Technical Memorandum

To: Ms. Laine Carlson
Water Systems Consulting, Inc.

From: Thomas Harder, P.G., C.HG.
Thomas Harder & Co.

Date: 29-Nov-17

Re: Sand Canyon Recharge Evaluation

This Technical Memorandum (TM) presents an evaluation of groundwater recharge potential within Sand Canyon near the City of Big Bear Lake, California (see Figure 1). The evaluation is being conducted as part of a larger study to assess the feasibility of delivering surface water from Big Bear Lake to Sand Canyon using a combination of existing and new pumps and pipeline infrastructure. The water from Big Bear Lake would include treated water stored in the lake from a Big Bear Area Regional Wastewater Agency (BBARWA) treatment plant. Given the source of water, it will be necessary to consider California Division of Drinking Water (DDW) regulations for indirect potable reuse in evaluating the location of recharge within Sand Canyon.

The specific purpose of this evaluation was to consider the following:

1. Given the surface configuration of the Sand Canyon channel and the hydrogeology of the area, how much water can be recharged in Sand Canyon?
2. Where in Sand Canyon would the recharge facilities need to be located in order to meet DDW regulations for subsurface residence time of recharge water prior to extraction?
3. As there is a diluent requirement for recharge of recycled water in surface basins and given that regulations allow for consideration of subsurface underflow as a diluent source, how much natural underflow can be applied to the diluent requirement in Sand Canyon?

Sources of Data

A number of hydrogeological studies have already been conducted in Sand Canyon. These include:

- Geoscience, 1990. Geohydrologic Characteristics and Artificial Recharge Potential of the Sand Canyon Area. Dated December 1990.
- Geoscience, 2002. Results of Drilling, Construction, Testing and Pump Design for the Sheephorn Well. Dated February 1, 2002.

Analysis Methodology

Geoscience (1990) had previously conducted a travel time analysis for the Sand Canyon area using a numerical groundwater flow model. The downgradient extent of recharge ponds was identified as the point where Teton Road crosses the channel (see Figure 2). Based on this analysis, the travel time to the proposed downgradient extraction wells (proposed to be near TH-5) was more than six months. However, the analysis was based on a range of assumed hydraulic conductivity of 13 ft/day to 40 ft/day. Further, the range of effective porosity was 0.15 to 0.2. These values are relatively high and estimated based on the lithology of sediments encountered during drilling of test boreholes in the area. Subsequent pumping tests from the City of Big Bear Lake Department of Water's (the City's) Sheephorn Well (see Figure 2) indicate that the hydraulic conductivity of the aquifer is less than 1 ft/day. Further, other pumping tests in the area have shown that the effective porosity (which is equivalent to the specific yield in an unconfined aquifer) is on the order of 0.04.

In order to reevaluate the potential travel time and mounding from recharge basins upstream of Teton Road using updated aquifer properties, TH&Co developed a two-dimensional analytical flow model of the Sand Canyon area (see Figure 3 for model area). The analysis was conducted for steady state conditions using the model code WinFlow[1]. All travel time analyses were conducted using the particle tracking feature which allows for the estimation of groundwater travel time between two points from advective groundwater flow. The analysis incorporated the following assumptions:

- The area of the Sand Canyon channel identified for recharge is shown on Figure 3 and is equivalent to approximately 4.2 acres.
- The volume of water applied to the Sand Canyon recharge area was based on an assumed recharge rate of 0.5 ft/day, applied to the recharge basins over a 6-month period. Thus, the total volume of managed recharge for the simulation was 384 acre-ft.

[1] WinFlow Version 3, Environmental Simulations Inc., 2003.

- The analysis was conducted with the Sheephorn Well pumping at a rate of 125 gallons per minute (gpm) for 7 hours per day and the Sand Canyon Well pumping at a rate of 115 gpm for 9 hours per day.
- The initial groundwater levels were conditioned to a groundwater level contour map published by Geoscience (1990)[2] (see Figure 3). This contour map was generated based on data collected during a relatively dry hydrologic period.
- The hydraulic conductivity of the aquifer beneath the basins is assumed to be 1 ft/day.
- The porosity of the aquifer sediments is assumed to be 0.04.
- The sediments in the vadose zone and aquifer are homogeneous.

Findings

Recharge Potential

The primary limit to recharge rates in the Sand Canyon area appears to be available subsurface storage space to accommodate the groundwater mound. The target maximum groundwater level relative to the land surface was 20 ft below ground surface. Previous studies in the Big Bear area have shown that this depth is protective of liquefaction. This groundwater level was achieved at a recharge rate of 2.1 acre-ft/day in the recharge area, with the shallowest groundwater levels occurring beneath the furthest downgradient recharge basins. At a recharge rate of 2.1 acre-ft/day, the maximum predicted recharge for this study was approximately 380 acre-ft/yr, based on a six-month recharge period.

Recharge Water Subsurface Travel Time to the Nearest Downgradient Well

The particle tracking analysis shows that the recharge water will reach the nearest production well (Sheephorn Well) in a little more than approximately 13 months (see Figure 4). Assuming the Sand Canyon recharge project would fall under the definition of a Groundwater Replenishment Reuse Project (GRRP), per DDW regulations, the required subsurface retention time for the recharge water is 2 months. For preliminary recharge siting purposes, a "credit" of 0.25 is applied for travel time calculations using an analytical model, as was done for this analysis. Thus, the credited retention time is interpreted to be 9.75 months (39 x 0.25). This credited retention time is less than the retention time simulated for this analysis (13 months), indicating that the sites simulated are feasible based on the data assumptions in the analysis.

The limiting factors for recharge capacity, as identified by this analysis, were infiltration rate and groundwater mounding in proximity to the land surface. Further data collection will be necessary to determine the total recharge potential of the Sand Canyon area of interest. The most

[2] Geoscience, 1990. Geohydrologic Characteristics and Artificial Recharge Potential of the Sand Canyon Area.

representative infiltration rates can be obtained through a pilot infiltration test. The test would consist of a controlled release of water into a portion of the channel where the water can be dammed up and temporarily ponded. The water level stage in the ponded area can be measured using a staff gage. Once the depth of the ponded area was sufficient (1 to 2 ft deep), the discharge into the channel would be discontinued and the rate of infiltration measured using the staff gage. Optimally, a succession of multiple wetting and drying cycles would be conducted to obtain an average infiltration rate. If possible, the test should also be conducted at multiple locations along the channel, to determine differences in infiltration rate with location.

Native Subsurface Underflow to the Recharge Area

As the aquifer beneath the Sand Canyon area is conceptualized as being unconfined, native subsurface underflow contribution to the portion of the aquifer beneath the recharge area was estimated based on the Dupuit Equation[3], which is expressed as:

$$Q = 0.5K\left(\frac{(h_1 - h_2)^2}{L}\right)$$

Where:

Q	=	Subsurface flow, (acre-ft)
K	=	Hydraulic Conductivity, (ft/day)
h_1	=	Initial Hydraulic head, (ft amsl)
h_2	=	Ending Hydraulic head, (ft amsl)
L	=	Flow Length (ft)

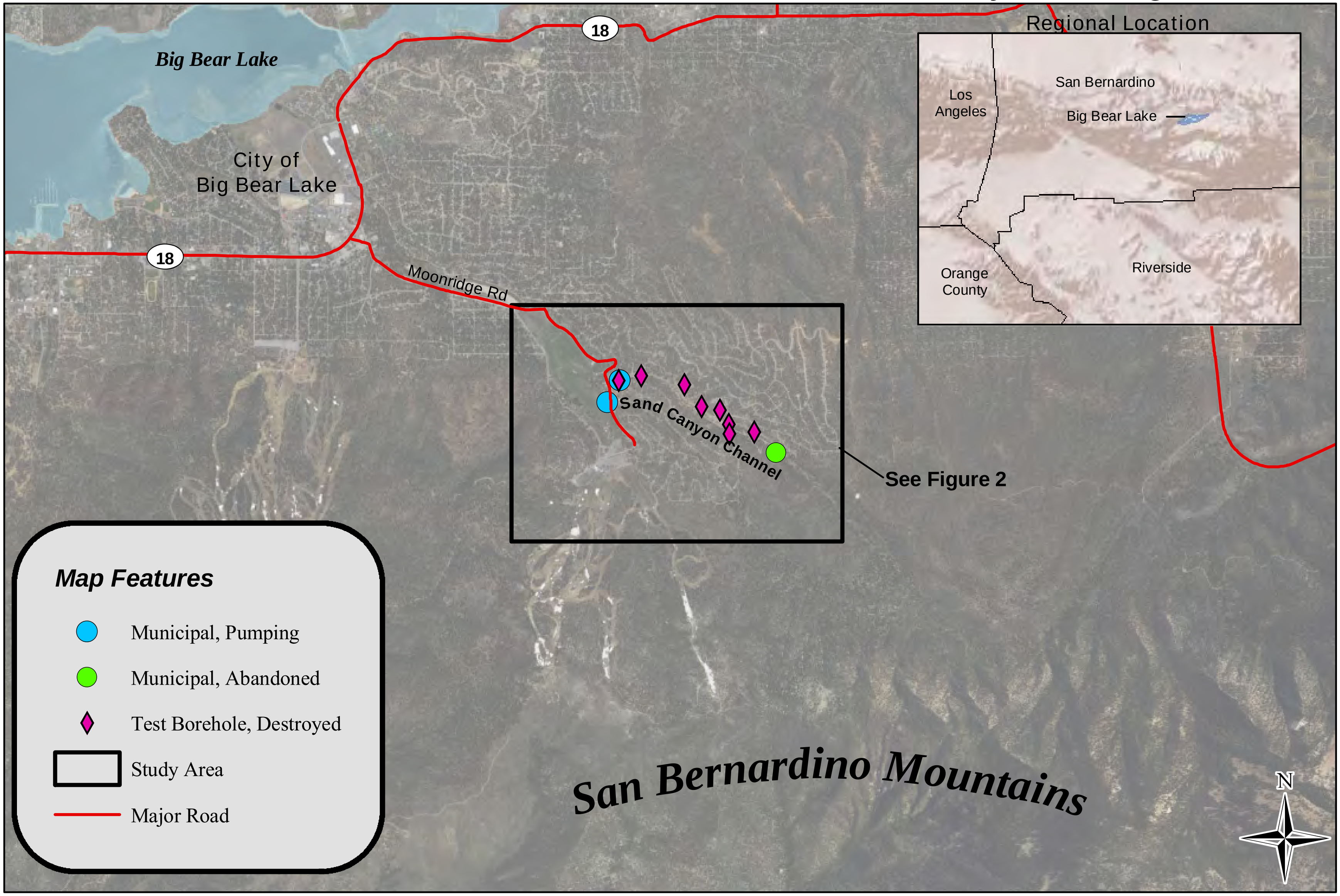
The change in hydraulic head was determined based on the contour map published in Geoscience (1990). The hydraulic conductivity was assumed to be 1 ft/day based on a pumping test conducted in the Sheephorn Well. A summary of the underflow analysis is provided in Table 1. The volume of underflow that may be applied toward the diluent requirement will likely depend on DDW review and interpretation of the data. A range of potential diluent credit was developed such that the low end of the range represents the underflow directly beneath the Sand Canyon channel and the high end of the range represents the entire flow net that ultimately contributes

[3] Fetter, 1994. Applied Hydrogeology, 3rd Edition. MacMillan College Publishing Co.

underflow to the Sand Canyon area, as shown on Figure 1. The range is approximately 58 acre-ft/yr to 247 acre-ft/yr (see Table 1).

WSC Water Systems Consulting, Inc.

Sand Canyon Recharge Evaluation



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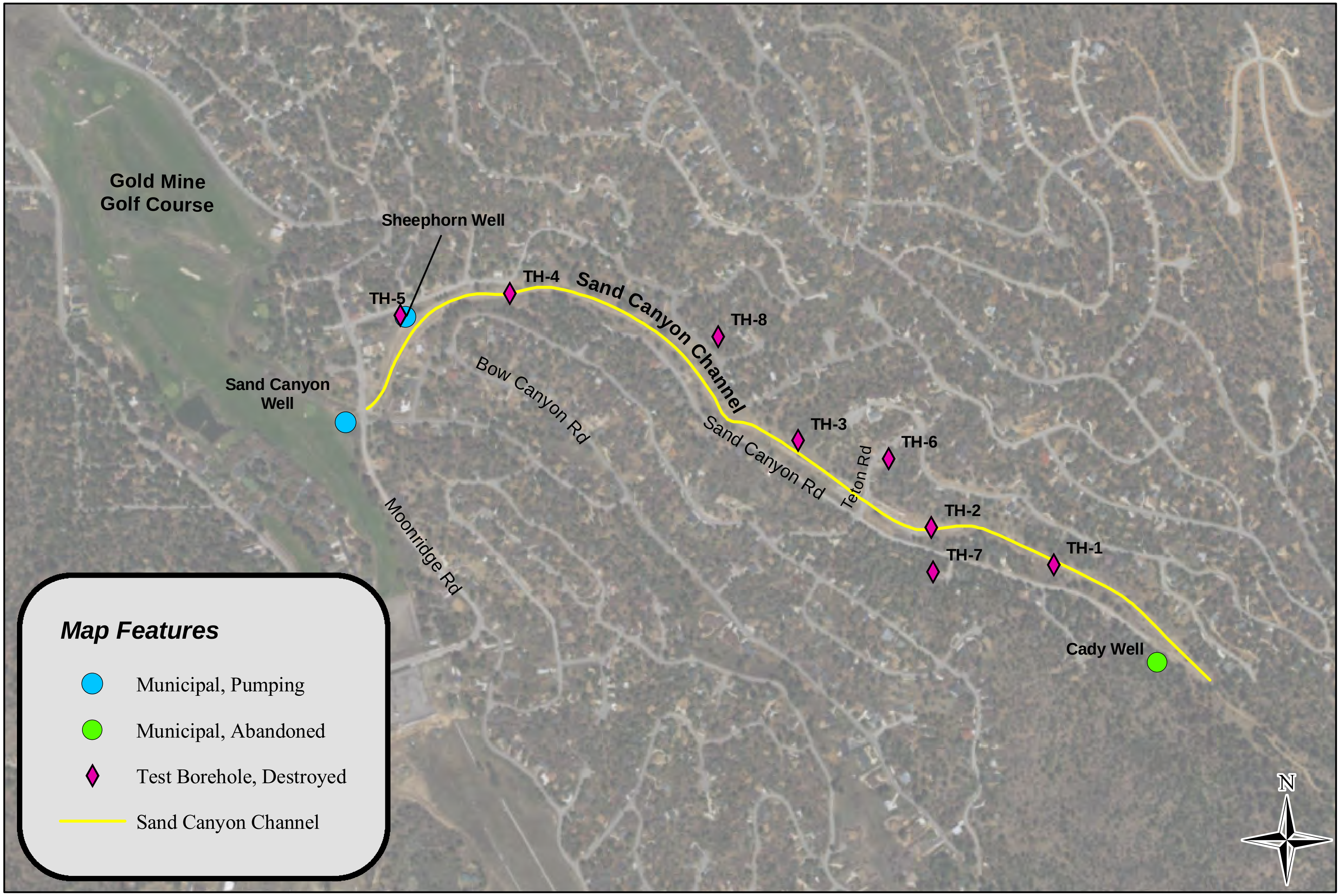
Area Map

Figure 1

Sand Canyon Recharge Evaluation



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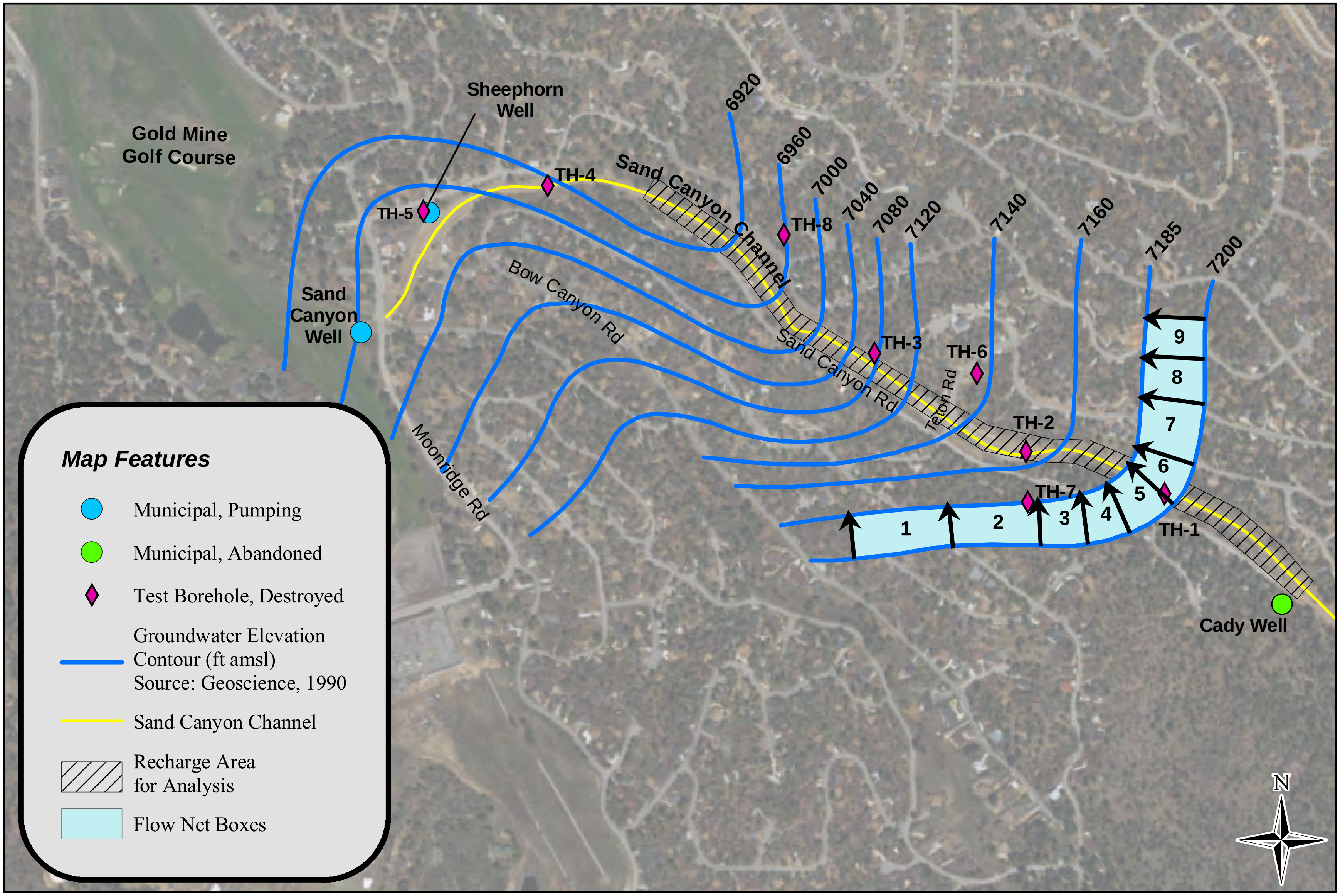
Site Location

Figure 2

Sand Canyon Recharge Evaluation



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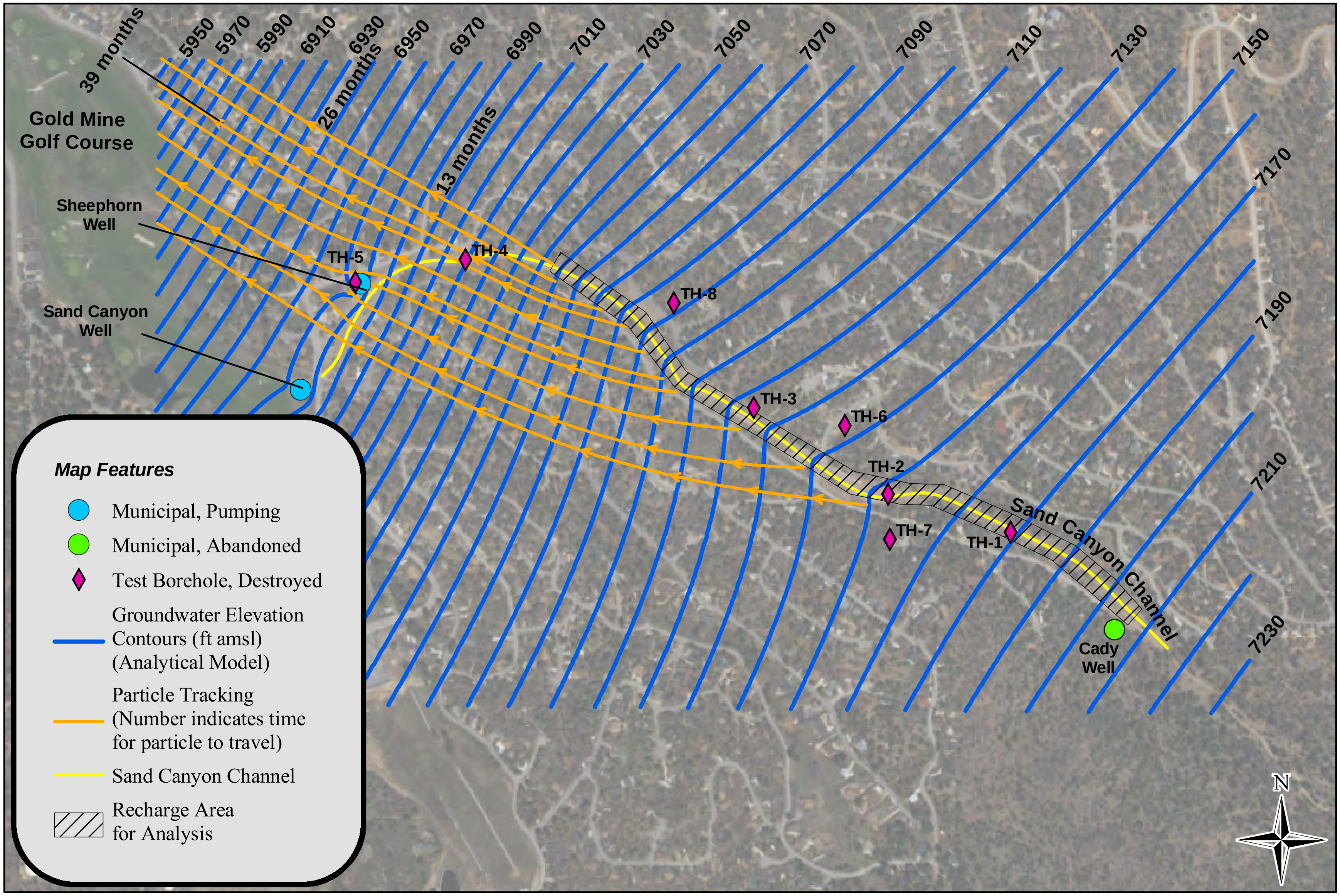
Sand Canyon Underflow Analysis

Figure 3

Sand Canyon Recharge Evaluation



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0 250 500 1,000 Feet

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Recharge Travel Time Analysis

Figure 4

Sand Canyon Underflow Analysis

Cell Name	Hydraulic Conductivity [K] (ft/day)	Flow Cell Width (ft)	Initial Hydraulic Head [h_1] (ft)	Ending Hydraulic Head [h_2] (ft)	Length of Flow Cell [L] (ft)	Flow Rate [Q] (ft^3/day)	Flow Rate [Q] (acre-ft/yr)
1	1	490	145	130	213	4,745	40
2	1	439	145	130	205	4,417	37
3	1	296	145	130	223	2,738	23
4	1	307	145	130	177	3,577	30
5	1	305	145	130	200	3,145	26
6	1	296	145	130	161	3,792	32
7	1	281	145	130	275	2,108	18
8	1	254	145	130	210	2,495	21
9	1	235	145	130	197	2,460	21
					Total Flow	**29,476**	**247**

Range in potential diluent credit = 58 - 247 acre-ft/yr

Notes:

Initial and ending hydraulic heads relative to assumed aquifer bottom.
Yellow highlighted values represent underflow directly beneath the Sand Canyon channel.