown here. Currently the required source for the Apple Valley System is184 gpm while the required source for the Cedar Point system is 38 gpm. See table 1 for more information and further projections.

Table 1 Required Source Capacity

Year	Total Pop.	Est. Apple Valley ERC	Est. Cedar Point ERC	Req. Source Apple Valley (gpm)	Req. Source Cedar Point (gpm)	Total Est. ERC	Total Est. Req. Source (gpm)
2015	837	282	58	184	38	340	222
2020	999	337	69	220	45	406	265
2030	1,424	480	99	314	64	578	378
2040	1,887	636	131	416	85	767	501
2050	2,399	809	166	528	109	975	637
2060	2,953	995	205	650	134	1,200	784

REVIEW OF DATA

Precipitation

Little and Big plains increase in elevation from approximately 4675 feet to 4900 feet traveling from the north west heading south east through the valley. This puts the average elevation in Apple Valley around 4800 feet. The closest weather stations to Apple Valley are the La Verkin station 10.5 miles northwest and the Colorado City Station 11 miles to the southeast. The Zion National Park weather station, which is approximately 11 miles to the northeast, is arguably the wettest area in this part of the state. The average precipitation here is only 16.1 inches. Even though there are no weather stations on top of the high land areas surrounding Apple Valley, it is reasonable to assume that these areas receive less than 16 inches of rain a year. Interpolation shows that the approximate amount of annual precipitation in Apple Valley to be near 13 inches.

Table 2 Average Annual Precipitation (in)

Zion NP	16.1
La Verkin	11.6
Colorado City	13.5
Apple Valley (Interpolated)	13.0

Population Projections

The Governor's Office of Management and Budget projects that Apple Valley, along with Washington County, will grow at a fairly aggressive rate at approximately 3.61% annual growth from 2010-2030. This is not surprising as Washington County has seen significant growth in past years. In fact, previous to the 2008 recession, St. George was one of the fastest growing areas in the country. With Apple Valley being in a warm climate, (although it is about 5-10 degrees cooler than St. George) and having close proximity to popular National Parks, it is expected to grow at a fairly rapid pace. It seems that the lack of water in this arid valley might be a limiting factor for growth.

Table 3 Population Estimates

	Census			Projections		
Geography	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Washington County	138,115	196,762	280,558	371,743	472,567	581,731
Apple Valley town	701	999	1,424	1,887	2,399	2,953
Balance of Washington County	6,988	9,955	14,195	18,809	23,910	29,433

Water Quality

According to the Consumer Confidence Report produced by the Apple Valley Water Company in 2011, there were no violations of the contaminants tested (turbity, alpha emitters, arsenic, barium, chromium, copper, lead, nitrate, selenium, sodium, sulfate and total dissolved solids). Additionally, in 2009 Well #1 showed 0.73 picoCuries per liter (pCi/L)and Well #2 showed 2.6 pCi/L of Radium-228. This is below the maximum contaminant level (MCL) of 5 pCi/L. Likewise the Consumer Confidence Report for Cedar Point in 2013 showed that there were no violations of the contaminants tested.

Drilling new wells is often a risky endeavor when it comes to water quality, because there is no way of testing the water before it is drilled. Total dissolved solids (TDS) is often a contributing contaminant in groundwater. Because TDS is caused by erosion of natural deposits, gypsum which is soluble in water, is often a high contributor of TDS. Shale beds that underlay and overlay the Shinarump member contain a lot of gypsum. This makes drilling in the Shinarump member a risky endeavor to encounter high levels of TDS. However, many wells in the Apple Valley area have been drilled into this member, and are below the MCL on TDS.

GEOLOGY OF APPLE VALLEY

Triassic Aquifer

The Triassic Aquifer is the shallowest aquifer in the Apple Valley area. This aquifer is spread along the Virgin Valley, the Little and Big Plains, and into Arizona. It is generally bounded by the Vermillion Cliffs on the East, and is likely bounded by a Moenkopi formation just east of the Hurricane Fault. This is the aquifer from which all of the wells in Apple Valley are drawing. More discussion on the aquifer including the potentiometric surface will be discussed throughout the report.

C Aquifer

This is the lower aquifer in the Apple Valley area. This aquifer is a deep lying aquifer underneath the Moenkopi formation. This aquifer will not be discussed in depth in this report as the potentiometric surface is approximately 1,600 to 2,000 feet below ground elevation in the Apple Valley area as mapped by Inkenbrandt (2013). The amount of drilling through the hard Moenkopi and power required to pump this deep aquifer makes it unfeasible as a drinking water source.

Gould Wash

Many private wells have been drilled in the Gould Wash area over the years. These wells seem to target the unconsolidated alluvial sediments underneath the valley of Gould Wash. Many of these wells drilled in this area are dry, and well logs are poor. However, a loose interpretation of the well logs, indicates that the alluvial sediments are not thicker than 300 feet. The water table in this area seems to be about 100-150 feet down. This leaves a very small volume of saturated sediments. It should be noted that often in heterogeneous alluvial aquifers there exists long narrow "streams" of high permeable sand and other material, but these exist only between predominantly silt and clay beds. This often results in dry wells that are drilled near good-producing wells.

Recharge for the alluvial aquifer occurs from the higher mesas and buttes. These areas, however, do not receive abundant precipitation; rarely more than 15-16 inches of precipitation annually. This area must be the primary recharge, because the formation dips gently to the north, and there are no recharge areas to the south.

Shinarump

Generally throughout the Big Plain valley the confining strata for the aquifer is the Moenkopi Formation. Many of the well logs indicate that the drillers stopped once they reached the hard Moenkopi formation. Generally speaking, the Shinarump Member lies directly on top of the Moenkopi, and is a water-bearing stratum. The thickness of the Shinarump appears to be directly related to the ability of a well to produce water. Many wells have been sunk in the Shinarump sandstone, with mixed results. Few wells, however, produced more than 50 gpm upon test pump. Wells sunk on the western edge of Big Plains largely produce less water than those further east in the Valley. The Shinarump member along the western portion of the valley is as thin as 40 feet, while further east it is as thick as 150 feet.

Basalt/Lava Flows of the Little Plain Valley

Well logs indicated that deposits of cinders are interlaid with basalt flows starting in the little plain area and extending west roughly through sections 30,19,24,23,and 22, where this formation seems to surface. There are several wells through this area, that when drilled, were good producing wells. Well Identification Number (WIN) 17686 near the west quarter corner of section 27 was tested at 200 gpm when drilled in 1998. WIN 8181 near the center of section 23 was tested at 800 gpm in 1978. Additionally, WIN 9468 near the center of section 30, was tested at 275 gpm in 1978. All three of these wells are in basalt rock near 180 feet. Even BPWSSSD Well #1 and Well #2 indicate a similar trend. When Well #1 (WIN 8848) was deepened and redeveloped in 2004, the drill log indicates that at 180 feet 25 gpm was picked up. As the well was deepened even more, from 180 feet to 230 feet, 200 gpm was picked up in small fractures. This gave a total yield of nearly 250 gpm during a test pump. The well log for Well #2 (WIN 35571) is less detailed, but it indicates a test pump of 440 gpm in the same lava-basalt formation. However, south of well #2, another well (WIN 25049) and even further south (WIN

16660) indicate that the cinder/basalt/lava flows end and that strata's of mudstone and clay begin to dominate. These wells in this area do not produce near as much at 40 gpm and 3 gpm respectively, although fractured limestone deeper, around 300 feet, may provide some yield.

The basalt/lava flows seem to extend a little further east of BPWSSSD well #2 as WIN 11106 indicates that the wells drilled for the gas station at the intersection of Highway 59 and Apple Valley Drive encountered these flows. However, test pumps indicated no more than 18 gpm were tested here.

MODEL RESULTS

Analysis Approach

Ensign Engineering has created a GIS model using ESRI's ArcGIS suite of the well locations in Apple Valley, containing the available information from well logs. The model shows the wells on a 3-dimensional map with the well bore color-coded to indicate the various strata through which it was drilled, and the level(s) at which water was encountered. This information is used to generate a potentiometric surface, according to water levels reported by well drillers. Since well logs in this area vary in time from the late 70's to present, and during that time the potentiometric surface has undoubtedly changed slightly, this surface should be interpreted somewhat liberally. This model also shows approximate sub-surface geological features, namely: the lava/cinder formation in Little Plain, the upper alluvial sediments of Gould Wash, the Shinarump member of Big Plain, and the confining layer of the Moenkopi formation. Exploring this model gives a unique perspective to the sub-surface geology in Apple Valley.

Although every attempt was made to create an accurate model of the sub-surface, the model should be viewed as a general guide rather than a definitive representation of the sub-surface. The challenge of using well logs for this exercise is that the completeness of well logs varies from driller to driller, and the interpretation of materials which are extracted from the bore is subjective. Some well logs appear to cite locations that are not consistent with aerial mapping (the well houses for the Cedar Point wells can be seen clearly on aerial photography, yet the driller's log for at least one of the wells appears to indicate a location more than a quarter of a mile away from the nearest well).

Gould Wash/Little Plains

Water in this area is typically gained through the lava and cinder flows in the area. A cross section is shown in figure 1. This area typically has a large portion of sand in the upper alluvial layers. Because of the alluvial "shoestrings" throughout this area, this thickness and make-up of the sediments in this area can vary greatly.

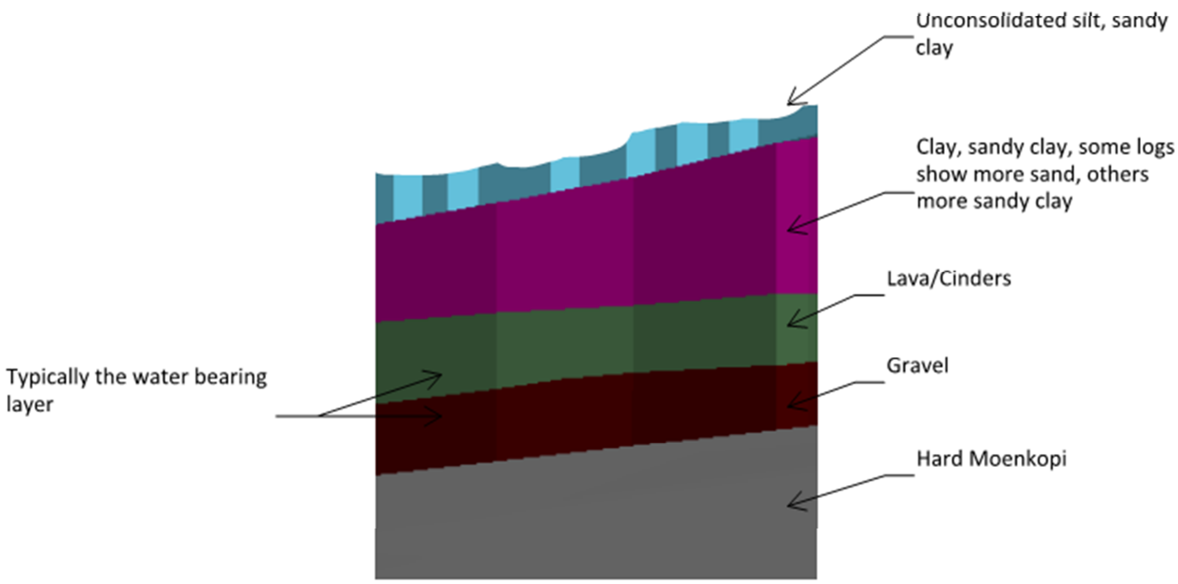

Figure 1. Typical cross-section of Gould Wash/Little Plains area

Big Plains/Cedar Point

Water in this area is typically in the Shinarump member. As discussed the thickness of the member varies, but is generally thicker to the east, near the bluffs near Cedar Point. The upper alluvial sediments vary in make-up, but near Cedar Point the upper layer is composed of mainly sand, followed by clay, but sometimes silt. Further north the sediments are predominantly clay. See figure 2 for a typical cross section in the Big Plains area.

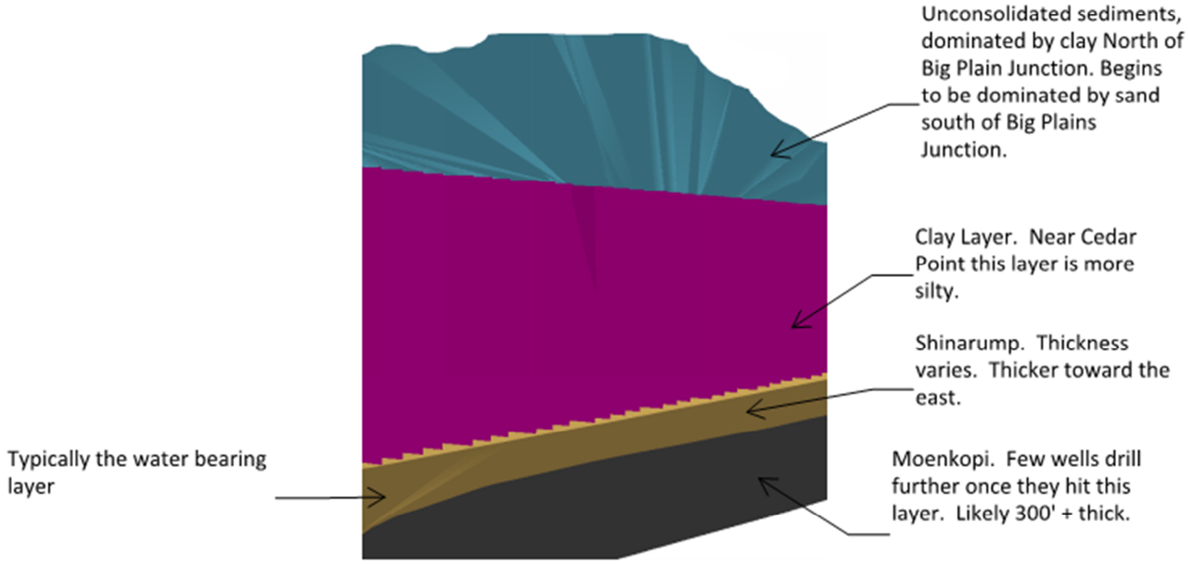

Figure 2. Typical cross-section of Big Plains/Cedar Point area

Canaan Gap

For the most part the Canaan Gap area is very thin in both alluvial sediments and the shinarump member. For that reason most wells in this area do not produce very much water. There is one area were there is an exception to this. WIN 25606, WIN 8073, and WIN 25864 near 37.010657, -113.097418 seem to produce significantly more water than the rest of the wells in the area. The well logs suggest there are many alluvial layers of silt, sand, clay, and gravel. Perhaps these wells are in a “shoe-string” segment of the aquifer were the permeability is much higher. Locating the exact boundaries of this formation would be difficult. See figure 3 for the typical cross-section in the Canaan Gap area.

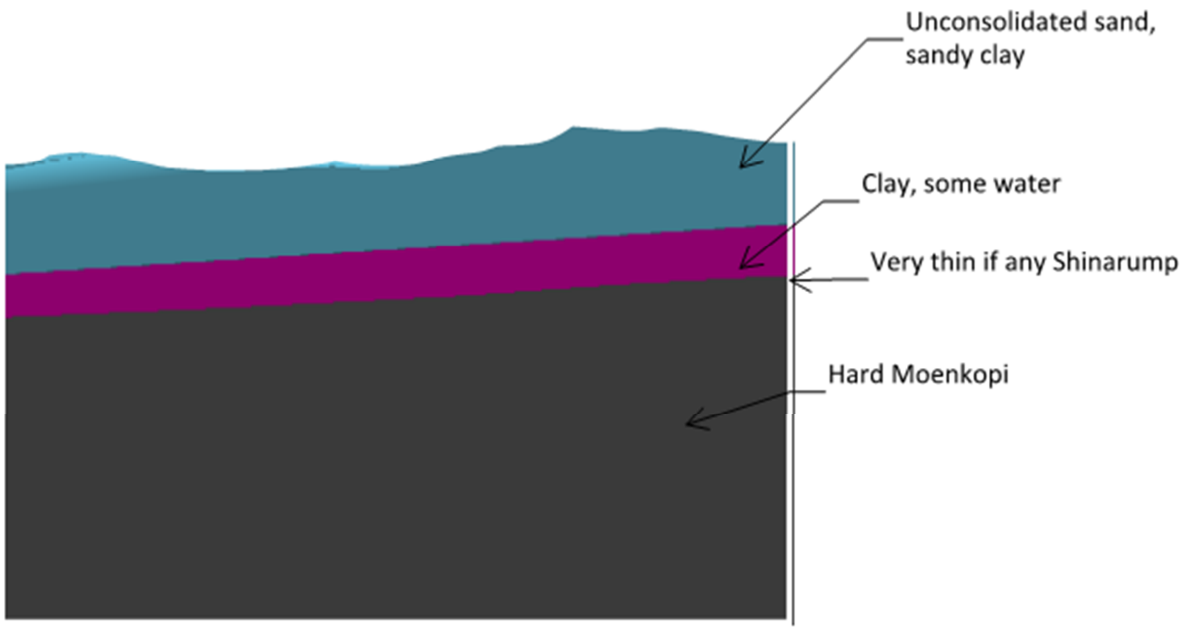

Figure 3. Typical cross-section of Canaan Gap area

Potentiometric Surface

After creating probable lithologies and gathering data from well logs, a potentiometric surface can be created for the aquifer underlying Apple Valley. An interpolation technique called Natural Neighbor was used to create the surface in ArcGIS. This surface was checked against other studies, and any adjustments were made to create an accurate surface. The potentiometric surface is the level to which the groundwater would rise if pierced with wells. From this surface we analyzed groundwater flow paths. EX-007 shows the potentiometric surface and flow paths. This figure is very telling in showing the recharge areas as well as flow paths within the aquifer. Recharge from Canaan Mountain flows toward Highway 59. Recharge on the far east side of Little Creek Mountain also flows toward 59, although once in the valley the gradient is mild. The middle and western portions of Little Creek flow west toward Hurricane Fault with some flow into the Gould Wash area and some into the Canaan Gap area. Most of Gooseberry Mesa flows toward the Virgin River at a gradient of 8-12%.

AQUIFER BALANCE

Generally, Basin and Range aquifers can potentially be recharged in one of six ways namely: upland precipitation, valley floor precipitation, streamflow infiltration, infiltration from irrigation, interbasin flow, and underflow. Stream-flow infiltration and upland precipitation generally contribute the most to aquifer recharge. Likewise aquifer discharge has five principal components, namely: withdrawal by wells, evapotranspiration, underflow, discharge to streams, and interbasin flow. The largest components of this are withdrawal by wells and evapotranspiration. A popular approach to aquifer evaluation is to do a mass balance analysis on the aquifer to determine its net recharge or discharge on a yearly basis. This is the approach used in this study.

First it is important to determine the boundaries of the study area. Since the entire aquifer extends through the Virgin Valley, through Apple Valley, and into a fairly large area in Arizona, it is impractical to do a mass balance on the entire aquifer in this study. Since Apple Valley is largely the up gradient area of the aquifer, it was determined that a recharge area be created for the Wells in and around Apple Valley. From this area, recharge and discharge quantities can be calculated. The area was determined based on the potentiometric surface and surface geologies. As mention groundwater flow for a large portion of Little Creek Mountains likely flows west and does not contribute to areas within Apple Valley.

Aquifer Recharge

Recharge from Uplands Precipitation

The bluffs and mesas surrounding Apple Valley are estimated to have an annual precipitation of 16 inches per year. Much of this rainfall is lost by evaporation and evapotranspiration. Several studies conducted by USGS indicate an average recharge to basin and range aquifers in Washington County and Northern Arizona is about 5% of total annual precipitation (Robson & Banta 1995, Heilweil 2015). Another study completed by USGS estimates 5-15% recharge occurs to the Navajo and Kayenta aquifers in Washington County (Heilweil 2000). Recharge for this study was estimated to be 15%. From the study area, approximately 30,000 acres of upland contribute directly to the Apple Valley area. From these figures it is estimated that 6,000 acre-feet/year of recharge to the aquifer occurs from upland precipitation.

Recharge from Stream Flow

There are no perennial streams in the Apple Valley area, however, during large rain events several ephemeral streams flow with significant volume. Estimating recharge from streams is difficult with insufficient data, however, test done in Washington County in 1997 (Wolkowsje and others, 1998, table 1) and later followed by a USGS study (Heilweil, 2000) indicate that approximately 200 acre-feet per year of recharge was attributed to 62.4 miles of ephemeral stream bed or 3.2 acre-feet per year per mile of stream bed. There are approximately 20 miles of major ephemeral stream beds in Apple Valley, which would indicate a recharge of 64 acre-feet. Infiltration rates are likely not the exact same in Apple Valley as they are in places were the previous test was performed, nonetheless, this shows very little recharge is attributed to stream flow in this region.

Recharge from Valley Floor Precipitation

Precipitation on the valley floor is estimated to be 13 inches per year. There are approximately 20,000 acres of valley floor, and using the same recharge amount of 15% discussed earlier the recharge attributed to precipitation on the valley floor is approximately 3,250 acre-feet per year.

Recharge from Irrigation

Over the years select areas of Apple Valley have been irrigated. Some of those areas are now currently not being irrigated including the Kokopelli Golf Course and some pivots. Irrigable acres were determined from recent aerial photography to be 340 acres. Assuming 6 acre feet/acre of irrigation (Consumptive crop use), and 50% of irrigation recharges the aquifer, approximately 1,020 acre-feet per year of recharge to the aquifer occurs from irrigation.

Recharge from Interbasin Flow and Underflow

Recharge from interbasin flow and underflow is generally more common in large aquifers. Although it has not been proven that neither of these are occurring in Apple Valley it is assumed that no recharge is attributed to them. With the hard Moenkopi formation underlying the aquifer, as well as the relatively thin alluvial sediments it is unlikely that interbasin flow and Underflow are occurring.

Net Recharge

Summing all of the sources of recharge gives a total recharge to the Apple Valley portion of the aquifer to be 10,334 acre-feet per year.

Aquifer Discharge

Discharge from Wells and Springs in Apple Valley

It is unknown how much water is being discharged from the aquifer with all the various private and public water wells in the area. To try to evaluate the amount of discharge from the aquifer the Utah Division of Water Rights website was researched to determine the amount of water rights laid claim on in the Apple Valley Aquifer. It was determined that approximately 9,085 acre-feet of approved and proved water rights are in the Apple Valley area. It may be the case that all of these water rights are not being fully used, however, without consumptive use data on all of the private wells throughout the area this is a reasonable assumption.

Discharge from Evapotranspiration

Evapotranspiration is difficult to measure and calculate on this type of scale. USGS studies for WCWCD excluded evapotranspiration as a separate entity and compensated for it in percentage of rainfall that recharges the aquifer. It seems reasonable in this case to do the same. With little agricultural area relative to basin, this is likely not a major contributor.

Discharge into Streams

Discharge into streams is assumed to be zero as there are no perennial streams in the Apple Valley area.

Discharge out of the Apple Valley Area

Since the aquifer extends beyond the Apple Valley area a reasonable amount of groundwater is expected to continue to other areas of the aquifer. When studying the potentiometric surface, there appear to be two locations were groundwater can exit the Apple Valley area. The first is the Gould Wash area near highway 59 on the North West area of the valley. The second is Canaan Gap area south and east of Little Creek Mountain. All other areas surrounding Apple Valley have a higher potentiometric surface and thus would flow into Apple Valley.

The flow rate in the aquifer can be expressed by the equation

$$Q=k*Y*b*I$$

where Q is the flow rate of the aquifer, k is the hydraulic conductivity, Y is the thickness of the aquifer, b is the width of the aquifer, and i is the gradient can be used to determine how much water is leaving the aquifer at both of these locations. The width of the aquifer near Gould's Wash is estimated to be 5,000 feet wide. From the 3-D model created and well log data, the thickness of the aquifer in this region is about 120 feet. The hydraulic conductivity in this area is hard to determine because of the lava flows intermixed with clay and silt alluvial flows. It is estimated that the hydraulic conductivity is 12 feet/day. The gradient is 2.40% based on potentiometric surface mapping. This results in a flow rate at 1,449 acre-feet/year.

The width of the aquifer in the Canaan Gap Area, and the area to the south toward Hildale is about 40,000 feet wide. The thickness of the aquifer in this area is 50 feet with a gradient of 0.70% and hydraulic conductivity of 1 foot/day. The flow rate through this area of the aquifer is approximately 117 acre-feet/year.

Discharge from Interbasin Flow

Discharge from interbasin flow is assumed to be zero. No evidence points to large fractures that would route the water into another basin.

Net Discharge

Summing all of the sources of discharge together gives an annual discharge of 10,651 acre-feet.

Ground-water Budget

It is estimated that the net budget for ground-water in the Apple Valley region is approximately 317 acre-feet per year of overdraft (see table 3). Caution should be used when referencing this number. Although every attempt to collect data and make sound engineering assumptions was made, because of the lack of concrete data the budget for the aquifer should be reference only. More or possibly no overdraft could actually be occurring. This type of uncertainty is almost always the case in aquifer evaluation. This evaluation does show that developing sustainable wells in Apple Valley is going to be very difficult because of the stress already on the aquifer.

Table 4. Ground-water Budget

Recharge			Discharge		
Recharge from Uplands Precipitation	6,000	acre-feet/yr	Certified Water Rights	9,085	acre-feet/yr
Recharge from Valley Floor Precipitatio	3,250	acre-feet/yr	Flow Rate out of Gold Wash Area	1,449	acre-feet/yr
Recharge from Irrigation	1,020	acre-feet/yr	Flow Rate out of Canaan Gap Area	117	acre-feet/yr
Recharge Asociated with Stream Flow	64	acre-feet/yr	**Total Recharge**	**10,651**	**acre-feet/yr**
Total Recharge	**10,334**	**acre-feet/yr**			
			Overall Budget	**(317)**	**acre-feet/yr**

SUMMARY OF WATER RIGHTS FOR BPWSSSD

Water rights are linked by the State either to wells, streams, or springs (point of diversion), and are also tied to a place of use. The water rights which currently exist in the area around Cedar Point subdivision are contained within Township 43 South, Range 11 West (with the exception that Canaan Springs are within Range 10 West). Most wells are located in Sections 14, 15, 22, and 23. A list of the existing rights in this area, as well as a map of the locations is attached.

Table 5 Unencumbered Water Rights

Water Right #	App#	Quantity (ac-ft)	Cert. #	Priority Date
81-3169	A38149	202.5	11190	3/29/1967
81-1798	A38149a	5	12061	3/29/1967
81-2740	A39405	1	10502	5/28/1969
81-3200	A40199b	62.5	12055	11/23/1970
81-1799	A40199b	1	12055	11/23/1970
81-3106(1)	A40599b	22	12054	4/22/1971
Total:		294		

The 294 acre feet of the unencumbered water rights are currently being used by Big Plains Water and Sewer Special Service District. 81-3106(1) 22 of 52.02 ac-ft under this water right are actively being used.

Table 6 Encumbered Water Rights

Water Right #	App #	Quantity (ac-ft)	Cert. #	Priority Date
81-4014	A39405	155	10502	5/28/1969
81-3106(2)	A40599b	30.02	12054	4/22/1971
81-4599	A43996	259	Not Listed	8/5/1974
81-3011	A43996a	132.58	12955	8/15/1974
81-4600	A43996a	198	12955	8/15/1974
81-4676	A43996a	48	12955	8/15/1974
Total:		822.60		

The 822.60 encumbered water rights are currently not being used by Big Plains Water and Sewer Special Service District. 81-3106(2) 30.02 of 52.02 ac-ft under this water right are set aside in the water rights bank. So currently 26.33% of the water rights held by Big Plains are currently in use.

It is recommended that the strategy for BPWSSSD going forward be to purchase additional water rights as they become available. Purchasing these existing rights does not put more stress on the aquifer, and allows BPWSSSD to secure water rights for future growth to occur.

POTENTIAL SOURCES

Drill New Wells

There are a few places through Apple Valley that may produce water. The lava beds near Well #1 and Well #2 in Apple Valley seem to consistently produce the most water. South of Well #1 and Well #2, further down Jepson Canyon, produce less water however. The lava beds seem to get pinched out against intermixed clay, limestone, and silt layers in this area. The lava beds also seem to get pinched out further east of wells #1 & #2. The best locations near this area for a well may be just north and west of well #1. Being near to the existing pipeline in this area will save pipe costs. One concern of placing a well in this location is that currently Wells #1 and #2 are producing enough water to exceed source requirements in the Apple Valley System. If a pipeline were constructed between the Apple Valley and Cedar Point systems this additional well would be much more beneficial as the Cedar Point system is in dire need of additional source. A reasonably assumed borehole for this area can be estimated from 3-D model and drill logs in this area and is shown in figure 4.

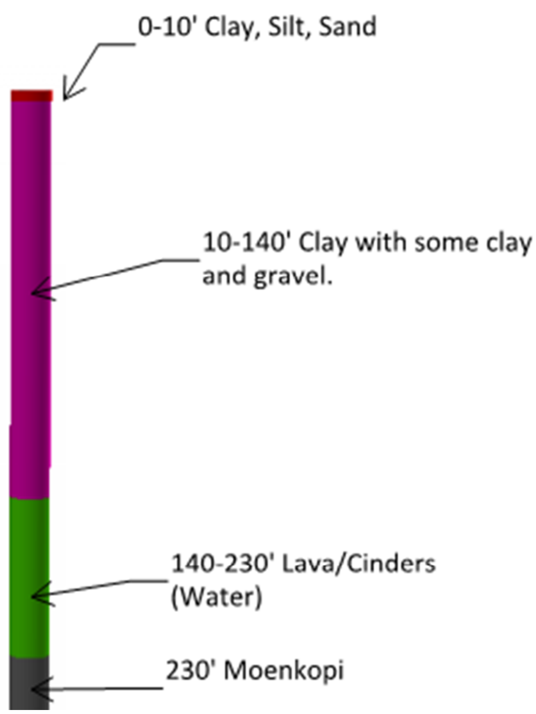

Figure 4. Possible borehole near Well #1 and Well #2

The second location which might prove to produce water is approximately half a mile west of the Smithsonian Butte. There is a fault mapped by Moore and Sable (2001), trending north, which might produce a lot of water. In sandstone formations, such as the shinarump, fractures usually convey the most amount of water. There are two concerns about placing the well in this location. The first is the ability to intersect the fault with a drill rig. This location will produce the most water if the driller is able to hit the fault where it intersects the water table. Doing this is easier said than done. Although the fault is mapped, it isn't mapped with a high degree of certainty or accuracy. Additionally, if the fault dips, it would be necessary to move the drill rig away from the where the fault is expressed on the surface, and attempt to intersect the fault at the right depth. Second, this area is not near any existing water infrastructure. The cost of siting a well in this location would also include approximately 4 miles of pipeline to connect it to the Cedar Point System.

The third location were a suitable well might be drilled is along Main Street near or just north of Big Plain Junction. Wells near this location seem to be the best producing wells. Well logs show wells producing over 200 gpm. Local geology doesn't show an exact reason why this location has better producing wells. The shinarump member is thicker in this region, which would offer some increase in production. However, recharge from the wilderness study area to the east might also contribute more to this area of the valley than other areas. The water bearing member is deeper, however. The drawback to placing a well in this location is once again proximity to existing infrastructure. A reasonably assumed borehole can be estimated from 3-D model and drill logs in this area and is shown in figure 5.

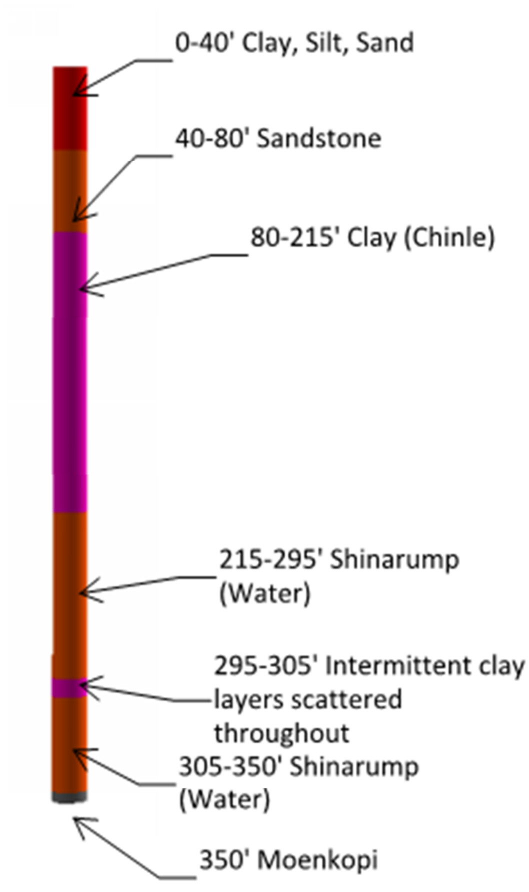

Figure 5. Possible borehole near Big Plain Junction

Another location where a well might have the best chance of producing water would be the south east portion of the Big Plain. More specifically, east of well 59 would likely be a good location. As discussed earlier the geologic tilt is to the east, therefore the greatest amount of water will likely be furthest east in this formation. This area will likely not produce a lot of water, but 25-50 gpm might be expected. This location is a rather safe bet, but likely won't completely solve source problems in Apple Valley if aggressive growth is considered. A reasonably assumed borehole can be estimated from 3-D model and drill logs in this area and is shown in figure 6.

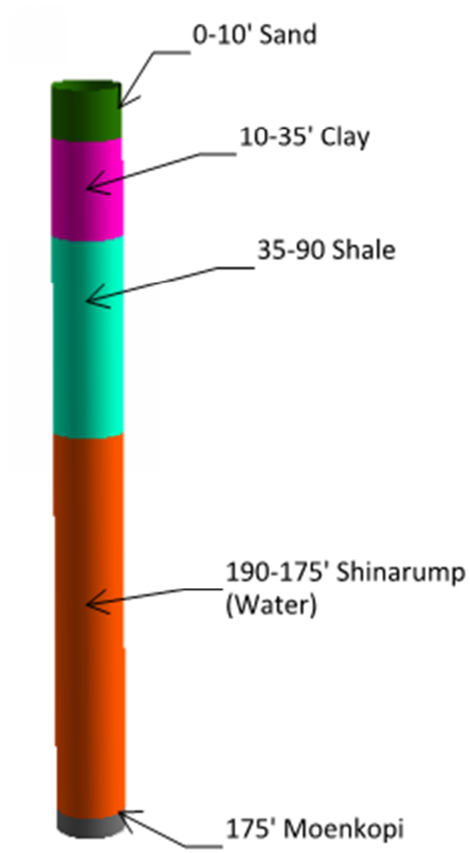

Figure 6. Possible borhole near 59 Well

Rehabilitation of Existing Wells

Three wells where rehabilitated in the summer and fall of 2015: Cook, Jessop, and 59 well. The rehabilitation of these wells really helped with dire source needs during the summer and will hopefully help with source needs in the immediate future.

In July of 2015 the wells that supply water to the Cedar Point subdivision began to lose production. Work was initially done on the Cook Well, which is located 1800 East and 2000 South in Apple Valley, and included pulling the casing and pump and running a camera down the well. The pump and casing were in good condition by showed signs of bacterial growth. A chemical shock treatment was done and the well was brushed and bailed to clean it and place it into production. After completion the well produced 30 gpm.

The second well that was renovated was the Jessop Well which is located at 1900 East and 1700 South. This well began to slow production and the pump was cavitating. The pump and casing were pulled and a camera was placed in the well to see the problems. This well is an open hole bottom and had collapsed. Because of this the well was deepened 100 feet and a sleeve as placed to prevent further collapsing. Production was returned.

Well 59 is a well located near Highway 59 that was drilled but never developed. The well was full of debris and had to be cleaned. Once cleaned a pump test was done measuring flow and draw down. The well was able to stabilize and produce 115 gpm. This well will need to be equipped and connected to the system before being put into production.

Purchase Existing Wells from Private Owners

The Cedar Point water system primarily exists to provide water to the Cedar Point subdivision, which is located in Township 43 South, Range 11 West, Salt Lake Meridian. The system lies mostly in sections 14, 15, and 23. A number of private wells are located in these sections, and in adjacent Section 22. It would be desirable to acquire existing wells close to the system to bolster the supply for the subdivision and for other residences that wish to be connected.

A survey of the well information for these existing wells (from the State Division of Water Rights website) indicates a range of depths from 157 to 275 feet, and recorded production rates from 10 to 35 gallons per minute, per testing by the well drillers. It is important to note, however, that the test results for wells, as noted in the drillers' logs, may not be a good indication of actual production. Test pumping methods are inconsistent from driller to driller and well to well.

Purchase Existing Springs from Private Owners

Canaan Springs, in the south end of the Big Plains service area, are reported to have water of very good quality. According to the Utah Division of Water Rights, rights to the springs are held by Merlin Webb, under the name of Canaan Springs Water Company. The springs are an attractive source of water for the Cedar Point system, and are located approximately two miles east of the storage tank. However, the District will likely not pursue the acquisition of these springs unless there is some indication that the owner is a willing seller.

A smaller spring has been identified in the vicinity of the storage tank, in the southwest quarter of Section 12 (T 43 S, R 11 W) (information on ownership?). This source is convenient to the tank site (less than 600 feet away); incorporating it into the system may require pumping. It is reported to have a production of 5 gpm, which makes it hard to justify installing a booster station.

Securing Capacity in the Lake Powel Pipeline

The proposed Lake Powell Pipeline is a project that will bring water 82,000 acre-feet of water to Washington County Water Conservancy District and 4,000 acre-feet of water to Kane County Water

Conservancy District via a 69-inch pipe from Lake Powell to Sand Hallow. The proposed alignment has the pipeline nearing the southern boundary of Apple Valley. It is anticipated that water deliveries will begin in 2025.

Two options exist with the Lake Powell pipeline. The first is that BPWSSSD might explore exchanging Lake Powell water with higher quality water from privately owned wells or springs that are currently being used for irrigation. The second is treating the water from the Lake Powell pipeline, and using that directly as a drinking water source. Either alternative would require buying water from WCWCD. BPWSSSD applied for water from the Lake Powell Pipeline, but has yet to come to an agreement with WCWCD.

APPENDIX A

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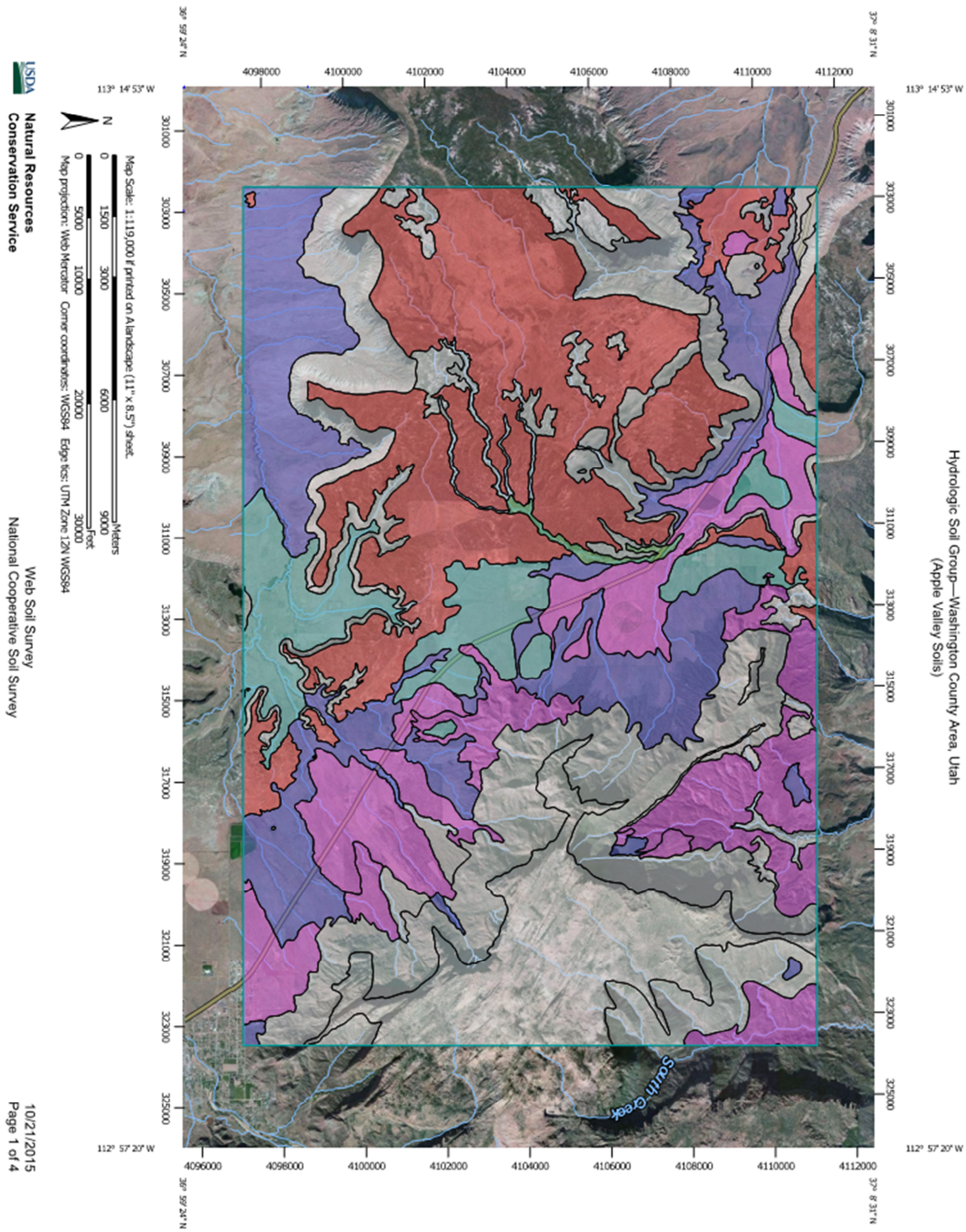
APPENDIX B

Soils Data



Hydrologic Soil Group—Washington County Area, Utah
(Apple Valley Soils)

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Washington County Area, Utah
Survey Area Data: Version 9, Sep 23, 2015

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 7, 2010—Nov 3, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Washington County Area, Utah (UT641)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
BA	Badland		424.9	0.6%
BB	Badland, very steep		5,222.1	7.1%
BOD	Bond sandy loam, 1 to 10 percent slopes	D	16,397.9	22.4%
CI	Cinder land		641.3	0.9%
CoC	Clovis fine sandy loam, 1 to 5 percent slopes	C	2,980.6	4.1%
EA	Eroded land-Shalet complex		114.0	0.2%
FA	Fluvaquents and torrifluvents, sandy	A/D	250.3	0.3%
GA	Gullied land		558.5	0.8%
GP	Gravel pits		5.8	0.0%
MBG	Mathis-Rock outcrop complex, 20 to 50 percent slopes	A	4,718.8	6.4%
MFD	Mespun fine sand, 0 to 10 percent slopes	A	518.4	0.7%
NaC	Naplene silt loam, 2 to 6 percent slopes	C	2,387.2	3.3%
PAC	Palma loamy fine sand, 1 to 5 percent slopes	A	3,608.0	4.9%
PbC	Palma fine sandy loam, 1 to 5 percent slopes	A	2,750.5	3.8%
PED	Pastura-Esplin complex, 0 to 10 percent slopes	D	762.4	1.0%
RaC	Redbank fine sandy loam, 1 to 5 percent slopes	B	7,644.5	10.4%
RO	Rock land		1,297.7	1.8%
RT	Rock outcrop		7,304.3	10.0%
SH	Schmutz loam	B	4,133.1	5.6%
SY	Stony colluvial land		11,570.3	15.8%
W	Water		3.2	0.0%
YZE	Yaki-Zukan complex, 1 to 35 percent slopes	D	16.0	0.0%
Totals for Area of Interest			**73,309.7**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

APPENDIX C

Exhibits