13

Analysis of Groundwater Availability and Recharge in the Sundance Project Area

Pilot Hill, California

Submitted to: El Dorado County Planning Commission

Date: November 12, 2010
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Table of Contents

Abbreviations and Acronyms

a-ft	acre-feet
BOS	El Dorado County Board of Supervisors
CDEC	California Data Exchange Center
CIMIS	California Irrigation Management Information System
Commission	El Dorado County Planning Commission
DWR	California Department of Water Resources
GDPUD	Georgetown Divide Public Utilities District
GDRCD	Georgetown Divide Resource Conservation District
in	inches
NRCS	Natural Resources Conservation Service
Planning	El Dorado County Planning Department

Executive Summary

The Sundance Subdivision is a proposed development of 28 lots on approximately 300 acres near the area of Pilot Hill, El Dorado County, California. The development requires a rezone for the change in current land use as well as approval of the development's tentative map and environmental documentation (Mitigated Negative Declaration) by the County. These items are currently in front of the County Planning Commission and will subsequently go to the El Dorado County Board of Supervisors at a later date. (**Rezone Z07-0040/ Tentative Map TM07-1454/ Special Use Permit S09-0012/ Sundance Subdivision).**

As part of the effort to evaluate the potential impact of the development on the water resources in the area and environment, the developer engaged a hydrogeologist to investigate the long term viability of using groundwater for the development (*Hydrogeologic Investigation Assessment Report, Sundance Subdivision, Holdrege & Kull, October 28, 2008*). This groundwater study attempted to quantify the theoretical groundwater recharge from normal annual precipitation on the site and compare that with the potential needs of the subdivision. However, there were several assumptions and detailed calculations in this particular analysis that raised questions. Addressing these concerns could substantially affect the conclusions of the *Hydrogeologic Investigation Assessment Report*.

The report that follows presents a revised groundwater recharge analysis for the Sundance area based on additional available rainfall and soils data and updated assumptions that are more in line with the physical characteristics of the site and conventional analysis.

Additional Available Data

Additional data is available to refine the previous groundwater availability analysis. The rainfall gage at Pilot Hill (PIH) provides hourly precipitation data for 15 years. Soils information is on-line and can be compiled into a report specific to a designated property (Web Soil Survey). Evapotranspiration information is available statewide by zone.

Analysis

Groundwater storage can be calculated by accounting for the inflow and outflow of water to the soil/rock/landscape system. In the updated analysis, actual rainfall measurements were used to produce a time-step water balance calculation, estimating the water available for deep percolation or groundwater recharge on a daily basis for the Sundance site for the years 1995 through 2010. Soil permeabilities and available soil water capacities for the time-step analysis were derived from site specific soils information. The calculated groundwater recharge was summarized on an annual basis for comparison with projected water needs for the proposed subdivision and the surrounding parcels.

Findings

Groundwater recharge is not necessarily proportional to the annual precipitation.

For site specific soil characteristics, the average calculated recharge for all 15 years rainfall record is about 1.8 inches. However, the plotted data also shows the recharge varies significantly from year to year. There are many consecutive years where the recharge is much lower than the average. For example, during the period 2001 through 2004, the deep percolation averages only 0.5 inches and obviously much lower if one were to look only at 2001 and 2002 where nearly zero recharge was calculated. Over the last 4 years recharge has only been 60% of the long term average.

We can calculate a factor of safety to compare the available groundwater with the future water demand. A factor of safety of 1.0 means that there is just enough groundwater to satisfy the water demand for the area. Looking at the period of 2001 through 2004, the factor of safety for groundwater use would be:

$$FS = \frac{(0.5 \text{ inches} / 12 \text{ in/foot}) \times 895 \text{ ac}}{0.75 \text{ a-ft/unit} \times 117 \text{ units}} = \mathbf{0.43}$$

Conclusions

1. Existing rainfall records for the Pilot Hill gage provides 15 years of hourly data that can be used to calculate the time distribution of groundwater recharge in the Sundance and surrounding area.
2. It is important to include the parcels surrounding Sundance in the analysis of groundwater availability since both Sundance and the surrounding properties are dependent of the same groundwater source, storage, and recharge processes. Most parcels in the surrounding area are smaller and probably rely disproportionally on the existing Sundance property to aid in replenishment of groundwater supplies.
3. Annual variations in groundwater recharge can be significant. A long term average recharge may not properly exhibit significant periods of low annual recharge that exist and can lead to a critical over-estimation of available groundwater supplies, especially for areas where groundwater storage cannot be quantified.
4. Based on the groundwater recharge estimated for the period 2001 through 2004 for Sundance and the surrounding area, there is not enough recharge from rain falling on the area to support the annual water needs of Sundance and the surrounding properties at build out. The factor of safety of supply to demand for this 4-year period is 0.43.
5. The Sundance development as currently proposed will significantly impact the groundwater supply for neighboring properties and existing residents.

1 Introduction

The Sundance Subdivision is a proposed development of 28 lots on approximately 300 acres near the area of Pilot Hill, El Dorado County, California. Figure 1 shows the location of the development. It was proposed several years ago and has been reviewed by the county planning department in various forms over that time. The development requires a rezone for the change in current land use as well as approval of the development's tentative map and environmental documentation (Mitigated Negative Declaration) by the County. These items are currently in front of the County Planning Commission and will subsequently go to the El Dorado County Board of Supervisors at a later date. (**Rezone Z07-0040/ Tentative Map TM07-1454/ Special Use Permit S09-0012/ Sundance Subdivision).**

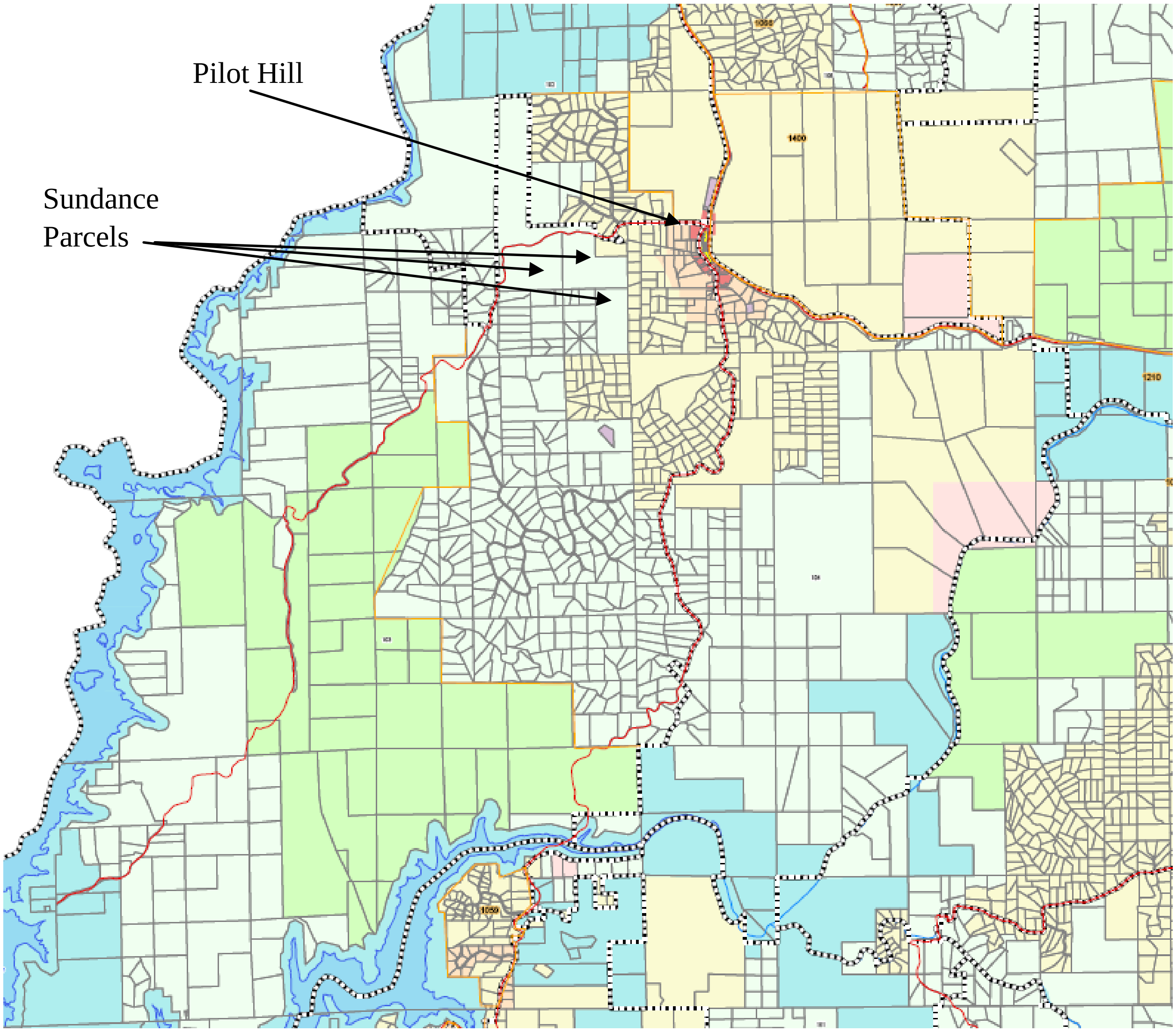
When the project was initially proposed, the developer planned about 29 lots using groundwater. After hearing from neighbors about their troubles with wells and their concerns about the project impacting their existing groundwater supply, the developer proposed increasing the number of lots but obtaining public water (Georgetown Divide Public Utilities District). Plans were resubmitted to the county with this updated configuration. However, later, the developer abandoned the plan of bringing in GDPUD water and went back to a 28 lot configuration again supplied by groundwater (2008-2009).

As part of the effort to evaluate the potential impact of the development on the water resources in the area and environment, the developer engaged a hydrogeologist to investigate the long term viability of using groundwater for the development (*Hydrogeologic Investigation Assessment Report, Sundance Subdivision, Holdrege & Kull, October 28, 2008*). This groundwater study attempted to quantify the theoretical groundwater recharge from normal annual precipitation on the site and compare that with the potential needs of the subdivision.

This general study approach used in the *Hydrogeologic Investigation Assessment Report* has been used by others in the past to estimate the amount of groundwater recharge that might occur on a property. However, there were several assumptions and detailed calculations in this particular analysis that raised questions. Rainfall information, for example, was synthesized instead of using actual records. The effect of the parcels surrounding the development was also ignored. A number of concerns were addressed in previous correspondence with the Commission, (*Letter of February 18, 2010, Comments on the Sundance Subdivision by Bill Bennett*). Addressing these concerns could substantially affect the conclusions of the *Hydrogeologic Investigation Assessment Report*.

The report that follows presents a revised groundwater recharge analysis for the Sundance area based on additional available rainfall and soils data and updated assumptions that are more in line with the physical characteristics of the site and conventional analysis. Because this work is technical in nature, it has been packaged in a report format.

Figure 1 Sundance Location



1.1 Previous Study Shortcomings

The *Hydrogeologic Investigation Assessment Report* had several shortcomings:

1. The study used rainfall probability estimates to calculate a theoretical annual average rainfall distribution instead of using actual rainfall data to determine rainfall distribution. Storm probability estimates are generally not used for water supply studies since they are theoretical and existing historical records are generally available. This probabilistic approach ignores drought and critical rainfall years in the analysis.

2. The study assumed an arbitrary annual runoff percentage (30%) as an input variable instead of calculating the runoff based on actual site soil properties.

3. The study ignored surrounding parcels beyond the boundaries of the subdivision and their current and future needs and impacts on the proposed development's water availability. Surrounding lands have generally smaller parcels. There are many 5-acre parcels that surround the site or that could be developed under current zoning. Dwellings on small parcels would theoretically use more water than they would receive from precipitation falling on and infiltrating into the ground on their property.

4. The study only estimated an overall **average annual** groundwater recharge (deep percolation) for the development and failed to look at the variability of the recharge over different hydrologic year types such as critical (drought), below average, above average, and wet.

5. The study did not consider the effect of drought years such as 1976-77.

6. The study did not quantify the available groundwater storage within the fractured rock foundation to know whether there was adequate water storage to carry over enough water to service residents and neighbors in a set of predictable critical or drought years. There is no extensive aquifer. Groundwater in a fractured rock medium is dependent of the water stored in fissures and cracks. Since the development is located on a hill, there is even less water storage available than in flat terrain. One cannot assess whether there is enough groundwater unless one determines if there is enough storage to carry the users through dry year cycles. The water supply report fails to do that.

7. The study did not include any information on wells surrounding the site, including those that had gone dry, those that required additional storage tanks, and those with low recoveries. Failure of at least 7 wells in the area has been reported over the past few years. Well production on existing parcels may indicate limited groundwater storage in the area.

1.2 Additional Available Data

Three pieces of information were readily available on the Internet to improve the groundwater recharge analysis conducted in the previous study:

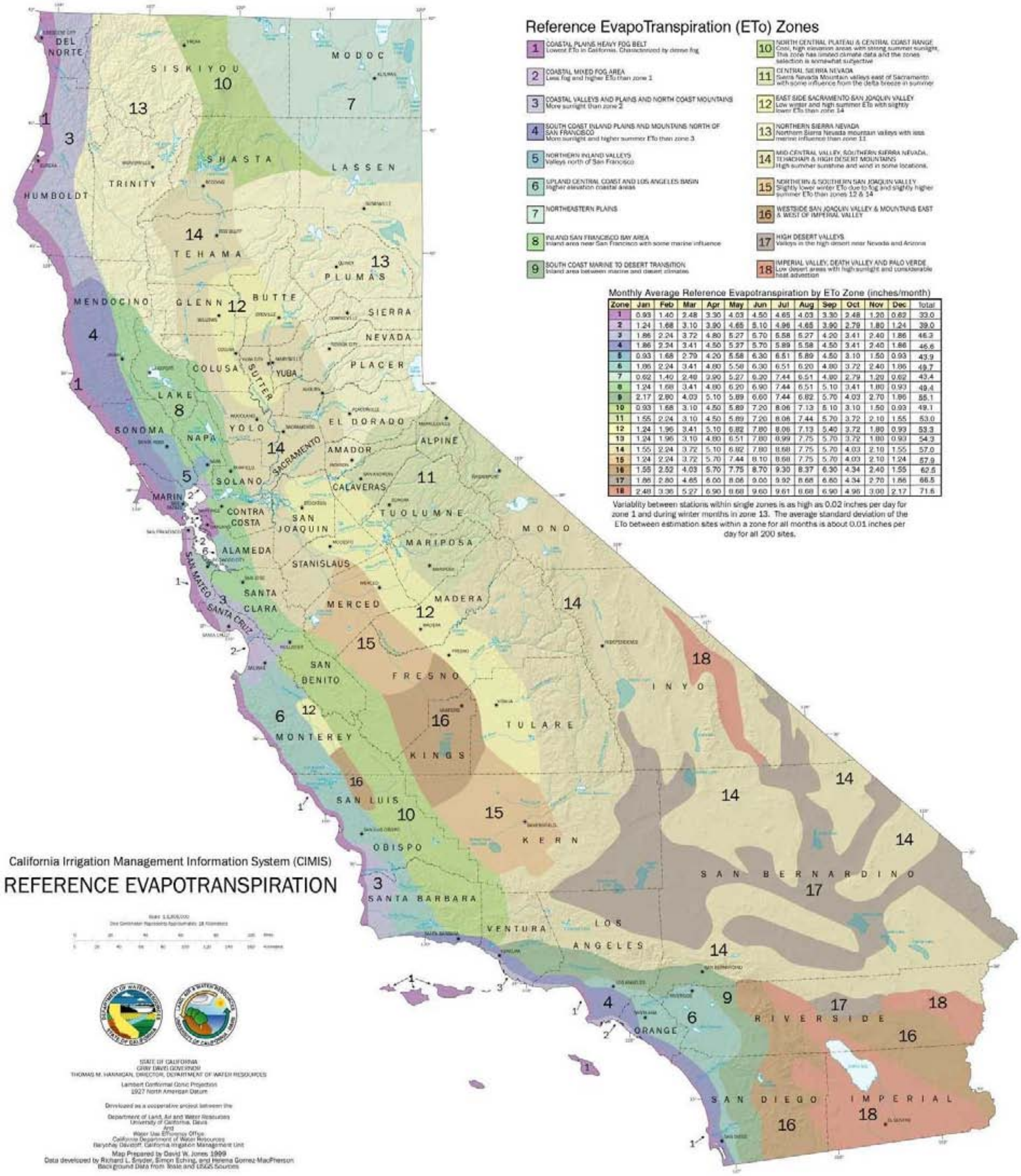
1. The rainfall gage at Pilot Hill (PIH), cooperatively maintained by the California Department of Forestry and Fire Protection, provides hourly precipitation data. Currently 15 years of this information from 1995 to 2010 is available on the California Data Exchange Center (CDEC) website. (http://cdec.water.ca.gov/)

2. The Natural Resources Conservation Service (NRCS) currently provides online soil survey information which can be downloaded in the form of a report, specific to a defined property or site (Web Soil Survey). The survey report characterizes the soils at the site and provides representative permeabilities and water holding capacities of the soils on the site which can be used for estimating infiltration specifically for the site. (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm)

3. Monthly evapotranspiration reference data has been compiled by regional zone by the California Department of Water Resources (DWR) under their California Irrigation Management Information System (CIMIS) Program. Figure 2 provides the Daily Average Reference Evapotranspiration by ETo Zone (inches/day) which can be used to closely approximate the daily water loss from the ground and vegetation to the atmosphere. (http://wwwcimis.water.ca.gov/cimis/welcome.jsp)

In addition to on-line references, the detailed mean annual precipitation distribution for El Dorado County was recently updated for the county by noted hydrologist, Jim Goodridge. Figure 3 shows that updated map. It verifies the mean annual precipitation for the Sundance development site is 32 inches per year. This map can also be obtained from the Georgetown Divide Resource Conservation District (GDRCD).

Figure 2



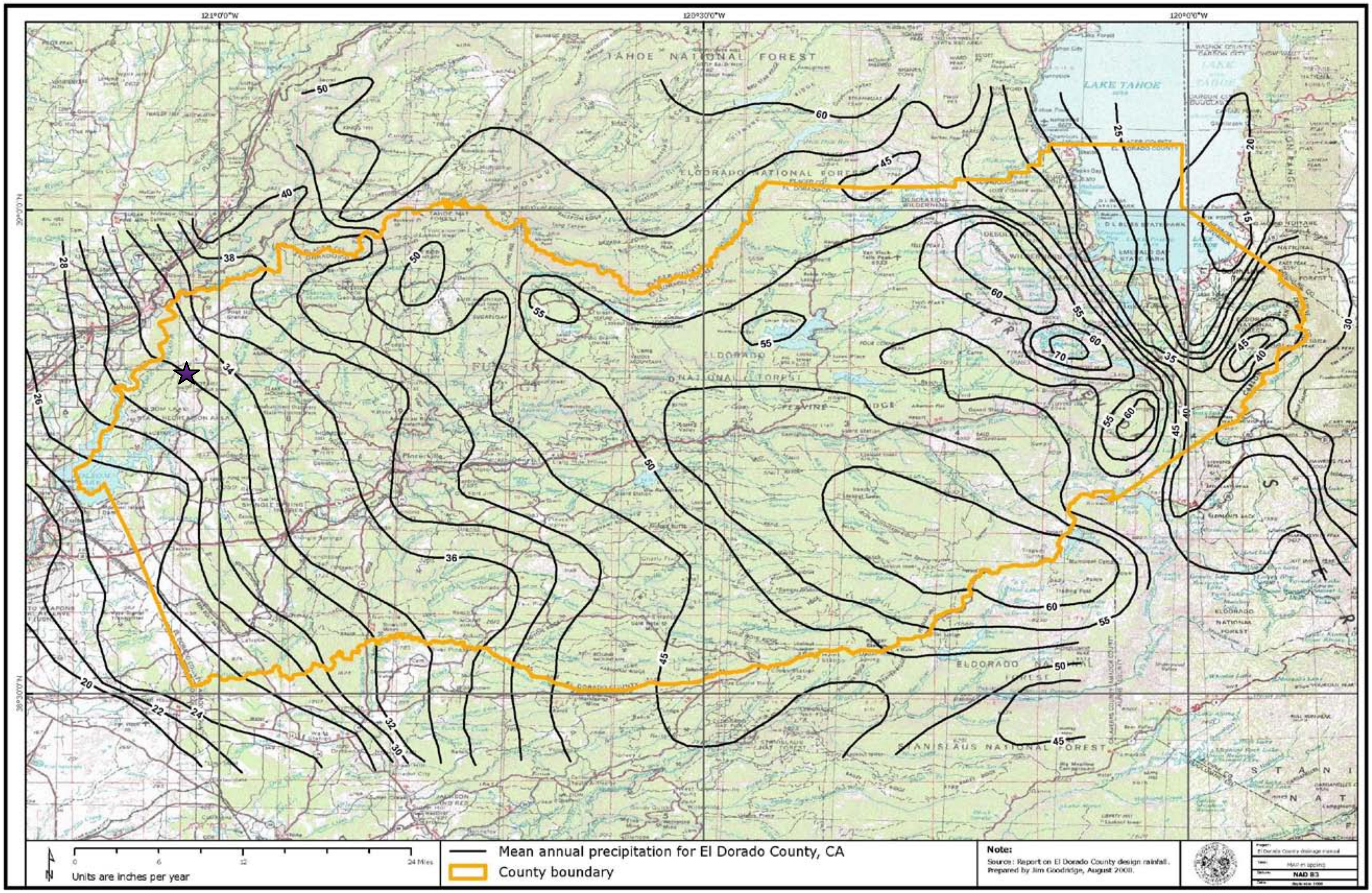
Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variability between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

10-1327.N.10

Figure 3



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2 Analysis

2.1 Water Balance Equation

Groundwater storage can be calculated by accounting for the inflow and outflow of water to the soil/rock/landscape system using a water balance equation:

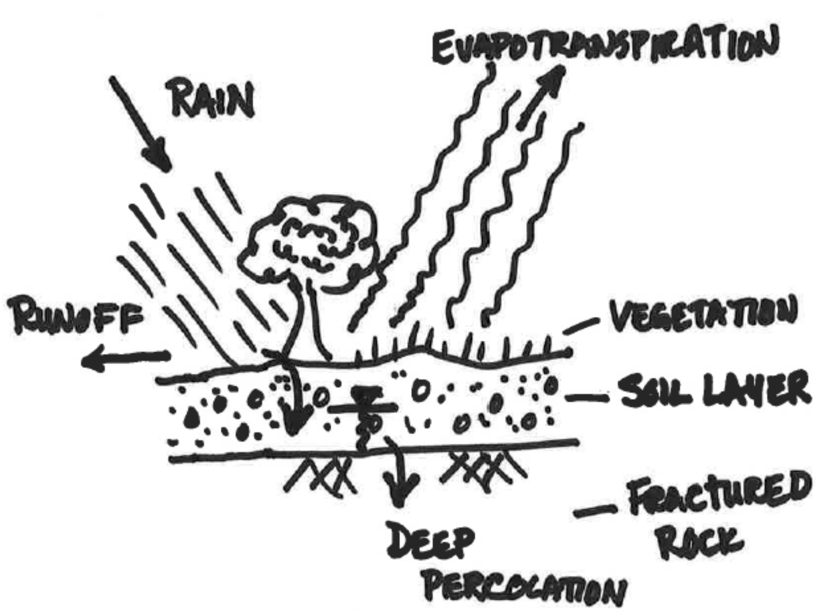
$$DV = P + R_{on} - R_{off} - E - S - U$$

Where:

DV = change in groundwater storage
P = precipitation
R_{on} = surface water running on to the site
R_{off} = surface water running off to the site
E = evapotranspiration water loss by soil and on-site vegetation
S = water held or retained by the soil horizon
U = water pumped from wells

Figure 4 provides a simple sketch to illustrate the water behavior at in the soil/rock/landscape system.

Figure 4 Water Behavior in the Soil/rock/landscape System



Precipitation brings water to the ground surface. The rate at which water infiltrates into the soil depends on the type of soil and its permeability. If it rains hard (rain rate more than the permeability or absorption rate of the soil), a good portion of that water flows on the surface of the soil and off the site as runoff. Rainwater that runs off from adjacent lands may bring surface flows on to the site (Run –on), although in the case of Sundance where the property is essentially on a ridge top, this would be zero. Water that does not run off the site is captured by the soil horizon. Water evaporates from the soil surface and plants that take water from the soil through their root systems also return water to the atmosphere through transpiration; these effects combined make evapotranspiration, which varies throughout the year. The soil horizon retains some water, depending on the soils carrying capacity, but extra water in the soil can percolate to the fractures within the foundation rock in the Sundance area (deep percolation) and be retained in the groundwater. Wells draw water from the groundwater stored in the fractures of the bedrock.

2.2 Calculations

In the updated analysis, actual rainfall measurements were used to produce a time-step water balance calculation, estimating the water available for deep percolation or groundwater recharge on a daily basis for the Sundance site for the years 1995 through 2010. Soil permeabilities and available water capacities for the time-step analysis were derived from site specific soils information from NRCS maps. The calculated groundwater recharge was summarized on an annual basis for comparison with projected water needs for the proposed subdivision and the surrounding parcels.

2.2.1 Rainfall Data Preparation

Historical recorded rainfall information available online from CDEC for the Pilot Hill gage provides the accumulated hourly rainfall since 1994. The Pilot Hill Gage location is within a mile of the Sundance development.

Station ID	PIH	**Elevation**	1200' ft
River Basin	AMERICAN R	**County**	EL DORADO
Hydrologic Area	SACRAMENTO RIVER	**Nearby City**	
Latitude	38.8317°N	**Longitude**	121.0092°W
Operator	CA Dept of Forestry	**Data Collection**	SATELLITE
Sensor 2	PRECIPITATION, ACCUMULATED (inches)	**(hourly)**	From 07/01/1994 to present

This on-line data was generally complete with only a few missing or null values of hourly accumulated precipitation. Most of these instances of missing data involved only one or two hourly values of zero rainfall amounts, which were easily corrected as since the records were of cumulative rainfall and the values following the missing number include the missing rainfall value. Only one segment of missing data was significant enough to where actual rainfall distribution needed to be approximated to fill in the record. In this instance, records from a nearby station, Auburn Dam Ridge, were used to approximate the shape of the rainfall distribution at the Pilot Hill gage for four days in 1997. The rainfall total for that period did not need to be adjusted in this gap analysis, which is included as a worksheet within the calculation workbook.

Since 1995 the gage recorded the following annual rainfall:

Year	*Rain (inches)*
1996	*35.35*
1997	*41.39*
1998	*52.18*
1999	*31.02*
2000	*38.21*
2001	*24.3*
2002	*24.14*
2003	*19.12*
2004	*21.17*
2005	*36.53*
2006	*48.39*
2007	*22.55*
2008	*21.25*
2009	*26.97*
2010	*30.38*
Mean	***31.53***

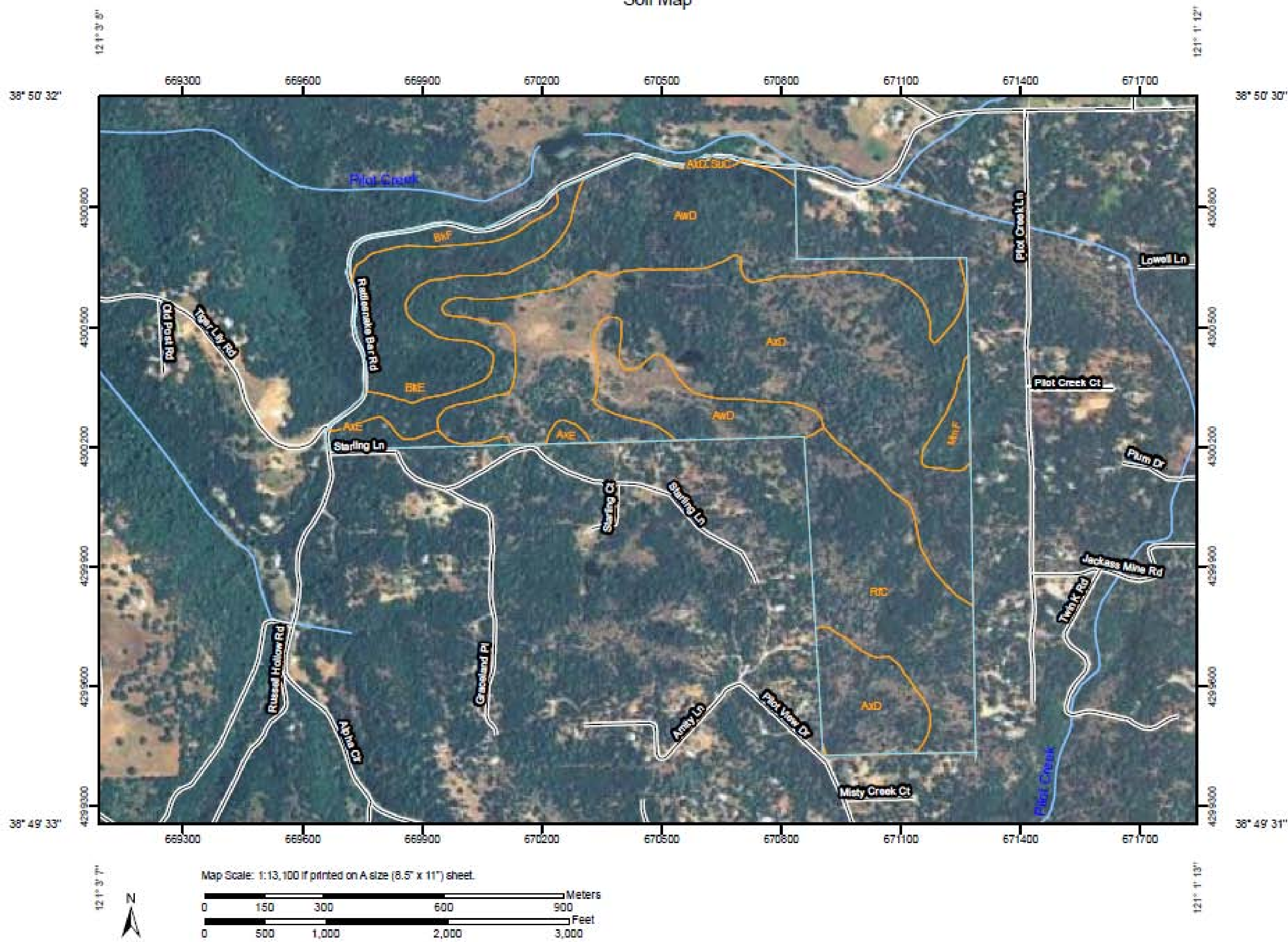
The mean annual rainfall of 31.5 inches over the 15 years of available record matches closely with the 32 inches indicated on the recently published El Dorado County Mean Annual Rainfall map.

2.2.2 Soil Properties

The NRCS Web Soil Survey can produce custom, site-specific maps with corresponding soil properties. A report was produced for Sundance parcels and another for the Sundance and surrounding parcels. Those reports are included in the attachments. Figure 5 shows the soils map for the Sundance parcels and Table 1 provides the soil distribution and soil properties for those parcels. Figure 6 shows the soils map and Table 2, the soil distribution, for the Sundance plus surrounding parcels.

Figure 5

Custom Soil Resource Report
Soil Map



Custom Soil Resource Report

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

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

MAP INFORMATION

Map Scale: 1:13,100 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

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

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 10N NAD83

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

Soil Survey Area: El Dorado Area, California
Survey Area Data: Version 4, Dec 14, 2007

Date(s) aerial images were photographed: 6/30/2005

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.

Table 1 Soil Distribution and Soil Properties for the Sundance Parcels

Sundance Parcels Only	**El Dorado Area, California (CA624)**			Ksat	Capacity
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**	in/hr	in
AwD	Auburn silt loam, 2 to 30 percent slopes	80.2	26.7%	0-0.06	2.3
AxD	Auburn very rocky silt loam, 2 to 30 percent slopes	129.9	43.3%	0-0.06	2.3
AxE	Auburn very rocky silt loam, 30 to 50 percent slopes	5.2	1.7%	0-0.06	2.3
BkE	Boomer very rocky loam, 30 to 50 percent slopes	27.9	9.3%	0.01 - 0.57	7.1
BkF	Boomer very rocky loam, 50 to 70 percent slopes	6.1	2.0%	0.01 - 0.57	4.9
MmF	Metamorphic rock land	4.5	1.5%	0.01 - 19.98	0
RfC	Rescue very stony sandy loam, 3 to 15 percent slopes	45.2	15.1%	0-0.06	7.1
SuC	Sobrante silt loam, 3 to 15 percent slopes	1.2	0.4%	0-0.06	3.9
Totals for Area of Interest		**300.0**	**100.0%**		

Figure 6

Custom Soil Resource Report
Soil Map

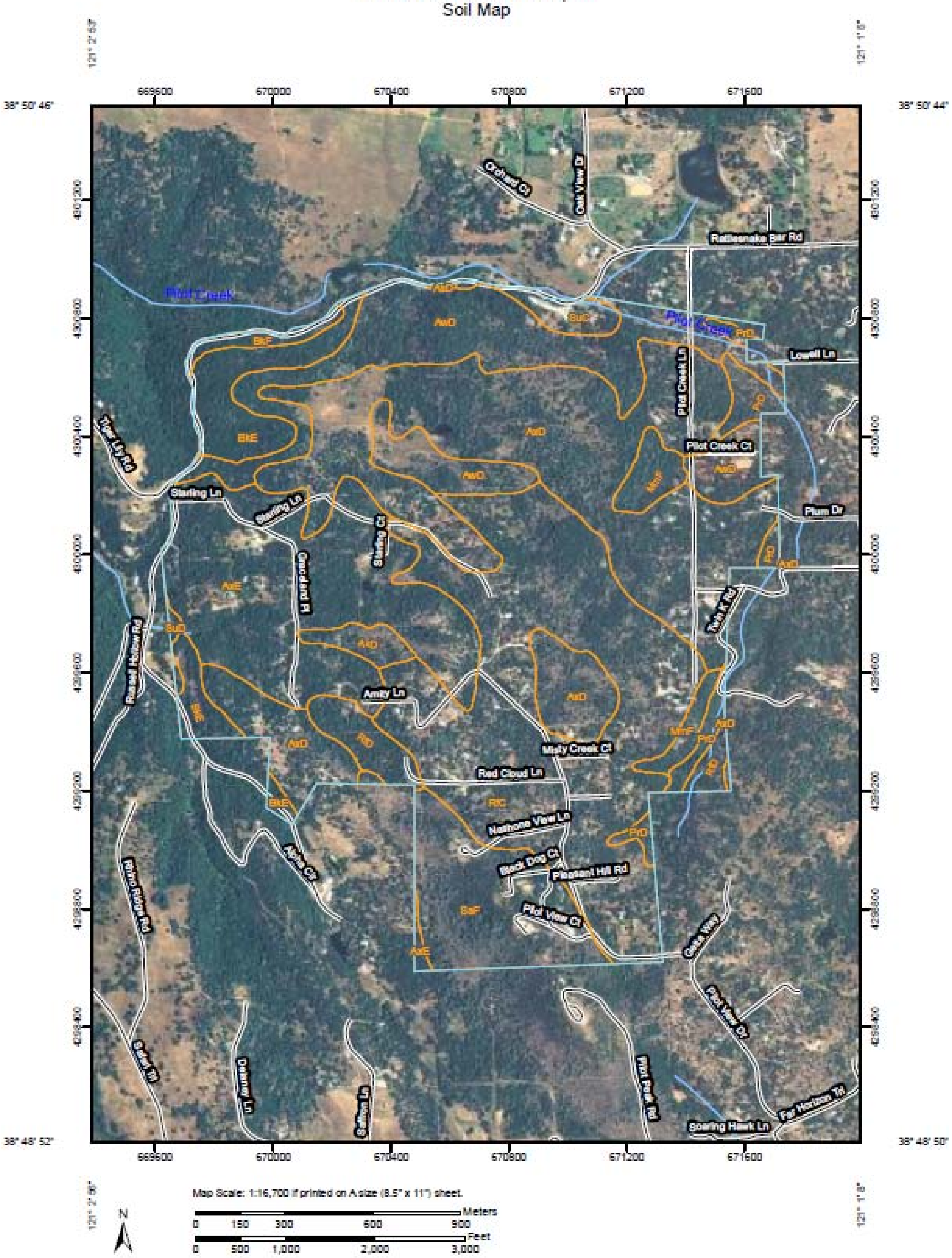


Table 2 Soil Distribution for Sundance and Surrounding Parcels

Map Unit Legend

El Dorado Area, California (CA624)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AwD	Auburn silt loam, 2 to 30 percent slopes	118.5	13.2%
AxD	Auburn very rocky silt loam, 2 to 30 percent slopes	246.2	27.5%
AxE	Auburn very rocky silt loam, 30 to 50 percent slopes	138.3	15.5%
BhD	Boomer gravelly loam, 15 to 30 percent slopes	0.0	0.0%
BkE	Boomer very rocky loam, 30 to 50 percent slopes	40.1	4.5%
BkF	Boomer very rocky loam, 50 to 70 percent slopes	6.5	0.7%
MmF	Metamorphic rock land	16.6	1.9%
PrD	Placer diggings	19.8	2.2%
RfC	Rescue very stony sandy loam, 3 to 15 percent slopes	218.3	24.4%
RfD	Rescue very stony sandy loam, 15 to 30 percent slopes	18.5	2.1%
SaF	Serpentine rock land	61.1	6.8%
SuC	Sobrante silt loam, 3 to 15 percent slopes	9.4	1.1%
SuD	Sobrante silt loam, 15 to 30 percent slopes	1.6	0.2%
Totals for Area of Interest		**894.9**	**100.0%**

As mentioned earlier, soil permeability is an important factor in determining infiltration, and thus, the rate of groundwater recharge for the site. The soil covering approximately 87 percent of the Sundance development area has a very low to moderately low permeability of from 0.00 to 0.06 inches per hour. This percentage holds for the area surrounding Sundance as well. An average permeability for the soils in the area would be about 0.03 inches per hour.

Similarly, the majority of the soils found on the Sundance parcels have a saturated water holding capacity of about 2.3 inches. Since there is a portion of the moisture of the soil horizon that will always remain in the soil and some water can be passed from the soil to the underlying rock without the soil being totally saturated, only a portion of the soil's water capacity range will be utilized during the recharge process. An effective water capacity of about half of the total saturated capacity, or 1.2 inches, would be appropriate for the recharge calculation. Increasing the capacity value in the calculation will decrease the deep percolation as more water will be used to fill the capacity of the soil.

2.2.3 Time-step Calculation and Spreadsheet Methodology

The time-step calculation spreadsheet is included in the attached disk.

The time-step calculation spreadsheet first determines the rain that occurs for each hour. The rain gage station provides the cumulative or accumulated rainfall for each hour. The difference between consecutive readings gives the rainfall that happened for that past hour.

The next calculation is whether the amount of rain exceeds the soils ability to absorb water. If that rainfall is less than or equal to the soil permeability, all that water enters the soil matrix. If it is greater than the permeability, then only an amount equal to that rate enters the soil and the remainder becomes runoff. The hourly infiltration of water to the soil matrix is totaled for each 24-hour period.

The daily infiltration of water is added to the previous water available in the soil (water in soil) and the daily evapo-transpiration determined from the DWR Daily Average Reference Evapotranspiration by ETo Zone (inches/day) is subtracted from that value (water in soil). If the water in soil matrix is greater than the effective water holding capacity of the soil, then that water becomes deep percolation. The daily deep percolation is then summed for the year.

3 Findings

3.1 Recharge

Figure 7 provides a summary of the calculated annual rainfall and calculated deep percolation for the years 1996 through 2010. Note that the groundwater recharge is not necessarily proportional to the annual precipitation. This is not surprising since the amount of infiltration and deep percolation is dependent on how the precipitation is distributed over time.

Figure 7

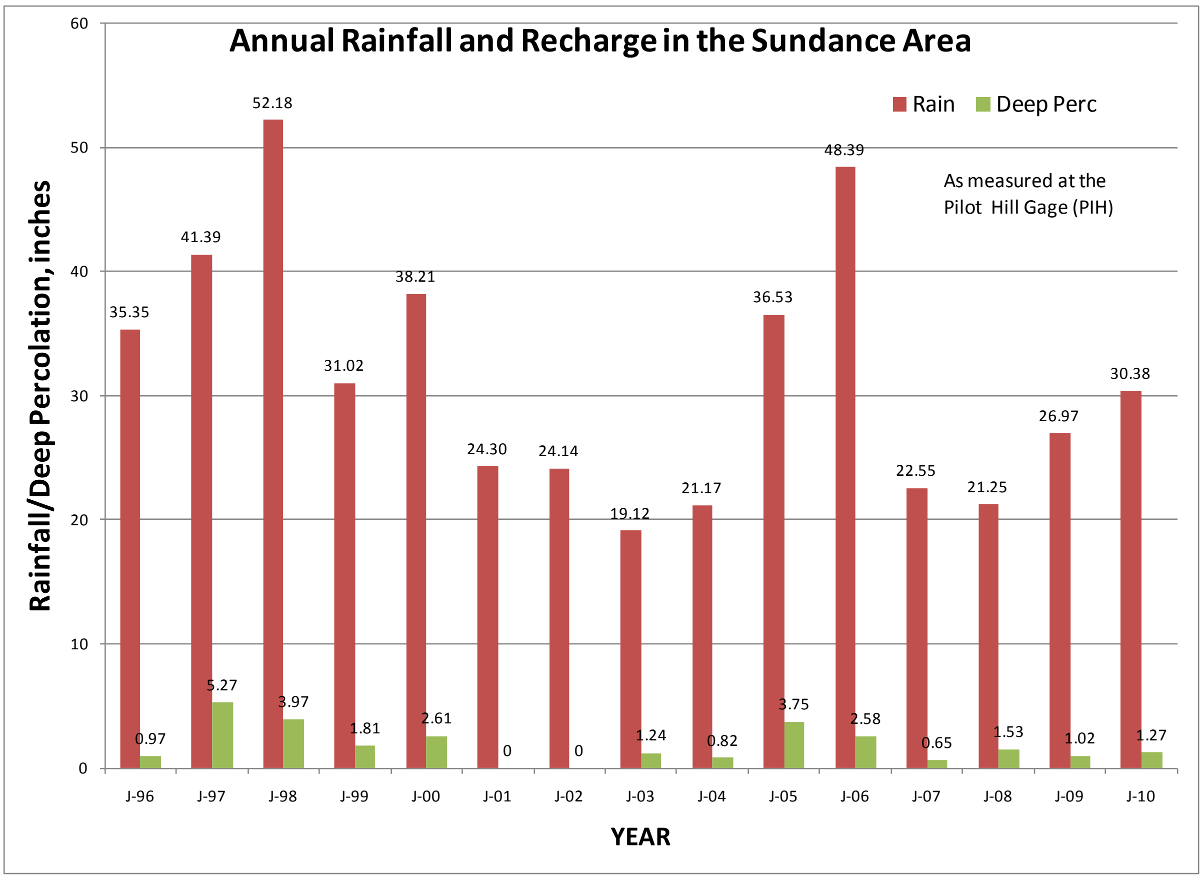
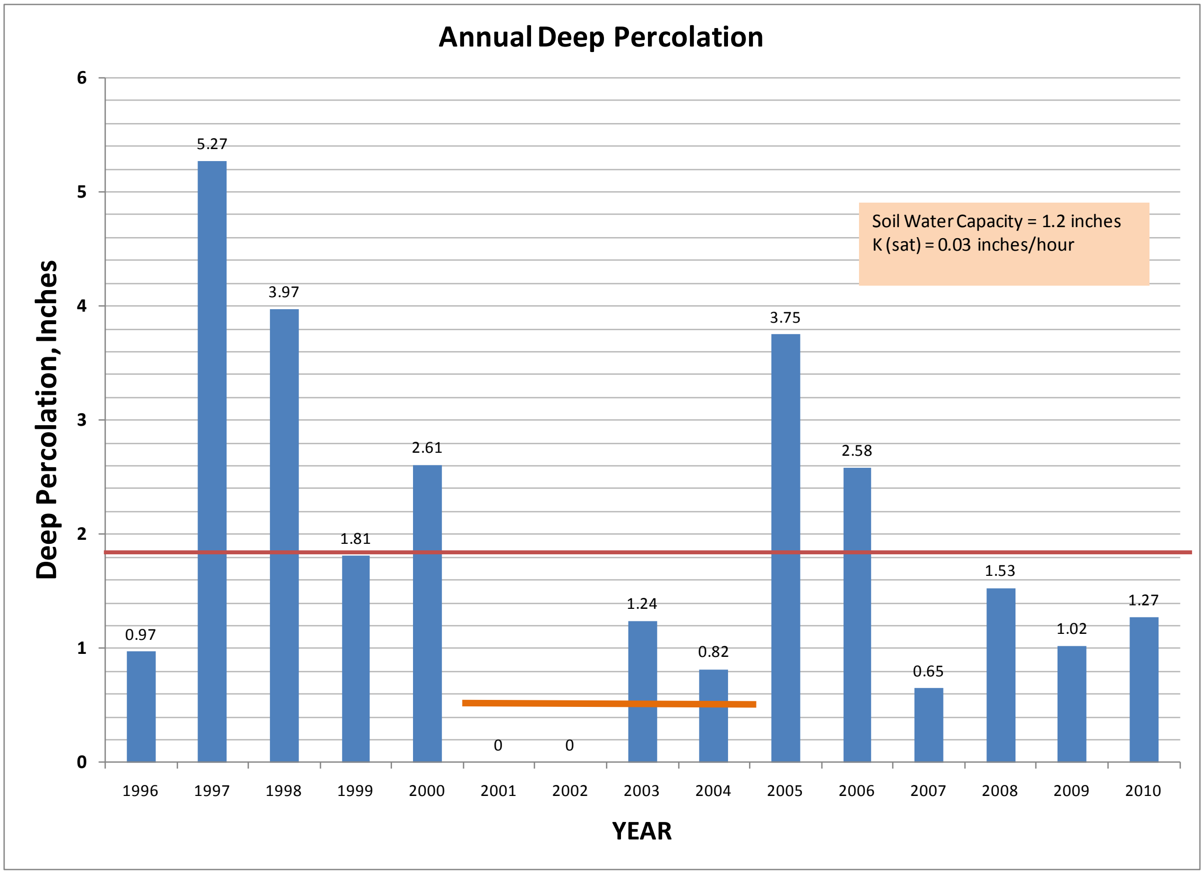


Figure 8 shows just the calculated annual deep percolation for the study period. For these soil characteristics, the average calculated recharge for all 15 years is about 1.8 inches (red line). However, the plot also shows the recharge varies significantly from year to year. There are many consecutive years where the recharge is much lower than the average. For example, during the period 2001 through 2004, the deep percolation averages only 0.5 inches

Figure 8



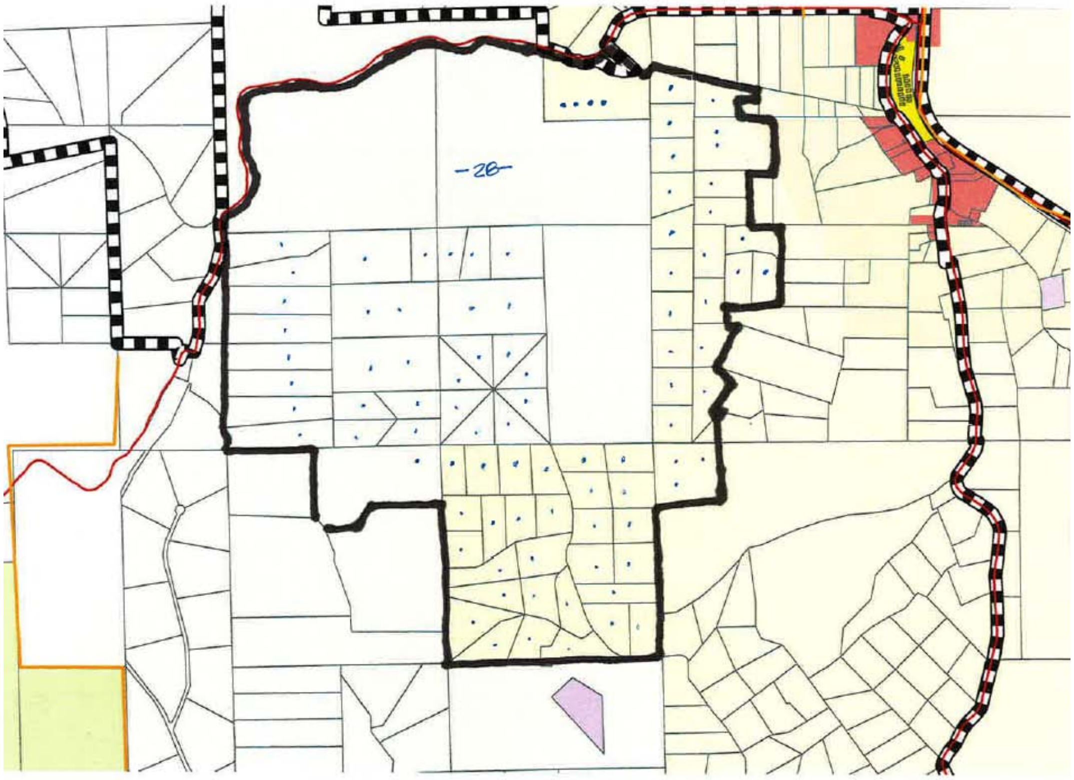
(orange line) and obviously much lower if one were to look only at 2001 and 2002. Even over the last 4 consecutive years the deep percolation has only been 60% of the long term average.

3.2 Water Availability for Sundance and Surrounding Properties

The parcels surrounding the Sundance development are either existing 5 to 10 acre parcels or are zoned Estate Residential, 5 acres and can be subdivided without rezoning or a General Plan amendment. Surrounding parcels will also rely on groundwater, and their groundwater use can impact the groundwater supply for Sundance and vice versa. The area surrounding Sundance must be analyzed together with the development in order to provide a complete picture of those potential impacts.

Figure 6 shows the Sundance and surrounding area, including the parcels on the Pilot Hill ridge. Figure 9 is a parcel map of the area that corresponds to the soil map presented in Figure 6. The current Sundance plan calls for 28 dwellings and the surrounding properties shown in the figure can accommodate another 89 primary dwellings, not including granny flats. Thus, a total of 117 primary dwellings will need to rely on groundwater in the future for this area, which has a surface area of about 895 acres.

Figure 9 Sundance and Surrounding Parcels (Analyzed Area)



We can calculate a factor of safety to compare the available groundwater with the future water demand. A factor of safety of 1.0 means that there is just enough groundwater to satisfy the water demand for the area.

Using the long term average calculated recharge (1.8 inches) and a use factor of 0.75 a-ft per dwelling, the factor of safety for groundwater use would be:

$$FS = \frac{(1.8 \text{ inches} / 12 \text{ in/foot}) \times 895 \text{ ac}}{0.75 \text{ a-ft/unit} \times 117 \text{ units}} = 1.5$$

However, as discussed earlier, the significant variation in annual recharge. There are two examples shown in Figure 8 of four year periods that have average recharge values significantly less than the long term average and of course many single years where recharge is even lower. Looking at the period of 2001 through 2004, the factor of safety for groundwater use would be:

$$FS = \frac{(0.5 \text{ inches} / 12 \text{ in/foot}) \times 895 \text{ ac}}{0.75 \text{ a-ft/unit} \times 117 \text{ units}} = \mathbf{0.43}$$

Without knowing the available storage within the fractured rock beneath the site, it is difficult to know whether there is enough groundwater stored to bridge multiple years of low recharge or for a given level of recharge, how many years could be accommodated. However, it seems that there would not be enough recharge to provide groundwater for the needs of the Sundance development and surrounding neighbors given a reasonable number of low recharge years (3-4).

4 Conclusions

1. Existing rainfall records for the Pilot Hill gage provides 15 years of hourly data that can be used to calculate the time distribution of groundwater recharge in the Sundance and surrounding area.
2. It is important to include the parcels surrounding Sundance in the analysis of groundwater availability since both Sundance and the surrounding properties are dependent of the same groundwater source, storage, and recharge processes. Most parcels in the surrounding area are smaller and probably rely disproportionally on the existing Sundance property to aid in replenishment of groundwater supplies.
3. Annual variations in groundwater recharge can be significant. A long term average recharge may not properly exhibit significant periods of low annual recharge that exist and can lead to a critical over-estimation of available groundwater supplies, especially for areas where groundwater storage cannot be quantified.
4. Based on the groundwater recharge estimated for the period 2001 through 2004 for Sundance and the surrounding area, there is not enough groundwater recharge from rain falling on the area to support the annual water needs of Sundance and the surrounding properties at build out. The factor of safety of supply to demand for this 4-year period is 0.43.
5. The Sundance development as currently proposed will significantly impact the groundwater supply for neighboring properties and existing residents.

5 References

1. *Groundwater Conditions and Well yields in Fractured Rocks,* Southwestern Nevada County, California, US Geological Survey, Report 83-4262, 1984.

2. *Hydrogeologic Investigation Assessment Report, Sundance Subdivision,* Holdrege & Kull, October 28, 2008.

3. Letter of February 18, 2010, *Comments on the Sundance Subdivision by Bill Bennett.*

4. *Planning Staff Memorandum,* Planning Commission from Jason Hade, Rezone Z07-0040/ Tentative Map TM07-1454/ Special Use Permit S09-0012/ Sundance Subdivision, September 10, 2010.