Spring Valley Aquifer Sustainability Study

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Prepared for:
Storied Development

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INTRODUCTION

This report has been prepared to update previous engineering evaluations related to the sustainability of the Spring Valley Aquifer (SVA) located approximately 6 miles southeast of Glenwood Springs, CO (**Figure 1**). The SVA is identified as a major alluvial aquifer resource in the Colorado Groundwater Atlas prepared by the Colorado Geological Survey. The purpose of this updated study is to incorporate more modern datasets into the analysis and determine if recent changes to precipitation, temperature, and resultant hydrology have altered the results of previous analyses, all of which found the aquifer to have sufficient water in aquifer storage and recharge to support Spring Valley Ranch (SVR) and other planned developments.

BACKGROUND

Colorado River Engineering (CRE) has reviewed previous studies related to the SVA.[1][2][3] These studies were undertaken in the early 2000's to quantify the water availability and compare it to the water demands associated with the SVR development as well as other planned developments which were all contemplated to rely on the SVA. Gamba (2000) determined the probable amount of annual recharge to the Spring Valley Aquifer (SVA) to be 10,059 acre-feet per year on average based on average annual precipitation (1951-1980) of 19,908 acre-feet, evapotranspiration (ET) losses of 9,249 acre-feet, and estimated surface flow losses down Landis Creek of 600 acre-feet. The probable annual recharge was quantified to be well above the expected total development groundwater **diversions**, which are not completely consumptive to the aquifer, of 1,100 acre-feet which included 600 acre-feet from SVR and 500 acre-feet from other developments. HRS provided review of the Gamba analysis with a resultant recharge estimate of 4,700 acre-feet, which estimated crop ET from free surface water evaporation. The results of these studies have been updated by CRE utilizing more modern datasets considering recent changes in precipitation, satellite derived vegetation types, and more detailed consumptive use estimates.

The Gamba analysis quantified the total water in storage in the aquifer to be 68,000 to 105,000 acre-feet of which 38,000 to 46,000 acre-feet is stored in the SVA and 30,000 to 60,000 acre-feet are available in the upland volcanic materials tributary to the SVA. The HRS analysis included a similar estimate of 82,000 acre-feet of water available in storage in the SVA. The aquifer serves as an underground reservoir to offset dry years with lower than normal recharge and to store water in above normal recharge years.

AQUIFER CHARACTERISTICS

The cited Gamba report provides a detailed explanation of the geologic conditions that formed the Spring Valley Hydrologic System, which is briefly summarized herein. The SVA tributary area

[1] Gamba, J. 2000. The Spring Valley Hydrologic System. Prepared for Bill Peacher.
[2] HRS Water Consultants, Inc, 2000. RE: Spring Valley Ranch – Review of Jerome Gamba & Associates, Inc. Report, The Spring Valley Hydrologic System.
[3] Wright Water Engineers, Inc. 2000. Water Requirements, Water Resources, and Spring Valley Area Water Balance. Prepared for Spring Valley Development, Inc.

which contributes to recharge is approximately 15.4 square miles (**Figure 1**) and varies in elevation from 6,870 to 9,400 feet. The aquifer was formed as soluble salts present in the underlying Eagle Valley Evaporite formation were dissolved by groundwater resulting in collapse, deformation, shear fracturing, and faulting of the overlying Maroon formation and volcanic rocks. These processes resulted in the high infiltration rate and water bearing capacity of the volcanic rocks. Millions of years of erosion have resulted in removal of softer, unconsolidated cinders and ash from the surface and exposed the weather resistant basalt rocks. The ash and cinder lenses that remain below the basalt provide pockets of highly porous materials that detain groundwater, also called “hanging aquifers”. Water is channeled into these pockets via fractured and rubblized basalt on the surface. These areas are interconnected by subsurface fractures that slowly transmit water from higher elevations to lower elevations. The upland areas are the primary area of recharge.

The SVA, which is a portion of the full contributing area of the aquifer, is a composite of a series of confined aquifers within the sediments overlaying bedrock which produce artesian wells. The confined aquifers in the lakebed sediments are comprised of sand and sandy gravel horizons confined between layers of clay or sandy, gravely clays. The bedrock form of the lake basin is a “half graben” with a fault on the south side of the basin. The blue gray clay layer acts as a seal between the lake sediments and underlying volcanic rock materials.

PRECIPITATION INFILTRATION

There have been several updates to Colorado’s annual average precipitation analysis since the 1951-1980 dataset utilized by Gamba. Climate normals are updated every 10-years to reflect the most recent 30-year period; the 1991-2020 climate normals were recently released. These data are available at a station scale but are also available as a gridded dataset produced by the PRISM Climate Group on an 800-meter resolution grid. This gridded data was overlain on the geologic unit map within the SVA tributary area as defined on Figure C-1-E of the Gamba report. A geology map is attached as **Figure 2**. The 1991-2020 average annual precipitation (**Figure 3**) was calculated for each geologic unit which include: PPM – Pennsylvanian/Permian Maroon Formation, Tb – Tertiary Volcanic Materials, and Ql – Quaternary Lake Sediments (aka SVA). The average annual precipitation over the SVA tributary area was calculated to be 18,384 acre-feet compared to the 19,908 acre-feet utilized by Gamba. This is a reduction of 1,524 acre-feet or 7.7%.

*Table 1: Estimated Precipitation and Infiltration into the SVA. **

Geologic Unit	Area (ac)	Infiltration Rate	Mean Precip (mm)	Mean Precip (in)	Average Annual Precipitation Volume (AF)	Estimated Infiltration (AF)
PPM	2132	20%	612	24	4281	856
Tb	6290	60%	570	22	11763	7058
Ql	1453	60%	491	19	2341	1404
Total	**9875**				**18384**	**9318**

**Note minor discrepancy in total acreage based on digitization of boundaries from Gamba, 2000.*

The infiltration rates by geologic unit utilized in the Gamba analysis were also utilized in the CRE analysis, as they were deemed to be appropriate, and are included in **Table 1**. The local geology exhibits relatively quick infiltration rates. Based on the assumed infiltration rates of the geologic units, the estimated infiltration has been quantified to be 9,318 acre-feet compared to the 10,314 acre-feet calculated by Gamba. This is an infiltration reduction of 996 acre-feet or 9.7% and is largely attributed to the reduced precipitation inputs.

The full annual amount of ET was assumed to deplete the available precipitation inputs, regardless of whether water was available in soil moisture and available to plants or not, which bases the analysis on a conservative aquifer recharge amount.

AQUIFER RECHARGE

The total amount of infiltration is not realized as recharge to the aquifer due to losses from ET and surface runoff. Using the Gamba methodology, the probable recharge was determined using the following formula:

Recharge = Precipitation – Evapotranspiration - Landis Creek surface flows   Eq 1.1

Evapotranspiration was quantified by overlaying the National Land Cover Dataset (NLCD) (**Figure 4**), a satellite derived depiction of land cover, on the SVA Tributary area boundary and quantifying the area of various vegetation types. The NLCD was cross-checked with aerial photos to ensure accurate depiction of land cover types. If discrepancies were found, the area was included with other vegetation types supported with aerial photography. Native vegetation ET rates were obtained from the book values from the Handbook of Applied Hydrology, however, there are also large, irrigated pastures located within the SVA aquifer. The potential evapotranspiration (PET) from these irrigated pastures was updated using the Lease-Fallow Tool and ASCE standardized methodology for pasture grass using the study period 2000-2019, which was conservatively quantified to be 30-inches per year. Other vegetation types are shown in **Table 2**, below. Shrub/Scrub utilized high range values for sagebrush in western regions of 10-inches. Deciduous forest utilized the value for aspen of 23-inches. Evergreen forest utilized the average of the values for lodgepole and Engelmann spruce-fir of 17-inches. Mixed forest utilized the average value of the deciduous and evergreen forests which is 20-inches. All of these values are greater than those in the Gamba analysis and represent an increase in demands due to changes in climate as well as more spatial detail to refine the vegetation types. The total annual potential ET was quantified to be 13,842 acre-feet/year and represents a conservative value which assumes water is always available to meet the demands of the various vegetation types.

Table 2: Estimated losses to from evapotranspiration by vegetation type.

Vegetation Type	Acreage (ac)	ET (in/yr)	ET Losses (AF/yr)
Hay/Pasture/Herbaceous	756	30	1904
Shrub/Scrub	5031	10	4192
Deciduous Forest	3872	23	7421
Evergreen Forest	139	17	197
Mixed Forest	77	20	129
Total	**9875**	**100**	**13842**

Utilizing the Equation 1.1 results in the following estimated recharge:

Recharge = 18,384 – 13,842 - 600 = 3,942 acre-feet

These values represent average recharge conditions using conservative depletion assumptions. This is water available for groundwater withdrawals without creating an aquifer deficit, i.e., “mining”, since it will be replenished on an average annual basis. The CRE estimated recharge is 6,117 acre-feet less than what was estimated by Gamba due to decreased precipitation inputs and increased demands from evapotranspiration which are partly due to temperature and partly due to increased spatial representativeness. The estimated annual recharge is similar to the HRS results which quantified 4,700 acre-feet of recharge on average.

ANTICIPATED DIVERSIONS & DEPLETIONS

The development water demands for Storied Development’s amended SVR PUD plan (currently being reviewed by Garfield County) will be less than the previously approved SVR PUD demands; and less than the demands already decreed and covered by existing court approved augmentation plans in Case Nos. 87CW155 and 98CW254, the latter being the operative plan for augmentation. Basalt Water Conservancy District (BWCD) augments the structures, including wells, surface and storage structures, which will supply water for the development. In sum, the 98CW254 augmentation plan allows for an annual water demand of 1457 acre-feet of diversions, a total annual consumptive use of 974 acre-feet in a dry year, and an overall augmentation requirement of 420 acre feet. The 98CW254 decree allows for modifications and reconfigurations of the number of EQRs and amounts of irrigated acreage so long as the overall SVR PUD consumptive use does not exceed 974 acre-feet annually. **Tables 3-5** (attached) provide details of the potable, non-potable, and total diversions and depletions that are augmented pursuant to the BWCD contracts, as incorporated and approved in Case No. 98CW254.

Potable diversions, which are attributed solely to groundwater sources, total 473.1 acre-feet with associated depletions of 177.5 acre-feet and include domestic in-house and irrigation uses associated with 695 EQR's and 90 acres of domestic irrigation. The non-potable diversion, of which a portion will be satisfied by senior surface water rights, total 983.9 acre-feet with associated depletions of 796.96 acre-feet which includes uses of non-domestic irrigation for 420 acres and 24 acres of open surface water evaporation. Overall, the total project diversion demands are 1,457 acre-feet with associated depletions of 974 acre-feet. Again, Case No. 98CW254, paragraph 10.c. allows for modification to the number of EQRs and irrigated acreage if the depletions do not exceed 974 acre-feet.

In contrast, Storied Development's amended SVR PUD proposal seeks to modify certain components of the previously approved PUD including the type and number of development units, irrigation requirements, and to add snowmaking as a use of its non-potable water system. CRE has calculated the water requirements for the revised PUD plan and in sum, the total water demand for the revised PUD plan is 1,221 acre-feet/year, with total consumptive use of 688 acre-feet/year. This is less than the contemplated and approved water demand associated with the currently approved PUD; however, for purposes of this report and aquifer sustainability analysis, CRE utilizes the larger acre foot demands and depletions described above and approved in the 98CW254 case.

Because most of the lands to be irrigated are located within the SVA tributary area, irrigation return flows will accrue to the aquifer and will not be totally consumptive to the aquifer. It is also anticipated, based on land use approvals and engineering related to the expansion of the Spring Valley Sanitation District, that treated wastewater effluent will also be returned within the SVA tributary area. It was estimated that approximately 25% of the treated effluent would return to the SVA by infiltration from the discharge point(s) along the Spring Valley Drainage basin minimizing adverse impacts to the Spring Valley environment.[4] In addition, Storied Development will have rights to use the Spring Valley Sanitation District Pipeline decreed in Case No. 00CW21 in the amount of 3.48 c.f.s., conditional, for irrigation within the Spring Valley Sanitation District service area which encompasses the SVA tributary area. The direct use of treated effluent for irrigation will reduce the demand for groundwater and will supplement aquifer recharge.

Lagged well depletions will be calculated pursuant to the BWCD decree (Exhibit F, Case No. 87CW155) based on the locations of the constructed wells. The well location will determine the lagged depletion zones which are used to quantify the timing of depletions to the stream from well pumping. Case Nos. 87CW155 and 98CW254 classified the Spring Valley wells in Groups F1 (SVA) and F2 (Upland Aquifers). The monthly depletion percentages by Well Group are shown in

[4] Wright Water Engineers, Inc. March 24, 1999. RE: Spring Valley Sanitation District Service Plan Amendment (Exhibit 4.3 to Spring Valley Sanitation District Engineering Report for Application for site approval for modification or expansion of an existing domestic wastewater treatment plant and application and certification procedures for lift station and interceptors dated September 1999)

the following table which was attached as an exhibit in Case No. 87CW155. The timing of depletions dictates the monthly augmentation replacement requirements during periods of downstream call.

Table 6: Monthly Depletion and Delayed Return Flow Factors Decreed in Case No. 87CW155

EXHIBIT F
BASALT WATER CONSERVANCY DISTRICT
AUGMENTATION PLAN - CASE NO. 87CW155
MONTHLY DEPLETION AND DELAYED RETURN FLOW FACTORS

MONTH	WELL GROUP						
	A	B	C	D	E	F1	F2
NOV	0.058	0.089	0.072	0.087	0.082	0.086	0.068
DEC	0.057	0.086	0.063	0.088	0.083	0.082	0.068
JAN	0.057	0.082	0.059	0.085	0.083	0.079	0.068
FEB	0.057	0.080	0.057	0.084	0.084	0.077	0.068
MAR	0.057	0.077	0.056	0.083	0.084	0.075	0.068
APR	0.062	0.076	0.061	0.082	0.084	0.074	0.072
MAY	0.108	0.076	0.085	0.081	0.084	0.076	0.089
JUN	0.134	0.080	0.112	0.080	0.084	0.082	0.109
JUL	0.132	0.085	0.123	0.081	0.083	0.090	0.116
AUG	0.108	0.089	0.116	0.081	0.083	0.094	0.106
SEP	0.100	0.090	0.106	0.083	0.083	0.094	0.092
OCT	0.070	0.090	0.090	0.085	0.083	0.091	0.076
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000	1.000

TOTAL SPRING VALLEY AQUIFER DEMANDS

In addition to the demands associated with Spring Valley Ranch, several other subdivisions and individual properties rely upon the Spring Valley Aquifer for all or a portion of their overall water supplies. The following developments and associated plans for augmentation were reviewed and are summarized in **Table 7**. The demands include Spring Valley Ranch, Los Amigos (Elk Springs/Pinyon Mesa), Colorado Mountain College, Berkeley/Lake Springs Ranch, Lookout Mountain Ranch, and individual lot owners. It is not known if Lookout Mountain Ranch relies on the SVA for a portion of their water supplies because well construction logs and accounting are unavailable; however, the total demand was included in the interest of being conservative. There are approximately 30 individual properties with wells (or future wells) accessing the SVA area with an estimated annual diversion of 30 acre-feet and an estimated depletion of 10 acre-feet, which is based on engineering judgment. The total diversion from all developments relying on the SVA totals approximately 1,920 acre-feet while the total depletions are approximately 1,263 acre-feet. The total diversions represent 49% of the anticipated recharge while the total depletions represent only one third of the anticipated annual recharge to the SVA. The analysis illustrates that the anticipated uses, based on conservative assumptions, do not result in long-term mining of the groundwater aquifer as the average annual demands of the developments are met by the average annual recharge to the aquifer. In addition, these demands do not consider the fact that a portion of the SVR irrigation demands will be met with senior, surface water rights, which results in irrigation return flows that deep percolate and recharge the SVA. The sustainability analysis is conservative and supports the conclusion that there is adequate groundwater supplies for all users of the SVA. This analysis, in conjunction with a groundwater monitoring plan, allows all SVA water users to manage the water resource in a sustainable manner.

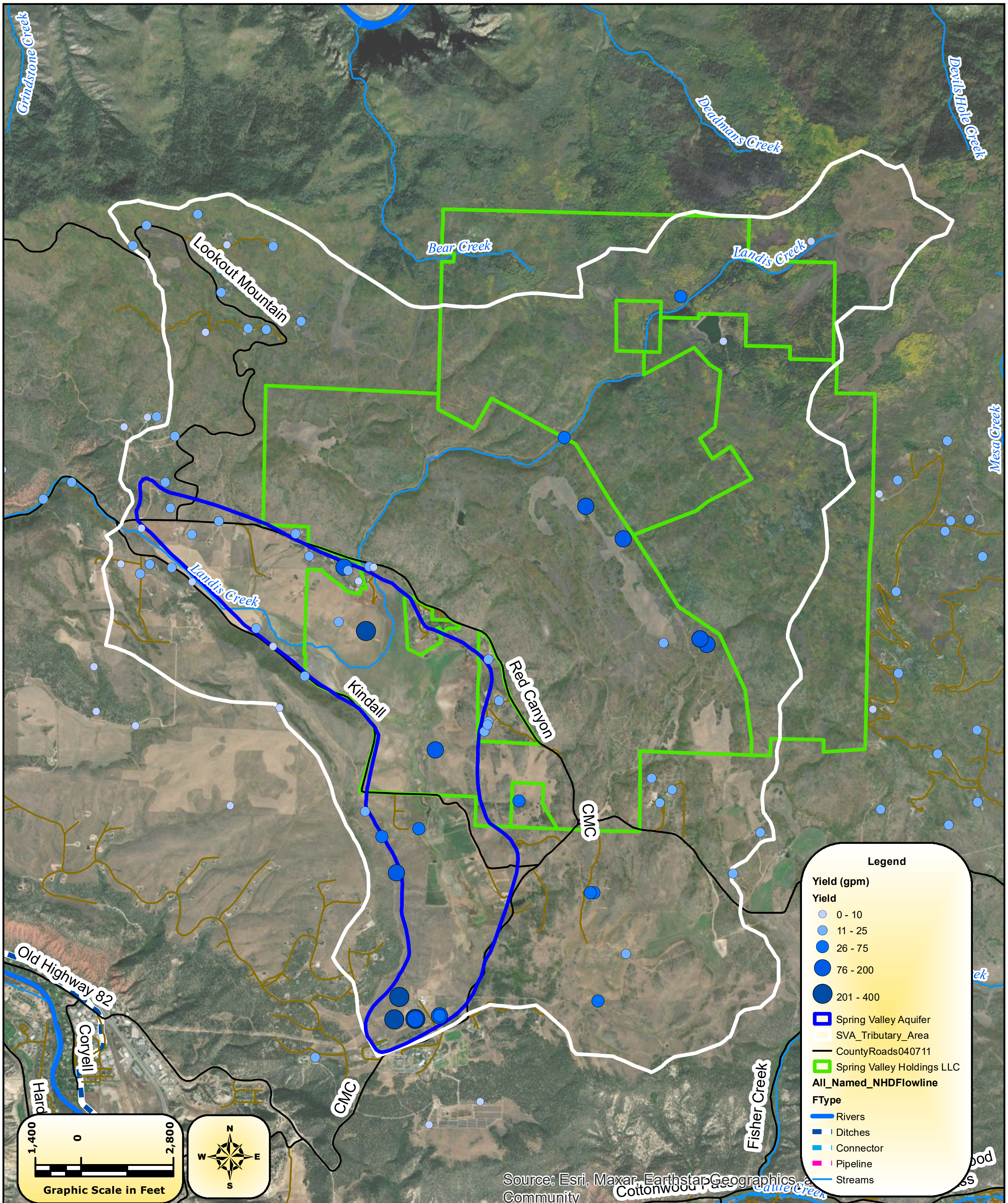
Table 7: Total Diversions and Depletions for Spring Valley Developments Based on Decreed Plans for Augmentation

Development	Case No.	Annual Diversion (AF)	Annual Depletion (AF)
Spring Valley Ranch	98CW256	1457.0	974.0
Los Amigos (Elk Springs and Pinyon Mesa)	98CW312	159.8	117.0
Colorado Mountain College	99CW99	132.3	53.1
Lake Springs Ranch/Berkeley	W-3571	105.2	97.6
Individual Lot Owners	N/A	30.0	10.0
Lookout Mountain Ranch	84CW100	36.0	11.0
Grand Total		**1920.3**	**1262.8**

SUMMARY

The estimated average annual recharge of 3,942 acre-feet is more than three times the estimated depletion of 1,263 acre-feet for all users of the SVA. Under the proposed amended PUD plan, groundwater withdrawals for irrigation will be less than calculated due to utilization of Landis Creek surface water rights, which have historically been used to irrigate the property, and only using groundwater for supplemental irrigation supplies. In addition to the annual recharge, it has been estimated by Gamba that there is 68,000 to 105,000 acre-feet of water in storage in the SVA and upland areas which essentially serve as an underground reservoir to balance extreme dry year and extended drought-year recharge with water demands. As was found in previous studies, there is sufficient water in storage in the SVA and available from annual recharge to serve all the proposed uses without injuring the groundwater resource.

The groundwater levels in the SVA will experience seasonal and year to year fluctuations due to variability in precipitation and snowpack inputs. Each of the subdivisions that pump water from the SVA have a long term vested interest in a comprehensive groundwater monitoring plan to understand baseline and future groundwater conditions. A groundwater monitoring plan is currently being developed for implementation by these water users.



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Spring Valley Aquifer and Wells Vicinity Map

Figure: 1

Document Name: SpringValleyRanchAquifer.mxd		Client:
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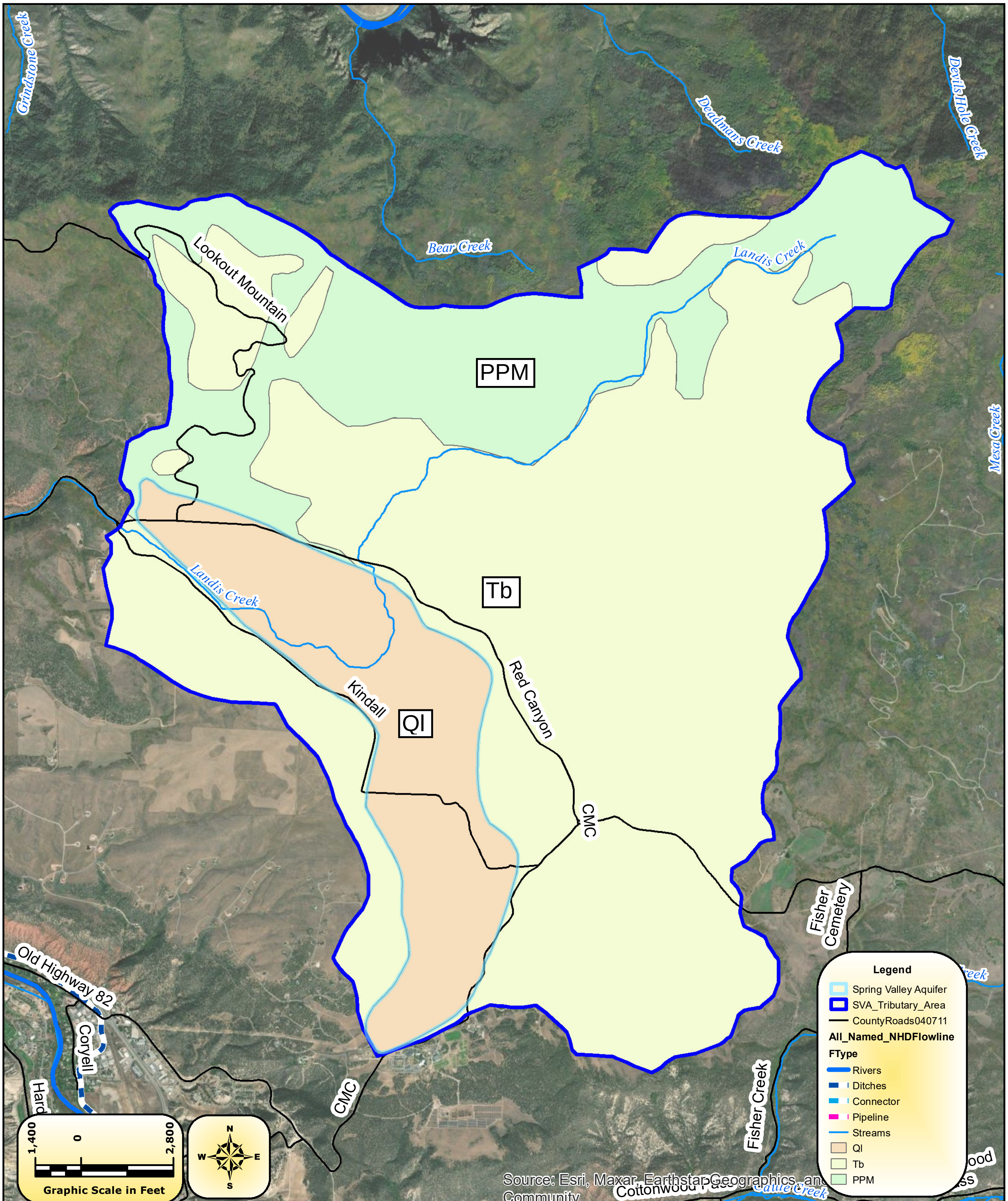

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Spring Valley Aquifer Geologic Units

Figure: 2

Document Name: SpringValleyRanchAquifer.mxd

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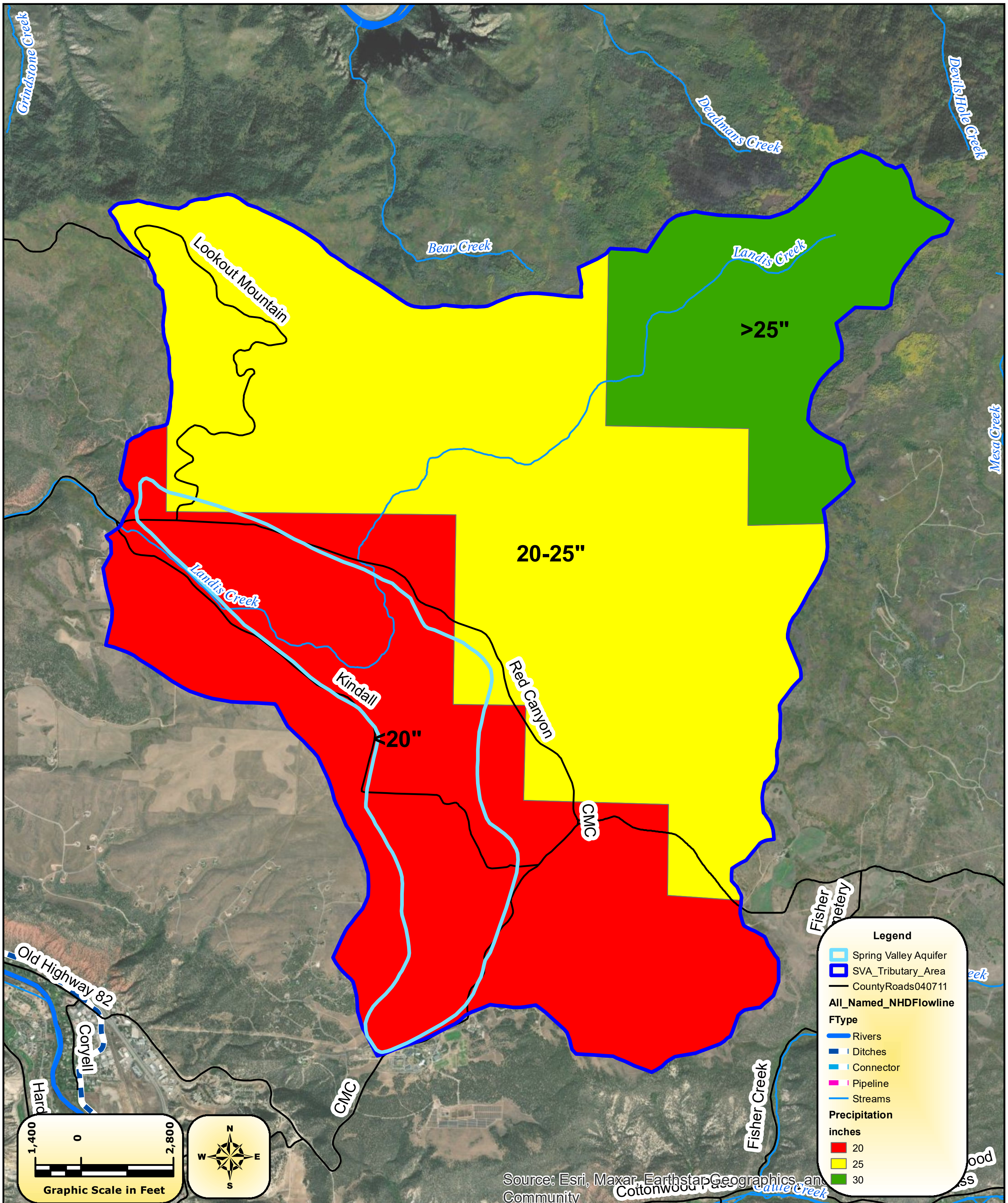

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Spring Valley Aquifer
1990-2020 Normal Precipitation (in)

Figure: 3

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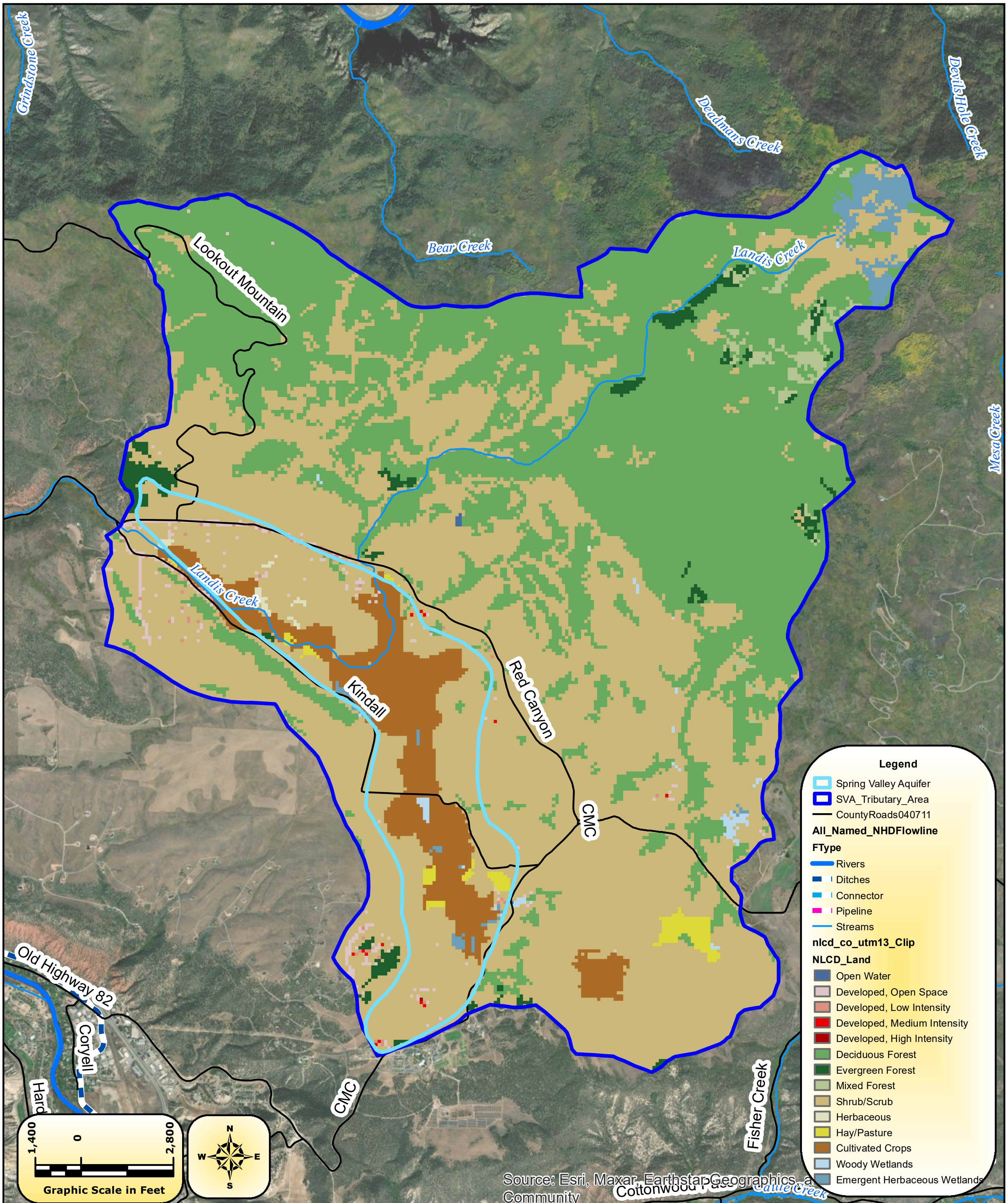

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Spring Valley Aquifer
National Land Cover Data

Figure: 4

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Table 3: Potable Demands							
Month	% Occupancy	Diversions (AF)			Depletion (AF)		
		In-House	Domestic Irrigation	Total Diversion	In-House	Domestic Irrigation	Total Depletion
Jan	100%	23.1	0.0	23.1	1.5	0.0	1.5
Feb	100%	21.1	0.0	21.1	1.3	0.0	1.3
Mar	100%	23.1	0.0	23.1	1.5	0.0	1.5
Apr	100%	22.4	16.9	39.3	1.4	13.5	14.9
May	100%	23.1	27.0	50.1	1.5	21.6	23.1
Jun	100%	22.4	41.6	64.0	1.4	33.3	34.7
Jul	100%	23.1	47.3	70.4	1.5	37.8	39.3
Aug	100%	23.1	39.4	62.5	1.5	31.5	33.0
Sep	100%	22.4	24.8	47.2	1.4	19.8	21.3
Oct	100%	23.1	3.4	26.5	1.5	2.7	4.2
Nov	100%	22.4	0.0	22.4	1.4	0.0	1.4
Dec	100%	23.1	0.0	23.1	1.5	0.0	1.5
Total		**272.7**	**200.4**	**473.1**	**17.2**	**160.3**	**177.5**

EQR	695
Gal/EQR/day	350
Domestic Irrigation (ac)	90
Lawn/Golf/Open Space Unit Irrigation Diversion (AF/ac)	2.24
Lawn/Golf/Open Space Unit CU (AF/ac)	1.79
Lawn/Golf/Open Space Efficiency %	80%
Domestic Depln (%)	6.3%

Table 4: Non-Potable Demands

Month	Diversions (AF)			Depletions (AF)		
	Non-Domestic Irrigation	Pond Evaporation	Total	Non-Domestic	Pond Evaporation	Total
Jan	0.0	0	0.0	0	0	0
Feb	0.0	0	0.0	0	0	0
Mar	0.0	1.9	1.9	0	1.9	1.9
Apr	78.8	4.1	82.9	63.04	4.1	67.14
May	126.0	7	133.0	100.8	7	107.8
Jun	194.3	9.6	203.9	155.44	9.6	165.04
Jul	220.5	9.8	230.3	176.4	9.8	186.2
Aug	183.8	7.2	191.0	147.04	7.2	154.24
Sep	115.5	5.5	121.0	92.4	5.5	97.9
Oct	15.8	3.1	18.9	12.64	3.1	15.74
Nov	0.0	1	1.0	0	1	1
Dec	0.0	0	0.0	0	0	0
Total	**934.7**	**49.2**	**983.9**	**747.76**	**49.2**	**796.96**

Irrigated Area (ac)	420
Evaporation Area (ac)	24

Table 5: Total Potable and Non-Potable Demands								
Month	Total Diversion				Total Depletion			
	In-House	Irrigation	Evap	Total	In-House	Irrigation	Evap	Total
Jan	23.1	0.0	0	23.1	1.5	0.0	0	1.5
Feb	21.1	0.0	0	21.1	1.3	0.0	0	1.3
Mar	23.1	0.0	1.9	25.0	1.5	0.0	1.9	3.4
Apr	22.4	95.7	4.1	122.2	1.4	76.6	4.1	82.1
May	23.1	153.0	7	183.1	1.5	122.4	7	130.9
Jun	22.4	235.9	9.6	267.9	1.4	188.7	9.6	199.7
Jul	23.1	267.8	9.8	300.7	1.5	214.2	9.8	225.5
Aug	23.1	223.2	7.2	253.5	1.5	178.6	7.2	187.2
Sep	22.4	140.3	5.5	168.2	1.4	112.2	5.5	119.2
Oct	23.1	19.2	3.1	45.4	1.5	15.4	3.1	19.9
Nov	22.4	0.0	1	23.4	1.4	0.0	1	2.4
Dec	23.1	0.0	0	23.1	1.5	0.0	0	1.5
Total	**272.66**	**1135.10**	**49.20**	**1456.96**	**17.18**	**908.08**	**49.20**	**974.46**