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Alternative Submittal
Hydrogeologic Support Study

Martis Valley Groundwater Basin

Nevada and Placer Counties, California

Prepared by GEI Consultants, Inc.

Prepared for Truckee Donner Public Utility District

On behalf of Truckee Donner Public Utility District (TDPUD), Northstar Community Service District (NCSD), Placer County Water Agency (PCWA), Town of Truckee, Nevada County, and Placer County

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TRUCKEE DONNER PUBLIC UTILITY DISTRICT
ALTERNATIVE SUBMITTAL HYDROGEOLOGIC SUPPORT STUDY
MARTIS VALLEY GROUNDWATER BASIN

Certifications and Seals

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Abbreviations and Acronyms

Act (or SGMA)	Sustainable Groundwater Management Act
AF	acre-feet
AFY	acre-feet year
amsl	above mean sea level
bgs	below ground surface
BMOs	Basin Management Objectives
CASGEM	California Statewide Groundwater Elevation Monitoring
CIMIS	California Irrigation Management Information System
DRI	Desert Research Institute
DWR	Department of Water Resources
ET	evapotranspiration
GAMA	Groundwater Ambient Monitoring and Assessment
GMP	Groundwater Management Plan
gpm	gallons per minute
GSA	Groundwater Sustainability Agency
GSFLOW	USGS hydrologic modeling code
GSP	Groundwater Sustainability Plan
LUFTs	Leaky Underground Fuel Tanks
MCL	maximum contaminant level
MODFLOW	USGS groundwater modeling code
msl	mean sea level
MVGB	Martis Valley Groundwater Basin

NCSD	Northstar Community Service District
PCWA	Placer County Water Agency
PRMS	Precipitation Runoff Modeling System
SGMA	Sustainable Groundwater Management Act
SI	Sustainability Indicator
SWRCA	State Water Resources Control Board
T-TSA	Tahoe-Truckee Sanitary Agency
TDPUD	Truckee Donner Public Utility District
TROA	Truckee River Operating Agreement

Executive Summary

This Alternative Submittal Hydrogeology Support Study describes the basin setting and hydrogeologic conceptual model, including groundwater conditions and water budget for the Martis Valley Groundwater Basin (MVGB). A base period for the submittal, based on precipitation data and other available information was established as 1991 through spring of 2016, a period of 25 years. Sustainability goals, undesirable results, and quantifiable local-scale sustainability criteria have been developed, where applicable, along with public input. Monitoring network data was used to assess both groundwater and surface water conditions within the framework of the Sustainable Groundwater Management Act (SGMA) of 2014 and the associated Groundwater Sustainability Plan regulations (2016). Draft best management practices in development by DWR were not explicitly incorporated into this submittal support document due to the limited timeframe for submittal preparation and delivery (January 1, 2017).

The MVGB has been managed by stakeholders using the 2013 Martis Valley Groundwater Management Plan (GMP) (TDPUD, NCSD, PCWA, 2013). Management of the MVGB will continue using the GMP along with this Alternative Submittal. The GMP was relied upon for much of the definition of hydrogeologic conditions in the basin. The stakeholders have actively managed the basin through development of additional tools (a recently released watershed model and geologic database). The watershed modeling tool could not be directly utilized for groundwater analysis, but provided helpful information regarding groundwater recharge.

The distribution of geologic units within of the Basin is complex and has been formed by multiple processes, including: volcanism, glaciation, faulting, sedimentary deposit and erosion. These processes occurred in various orders, producing locally varying stratigraphic sequences. Wells in the MVGB obtain groundwater from shallow alluvium, fractured Lousetown volcanic flows and interbedded sediments, and sediments of the Truckee Formation. These geologic units comprise the water-bearing formations in the MVGB. Portions of the deeper aquifer system exhibit confined conditions; however, regionally extensive, fine grained or competent volcanic rock confining units have not been delineated. Faults and associated fractures in the basin also can locally interconnect or compartmentalize aquifer units and complicate understanding of the degree of communication between aquifer units.

Individual hydrographs for 14 California Statewide Groundwater Elevation Monitoring (CASGEM) monitoring wells show historic trends for both the fall and spring seasons. The hydrographs indicate that groundwater elevations are locally variable in the MVGB both temporally and spatially. Groundwater data suggest that local pumping (increases or decreases) or recharge influences impact short-term groundwater elevation trends. Seasonally, the monitoring wells reflect higher water levels in the spring and lower levels in the fall, when impacts from pumping and reduced natural recharge are more apparent.

Overall, groundwater levels have been stable in the MVGB, even through the drought of the early 1990s and the most recent drought conditions over the past 6 to 9 years. Changes in

historical pumping and climate (wet and dry years) have affected groundwater level trends in specific time periods, although at the basin scale any significant changes appear to be localized.

Groundwater elevation trends and flow directions from a contour analysis for Spring 2016 are dictated by the locations of recharge zones, bounding low conductivity material, and discharge areas for groundwater along streams, the Truckee River, springs and wetlands. A relative measure of the cumulative change in groundwater storage in the MVGB was also estimated from observed changes in groundwater levels from CASGEM monitoring wells from Spring 1996 through Spring 2016. The analysis shows that groundwater levels have risen or remained stable over the past 20 years throughout much of the basin and suggests that at the basin scale the change in groundwater storage is positive.

The majority of the reaches of the Truckee River and Martis Creek are interconnected with the MVGB aquifer system and are receiving inflows from groundwater. Inspection of United States Geological Survey (USGS) streamgage data during the recent drought conditions show that baseflow in the Truckee River continues to be supported by groundwater inflow even when discharges from upstream surface water reservoirs are curtailed or shut off through controlled releases. A recent study by Stantec (2016), which included new monitoring data, further investigated potential interaction between surface water flow and groundwater pumping. There have not yet been quantifiable evidence of streamflow depletions that have produced undesirable results, although the MVGB aquifer and surface water features are interconnected.

The water budget shows that the largest water inflow component to the MVGB (about 53 percent) is from the Truckee River, Donner Creek, and Boca Reservoir. The next largest component of inflow is precipitation which was derived from modeling. The fifth largest component of inflow is from Prosser Creek. These five sources account for 92 percent of the total hydrologic inflows to the MVGB. Water budget inflow components are 74 percent quantified with high quality gaging data and estimated groundwater recharge from precipitation from recent modeling by the Desert Research Institute (Rajagopal, 2015).

Water budget outflow components are over 80 percent quantified with high quality surface water gaging and metered flows from municipal water supplies. Better quantification of evapotranspiration would improve water budget outflow certainty to approximately 98 percent. Annual groundwater pumping estimates ranged from about 4,600 AF in 1990 to a maximum of 8,400 in 2006. The average, basin-wide annual groundwater extractions through the calibration period is on the order of 7,000 acre-feet/year (AFY). The water budget estimates that the basin has an average annual surplus of about 15,000 AFY from 1990 through 2014. Adding this surplus to average annual pumping suggests the sustainable yield for the MVGB is about 22,000 AFY (GEI, 2016).

Future groundwater demands documented in the most recent 2015 TDPUD Urban Water Management Plan are forecast at approximately 13,000 AFY of groundwater demand at the end of their planning horizon in 2035 (buildout). It is well below the sustainable yield estimate of 22,000 AFY. The Truckee River Operating Agreement (TROA) in the TROA Settlement Act also limits the total net depletion of water in Martis Valley to 17,600 AFY for surface water and groundwater, which is also greater than the maximum projected annual demand.

The Desert Research Institutes's (DRI) integrated surface water and groundwater modeling study considered the impacts of various future climatic conditions on water resources in the MVGB (Rajagopal, 2015). This noted that climatic changes likely have a much larger impact on surface water resources than groundwater demand, primarily because pumping only comprises approximately 2 percent of the basin-wide water budget at buildout (2035). The fact that projected demands fall well below both the estimated sustainable yield and the TROA total net depletion of water suggests that future groundwater withdrawals will be sustainable and also provide for a buffer for groundwater management practices to offset local deviations from historically sustainable trends.

Considering the total ensemble of monitoring well data, groundwater elevations in 13 out of 14 CASGEM monitoring wells can be classified as either stable or substantially higher than their average groundwater elevation by Spring 2016 (11 within the stability range by Spring 2016 and two trending upwards). This indicates that over 90 percent of the wells in the basin have water level elevations that are quantifiably stable (+/- 10 feet). No undesirable effects have been observed due to groundwater pumping over the same time period. The one well that is not in the stability range by Spring 2016 is still rebounding after the prolonged drought and is only approximately 12 feet below its average historical value. The recent study performed by Stantec in 2016 investigated this area. The 14 monitoring wells cover a significant portion of the basin and include areas both adjacent and distal to surface water features.

A sustainable basin status has persisted for at least 25 years of groundwater and surface water monitoring, including periods of extended dry climatic conditions and significant growth. Given the historical stability and sustainability of groundwater conditions within the basin, as supported by numerous studies, there have been no quantifiable undesirable results observed in basin for any SGMA specified sustainability indicator (SI). Conclusions as to what could produce undesirable results were derived primarily from assessments of historic water level elevations, estimated water budget components, and comparison of basin pumping to the sustainable yield. Thus, spatial and temporal groundwater level trends were investigated along with an analysis of the basin water budget to develop sustainability criteria. Quantitative sustainability criteria, such as minimum thresholds and measurable objectives, were set to maintain sustainable conditions for each SI while continuing to provide for beneficial uses. Management thresholds were also established to allow for proactive management activities to be initiated should water levels approach minimum thresholds. The management thresholds provide an "early warning" for groundwater managers and are intended to prevent specified undesirable results and address unexpected changes in sustainable conditions before minimum thresholds are breached.

No quantifiable undesirable results have been detected in the MVGB for the SGMA-specified six sustainability indicators, which include; chronic groundwater level declines, reduction of groundwater storage, seawater intrusion, groundwater quality, subsidence and interconnected surface water. However, measurable objectives and minimum thresholds were developed at levels that are deemed to protect the sustainability of the basin and allow for future management activities to address any unforeseen impacts. These sustainability criteria will be evaluated in the future and can be altered to better reflect observed sustainable conditions from future monitoring activities and studies.

1 Introduction

In 2014, the Sustainable Groundwater Management Act (SGMA or Act) was signed by the governor requiring groundwater to be sustainably managed. The Act requires four basic components: 1) development of a Groundwater Sustainability Agency (GSA); 2) development of a Groundwater Sustainability Plan (GSP) or development of an Alternative Submittal; 3) implementation of the specific plan and management to meet quantifiable sustainability objectives; and 4) reporting of the implementation activities and whether the basin is being sustainably managed to the California Department of Water Resources (DWR). The Act's requirements apply to groundwater basins designated by DWR as medium and high priority. The Martis Valley Groundwater Basin (MVGB) has been designated as a medium priority basin and is required to comply with the Act.

GEI Consultants, Inc. (GEI) prepared this report for 1) Truckee Donner Public Utility District (TDPUD), 2) Northstar Community Service District (NCSD), 3) Placer County Water Agency (PCWA), 4) Town of Truckee, 5) Nevada County, and 6) Placer County (local SGMA Agencies) to support their efforts to develop an Alternative Submittal for the MVGB that is in compliance with regulations developed to implement the Act. The TDPUD is leading this effort although all aforementioned entities have participated in various meetings to track project progress and some have communicated pertinent hydrogeologic information to GEI to facilitate greater understanding of basin conditions and management/monitoring activities. TDPUD and MVGB stakeholders have also participated in the development of minimum thresholds and measurable objectives.

Contents of this report provide Alternative Submittal components for the description of the MVGB area, conceptual model, water budget, sustainability management criteria, and hydrogeologic monitoring networks. The intent of this document is to provide the local SGMA Agencies with sufficient hydrogeologic information and analyses to support the development of an Alternative Submittal that is functionally equivalent and substantially compliant with Articles 5 and 7 of the approved regulations governing GSP's (California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2).

Chapter 10 of SGMA - State Evaluation and Assessment, describes the need for DWR to develop and adopt emergency regulations that concerns plan review and implementation along with a section 10733.6 – Alternative Submittals. Section 10733.6 states – *"If a local agency believes that an alternative described in subdivision (b) satisfies the objectives of this part, the local agency may submit the alternative to the department for evaluation and assessment of whether the alternative satisfies the objectives of this part for the basin."* The subdivision (b), referred to above describes that an alternative may be submitted if the basin meets any one of the following three criteria:

1) A plan developed pursuant to Part 2.75 (commencing with Section 10750) or other law authorizing groundwater management.

2) Management pursuant to an adjudication action.

3) An analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of *at least 10 years*.

This document presents supporting information for MVGB's Alternative Submittal pursuant to 10733.6 (b) (3); including, a narrative of the historical and current state of the MVGB as well as analyses that demonstrate that the basin has operated within its sustainable yield from a period of time spanning from Spring 1991 to Spring 2016, a 25-year period that exceeds the required minimum of a 10-year period. Much of the background material in this report is from the 2013 Martis Valley Groundwater Management Plan (GMP), included as **Appendix A** (TDPUD, NCSD, PCWA, 2013). Basin conditions have largely remained steady over an approximately 25-year period that extends through the recent, multi-year drought. This report contains the raw and interpreted hydrogeologic data used to demonstrate that the MVGB has been managed sustainably, which is compliant with the Alternative Submittal approach established by the GSP regulations.

2 Description of Plan Area

A general description of the Martis Valley Groundwater Basin is provided below. The MVGB does not share a boundary with any other DWR delineated groundwater basin and has one outflow via surface water flow and groundwater discharge to the Truckee River at the northeastern perimeter of the basin.

2.1 Martis Valley Groundwater Basin Setting

The Martis Valley Groundwater Basin (No. 6-67, DWR, 2006) is a 35,600 acre (57 square mile) intermontane, fault-bounded basin east of the Sierra Nevada crest. **Figure 1** shows the basin location and topography. The Martis Valley is the principal topographic feature within the basin, although the basin extends to the north and west of the topographically well-defined valley. The floor of Martis Valley is terraced with elevations between 5,700 and 5,900 feet above mean sea level. The valley is punctuated by round hills around the valley perimeter. Mountains along the southern margin of Valley rise dramatically to elevations in excess of 8,000 feet above mean sea level.

The Truckee River crosses the basin from the southeast to the northwest in a shallow, incised channel. Principal tributaries to the Truckee River within the MVGB are Donner Creek, Martis Creek, and Prosser Creek; as well as discharge from Boca Reservoir slightly before the Truckee River leaves the basin. Major surface water storage reservoirs inside MVGB include Martis Creek Lake and Prosser Creek Reservoir. Donner Lake and Boca Reservoir lie just outside the basin boundaries, but release surface water into the MVGB.

Generally, the climate in the MVGB area consists of warm and relatively dry summers and cold winters with greater precipitation, much of it occurring as snow. Average monthly temperatures reach a low of 15° in December and a high of 82° in July. Due to orographic effects, precipitation is greater at higher elevations Average precipitation is estimated to be 23 inches in the lower elevations of the eastern portion of the basin to nearly 40 inches in the western area. The long-term (1934 to 2014) average annual precipitation is 30.41 inches based on measurements from the Truckee Ranger Station precipitation station (Station No. 42467), which is located in the central of the MVGB as shown on **Figure 1**. Higher streamflows occur from May through June, during periods of greatest snowmelt; however, flows along the Truckee River are heavily regulated and are dependent upon releases from Lake Tahoe Dam as well as from Donner Lake and Prosser and Boca Reservoirs in and around the MVGB (TDPUD, NCSD, PCWA, 2013)

2.2 Density of Wells

Groundwater in the MVGB is the dominant source for all municipal, industrial, irrigation and domestic purposes. Based on well logs obtained from DWR in 2012 for the development of the 2013 MVGB GMP, there are approximately 200 wells within the bounds of the MVGB (TDPUD, NCSD, PCWA, 2013). Primary communities reliant upon groundwater include the

Town of Truckee and vicinity as well as the Northstar Resort developed area. Municipal water supplies are managed by the TDPUD and NCSD, respectively.

Known well and boring locations are shown on **Figure 2**. Well density estimates ranges from 0 to 31 wells per square mile, with higher densities of mostly domestic wells occurring in populated areas south of Prosser Reservoir and near the Town of Truckee along the course of the Truckee River. Municipal wells, which comprise the majority of groundwater pumping in the MVGB, and CASGEM monitoring wells are scattered throughout the basin and often are in areas of lower or moderate well density. No specific breakdown of the number of wells by type is available for the basin given existing data; however, approximately 130 private well owners within the basin were identified in 2001, including both domestic users and Teichert Aggregate (Nimbus, 2001). There are 18 active municipal production wells within the basin (**Figure 2**) and 14 active monitoring wells that have publically available water level data (via DWR's Water Data Library). Average, basin-wide groundwater pumping is about 7,000 acre-feet per year (AFY) from 1990 to 2014, or less than 2% of the average annual basin outflow, and ranges from about 3,200 AFY to 7,400 AFY (GEI, 2016).

3 Hydrogeologic Conceptual Model

This chapter provides a characterization of existing geologic and hydrologic conditions in the MVGB. Much of the information provided in this Section is also addressed and/or referenced in the 2013 Martis Valley GMP (TDPUD, NCSD, PCWA, 2013) as well as additional studies and DWR provided data. The soil type, regional geology, geologic structure and aquifer characteristics are presented as the framework for the sections that follow. These sections address the reasoning for the claim that the basin has been sustainably managed and supports sustainability management criteria and analyses required for DWR's acceptance of the Alternative Submittal for MVGB.

3.1 Regional Geology

The MVGB is a valley in the Sierra Nevada physiographic region. It was etched into low permeability bedrock following uplift along regional faults. The valley has been filled with unconsolidated sediments and volcanic rocks and deposits of many different formations, as shown by the regional distribution of surficial geologic units on **Figure 3**. The distribution of geologic units within of the basin is complex and has been formed by multiple processes, including: volcanism, glaciation, faulting, sedimentary deposit and erosion. These processes occurred in various orders, occasionally producing locally varying stratigraphic sequences. The basin is surrounded and underlain by non-water bearing Cretaceous granitic and Tertiary volcanic rocks (andesite) (TDPUD, NCSD, PCWA, 2013).

Although, the geologic history and stratigraphy of the MVGB is complex, generalized interpretations have been developed that adequately describe the primary water bearing geologic formations. **Figure 4** provides the stratigraphic relationships for these primary geologic formations (TDPUD, NCSD, PCWA, 2013). The basement granitic and volcanic rocks are overlain by (in generally descending depth) Quaternary Glacial Till and Outwash, Juniper Flats Alluvium, Prosser Creek Alluvium, Lousetown Volcanic (and volcanic sediments), and the Truckee Formation. The Lousetown Volcanics are fractured and contain significant groundwater. Note that in some units, interfingered sediments, both fine grained and coarse, are present as a result of the previously mentioned sequence of geologic processes. These interbeds have not been classified as being regionally pervasive although they can locally affect well production and groundwater conditions.

Figure 3 shows the locations of three geologic cross sections that were also developed as part of the 2013 MVGB GMP. The cross sections are shown on **Figures 5 through 7** and provide an interpretive view of the complex distribution of geologic units and structural features in the subsurface (TDPUD, NCSD, PCWA, 2013). These geologic interpretations were based upon the development of a geologic database for the GMP. Approximately 200 well logs from DWR and local agencies were compiled in a GIS-compatible geodatabase and geologic formations and properties were identified at depth. Previous geologic studies and mapping of the geology and specifically structure of the basin (referenced in the 2013 MVGB GMP) were compared and incorporated, where relevant, into the cross sections derived from the geologic database.

Appendix Z (digital submittal) provides the well logs used to create the geologic sections. Additional discussion and details of the geology of the MVGB is provided in the GMP (TDPUD, NCSD, PCWA, 2013).

3.2 Structure

The MVGB is a faulted bedrock valley that has since been filled with sediments and volcanics. There are multiple faults in the basin; **Figure 3** shows faults located by the California Geologic Survey on their 2015 map but does not include all faults noted in the GMP (TDPUD, NCSD, PCWA, 2013). Vertical interpretations of the fault offsets are shown on **Figures 5 through 7**. Additional description of these structural features can also be found in the 2013 MVGB GMP. Most of the faults are unnamed and inactive but generally trend northwest-southeast and can be the source of laterally confining conditions, compartmentalization of the MVGB aquifer, or a conduit for groundwater flow.

Historically, the Martis Fault was identified, and generally trends along the course of Martis Creek and Martis Creek Lake along a northward trend (TDPUD, NCSD, PCWA, 2013; Figure 2-13). More recently, the active Polaris Fault has been identified, along with several associated fault splays, subparallel to the Martis Creek Fault (Hunter and others, 2011). The Polaris Fault has been proven to be a lateral barrier to groundwater flow (Interflow, 2014). Seeps, springs, and thermal springs are present in the vicinity of the recently-mapped Polaris Fault (Hunter and others, 2011). The effects of the other un-named faults on groundwater flows in the basin are unknown; however, they may serve as both a conduit for groundwater flow as well as a feature that can constrain and compartmentalize groundwater flow. Groundwater discharge areas in the form of seeps and springs are also found within these areas and along the periphery of the MVGB, including thermal springs in the vicinity of the recently-mapped Polaris Fault (Hunter and others, 2011).

3.3 Soils

Surficial distribution and classification of soil types within the basin by the Natural Resources Conservation Soil Service (NRCS) are shown on **Figure 8**. The soils are delineated by hydrologic group, as determined by the potential infiltration rate of surface water. Generally, higher permeability soils are located along the major surface water drainages in the basin. Lower infiltration rate soils typically reflect higher elevation areas that distal to streams or creeks. However, due to the geology of this basin, less permeable volcanics are either exposed or present at shallow depths beneath the soil profile. Therefore, recharge rates through soils is limited in higher elevation areas not immediately adjacent to surface water drainage features. Thus, it is important to consider subsurface geology as a limiting constraint on actual deep percolation to the MVGB aquifer (Rajagopal and others, 2015).

3.4 Basin Boundaries

The basin boundary used for the MVGB conceptual model is identical to that delineated by DWR in Bulletin 118 (**Figure 1)**; however, consideration was given to relevant data outside the basin to better understand water inflows, geology, and surface water management. The edges of the basin is well defined and is surrounded by relatively impermeable Tertiary (Miocene) granitic and andesitic volcanic rocks to the south, west and east as demonstrated by the surficial geology shown on **Figure 3**. These geologic units slope downwards into interior of the Basin and constituent the bottom of the basin. The northern basin boundary is a topographic watershed divide, and, as shown on **Figure 5**, the Lousetown Volcanics and Truckee Formation continue outside of the MVGB to the north. Due to their structure dipping towards the center of the basin, groundwater inflow from forested and undeveloped lands to the north may contribute water to the MVGB. The overlying geologic units shown on **Figures 4 through 7** comprise the primary basin aquifer. The basin is estimated to range from ground surface near the edges of the basin to depths approaching or exceeding 1,500 feet below ground surface (bgs) in the central portions of the basin.

3.5 Aquitards

Based on the geologic sections there are no regionally continuous clay or competent rock aquitards in the basin. In the vicinity of the Truckee-Tahoe Airport there is some accumulation of clays in the Prosser Creek Alluvium which may provide locally semi-confined or perched water conditions. Likewise, water can be produced from faults and fractures within the Lousetown Volcanics (Qv). However, portions of the volcanic flows are massive, unfractured, and largely impermeable to lateral or vertical groundwater flow. In some cases, water encountered in deeper portions this fractured system or below it (extending into the Truckee Formation) can be pressurized, producing static levels several hundred feet higher than where water was initially encountered. This suggests the presence of localized to sub-regional confined groundwater conditions for aquifer units below more competent volcanic flows (TDPUD, NCSD, PCWA, 2013). In general, artesian flowing wells have been reported in the southern portion of the basin near Bald Mountain. However, the lateral extent and degree of confined conditions is unknown. Approaching the MVGB boundaries, many tertiary volcanic geologic units are exposed or otherwise unconfined. Cross sections also demonstrate surficial or near surface presence of the Lousetown Volcanics in the interior of the basin as well as the Truckee Formation where it has been vertically offset at a fault. It is unclear if confined conditions become more prevalent at greater depths or if they are structurally dependent due to faulting and aquifer compartmentalization. At a minimum, competent volcanic units can serve as localized confining units, although there is insufficient evidence at a regional scale to consider it a pervasive aquitard.

3.6 Principal Aquifers

Wells in the MVGB obtain groundwater from recent, shallow alluvium as well as from fractured Lousetown volcanic flows and sediments and the Truckee Formation (**Figure 4**). These sediments and volcanics comprise the principle aquifer units in the MVGB. Portions of the deeper aquifer system exhibit confined conditions as noted above. Regionally extensive, fine grained, or competent volcanic rock confining unit have not been delineated. Faults and associated fractures in the basin may also interconnect aquifer units and can locally complicate understanding of the degree of communication between aquifer units. Additionally, as seen in each cross sections, Tertiary volcanic units are often in close proximity to land surface and surface water features (**Figures 5 through 7**), suggesting that upper portions of the “deep” aquifer may locally be unconfined. Evidence of unconfined and semi-confined areas of the basin groundwater system can be gleaned using the distribution of previously defined geologic units and information regarding water level responses for shallow wells and production wells installed in the Lousetown and Truckee Formation.

All municipal production wells are screened into the Lousetown Volcanics, at a minimum, and some penetrate the Truckee Formation. CASGEM monitoring wells are primarily screened within the Lousetown Volcanics, although there are several piezometers and wells that are completed within the upper alluvial aquifer (**Figure 2**, **Appendix Z**). However, currently there are no viable nested or coupled wells that would show the magnitude of vertical gradient or a degree of groundwater interconnection of shallow and deeper aquifer units.

Given the current level of understanding of the complex basin hydrostratigraphy; this report will consider two primary water bearing units within the MVGB; a shallow alluvial aquifer and a “deep” volcanic and tertiary sediments aquifer unit. Both are comprised of multiple geologic formations that are heterogeneous and vary in thickness. As previously noted, the deep water bearing unit is not overlain by saturated alluvial sediments in a significant portion of the basin.

The shallow, unconfined aquifer unit is composed of recently deposited, coarse-grained sediments, where saturated. This aquifer unit is typically associated with current and historic surface water drainages, lakes, floodplains, and glaciated terrain. Geologic formations comprising this aquifer unit include the: Prosser Creek Alluvium, Quaternary Glacial Till and Outwash, and Juniper Flats Alluvium. The Prosser Formation (Qpc) includes interlayered silts, sands, and clays and, as such, has variable water bearing capacity. Water-bearing portions of the shallow water bearing unit are also locally hydrologically connected to overlying glacial outwash, alluvium and surface water bodies.

The deep aquifer consists of the Lousetown Volcanics (and volcanic sediments) and the Truckee Formation, although both of these formations vary in thickness and proximity to ground surface across the basin (**Figures 5 through 7**). Groundwater flows along faults, fractures, and weathered components within the Lousetown Volcanics (Qv), though portions of the volcanic flows are massive and unfractured and may cause confining conditions. The Truckee Formation (Tt) is composed of interlayered silts, sands, and clays, and also has variable groundwater availability. Well driller’s logs document sands and gravels within the Truckee Formation in the center of the basin, near the Truckee Tahoe Airport, at depths of approximately 900 to 1,000 feet, and from 200 to 700 feet in the southern portion of the basin near Shaffer’s Mill and Lahontan Golf Clubs (TDPUD, NCSD, PCWA, 2013).

3.7 Aquifer Hydraulic Characteristics

There is limited information on field derived hydraulic properties for the various water bearing aquifer units in MVGB; however, well yields provide an indirect level of understanding on groundwater production potential and ability to transmit water. Storativity estimates have generally centered on a value of 0.05 for the purposes of calculating storage. Note that for the volcanic units, both production rates and associated hydraulic parameters can be highly variable depending upon local faulting and fracturing, as well as the presence of coarse or fine grained interfingered lenses at depth. The following information is provided in the 2013 MVGB GMP (TDPUD, NCSD, PCWA, 2013).

Well yields in the alluvial formations (Prosser Creek Alluvium and where saturated the Quaternary Glacial Till and Outwash, Juniper Flats Alluvium) typically range from 12 to 100 gpm, though larger-diameter production wells have estimated yields as high as 500 gpm according to State well driller's logs.

Hydraulic properties of the Quaternary glacial moraines contrast sharply with those of the glacial outwash deposits. The moraines consist of poorly-sorted clay to boulder-size materials, while the glacial outwash deposits are primarily well-sorted sands and gravels. As a result, the glacial outwash tends to transmit water relatively easily, while moraines typically have lower permeabilities and less water production capabilities.

Well yields in the Truckee Formation range from 280 gallons per minute (gpm) in the eastern portion of the basin (Hydro-Search, 1995) to more than 1,000 gpm in faulted areas underlying the southwestern portions of the MVGB (Herzog, 2001). Although most production well information includes wells that are screened across both the Lousetown and Truckee Formations in the sourthern portion of the basin, yields have been estimated to also be in the 250 gpm to more than 1,000 gpm range, similar to that of the Truckee Formation.

The Desert Research Institute (DRI) developed an integrated surface and groundwater flow model for the Martis Valley watershed portion of the Truckee River Basin. The model considered a groundwater component for the MVGB as a component of the greater watershed model. DRI generalized the aquifers into 3 hydrostratigraphic layers, only two of which were considered to be viable for water production. The topmost layer was limited in spatial extend to recent alluvium related to deposition from surface water features, while the deeper unit generally represented volcanics surrounding and underneath the younger, unconsolidated material. The model was calibrated using homogeneous and isotropic conditions for individual layers at the watershed scale; they do not represent local conditions. Compilation of regional aquifer testing information and associated hydraulic parameters is included as a data gap.

3.8 General Water Quality

Groundwater in the MVGB is of good quality and is currently monitored as part of the water provider agencies' agreements with the California Department of Drinking Water. Each agency releases an annual water quality report for their service areas in the MVGB. The USGS carried out groundwater monitoring activities in the MVGB in cooperation with the California State Water Resources Control Board (SWRCB) as part of the California Groundwater Ambient Monitoring and Assessment (GAMA) Program (Fram and others, 2007) and sampled 14 wells in the MVGB for a wide range of constituents during summer 2007. The concentrations of most constituents detected in these samples were below drinking-water thresholds, with two exceptions: a) concentrations of arsenic were above the Maximum Contaminant Level (MCL) in 4 of the 14 wells sampled, and b) manganese concentrations were elevated above the MCL in one well. Arsenic levels above the MCL have also been reported by the TDPUD; however, this issue has been addressed operationally by the TDPUD.

3.9 Precipitation

The long-term (1934 to 2014) average annual precipitation is 30.41 inches based on measurements from the Truckee Ranger Station precipitation station (Station No. 42467), shown on **Figure 1**. Precipitation occurs as both rain and snow throughout the basin, primarily in the winter season. Summers tend to be drier, while snowmelt and associated streamflow and groundwater recharge occur in the spring. **Figure 9** shows the annual precipitation departure from the mean and demonstrates the relatively dry conditions in recent years. **Table 1a** and **Table 1b** show general classifications for wet, above normal, below normal, and critically low precipitation water years in the top row (GEI, 2016). Wet conditions were defined as annual precipitation above 39 inches, and above normal conditions were defined as between 30 and 39 inches. Below normal conditions were defined as annual precipitation between 21 to 30 inches and critically dry conditions were defined as below 21 inches. These same classifications are presented by year on the monitoring well hydrographs presented later in this report.

Precipitation (in AFY) that fell directly on the groundwater basin was obtained from DRI's integrated, watershed modeling for 1983 through 2011 (DRI, 2013; included in 2013 MVGB GMP); however, their estimates did not cover the complete period for water budgeting purposes in GEI's Sustainable Yield Estimate project (GEI, 2016). Therefore, missing years were estimated using precipitation measurements from the Truckee Ranger Station precipitation station and selecting total precipitation in AFY from DRI for years with similar precipitation. From DRI's modeling, recharge from precipitation is estimated to comprise about 22 percent of the total inflow to the basin, the second largest component of inflow in the water budget (GEI, 2016). Additional information on precipitation trends and patterns is available in both the MVGB GMP as well as DRI's modeling report that was provided to the U.S. Bureau of Reclamation (Rajagopal and others, 2015; **Appendix B**).

3.10 Evaporation and Evapotranspiration

Evaporation from surface water bodies in the MVGB primarily occurs at Prosser Creek Reservoir, Boca Reservoir, along the Truckee River, and at small ponds and wetlands scattered throughout the basin. However, evaporation is estimated to only comprise an extremely small fraction of basin outflows. Evapotranspiration (ET) in the MVGB generally occurs from native vegetation, such as evergreen forest and shrubland, and from nine golf courses. The greatest amount of ET is generally in the summer and fall, when there is less precipitation (GEI, 2016).

There are no California Irrigation Management Information System (CIMIS) evapotranspiration stations in the MVGB. However, CIMIS statewide reference ET (ETo) zone maps provide an estimate. The MVGB region is in Zone 13, which has an average ETo of 54.3 inches per year. This value is higher than most other CIMIS zones. ETo (from a non-CIMIS station) at Tahoe City only about 300 feet higher than Truckee ranges between 35.5 and 42.5 inches per year, significantly less than average annual reference ETo estimates provided by statewide CIMIS ETo (TetraTech, 2007).

3.11 Groundwater Recharge Areas

Groundwater recharge to the basin were defined as part of creation of a groundwater model for the MVGB by Desert Research Institute (Rajagopal and others; 2015). DRI used PRMS (coupled with a MODFLOW groundwater flow model via GSFLOW) to simulate land surface hydrologic processes of evapotranspiration, runoff, infiltration, and interflow by balancing energy and mass budgets of the plant canopy, snowpack, and soil zone on the basis of distributed climate information (PRMS, MODFLOW and GSFLOW codes are supported by the USGS). The PRMS model was used to develop annual recharge estimates for the years 1983 to 2011. **Figure 10** shows the distribution of estimated average annual recharge rates throughout the watershed encompassing MVGB. The actual recharge varies from year to year based on the amount of precipitation received.

The PRMS computed recharge consists of the sum of shallow infiltrated water as well as deep percolation to the MVGB aquifer. This study also noted that groundwater recharge typically occurs through coarse alluvium associated with fluvial deposits, along mountain fronts, and across exposures of Quaternary alluvium in the central portions of the basin. Additional recharge also occurs at higher elevations in weathered and fractured volcanic upland areas; however, recharge rates are limited by the low permeability of these geologic units (Rajagopal and others, 2015).

Groundwater recharge also occurs along creeks and rivers (Interflow, 2003). In particular groundwater recharge is interpreted to occur along short segments of the Middle and West Martis Creeks near the southern edge of the basin and along Prosser Creek above Prosser Reservoir**.** The losing reaches of these creeks, which provide groundwater recharge, are shown on **Figure 11**.

3.12 Groundwater Discharge Areas

Groundwater discharge generally occurs along most of the courses of creeks and the Truckee River as well as at springs and seeps that feed both surface water flow and wetlands (Interflow, 2003). Several springs are located along the Martis Creek Fault or the Polaris Fault, suggesting that it is a barrier to groundwater flow. **Figure 11** shows the locations of the primary groundwater discharge areas and groundwater supported ecosystems (wetlands) in relation to gaining (discharge) and losing (recharge) reaches of primary surface water features.

In 2002, a below normal precipitation year, the groundwater discharges were estimated at 11,300 AF (Interflow, 2003). The majority of the groundwater discharge, although not quantified, occurs into the Truckee River between Glenshire and Boca bridges, near the eastern end of the basin where the alluvium abuts onto shallow bedrock (Interflow, 2003). Therefore, river gaging station data can reasonably be used to measure most of the outflow of groundwater from the basin (**Figure 1**).

3.13 Surface Water Bodies

There are several storage and dynamic surface water bodies (containing water in excess of 100 AF) within the MVGB, including reservoirs, impoundments, and the Truckee River. **Figure 1** shows these surface water bodies relative to other pertinent geography and hydrologic features in the basin.

The Truckee River conveys water from the Lake Tahoe watershed and portions of the Martis Valley watershed into and through the MVGB. Due to its length, numerous tributaries and heavily regulated nature (with releases coming from multiple reservoirs), it can contain significant amounts of water at any given time. Likewise, when releases are curtailed due to drought and regulatory constraints, flows in the river vary significantly.

The Prosser Creek Reservoir is the largest water body in the MVGB and may provide recharge to the unconfined Processor Formation and Lousetown Volcanics, as suggested on **Figure 5**. Releases from this reservoir feed flows in Prosser Creek, which converges with the Truckee River at the northeastern edge of the basin.

The Martis Creek Lake is the next largest surface water body. A flood control dam was constructed to create the impoundment, but due to seepage through and around the dam, it has never been filled to capacity (Nimbus, 2001). Some water is retained in the reservoir and provides recharge to the Prosser Formation and glacial outwash deposits.

A number of small impoundments, less than 100 AF, may provide additional recharge to the basin including the Union Mills Pond in the Glenshire subdivision, Dry Lake adjacent to the Waddle Ranch Preserve, and Gooseneck Reservoir, near the Lahontan Golf Club (**Figure 1**). Though originally constructed for cattle-grazing and/or millpond operations, these impoundments are now managed primarily for open space, recreational/aesthetic, or wildlife purposes.

3.14 Imported Water Supplies

Wastewater is imported and collected by the Tahoe-Truckee Sanitary (T-TSA) from the north shore communities surrounding Lake Tahoe in addition to wastewater from within the Martis Valley. Wastewater inflows to the treatment plant are measured through meters or weirs. After treatment the water is discharged to leach fields near the town of Truckee, south of the Truckee River as shown on **Figures 1 and 11**.

Annual effluent inflows to the treatment plant from the Lake Tahoe area and from within MVGB were obtained from T-TSA for 1981 through 2014, a 32-year period. The inflows from the Lake Tahoe area increased rather significantly up to 1987 and have remained rather stable since that time. The average inflow from the Lake Tahoe area between 1987 and 2014 was about 2,700 AFY, representing approximately one percent of the total inflow to the basin.

3.15 Groundwater Storage

In 1975 HSI estimated the groundwater storage in the basin to be 1,000,000 AF. HSI used a surface area of the basin of approximately 37,600 acres with an average depth of 400 feet and a specific yield of 0.07.

Nimbus Engineers (2001), calculated 484,000 AF of groundwater in storage based on the total basin volume of 9,680,000 acre-feet and an unconfined storativity (specific yield) of 0.05. The value for storativity is a composite of values based on the wide variety of geologic materials encountered in the basin. This is a more conservative estimate of groundwater storage as the basin fill can be up to 1,500 feet thick, which more than triples estimated storage. Assuming all groundwater pumping from wells at buildout removed water from storage, annual withdrawals would only deplete storage by approximately 1 percent.

3.16 Data Gaps in the Hydrogeologic Conceptual Model

A few data gaps were identified during the preparation of this Hydrogeologic Conceptual Model but do not significantly affect the overall hydrogeologic understanding of the basin and its sustainability. As these gaps are filled via future studies and analyses, greater basin understanding will continue to promote sustainable groundwater conditions in the MVGB. Additional information should be acquired to:

- Evaluate whether other fault systems crossing the basin, besides the Polaris and Martis Creek faults, are barriers to groundwater flow;
- The location and nature of confined groundwater conditions within or below the Lousetown Volcanics;
- Compilation of hydraulic parameters from previous aquifer testing;
- Performance of aquifer tests to obtain additional hydraulic parameters and understanding of flow boundaries for localized zones in the MVGB. Update and potentially refine the previous watershed modeling effort to reflect current and simulate future aquifer conditions within the MVGB.

4 Groundwater Conditions

This chapter provides a description of current and historical groundwater conditions in the basin, including data through spring of 2016.

4.1 Groundwater Levels

Figure 2 shows the locations of 14 CASGEM wells that have groundwater elevations recorded from 1991 through Spring 2016. Generally, the wells are scattered throughout the basin and include areas with negligible or no pumping influences as well as areas with production wells located within a few miles. Individual hydrographs for these 14 CASGEM monitoring wells are presented in **Appendix C** and show historic trends for both the fall and spring. The hydrographs indicate that groundwater elevations are locally variable in the MVGB both temporally and spatially. Generally wells installed at higher elevations have higher water levels and historic trends in levels may trend up or down over a given period of time. These data suggest that local pumping (increases or decreases) or recharge influences likely impact short term groundwater elevation trends. Seasonally, the monitoring wells reflect higher water levels in the spring and lower levels in the fall, when impacts from pumping and reduced natural recharge are more apparent.

Figure 12 presents groundwater level monitoring data from CASGEM wells in the MVGB in a single graph. Overall, groundwater levels have been relatively stable in the MVGB, including during the drought of the early 1990s, the wet years of the late 1990s, and recent drought conditions over the past 5 to 9 years. Water levels generally range in elevation from just above 5,600 feet above mean sea level (amsl) to just over 6,100 feet amsl. Changes in historical pumping and climate (wet and dry years) have affected water level trends in specific time periods, although at the basin scale any significant changes appear to be localized.

The hydrographs also provide some well specific information on local groundwater conditions:

- Well 17N16E11F001M (northeast of downtown Truckee) experienced a nearly 50-foot rise in water level in the late 1990s, and then declined steadily over the following decade. The rise coincides with above-average precipitation and streamflow. Water levels also rose substantially by about 50 feet again in 2010 and 2011, and is likely related to reduction in local municipal pumping.

- Levels in Well 17N17E29B001M (Northstar area) and 17N17E19K001M (between Northstar and Truckee Airport areas) were relatively steady throughout the monitoring period until summer 2007, when seasonal fluctuations began to occur in response to local pumping by TDPUD and NCSD as well as drought conditions (Stantec, 2016; Appendix E). Spring groundwater levels have declined by an average of approximately 9 feet for these two wells, between Spring 2007 and Spring 2015.

- Groundwater levels in well 17N17E05D001M (Truckee River east of Truckee) have increased steadily over the period of record, rising over 10 feet from 1990 to present day.
- In well 17N16E17F002M (Donner Creek area), groundwater levels fluctuated seasonally but generally remained constant year to year.

There are currently no CASGEM or clustered or nested monitoring wells in the basin to be able to evaluate and quantify the magnitude of vertical gradients between the principle aquifers in MVGB. However, anecdotal information regarding production well installations for NCSD and PCWA south of the Truckee River suggest that water levels in wells screened into deeper portions of the Lousetown Volcanics originally exhibited artesian conditions, suggesting confined conditions. Even though there is some uncertainty as to the confined or unconfined nature of the portion of the aquifer monitored by deeper wells, static water level measurements in shallow aquifer monitoring wells generally correlate with those at nearby wells. No distinct and extensive cones of depression are apparent within the basin, and water levels also correlate well with the streambed elevations at nearby gaining reaches of streams and the Truckee River.

4.2 Groundwater Contours

A groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with Spring 2016 for the MVGB aquifer was prepared using data from the CASGEM well monitoring array. The groundwater contours were not generated by contouring software, but were instead hand-derived to reflect regional geology as well as local groundwater recharge and discharge locations such as streams, springs, and wetland areas. DWR's web-based contouring program does not produce groundwater level contours for the MVGB. Groundwater elevation contours and generalized flow directions for Spring 2016 are shown on **Figure 13**. The overall trends and flow directions are dictated by the locations of recharge zones, bounding low conductivity material, and discharge areas for groundwater along streams, the Truckee River, springs and wetlands. Localized differences in groundwater levels (both positive and negative) have occurred over time due to changes in pumping patterns and prolonged drought conditions.

The DRI groundwater flow model can produce seasonal groundwater contours for the groundwater basin; however, groundwater water contours were not provided in the documentation produced by DRI. Furthermore, the integrated climatic, surface water, and groundwater model was designed to be a watershed modeling tool to assess climate conditions on streamflow, and it employed a simplified and homogeneous "reservoir" aquifer conditions at a coarse resolution (300 meters by 300 meters). Additionally, homogeneous and isotropic hydraulic parameters were used for the model layers, and a uniform thickness was applied to the deeper aquifer units. Thus, the best indicator of the current flow regime in the MVGB are the Spring 2016 contours.

Although it is difficult to discern specific pumping centers in the MVGD, it is apparent that groundwater gradients generally steepen approaching the gaining reaches of the Truckee River and Martis Creek. Flatter groundwater gradients have been interpreted further away from major groundwater discharge areas. Although there are areas of the basin that have limited monitoring data, the resolution of monitoring is suitable to constrain groundwater elevations and flow directions in the vicinity of most municipal wells, especially when topography near gaining reaches of surface water features are used.

One well, 17N16E13K003, exhibited unexpected water level elevations that were approximately 70 feet lower than well 17N16E13K001, which is located at the same site and screened at a deeper elevation. Field inspection of this well site noted that both monitoring wells lacked end caps. Because well 17N16E13K003 exhibits water levels that are 1) at depths not observed for approximately 2 miles downstream along the Truckee River, 2) deeper than those observed in adjacent wells monitoring screened in deeper aquifer intervals, 3) trending differently than the well located at the same site, and 4) incongruous with the general groundwater flow regime both locally and regionally; it was not used in contour development and excluded from detailed quantitative analyses for the purposes of the Alternative Submittal. Use of groundwater level data from the remaining 13 CASGEM monitoring wells was contoured without anomalous variations and generally agreed with gaining reaches of the Truckee River and tributaries.

4.3 Seawater Intrusion

There is no seawater in the vicinity of the basin. The approximate depth of the base of the groundwater basin is approximately one mile above sea level and bounded by bedrock. Thus, there is no likelihood of impacts from seawater.

4.4 Groundwater Quality Issues

The Tahoe-Truckee Sanitation Agency (T-TSA) operates a water reclamation plant which includes the discharge of tertiary-treated effluent into glacial outwash and Prosser Formation alluvium downstream of the Town of Truckee on the south side of the Truckee River. Hydrogeologic investigations in the vicinity of the plant indicate that effluent flows laterally toward the Truckee River and Martis Creek, discharging to these water bodies after a minimum 50 day travel time (CH2MHill, 1974). DWR (2006) noted that a water quality monitoring program is in place to evaluate potential changes to ground- and surface-water quality.

As of 2012, sixty-three leaking underground storage tank (LUST) cleanup sites had been identified by the SWRCB’s GeoTracker database in the MVGB (TDPUD, NCSD, PCWA, 2013). Of these 63 sites, cleanup actions for 49 are documented as “completed”, while 14 are listed as “open” or “active.”

By August 2016, only eight “open” sites remain on the Geotracker website as listed in **Table 2**. Contaminants of concern at each site and their status are also provided on the table. The location of these sites are shown on **Figure 14**. Of these eight sites, four are eligible for closure.

Table 2. Groundwater Contamination Sites – Martis Valley

RWQCB CASE NUMBER	LOCAL AGENCY	BUSINESS NAME	CASE TYPE	STATUS DATE	STATUS	POTENTIAL CONTAMINANTS OF CONCERN
6A290407N02		HIRSCHDALE LANDFILL	Land Disposal Site	1/1/65	Open	
6A310006006		SHARP PROJECT	Land Disposal Site	1/1/65	Open	
T6S045	NEVADA COUNTY	CALTRANS EQUIPMENT BUILDING NO. 2	Cleanup Program Site	1/22/09	Open - Inactive	Waste Oil / Motor / Hydraulic / Lubricating Diesel
6T0047A	NEVADA COUNTY	CHEVRON SS #9-0612	LUST Cleanup Site	9/1/13	Open - Verification Monitoring	Gasoline
6T0353A	NEVADA COUNTY	FORMER PAT & OLLIES SIERRA SUPERSTOP	LUST Cleanup Site	1/8/16	Open - Eligible for Closure	Gasoline
6T0124A	NEVADA COUNTY	NV COUNTY FORMER DEPARTMENT OF TRANSPORTATION YARD	LUST Cleanup Site	1/21/15	Open - Eligible for Closure	Gasoline
T6S001	NEVADA COUNTY	DEPENDABLE TOW	Cleanup Program Site	1/21/15	Open - Eligible for Closure	Gasoline
T6S002	NEVADA COUNTY	FORMER BERRY-HINCKLEY INDUSTRIES TRUCKEE BULK FUEL TERMINAL	Cleanup Program Site	8/4/14	Open - Eligible for Closure	

Note: Status Date is last correspondance or filing but is not necessarily the date of the on the on-line report available for review. Case status from Geotracker website, August 29, 2016

Additional details were obtained for each of the sites from County files and are provided in **Table 3**. The status indicates five sites have been directed to destroy or have destroyed their monitoring wells.

Table 3. Groundwater Contamination Site Details – Martis Valley

RWQCB CASE NUMBER	BUSINESS NAME	STATUS
6A290407N02	HIRSCHDALE LANDFILL	Monitor Well Destruction No Further Action Letter issued on November 8, 2005.
6A310006006	SHARP PROJECT	Status unknown.
T6S045	CALTRANS EQUIPMENT BUILDING NO. 2	Status unknown.
6T0047A	CHEVRON SS #9-0612	Active.
6T0353A	FORMER PAT & OLLIES SIERRA SUPERSTOP	Lahontan RWQCB directed Business (RP) to submit MW destruction work plan on March 8, 2016.
6T0124A	NV COUNTY FORMER DEPARTMENT OF TRANSPORTATION YARD	Site is eligible for closure. RP notified by Lahonton RWQCB to destroy monitor wells as of June 23, 2015
T6S001	DEPENDABLE TOW	Lahontan RWQCB directed Business to destroy monitoring wells on June 23, 2014.
T6S002	FORMER BERRY-HINCKLEY INDUSTRIES TRUCKEE BULK FUEL TERMINAL	Monitoring well destruction permits expired. Alternate destruction method proposed by RP; not yet approved

Note: Site status from Nevada County.

No information is currently available to assess groundwater contamination or the extent of any plumes at the remaining three sites.

4.5 Subsidence

Permanent land subsidence can occur when groundwater is removed by pumpage or drainage due to the depressurization and irreversible (non-elastic) compression of fine-grained sediments typically comprising an aquitard. There is no evidence of a regionally extensive, thick clay or fine-grained units; or any units that would be considered to be very compressible if depressurized. Limited data on land subsidence within the MVGB is available, but no indications of land subsidence have been reported in the documents reviewed as part of the Martis Valley Groundwater Management Plan (TDPUD, NCSD, PCWA, 2013). Furthermore, there has been no evidence of drawdown of a magnitude that would create significant subsidence locally or regionally. Thus, given the basin geology and lack of groundwater depletion, subsidence is highly unlikely to cause any undesirable impacts in the MVGB.

4.6 Change in Groundwater Storage

A spreadsheet analysis of the MVGB water budget was recently developed to estimate the sustainable yield for the basin (GEI, 2016). Due to the late release and complexity of the DRI watershed model, this work was performed to assess the historic and current sustainable management of the basin. **Figure 15** depicts estimates of the annual and cumulative change in groundwater in storage, based on the best available data between approximately 1991 through 2015. The analyses and data used to generate this figure are further detailed in Section 5 as well as in the report included as **Appendix D**.

A relative measure of the cumulative change in groundwater storage was also estimated from observed changes in groundwater levels from CASGEM monitoring wells from Spring 1996 through Spring 2016. **Figure 16** presents the interpolated change in water level throughout the bulk of the MVGB and shows that groundwater levels have risen over the past 20 years throughout the majority of the basin, and, therefore, the change in storage is positive.

The greatest rises in water levels, in excess of 50 feet, were observed at wells 17N16E13K001M and 17N16E11F001M, located to the south and north of the Truckee River in the central portion of the basin. These changes are likely due to nearby reductions in pumping. There is a small area of reduction in groundwater storage in the far southern portion of the basin on the order of about 10 to 20 feet. This reduction has occurred during a period of dry climatic conditions coinciding with pumping at new municipal well locations. This area of storage change has already been further investigated by NCSD with a project designed to assess any potential impacts of local NCSD pumping on streamflow as well as groundwater reserves (Stantec, 2016; Appendix E). This quantifiable change in storage is based on two monitoring wells out of 11 with long-term water level data and is adjacent to the southern edge of the MVGB.

4.7 Interconnected Surface Water

Figure 11 identifies the gaining and losing reaches along the major creeks and Truckee River within the MVGB. It is apparent from the figure that the majority of the reaches of the Truckee River and Martis Creek are interconnected with the shallow aquifer and are receiving inflows from groundwater. Groundwater discharges at springs also support perennial flows in Martis Creek tributaries to the east and inflows directly to Martis Reservoir (TDPUD, NCSD, PCWA, 2013). Other Truckee River tributaries, including Cold Creek, Donner Creek, and Trout Creek have also been concluded to be supported by groundwater inflows. These findings are documented in both the 2013 MVGB GMP and in a study performed by Interflow (2003). Recent drought conditions have shown that baseflow in the Truckee River continues to be supported by groundwater inflow (**Figure 11**) in conjunction with releases from reservoirs when discharges from upstream surface water sources, such as releases from Tahoe Dam, are curtailed or shut off (USGS stream gaging Station No. 10338000).

Although the MVGB aquifer and surface water features are interconnected, there have not yet been quantified evidence of streamflow depletions that have produced undesirable results. Additionally, the MVGB is under the purview of the Truckee River Operating Agreement (TROA).

4.8 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems are generally defined as ecologies dependent upon groundwater inflow along creeks, the Truckee River, at springs and seeps, and into wetland areas in the MVGB (**Figure 11)**. Due to observed regional conditions of stable or rising groundwater levels and a quantifiable increase in cumulative groundwater storage both temporally and spatially there is no evidence based upon water level information that groundwater demand has reduced inflows to groundwater dependent ecosystems.

The recent study by Stantec (2016), included as Appendix E, presents data from a recent investigation of surface water and groundwater interaction near NCSD and TDPUD wells close to the southern boundary of the MVGB (**Figure 2**). No quantifiable impact to surface water features was reported as a result of this work. Continuing studies within the basin will monitor the potential for localized impacts to sensitive basin ecologies. Historic dry years and drought conditions have impacted surface water flows, inflows from reservoirs outside of the basin, and groundwater recharge throughout the MVGB; however, the effects of climate are independent from historic groundwater usage and have been partially offset by reductions in pumping in recent years (GEI, 2016).

5 Water Budget

A water budget analysis was performed for the period 1990 through 2014 to further refine previous estimates of groundwater sustainable yield (GEI, 2016; **Appendix D**). This analysis leveraged previous work, including the 2013 Martis Valley GMP (TDPUD, NCSD, PCWA, 2013) and review of numerous previous groundwater studies focusing on sustainable yield and recharge within the basin. The water budget assessment was based upon calendar years and considered deviation from mean annual precipitation over the timeframe of the analysis, allowing for comparison of shifts in the various components of the water budget as a result of annual climatic conditions. The estimated sustainable yield and water budget components documented in this report are the most recent and thorough assessment of the water budget for the MVGB. It also provides an improved degree of confidence in the sustainable yield when assessing groundwater development in the basin within the SGMA framework as recent groundwater production volumes were obtained from municipalities.

5.1 Previous Studies

Previous studies that provide historic hydrogeologic and groundwater availability estimates, not necessarily sustainable yield, for the basin. Water balances were estimated by some studies, but there are some slight differences in the terminology and analytical approaches. Generally, over time the amount of what may be interpreted to be the basin sustainable yield has been revised upward. The following is a summary of pertinent estimates from previous work in the MVGB:

- Hydro-Search, 1995 – estimated a <u>maximum groundwater withdrawal</u> of 13,700 AFY.
- Nimbus, 2001 – estimated <u>available groundwater</u> to be ~24,700 AFY, but could be higher.
- Antonucci, 2002 – made projections of 19,000 AFY of <u>groundwater pumping</u> needed at build-out.
- Kennedy Jenks, 2002 - generally agrees with Nimbus but suggests <u>available groundwater</u> is about 24,000 to 27,000 AFY.
- InterFlow Hydrology, 2003 - estimated that the total amount of groundwater potentially available for use in Martis Valley on a <u>long-term sustainable basis</u> exceeds 34,000 AFY.
- Rajagopal and others, 2012 - estimated <u>groundwater recharge</u> with MVGB to be about 33,000 AFY.

The integrated surface water and groundwater model developed by the Desert Research Institute of Reno, Nevada utilized the Precipitation Runoff Modeling System (PRMS), a surface water routing model developed by the U.S. Geological Survey (USGS) to estimate runoff, evapotranspiration, and the amount of deep percolation through the soils (groundwater recharge). DRI prepared the PRMS model for the entire Martis Valley watershed then coupled it with a simplified groundwater flow model (MODFLOW) that includes the MVGB. DRI prepared a Technical Note (Appendix F of the GMP) and final report (Rajagopal and others, 2015; **Appendix B**) that summarize model development and the model estimated amount of groundwater recharge from precipitation. However, neither report provides a full water budget for the groundwater basin. Preliminary estimates of recharge from precipitation were provided for the 2013 Martis Valley GMP, although they were adjusted during later model refinements that have only recently been provided to TDPUD. Due to the emphasis of this modeling effort on watershed conditions, potential climate changes, and surface water flow modeling; the primary components of this study that were used in GEI's water budget analysis were only related to historic and current groundwater recharge within the MVGB.

The water budget analysis documented by GEI in 2016 quantified the total water entering and leaving the basin by water source type and includes: 1) *Inflows* to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as: lakes, streams, rivers, and springs; 2) *Outflows* from the groundwater system by water use sector, including evapotranspiration, groundwater pumping, groundwater discharge to surface water sources, and subsurface groundwater outflow (GEI, 2016). Because inflow and outflow from the basin occurs through bedrock areas, USGS gaging data at the basin boundaries were used to constrain the analysis. The water budget was compared to trends in observed groundwater levels to further support estimates of change in storage and confirm that water budget trends agree with measured groundwater level responses. In the future, additional investigations may be warranted to further refine estimates of water budget components that lack quantifiable measurements or have a higher degree of uncertainty. The modeling data developed by DRI may also be utilized in the future to further refine components of the water budget, if needed.

5.2 Water Budget

Tables 1A and 1B provide the estimated water budget for the MVGB. The water budget values are color coded to highlight values that were measured or have been previously estimated and, thus, have a higher level of certainty (black font). Values that have not been previously measured or estimated are shown in a purple font. Water budget components with less certainty were typically copied or adapted from previous years where quantifiable estimates were reported or set at average annual estimates and distributed throughout the water budget; these are shown in blue font.

The following discussion describes the historic water budget inflow and outflow components and degree of certainty given available data sources. All data was compiled on an annual basis, not water year.

The water budget shows the largest inflow component (about 53 percent) is from the Truckee River, Donner Creek, and Boca Reservoir. All of these sources have USGS gaging stations. The next largest component of inflow is precipitation which was derived from the PRMS modeling. These four sources represent 76 percent of total inflows to the basin with high data quality. The next largest component of inflow is from Prosser Creek. These five sources account for 92 percent of the total hydrologic inflows to the MVGB (**Table 1A**).

The water budget shows the largest outflow component (about 80 percent) is along the Truckee River, which is gaged. The next highest component is evapotranspiration (18 percent), which was has a higher degree of uncertainty due to using average reference ETo values and rough estimates of acreage. Municipal groundwater pumping averaged about 7,000 AFY from 1990

Table 1A
Martis Valley Groundwater Basin Water Budget
(in Acre-Feet per Calendar Year)

Groundwater Level Records - from Water Data Library

GSP Regulation Base Period for Evaluation (10 yr historic)

Calendar Years	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Water Year Type Based on Precipitation	C	BN	C	AN	BN	W	W	BN	W	AN	BN	BN	BN
Inflow													
Precipitation Total	65,000	150,000	120,000	105,000	95,000	175,000	80,000	230,000	180,000	200,000	190,000	170,000	125,000
Surface Water:													
Truckee River (USGS 10338000)	16,755	152	101	95,061	23,602	22,171	203,284	597,807	462,057	433,097	201,996	205,109	134,157
Donner Creek above Cold Creek (USGS 10338500)	14,118	13,901	9,484	35,404	8,326	53,431	44,743	39,024	39,096	33,738	22,806	9,412	20,851
Boca Reservoir (USGS 10344500)	61,106	58,716	40,110	66,536	144,872	130,030	205,978	239,934	151,244	199,534	96,799	85,215	123,008
Cold Creek (MP03)	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000
Adler Creek (MP-19)	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000
Prosser Creek (MP-22)	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000
Martis Creek (MP25)	500	500	500	500	500	500	500	500	500	500	500	500	500
West Martis Creek (MP-33)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Middle Martis Creek (MP-35)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
East Martis Creek (unknown)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Siller Ranch Springs Tributary (MP-32)	500	500	500	500	500	500	500	500	500	500	500	500	500
Monte Carlo Creek (unknown)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Ungaged surface inflow (small tributaries)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Groundwater Recharge - Adler Creek (MP-17 minus MP-18)	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Wastewater Recharge:													
T-TSA Import from Lake Tahoe (NTPUD, TCPUD,ASCWD,SVPSD or Granite Flats)	2,364	2,084	2,308	3,226	2,745	3,686	3,652	3,551	3,461	3,697	3,305	2,509	2,689
T-TSA Martis Valley Generated Wastewater (TSD)	1,400	1,624	1,512	1,378	1,176	1,826	1,725	1,927	2,050	1,770	1,949	2,005	2,173
Martis Valley Septic Systems (small)	485	485	485	485	485	485	485	485	485	485	485	485	485
Irrigation Deep Percolation	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Tiechert - gravel washwater discharges	319	319	319	319	319	319	319	319	319	319	318	319	319
Import NCSD Big Springs collection system	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Subsurface Inflows:													
Northstar Watershed	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220
Martis Peak Watershed	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108
Donner Lake Watershed	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008
Joint and Fracture Granites beneath Alluvium	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total Inflow	293,982	359,717	306,754	439,844	408,961	519,383	672,622	1,245,481	971,147	1,005,076	650,094	607,490	541,117

Calendar Years	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average	Percent of Total
Water Year Type Based on Precipitation	C	C	W	AN	BN	BN	BN	AN	BN	BN	C	C		
Inflow														
Precipitation Total	75,000	115,000	135,000	100,000	155,000	200,000	95,000	100,000	125,000	154,057	44,508	115,492	131,962	22.8%
Surface Water:														
Truckee River (USGS 10338000)	135,388	90,645	169,633	216,331	176,656	149,072	111,713	133,650	180,638	196,856	148,348	89,486	167,751	29.0%
Donner Creek above Cold Creek (USGS 10338500)	25,992	18,172	34,318	44,454	12,742	15,421	22,734	28,598	42,499	22,734	10,426	12,887	25,412	4.4%
Boca Reservoir (USGS 10344500)	82,826	108,672	45,033	229,001	99,188	103,242	70,373	63,784	202,286	79,712	112,654	90,355	115,608	20.0%
Cold Creek (MP03)	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	2.2%
Adler Creek (MP-19)	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	2.4%
Prosser Creek (MP-22)	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	15.4%
Martis Creek (MP25)	500	500	500	500	500	500	500	500	500	500	500	500	500	0.1%
West Martis Creek (MP-33)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	0.4%
Middle Martis Creek (MP-35)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	0.4%
East Martis Creek (unknown)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	0.4%
Siller Ranch Springs Tributary (MP-32)	500	500	500	500	500	500	500	500	500	500	500	500	500	0.1%
Monte Carlo Creek (unknown)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0.2%
Ungaged surface inflow (small tributaries)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		0.0%
Groundwater Recharge - Adler Creek (MP-17 minus MP-18)	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	0.3%
Wastewater Recharge:														
T-TSA Import from Lake Tahoe (NTPUD, TCPUD,ASCWD,SVPSD or Granite Flats)	2,644	2,543	2,733	3,069	2,263	2,016	1,972	2,084	2,487	1,994	1,871	1,692	2,666	0.5%
T-TSA Martis Valley Generated Wastewater (TSD)	2,543	2,532	2,543	2,722	2,610	2,689	2,677	2,689	2,801	2,420	2,431	2,296	2,139	0.4%
Martis Valley Septic Systems (small)	485	485	485	485	485	485	485	485	485	485	485	485	485	0.1%
Irrigation Deep Percolation	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		0.0%
Tiechert - gravel washwater discharges	319	319	319	319	319	319	319	319	319	319	319	319	319	0.1%
Import NCSD Big Springs collection system	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		0.0%
Subsurface Inflows:														0.0%
Northstar Watershed	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	0.6%
Martis Peak Watershed	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	0.2%
Donner Lake Watershed	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	0.2%
Joint and Fracture Granites beneath Alluvium	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Total Inflow	457,631	470,804	522,499	728,817	581,699	605,680	437,708	464,045	688,949	591,012	453,477	445,448	578,778	

Table 1B
Martis Valley Groundwater Basin Water Budget
(in Acre-Feet per Calendar Year)

Groundwater Level Records - from Water Data Library

GSP Regulation Base Period for Evaluation (10 yr historic)

Water Year Type Based on Precipitation	C	BN	C	AN	BN	W	W	BN	W	AN	BN	BN	BN
Calendar Years	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Outflow													
Surface Water Outflow													
Truckee River at Boca Bride Nr Truckee (USGS 10344505)	317,825	245,809	193,433	669,576	177,363	966,570	779,684	799,920	731,475	720,761	418,411	201,766	372,582
Groundwater Pumping:													
Truckee-Donner PUD (Total Potable)	3,206	3,221	3,258	3,272	3,653	3,389	3,758	3,930	3,949	4,566	4,859	5,208	6,423
Truckee-Donner PUD (Irrigation)	0	0	0	0	0	0	0	0	0	0	0	257	230
PCWA Lahontan (Zone 4)	0	0	0	0	0	0	0	0	0	35	31	7	5
Northstar Comm Services District	0	0	0	0	0	0	0	0	0	0	0	0	0
Schaffer's Mill Golf Course	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenshire Mutual Water Co	835	835	835	835	835	835	835	835	835	835	835	835	0
Donner Creek Mobile Home Park	55	55	55	55	55	55	55	55	55	55	55	55	55
Tiechert	354	354	354	354	354	354	354	354	354	354	354	354	354
Public Small Water Systems	10	10	10	10	10	10	10	10	10	10	10	10	10
Domestic Wells	180	180	180	180	180	180	180	180	180	180	182	194	200
Evapotranspiration (EVT)													
Golf Courses:													
Truckee Falls Golf Couse (now Coyote Moons)													
Coyote Moon Golf Course													
Lahontan Golf Club (2000 19 holes, 2015 27 holes)													
Ponderosa Golf Course (openned 1961)													
Northstar at Tahoe (approx. 1/3 out of basin)													
Tahoe-Donner													
Old Greenwood Golf Club													
Martis Camp Club													
The Timilick Club/Schaffer's Mill													
The Golf Club At Gray's Crossing													
Tahoe-Truckee Unified School District Turf Fields													
Residential Landscapes													
Native vegetation:													
Forest	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504
Sagebrush	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130
Wetlands (vicinity Martis Creek)	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540
Riparian													
Evaporation (surface water bodies)													
Prosser Reservoir	340	340	340	340	340	340	340	340	340	340	340	340	340
Martis Creek Lake	60	60	60	60	60	60	60	60	60	60	60	60	60
Truckee River	160	160	160	160	160	160	160	160	160	160	160	160	160
Pond in Glenshire subdivision	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Dry Lake adjacent to Waddle Ranch Preserve	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gooseneck Reservoir near Lahontan Golf Club	25	25	25	25	25	25	25	25	25	25	25	25	25
Union Mills	14	14	14	14	14	14	14	14	14	14	14	14	14
Tiechert - washwater pond	35	35	35	35	35	35	35	35	35	35	35	35	35
Donner Quarry Ponds	48	48	48	48	48	48	48	48	48	48	48	48	48
Subsurface Outflow													
Juniper Creek	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
To Truckee River	200	200	200	200	200	200	200	200	200	200	200	200	200
Groundwater Transfer out of Groundwater Basin (snow making)													
Total Outflow	427,521	355,520	303,181	779,338	287,506	1,076,449	889,932	910,340	841,914	831,852	529,791	313,742	484,915
Total Inflow - Outflow = Change-in-Storage	-133,539	4,197	3,573	-339,494	121,455	-557,066	-217,310	335,141	129,234	173,223	120,302	293,748	56,202
Groundwater	-125,223	4,183	3,505	-339,702	121,756	-557,423	-219,524	337,551	129,360	173,082	120,285	295,423	56,676
Surface Water													
Prosser Reservoir	-8,309	11	73	205	-298	347	1,222	-1,418	-131	146	20	-1,690	-470
Martis Creek Reservoir	-7	3	-5	3	-3	10	992	-992	5	-5	-3	15	-4
Truckee River	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Cumulative Groundwater Change-in-Storage	-125,223	-121,039	3,573	-339,494	121,455	-557,066	-217,310	335,141	129,234	173,223	120,302	293,748	56,202

Water Year Type Based on Precipitation	C	C	W	AN	BN	BN	BN	AN	BN	BN	C	C		
Calendar Years	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average	Percent of Total
Outflow														
Surface Water Outflow														
Truckee River at Boca Bride Nr Truckee (USGS 10344505)	371,846	310,524	413,838	708,289	348,099	333,981	286,487	346,362	633,934	380,172	341,366	243,916	452,560	80.2%
Groundwater Pumping:														
Truckee-Donner PUD (Total Potable)	6,454	7,128	6,668	7,426	7,195	6,978	6,639	5,722	5,313	5,727	5,674	5,149	5,151	0.9%
Truckee-Donner PUD (Irrigation)	223	256	200	239	271	275	335	603	549	841	636	699	225	0.0%
PCWA Lahontan (Zone 4)	30	52	44	73	79	160	141	122	88	90	117	144	49	0.0%
Northstar Comm Services District	0	0	0	0	0	200	398	142	146	219	224	274	64	0.0%
Schaffer's Mill Golf Course	0	0	0	0	0	0	0	0	258	254	275	236	41	0.0%
Glenshire Mutual Water Co	0	0	0	0	0	0	0	0	0	0	0	0	835	0.1%
Donner Creek Mobile Home Park	55	55	55	55	55	55	55	55	55	55	55	55	55	0.0%
Tiechert	354	354	354	354	354	354	354	354	354	354	354	354	354	0.1%
Public Small Water Systems	10	10	10	10	10	10	10	10	10	10	10	10	10	0.0%
Domestic Wells	204	208	212	216	223	220	220	220	220	220	220	220	199	0.0%
Evapotranspiration (EVT)														
Golf Courses:														
Truckee Falls Golf Couse (now Coyote Moons)														
Coyote Moon Golf Course														
Lahontan Golf Club (2000 19 holes, 2015 27 holes)														
Ponderosa Golf Course (openned 1961)														
Northstar at Tahoe (approx. 1/3 out of basin)														
Tahoe-Donner														
Old Greenwood Golf Club														
Martis Camp Club														
The Timilick Club/Schaffer's Mill														
The Golf Club At Gray's Crossing														
Tahoe-Truckee Unified School District Turf Fields														
Residential Landscapes														
Native vegetation:														
Forest	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	12.3%
Sagebrush	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	5.7%
Wetlands (vicinity Martis Creek)	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	0.3%
Riparian														
Evaporation (surface water bodies)														
Prosser Reservoir	340	340	340	340	340	340	340	340	340	340	340	340	340	0.1%
Martis Creek Lake	60	60	60	60	60	60	60	60	60	60	60	60	60	0.0%
Truckee River	160	160	160	160	160	160	160	160	160	160	160	160	160	0.0%
Pond in Glenshire subdivision	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Dry Lake adjacent to Waddle Ranch Preserve	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Gooseneck Reservoir near Lahontan Golf Club	25	25	25	25	25	25	25	25	25	25	25	25	25	0.0%
Union Mills	14	14	14	14	14	14	14	14	14	14	14	14	14	0.0%
Tiechert - washwater pond	35	35	35	35	35	35	35	35	35	35	35	35	35	0.0%
Donner Quarry Ponds	48	48	48	48	48	48	48	48	48	48	48	48	48	0.0%
Subsurface Outflow														
Juniper Creek	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0.2%
To Truckee River	200	200	200	200	200	200	200	200	200	200	200	200	200	0.0%
Groundwater Transfer out of Groundwater Basin (snow making)									598	598	598	598	598	0.1%
Total Outflow	484,232	423,642	526,437	821,717	461,341	447,288	399,696	458,646	746,582	493,597	454,585	356,711	564,259	
Total Inflow - Outflow = Change-in-Storage	-26,601	47,161	-3,938	-92,900	120,358	158,391	38,013	5,399	-57,632	97,415	-1,108	88,738	14,519	
Groundwater	-28,801	52,212	-12,772	-88,908	123,066	155,531	38,193	6,058	-58,318	97,245	2,141	86,408	14,880	
Surface Water														
Prosser Reservoir	2,210	-5,048	7,588	-2,750	-2,701	2,859	-185	-674	671	195	-3,300	2,305	-365	
Martis Creek Reservoir	-10	-3	1,246	-1,242	-7	1	5	15	15	-25	51	25	3	
Truckee River	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Cumulative Groundwater Change-in-Storage	-26,601	47,161	-3,938	-92,900	120,358	158,391	38,013	5,399	-57,632	97,415	-1,108	88,738		

Notes:

Black font = Are published values from USGS, historic reports, Partners files,

Purple font = Estimated values

Blue font = Average annual water balance components

---- = Water balance components that are considered to have neglible values or cannot be estimated reliabiably at this time

through 2014 and represents less than 2 percent of the total average annuual outflow from the basin (**Table 1B**).

As illustrated in the water budget, flows in the Truckee River do not correlate to annual precipitation classifications. This is due to managed releases from storage in Lake Tahoe and other reservoirs that supply flow to the Truckee River.

The average annual groundwater change in storage based on the water balance is approximately an increase of 15,000 AFY. The annual range in estimates is rather wide and future refinements of the water balance are warranted (such as using PRMS/MODFLOW estimates of groundwater uptake by vegetation) to better balance storage and evapotranspiration estimates. Because there are surface water reservoirs in or associated with MVGB hydrologic conditions, change-in-storage in the reservoirs is also taken into account.

To validate the water budget estimates against measured data, average groundwater levels from CASGEM monitoring wells were used as a surrogate to quantify the groundwater change in storage. **Figure 15** shows a plot of the cumulative change-in-storage in comparison to the groundwater levels. The change in groundwater levels trends fairly well with the cumulative water budget for years 1990 through 2000. The water budget does not fully replicate the change in groundwater levels from 2000 to 2009. Although it does generally match the relatively stable water level conditions from 2002 to 2006, the water balance is over predicting the amount of surplus water with respect to average water level change for portions of this time period. This was during the time when most of the golf courses and housing developments were constructed. Further evaluation of construction water pumping and evapotranspiration could improve the budget calibration. From 2009 through approximately the end of 2014, average groundwater levels generally rise then stabilize, similar to the trend in storage estimates.

The water budget inflow components are 74 percent quantified with high quality gaging data and percent recharge from precipitation from the recent PRMS modeling, with respect to the average estimated annual water budget volume (**Table 1A**). Quantifying inflows from Prosser Creek would improve the inflow characterization to over 90 percent. Water budget outflow components are over 80 percent quantified with high quality gaging and metered flows from municipal water supplies. Better quantification of evapotranspiration, by obtaining this component from the DRI modeling, would improve the budget outflow certainty to close to 98 percent. Regardless, the quantifiable understanding of the average annual hydrologic water budget for the MVGB is high. This is in part because the groundwater basin inflows and outflows at the Truckee River can be accurately quantified as they occur where the river and creeks encounter shallow bedrock with limited subsurface underflow, and the MVGB does not share a boundary with a neighboring groundwater basin and does not have the uncertainty associated with groundwater underflow estimates between basins.

5.3 Sustainable Yield

The definition of sustainable yield varies somewhat throughout the historic literature and from state to state.

The Sustainable Groundwater Management Act of 2014, defined sustainable yield as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." Undesirable results are a significant and unreasonable effects caused by groundwater conditions in the basin, such as: chronic lowering of groundwater levels, loss of storage, subsidence, seawater intrusion, degradation of water quality and depletion of interconnected surface water. Undesirable results are defined locally and consider estimates of future groundwater demand.

Annual groundwater pumping estimates during the base period of the GEI sustainable yield study (2016) ranged from a minimum of 4,640 AF in 1990 to a maximum of 8,370 in 2006. The average annual groundwater extractions through the calibration period is on the order of 7,000 AFY. The water budget estimates that the basin has an average annual surplus of about 15,000 AFY, with a plus or minus uncertainty level of about 20 percent. Adding the surplus to the existing pumping suggests that the sustainable yield is about 22,000 AFY (GEI, 2016).

5.4 Projected Water Budget

Future groundwater demands are documented in the most recent 2015 TDPUD Urban Water Management Plan (included with the Alternative Submittal materials from TDPUD), and estimate approximately 13,000 AFY of groundwater demand at the end of their planning horizon in 2035 (buildout). This value includes all groundwater demands in the MVGB and is well below the sustainable yield estimate of 22,000 AFY. Also TROA limits total net depletion of water in Martis Valley to approximately 17,600 AFY for surface water and groundwater, which is also greater than the total projected annual groundwater demand.

DRI's integrated surface water and groundwater modeling study considered the impacts of various future climatic conditions. This information provides helpful guidance for future management of the basin; however, as cited in the report, climatic changes likely have a much larger impact on surface water resources than groundwater demand, given that it only comprises approximately 2 percent of the basin-wide water budget at buildout. The fact that projected demands fall well below both the estimated sustainable yield and the TROA total net depletion quantity also give further buffer for groundwater management practices to offset future deviations from historic trends.

6 Sustainable Management Criteria

There is only one management area in the MVGB, covering the full extent of groundwater resources within the basin boundary. As such, relevant sustainable management criteria were developed for the basin as a whole. The hydrologic data previously presented in this report were used to assess if the groundwater basin has historically been managed in a sustainable manner with respect to balancing groundwater demands and the six primary Sustainability Indicators (SIs). Emphasis was placed on quantifiable historical measurements and analyses geared to substantially comply with SGMA regulations. The following presents a summary of sustainability goals; locally defined undesirable results; and suitable quantitative sustainability criteria, including both minimum thresholds and measurable objectives. Given the data currently available, the selected thresholds and objectives are deemed appropriate to maintain sustainable conditions per the SIs specified in SGMA. They are also intended to guide future monitoring, management, planning, and collaboration activities by providing a framework to detect and address any undesirable results.

6.1 Sustainability Goals and Management Objectives

The sustainability goals for the MVGB, as it relates to the following analyses, are meant to support the long-term quality and availability of groundwater in the MVGB (TDPUD, NCSD, PCWA, 2013). Additionally, the groundwater basin is to be managed in such a manner that no pervasive, significant and unreasonable effects are observed for the SGMA defined SIs; in particular, 1) no chronic and unreasonable lowering of groundwater levels and associated reduction in storage and 2) no significant depletions of surface water features that would adversely impact flows or their dependent ecosystems. Although there is currently no evidence of undesirable impacts related to water quality, seawater intrusion, or subsidence; these SI's will be tracked via ongoing groundwater and water quality monitoring programs. The following management objectives and sustainable criteria are intended to maintain sustainable groundwater conditions through the year 2042 and beyond.

Basin Management Objectives (BMO's) were developed for the MVGB as a part of the GMP, are intended to continue to support sustainable groundwater resources, and also address many of the sustainability goal guidelines provided in the SGMA regulations for a GSP (TDPUD, NCSD, PCWA, 2013). The previously defined BMO's, which serve as a precursor to SGMA sustainability objectives, are listed below:

- Manage groundwater to maintain established and planned uses.
- Manage groundwater use within the provisions of the Truckee River Operating Agreement (TROA).
- Collaborate and cooperate with groundwater users and stakeholders in the MVGB.
- Protect groundwater quantity and quality.
- Pursue the best available science and technology to inform the decision making process.
- Consider the environment and participate in the stewardship of groundwater resources.

6.2 Locally Defined Undesirable Results

Given the historical stability and sustainability of groundwater conditions within the basin, as indicated by the previously presented groundwater elevation hydrographs and historic groundwater budget estimates, there have been no quantifiable undesirable results observed in basin. A sustainable basin status has persisted for at least 25 years of groundwater and surface water monitoring, including periods of extended dry climatic conditions and growth. Planned future groundwater development also falls short of the estimated sustainable yield, suggesting that future detrimental effects on groundwater reserves is not likely (GEI, 2016). However, processes were used to assess and identify potential undesirable results currently present or potentially occurring in the future. These processes included investigation of spatial and temporal water level trends and an analysis of the basin water budget. Sustainability criteria were considered both qualitatively and quantitatively given the data available from previous studies and ongoing field data collection efforts. Quantitative sustainability criteria, such as minimum thresholds and measurable objectives, have been set to maintain sustainable conditions for each SI while continuing to provide for beneficial uses.

6.2.1 Processes to Define Undesirable Results

Due to a lack of quantifiably observed undesirable results within the MVGB, minimum thresholds could not be directly defined from SI-specific monitoring data (GSP regulations §354.26, 2016). However, to address the absence of measured undesirable results, historical groundwater elevation trends were evaluated as a proxy, representative measurements, for the potential for adverse impacts for several SIs, including: reduction of groundwater storage, land subsidence, and depletion of interconnected surface water. Groundwater levels were selected as a proxy dataset due to approximately 25 years of historical measurements and the direct and quantifiable linkage between groundwater elevations and the previously mentioned SIs. Additional measurements or estimates of surface water flow and storage are also considered and will continue to be used as supporting evidence of meeting sustainable criteria. Should undesirable results be detected and assessed via future monitoring data and studies, such information will be used to directly establish or adjust SI measurable objectives and minimum thresholds.

The following summarizes the processes used to assess potential undesirable results:

1. Potential chronic lowering of groundwater levels involved the direct assessment of CASGEM monitoring well data. Both absolute elevations of groundwater as well as temporal trends were reviewed. Spatial trends and the groundwater flow regime were also analyzed with respect to groundwater recharge and discharge features. Future pumping in the basin at buildout (approximately 13,000 AFY) was also considered relative to recent pumping (approximately 7,000 AFY) and the sustainable yield estimate (22,000 AFY).

2. Potential reduction in groundwater storage involves an assessment of decline in groundwater levels over time using monitoring well data. Spatial distribution of water level decline has also been calculated over a given timeframe and interpolated throughout the monitored portion of the MVGB. Sustainable yield and storage estimates have been

reviewed and/or updated using recent information and previous studies. A water budget analysis was also performed during the development of the sustainable yield study and was used to assess annual and cumulative changes in groundwater storage over time (GEI, 2016).

3. Seawater intrusion was not directly assessed due to the MVGB setting (including its elevation and distance from a seawater body); however, no high salinity water has been detected in the basin since the onset of groundwater development.

4. Water quality was assessed by reviewing potential contamination sites listed on GeoTracker and by reviewing water quality information provided by municipal water providers. For the few remaining contaminated sites remaining in the basin, cleanup is regulated by the California State Water Resources Control Board.

5. Land subsidence has not historically been an issue due to basin geology and lack of groundwater dewatering; however, the potential of adverse effects due to subsidence were assessed using historic groundwater water level monitoring data (temporal trends) and a geologic review of basin conditions as a proxy.

6. Potential undesirable depletions of interconnected surface water and associated impacts to ecosystems were evaluated using a variety of data sets. Initially, declines in groundwater levels at basin monitoring wells were assessed as a proxy for potential depletions of surface water flows because a lowered groundwater table can reduce inflows to surface water features. The proximity of monitoring wells to surface water flows were also considered, as pumping impacts closer to groundwater outflows can experience higher depletion rates. Secondly, flows out of the basin via the Truckee River were reviewed with respect to the overall basin water budget. This analysis also included a comparison of annual groundwater pumping versus other components of the water budget as well as the cumulative average annual water budget.

6.2.2 Locally Derived Criteria for Undesirable Results

Qualitative criteria used to define undesirable results were generally based on the following considerations. The following listing is not intended to be exclusive, and should new undesirable effects be discovered they will be assessed using existing data or a new study. Criteria for undesirable results includes:

1. Chronic lowering of groundwater levels causing:

    a. Wells to either go dry or lose functional pumping capacity;

    b. Depletion of surface water discharges that degrades surface water flows and associated ecosystems to an significant and unreasonable extent;

    c. Significant and unreasonable effort to maintain or deepen production wells;

    d. Undesirable results for other SI’s that are directly related to water level elevations.

2. Reduction in groundwater storage causing:
    a. Any of the issues presented for chronic lowering of water levels;
    b. Depletion of the aquifer to the extent that other components of the water budget are unreasonably affected;
3. Seawater intrusion causing:
    a. Degradation of drinking water supplies;
    b. Degradation of freshwater surface water features in the basin.
4. Degraded water quality causing:
    a. Drinking water quality to exceed state and federal drinking water standards;
    b. A threat to human health via contact or consumption.
5. Land subsidence causing damage to infrastructure, such as: roadways, pipes, sewers or buildings.
6. Depletions of interconnected surface water due to groundwater pumping causing:
    a. Flows in the Truckee River to violate the conditions of TROA;
    b. Unreasonable harm to local ecosystems due to local pumping;
    c. Drying up of creeks, streams, or wetlands that are groundwater dependent (neglecting influence of drought, typical seasonal fluctuations and retention of surface water in reservoirs)

6.3 Minimum Thresholds and Measurable Objectives

Quantifiable, numeric values for minimum thresholds and measurable objectives have been developed for each SI based upon the available hydrologic and geologic data for the MVGB. Sustainability thresholds and measurable objectives were established to avoid the undesirable results previously discussed. However, due to the relative stability of groundwater conditions in the basin, and lack of empirical evidence of undesirable results due to pumping, conclusions as to what could produce undesirable results are largely derived from assessments of historic water level elevations, estimated water budget components, and a comparison of basin pumping to sustainable yield. Basin water budget and sustainable yield are previously discussed in Section 5. Management thresholds have also been established to allow for proactive management activities to be initiated should water levels drop below the measurable objective and approach the minimum threshold. The management thresholds provide an “early warning” for groundwater managers and are intended to prevent specified undesirable results and address unexpected changes in sustainable conditions before minimum thresholds are breached.

6.3.1 Historic Groundwater Levels

Because groundwater level monitoring data is used as a proxy to assess potential undesirable results for several SIs, an analysis of previous groundwater level trends was performed. This allowed for a better understanding of long term groundwater conditions as well as the impact of drought and facilitated greater understanding of the current status of the basin. Minimum thresholds and measurable objectives were derived using this data review as background. Groundwater elevation hydrographs, provided on **Figure 12,** illustrate that regional groundwater levels have remained fairly stable in the MVGB. There are some fluctuations in water levels both up and down at a few wells, but a period of sustainable, regional groundwater levels is apparent for the entire period of monitoring, approximately 1991 through Spring 2016. From visual inspection of the hydrographs, groundwater levels from the majority of monitoring wells exhibit very little variation over time or have risen; with a minority of wells showing a minor decline in Fall season water levels during the recent drought (extending generally from 2010 through 2015) before rebounding by Spring 2016.

To better assess localized groundwater level trends, the hydrographs were normalized to show all data centered about a common x-axis. **Figure 17** presents the deviation of groundwater levels from the mean elevation for each monitoring well over the period of its data record. This essentially normalizes the water levels values to deviations from the mean and allows for a closer inspection of temporal water level trends and fluctuations for all wells on a single chart. Normalized water levels measured at three TDPUD wells are shown on **Figure 18**. These wells have a shorter monitoring timeframe that includes recent, extended drought conditions.

Nine of the 14 monitoring wells varied from their mean observed water level by less than 10 feet. This includes both seasonal low and high water levels as well as periods of sustained drought. The three TDPUD wells did exhibit variations from their mean groundwater levels greater than 10 feet; however, these wells are municipal production wells and show greater influence of recent pumping and groundwater rebound at those locations. By Spring 2016, all measured water levels were above their average for the drought years of Fall 2011 through Spring 2016. Thus, these wells were deemed to be relatively stable, although they did show apparent drought-related decline and rebound in 2016 during more wet conditions. Given the general range of fluctuation about the mean water level for all monitoring well water levels over approximately a 25-year period, a general range of +/- 10 feet about the mean elevation was selected as a stability criterion to better identify well locations that exhibited greater variations over time.

From inspection of **Figure 17**, two wells (17N16E11F001M and 17N16E13K001M; locations shown on **Figure 2**) exhibit a substantial rise in groundwater elevations over the monitoring time frame with respect to other monitoring well data. By Spring 2016 water levels for both wells exceed the historic mean by over 35 feet. Thus, when considering the total ensemble of monitoring well data, groundwater elevations in 13 wells out of 14 can be classified as either stable or substantially higher than their average value by 2016 (11 within the stability range by Spring 2016 and two trending upwards). This indicates that over 90 percent of the wells in the basin have water level elevations that are quantifiably stable (+/- 10 feet) and within sustainable limits, given that no undesirable effects have been observed due to groundwater pumping over the same time period.

Three monitoring wells (17N17E19K001M, 17N17E29B001M, and 17N16E13K001M; **Figure 19**) exhibit a slight downward trend in groundwater elevations over the recent drought-impacted years. However, water level elevations for two of these wells are back within the +/-10 foot stability range by Spring 2016 (**Figure 1**7); returning to within five feet of their 25-year average values even after years of drought. Only one well (17N17E19K001M) had a groundwater level in Spring 2016 that remained slightly less than 10 feet below its average elevation. This well is located approximately one mile from production wells operated by NCSD and TDPUD as well as close to tributaries to Martis Creek. Additional investigation is being performed, and Stantec (2016) has recently documented an assessment of potential causes for the observed decline (Appendix E). This study investigated the timing of groundwater level declines versus pumping and precipitation history, as well as information on nearby stream and spring flows and a local piezometer monitoring network. Information is also provided regarding water levels from Well 17N17E29B001M; which is stable as of Spring 2016 and is located close to NCSD well TH-1 (**Figure 2**). Well 17N16E13K003M has a depth of 274 feet and is adjacent to the Truckee Tahoe airport. It is located at the same site as monitoring well 17N16E13K001M, which is screened to 485 feet and has a substantially different water level trend over time (large rise in water levels) as well as significantly higher groundwater elevation measurements. Investigation of this site revealed two uncapped wells. Additionally, groundwater water elevations recorded for Well 17N16E13K003M are far below those recorded for nearby monitoring wells and are not observed in the MVGB until 1 to 2 miles downstream along the Truckee River. For the purposes of understanding groundwater flow and storage conditions, water level data from Well 17N16E13K003M has been excluded from further analyses until the well construction and data inconsistencies are resolved.

In summary, 13 of the 14 CASGEM monitoring wells exhibit quantifiably stable and sustainable groundwater conditions for a time period extending from 1991 to Spring 2016, with 9 wells exhibiting no significant fluctuation over time, two wells exhibiting substantial increases in water levels, two wells maintaining stable spring water level conditions as well as rebound from drought, and one well trending back towards its historic average water level value in 2016. The 13 monitoring wells with stable or rising groundwater levels cover a significant portion of the basin and include areas both adjacent and distal to surface water features.

Differences in seasonal (spring and fall) groundwater level hydrographs for each monitoring well can be seen in **Appendix C**. Fall hydrographs reflect a greater influence of pumping and low groundwater recharge. Spring hydrographs are more indicative of periods of lower pumping and higher groundwater recharge. In general, the fall season hydrographs should be at lower elevations relative to the spring hydrographs for a given well. If groundwater pumping is causing a chronic lowering of groundwater levels, then the fall hydrographs will diverge (downwards) from the spring season trends, causing a greater head difference between the data sets over time. For the hydrographs from the 14 CASGEM wells presented in **Appendix C**, all but two show spring hydrographs that show very similar trends to fall season groundwater levels, with no discernable divergence. This suggests that for much of the basin, there is no continuing decline in groundwater elevations due to groundwater pumping beyond typical seasonal fluctuations. This assertion assumes that pumping has not historically exceeded sustainable yield, which is regionally supported by previously presented water budget and hydrograph analyses. Two wells, 17N17E19K001M and 17N17E29B001M, both show a divergence between fall and spring water levels over time. These wells were also previously identified as showing recent declines during the recent drought. Hydrographs for well 17N17E19K001M reflects pumping from nearby TDPUD and NCSD wells (Stantec, 2016), and has shown no additional divergence between seasonal conditions over approximately the past eight years of below normal to critically dry conditions, suggesting that water levels have generally stabilized with respect to nearby pumping. Well 17N17E29B001M is immediately adjacent to a NCSD pumping well screened in a confined portion of the aquifer, and the divergence in seasonal hydrographs coincides with the onset of pumping near that location as well as below normal climatic conditions from 2007 through 2015. By Spring 2016, the seasonal divergence due to pumping was just under 30 feet and the spring season hydrograph was trending back up towards historic levels. This suggests that the season rebound of groundwater levels in this area is significant and will likely to continue without drought conditions.

Overall, a comparison of the seasonal groundwater hydrographs show that the MVGB is regionally stable with respect to pumping impacts on water levels. There is a localized area near municipal pumping wells near the southern basin boundary that has been influenced by recent pumping changes and/or new wells; however, recent data indicates that the aquifer may be stabilizing with respect to the current pumping regime.

6.3.2 Chronic Groundwater Level Declines

No temporally pervasive, significant and chronic declines in groundwater elevations have been observed over the historic period of monitoring. Thresholds and measurable objectives were assigned using historic observed trends and fluctuations in water levels and the conceptual hydrogeologic understanding of the basin. The quantitative sustainability criteria vary spatially to address local hydrogeologic conditions and also consider potential changes over time, such as the onset of a drought or short term periods of altered pumping distributions. Given the criteria used to quantify undesirable results, presented in Section 6.2.2, measurable objectives and minimum thresholds for future groundwater level declines were established.

Groundwater elevations from Fall 2015 were used as a baseline for the majority of the monitoring wells and are shown on the hydrographs in **Appendix C**. They serve as the starting point for assigning threshold values and reflect the dry season (lower water levels) in the MVGB during extended drought conditions. These water levels were deemed to represent current, sustainable basin conditions while still reflecting recent impacts due to drought conditions or localized pumping.

Historic water level fluctuations (represented as deviation from mean values) over approximately 25 years of monitoring (**Figure 17)** were used as the basis to set *spring season water level measurable objectives at 10 feet below the Fall 2015 baseline water level* for each well. As previously discussed in Section 3.2.1, this value corresponds with the generalized lower range of historically occurring fluctuations at most monitoring wells. Thus, this allows the measurable objective to include future water level fluctuations previously observed during sustainable conditions. Additionally, this water level offset also considers the potential impact of future shifts in pumping distribution as well as water level declines caused by future drought events and additional pumping to meet demands at buildout. Spring water level measurements were selected for comparison against these criteria to negate the effect of typical seasonal fluctuations due to local pumping and recharge.

Screened intervals and depths of active and identified municipal, commercial, industrial and private wells was also considered. The 2013 MVGB GMP (Page 2-26, Figure 2-17) demonstrates that approximately 90 percent of the wells in the basin are installed to depths at or greater than 100 feet and extend below the shallow aquifer unit. This suggests that a measurable objective of 10 feet below 2015 conditions in the vicinity of CASGEM monitoring wells, which are located in the vicinity of pumping wells, is highly unlikely to impact well performance or dry up production zones. This criteria is even more conservative given the fact that municipal, commercial, irrigation and industrial production wells are installed through saturated aquifer units hundreds of feet thicker than 10 feet.

The potential to produce undesirable results for all SIs was considered in defining minimum threshold values for groundwater levels. Although no undesirable results have been quantified yet, *minimum threshold values were established for spring groundwater levels at 20 feet below Fall 2015 conditions* for the majority of monitoring wells. This value was also established by reviewing regional well depths, well hydrographs and water level deviations from mean values. **Figure 17** generally shows that groundwater levels at the monitoring wells have had limited impacts from pumping during a periods of growth, drought, and increased groundwater demand throughout the last 20 years. Pumping has also declined over the past 10 years due to infrastructure improvements (such as repair of leaking pipelines), increased efficiencies and conservation; however, should pumping increase to ~13,000 AF/year and drought conditions occur again, a 20-foot drop from 2015 levels would be a sufficient trigger to address impacts and initiate groundwater management changes. Over the period of record of monitoring well data throughout the basin, temporary declines in water levels have been observed far in excess of 20 feet (up to ~40 feet at 17N16E11F001M, which has since rebounded) while sustainable basin conditions continued to be maintained. Thus, 20 feet serves as a conservative measure to protect against undesirable conditions, while leaving some operational "space" for shifts in pumping patterns or installation of new wells adjacent to monitoring locations. A 20 foot decline from 2015 conditions at monitoring locations is also unlikely to impact pumping from the vast majority of basin wells, which are screened at or below 100 feet below land surface.

A management objective of groundwater levels 15 feet below Fall 2015 water levels has been defined to be an "management threshold" for each monitoring well. Should spring season water levels reach this threshold, investigative and potentially corrective measures will take place to determine the likely cause of and mitigate the groundwater decline, as necessary. Possible causes may include changes in the spatial distribution of pumping, overall increase in groundwater withdrawals, or multi-year drought conditions. The establishment of a management objective allows for proactive measures such as additional monitoring and studies to be performed to provide greater understanding of basin conditions and identify any potential undesirable effects from pumping. Management practices may also be implemented at this objective level to prevent the realization of undesirable results or to support refinement of minimum thresholds.

Two monitoring wells (17N16E13K001M and 17N16E11F001M, shown on Figure 2) have had recent significant rises in groundwater elevations; likely due to decreases in local pumping. To better reflect the historic, sustainable groundwater levels observed at these locations, the measurable objectives and mimimum thresholds for these two wells were *established for spring groundwater levels at 10 feet and 20 feet below Fall 2011 conditions, respectively.* These criteria allow for future water levels to be maintained at or above historic groundwater elevations, while still considering the impact of previously observed changes in pumping.

No more than 25 percent of the currently verified CASGEM monitoring wells may violate the minimum thresholds during a given year; presently this corresponds to approximately 4 monitoring well locations. This is because 1) localized and potentially temporary pumping impacts may influence water levels at various monitoring wells in a given year, 2) time is required to assess and address the cause of the decline, and 3) localized impacts may be deemed to not be producing undesirable results at a regional or local scale. Allowing groundwater conditions and potential associated undesirable results to be investigated at several monitoring well locations at a time permits and encourages local adaptive groundwater management while preserving regional groundwater sustainability.

A measureable objective is also that existing and recently installed monitoring wells in the shallow aquifer along the southern fringe of the basin or adjacent to other significant surface water features in the basin should not show a permanent change of surface water conditions from gaining to losing conditions. This criteria is intended to primarily protect localized regions where surface water features are adjacent to production wells. A change in gaining or losing surface water conditions will be quantified as shallow groundwater levels dropping below the measured stage of surface water flow or land surface elevation (in the case of springs, seeps, or wetlands), and remaining below that level during spring conditions. If drought conditions or other changes in basin hydrology (such as curtailed releases from reservoirs) are deemed to cause the change in surface water depletion, then the sustainability criteria is not violated for that localized area. Additionally, any area where depletions beyond historical seasonal fluctuations are suspected to cause a change from gaining to losing surface water conditions due to pumping must be found to be directly causing significant and unreasonable negative impacts to a sensitive, local ecosystem. For example, pumping from deeper, confined aquifer units may not locally impact surface water conditions in a significant manner.

6.3.3 Reduction of Groundwater Storage

There is no direct evidence of a significant regional reduction in storage with respect to historic water level trends. **Figure 15** shows the estimated cumulative increase in storage over time derived from the GEI (2016) water budget analysis, while **Figure 16** provides an estimated areal distribution of the change in groundwater storage during spring season conditions from 1996 to 2016, or approximately 20 years. Both the water budget and water level assessments show an increase in cumulative storage over time. Although there are localized areas of limited declines in water levels (storage) in the far southeastern and far northern portions of the basin adjacent to basin boundaries, this is regionally compensated by rises observed in other areas. Note that this time frame also includes a substantial period of below average annual precipitation from approximately 2007 through 2016 (**Figure 9**). Even considering these hydrologic fluctuations, there are no observed undesirable results from changes in groundwater storage due to groundwater withdrawals. This conclusion is further supported by the estimate that more than 90 percent of the average annual basin water budget is comprised of releases to the Truckee River and its tributaries (**Table 1A and Table 1B**). Changes in regulated surface water inflows or climatic conditions are more likely to impact groundwater and surface water reserves in the future rather than the magnitude of groundwater pumping, which currently comprises less than 2 percent of basin outflows and is not projected to exceed 3 percent of the historic water budget (Rajagopal, 2015; GEI, 2016).

Measureable objectives and minimum thresholds for groundwater storage are directly related to groundwater level monitoring data, and have been set at the same values used for potential chronic lowering of groundwater levels. If groundwater levels are maintained at sustainable levels, there should be no adverse change in groundwater storage. Additionally, future pumping demands are not projected to exceed the currently estimated annual sustainable yield of approximately 22,000 AF/year (GEI, 2016) or the TROA stipulated total net depletion of annual groundwater and surface water usage in the MVGB, or approximately 17,600 AF/year. The TROA federally mandated constraint includes both groundwater and surface water components; thus, it covers groundwater storage change that may impact surface water features.

6.3.4 Seawater Intrusion

There are no undesirable results from seawater intrusion. None are considered to be likely in the future. Thus, because negative impacts for this SI are not present nor are likely to occur in the MVGB, no minimum thresholds were established for seawater intrusion. The measurable objective is that seawater is not observed in basin production wells, the water supply from which is routinely monitored to meet drinking water standards. Refer to Section 4.3 for additional information and discussion.

6.3.5 Water Quality

Water quality in the MVGB is generally good with respect to drinking water standards. There are no large contaminant plumes identified within the basin, and naturally occurring constituents of concern, such as arsenic and manganese are being managed operationally via blending and pumping adjustments so that no drinking water standards are exceeded. No induced migration of naturally occurring constituents of concern has been detected due to historic groundwater pumping. With the sustainability criteria established for sustainable groundwater levels and storage depletion, it is unlikely that new undesirable results related to groundwater quality will be caused by future pumping because of the lack of contamination sources and the lack of induced gradient of sufficient magnitude to produce migration into potable water bearing units. The measurable objective and minimum objective for the MVGB is to produce groundwater for all municipal potable water systems that continue to meet state and federal drinking water standards. The wells that produce water that will continue to be testing for drinking water standards (for the purposes of SGMA) are shown as municipal wells on **Figure 2**.

6.3.6 Subsidence

Currently there is no evidence of land surface subsidence in the MVGB. No thick, regionally extensive, compressible, fine grained units exist in the basin. There are only limited and localized areas of limited drawdown that has occurred in the vicinity of municipal pumping wells (in the southern portion of the basin) during a drought period. Thus, no conditions that would cause subsidence have been identified. Also, if water level and storage sustainability criteria are maintained, it is highly unlikely that impacts from subsidence will be observed in the future. Because there is currently no subsidence and it is highly unlikely to occur, compliance with the minimum thresholds and measurable objectives for groundwater levels, which will limit aquifer depressurization, is the proxy threshold for subsidence.

6.3.7 Interconnected Surface Water

Declines in water levels have not been observed adjacent to the Truckee River or the majority of its tributaries in the MVGB given the historic CASGEM monitoring well data (GEI, 2016). As shown on **Figure 11**, groundwater contributes to surface water flows for the majority of surface water reaches in the basin. This contribution continued even through the recent drought conditions and highly curtailed flows to the Truckee River from the Lake Tahoe Dam. Estimated average annual pumping in the basin comprises less than 2 percent of the total basin water budget and has decreased in recent years (GEI, 2016). Even at full buildout, total pumping is estimated to comprise just over 2 percent of the average historic water budget. Thus, sufficient water will continue to be available to feed surface water features in the MVGB from a regional perspective. Any localized impacts to interconnected surface water will be detected and monitored via existing groundwater monitoring wells and piezometers (shallow and deep wells) adjacent to gaining reaches, springs, and associated ecosystems. Streamflow measurements at USGS and local stream gages in the basin (**Figure 2**) will continue to be assessed to insure that groundwater withdrawals are not producing significant and unreasonable impacts in immediately adjacent reaches or regionally.

Measurable objectives and minimum thresholds for depletions of interconnected surface water include multiple criteria to address both regional and local scale impacts. Compliance with the minimum thresholds and measurable objectives for groundwater levels, which allow substantially less groundwater level decline in monitoring wells near key surface water features, will be used as the main proxy for a measurable indicator to prevent both regional and localized impacts. These criteria are intended to allow for some variation due to drought conditions and changes in pumping rates or spatial distribution while also limiting future declines that could decrease groundwater discharges to surface water. Thresholds were also set so that future changes in water levels have little risk of turning a gaining reach (groundwater discharge) into a losing reach (groundwater recharge). The three wells selected to have more stringent minimum thresholds to help prevent undesirable depletions, they include: 17N17E07P001M, 17N17E18C001M, and 17N17E05D001M (**Figure 2**). These wells were selected due to their proximity to the river and are deemed to be good indicators of future significant and unreasonable impacts to surface water flow. As of Spring 2016, all three wells have groundwater elevations above previous drought conditions. As previously described in **Section 6.3.2**, these wells have a minimum threshold *and* measurable objective of 10 feet below the Fall 2015 measured water level elevation. Same as the minimum threshold for other monitoring wells, but with no operational zone between measurable objectives and minimum thresholds.

Declines in groundwater levels have not been observed in monitoring wells adjacent to the Truckee River or the majority of other gaining surface water reaches in the MVGB (**Figure 11 and Figure 16**). One potential exception is the area adjacent to monitoring wells 17N17E19K001M and 17N17E29B001M, both of which have exhibited modest declines of less than 20 feet and 10 feet (using spring season water levels), respectively, over the past ten years. These wells are located close to the southern boundary of the MVGB and near the upper reaches of Martis Creek. Although the cumulative drawdown in this area is meager, nearby production wells are screened down to approximately 800 feet below land surface and are sealed off from the shallow alluvium to depths where low permeability units were encounted. After the recent extended drought conditions, water levels rebounded in 2016 to elevations closer to the historic means for both wells. The recent study by Stantec (2016) assessed potential impacts of local pumping and drought on water levels and surface water flows in this area and provides data and analyses supporting the lack of evidence for significant and unreasonable surface water depletions in this area (Appendix E). The study concluded that it is likely that both drought and pumping have produced a new equilibrium in the local piezometric surface. Additional monitoring will be performed to continue to assess if there is any impact on interconnected surface water from pumping in the confined, deep aquifer. There are several areas near the perimeter of the basin that may seasonally convert from gaining to losing conditions. Likewise, there are some areas that may dry up during extended dry periods. Localized areas experiencing such conditions are not deemed to be experiencing undesired effects, as losing conditions are based upon conditions not related to groundwater pumping that have repeatedly, historically occurred in the past.

Basin-wide groundwater pumping should also remain below the minimum threshold (and measurable objective) of the estimated sustainable yield, or approximately 22,000 AFY. The water budget analysis that quantified this estimate considered both surface water and groundwater conditions, and future pumping is not projected to exceed it (GEI, 2016). Further evidence of the significance of groundwater contribution recently supporting Truckee River flows can be seen in streamgage data from 2015. Considering flows in September of 2015, which was a month that represented a period of negligible rainfall during a drought, over 25 percent of the 80.6 cubic feet per second (cfs) of flow leaving the MVGB via the Truckee River can be accounted for by groundwater discharge. This analysis subtracted all inflows to the MVGB from the Truckee River as well as all releases from gaged reservoirs that supply flow to the river.

7 Monitoring Networks

The basin has a well-established groundwater and surface water monitoring program. **Figures 1 and 2** shows the spatial distribution of the monitoring network. The following sub-sections provide a description of current and historical monitoring locations in the MVGB. These monitoring points provide the best available information for basin groundwater conditions and were used to assess potential undesirable results for all six sustainability indicators.

7.1 Surface Water

Surface water enters the basin from within the watershed and from nearby watersheds. Major creeks and rivers have gaging stations. The locations of the gaging stations used to gage inflow and outflow from the basin are shown on **Figure 1**. The measurements are obtained by the USGS and are reported on their website. The data is reported in calendar years. Minor tributaries are not gaged.

The Truckee River conveys water from the Lake Tahoe watershed into the MVGB. The river is incised into bedrock from Lake Tahoe until it reaches Martis Valley. A USGS surface water gaging station (Station No. 10338000) is present near the edge of MVGB. Another USGS gaging station (Station No. 10338500) is located along Donner Creek that measures water released from Donner Lake into the MVGB. Boca Reservoir is outside of the MVGB; however, releases from the reservoir join the Truckee River prior to the river leaving the groundwater basin. A USGS gaging station (Station No. 10344500) is present on this tributary. These three sources of surface water into the basin account for over 50 percent of the inflow to the basin.

7.2 Groundwater Levels

As shown on **Figure 2**, there are 14 CASGEM monitoring wells within the MBGB; generally located adjacent to areas of municipal pumping. The majority of these wells have recorded water levels from 1991 through present day, and reflect seasonal fluctuations as well as longer term changes due to changes in pumping and climate. Spring and fall groundwater elevation measurements should continue to be collected.

Recently, shallow alluvial piezometers have also been installed at the southern basin boundary along Middle Martis Creek. Routine monitoring of groundwater levels from spring through fall conditions should be conducted to track the presence of lack of interaction between deep aquifer groundwater levels and shallow aquifer groundwater levels and surface water flows along Middle Martis Creek.

7.3 Groundwater Production

Groundwater is currently being pumped from the basin by the TDPUD, NCSD, and private well owners. Groundwater pumping values are recorded on a monthly basis and reported by these public water agencies by calendar year. The municipal wells are metered so the data is of high quality, plus extensive groundwater level data is also available for municipal production wells.

Water quality monitoring, with respect to current drinking water standards, also occurs for water produced at the municipal well locations.

7.4 Groundwater Quality

Water quality monitoring occurs for water produced from all municipal production wells. The California Division of Drinking water establishes the schedule for water quality sampling, which may vary from quarterly to annually.

8 Conclusions

This Alternative Submittal Hydrogeology Support Study document assessed the basin setting, hydrogeologic conceptual model and water budget for the Martis Valley Groundwater Basin. Reviews and assessments of groundwater conditions and water budget for the MVGB were performed. and sustainability goals, undesirable results, and quantifiable local-scale sustainability criteria were defined with input from stakeholders. Monitoring network data was used to assess both groundwater and surface water conditions within the framework of the Sustainable Groundwater Management Act (SGMA) of 2014 and the associated Groundwater Sustainability Plan regulations (2016). The following conclusions were developed from this effort.

- Wells in the MVGB obtain groundwater from shallow alluvium, fractured Lousetown volcanic flows and interbedded sediments, and the Truckee Formation. These shallow unconsolidated sediments comprise the shallow aquifer while the deeper volcanics and sediments comprise the deep principle aquifer. Portions of the deeper aquifer exhibit confined conditions, but regionally extensive, fine grained, or competent volcanic rock confining unit have not been delineated. Faults and associated fractures in the basin may also interconnect or compartmentalize the principle aquifers. Portions of the deep aquifer geologic units are exposed at ground surface near the edges of the MVGB.

- The 14 CASGEM monitoring wells in the MVGB indicate that groundwater elevations are locally variable in the MVGB both temporally and spatially. Seasonally, the monitoring wells reflect higher water levels in the spring and lower levels in the fall, when impacts from pumping and reduced natural recharge are more apparent.

- Groundwater levels have largely remained stable in the MVGB for at least 25 years, including during the drought of the early 1990s, the wet years of the late 1990s, and recent drought conditions over the past 9 years. Changes in historical pumping and climate (wet and dry years) have affected water level trends in specific time periods, although at the basin scale any significant changes appear to be localized.

- Groundwater elevation contours and generalized flow directions for Spring 2016 are dictated by the locations of recharge zones, bounding low conductivity material, and discharge areas for groundwater along streams, the Truckee River, springs and wetlands.

- The cumulative change in groundwater storage was estimated from observed changes in groundwater levels at CASGEM monitoring wells from Spring 1996 through Spring 2016.

- The majority of the reaches of the Truckee River and Martis Creek are interconnected with the MVGB aquifer system and are receiving inflows from groundwater. Recent drought conditions have shown that baseflow in the Truckee River continues to be supported by groundwater along with releases from reservoirs, even when discharges from upstream surface water reservoirs are non-existent or severely curtailed. Evidence of streamflow depletion producing undesirable results has not been quantified by recent studies.

- The Truckee River, Donner Creek, Boca Reservoir, and Prosser Creek account for 92 percent of the total hydrologic inflows to the MVGB.

- The average annual increase in groundwater in storage based on the water balance analysis is approximately 15,000 AFY, which corresponds with the observed increase in water levels for much of the MVGB. An interpolated change in water level for the MVGB shows that groundwater levels have generally risen over the past 20 years throughout the majority of the basin; also suggesting an increase in regional groundwater storage.

- Average annual groundwater extractions in the basin since 1990 is approximately 7,000 AFY; less than one third of the estimated sustainable yield of 22,000 for the basin. Future groundwater demands are estimated at approximately 13,000 AFY at buildout in 2035. This value is also well below the sustainable yield estimate as well as below the TROA total net depletion due to water usage in Martis Valley of approximately 17,600 AFY. Thus, at the basin scale, current and future pumping will remain well within estimated sustainable levels.

- A sustainable basin status has persisted for at least 25 years of groundwater and surface water monitoring, including periods of extended dry climatic conditions. Planned future groundwater development also falls short of the estimated sustainable yield, suggesting that future detrimental effects on groundwater reserves is not likely

- Over 90 percent of the CASGEM monitoring wells in the basin have groundwater elevations that are quantifiably stable (+/- 10 feet) and indicative of sustainable conditions, given that no undesirable effects have been attributed to groundwater pumping. Groundwater levels at 13 of the 14 CASGEM monitoring wells exhibit quantifiably stable conditions for a time period extending from 1991 to Spring 2016; with 9 wells exhibiting no significant fluctuation over time, two wells exhibiting substantial increases in water levels, two wells maintaining stable spring water level conditions as well as rebound from drought, and one well trending back towards its historic average water level value in Spring 2016. The CASGEM monitoring wells cover a significant portion of the basin and include areas both adjacent and distal to surface water features.

- *Chronic Groundwater Level Declines*: Minimum threshold values were established at 20 feet below Fall 2015 water levels for most monitoring wells. Measureable objective groundwater levels were set at 10 feet below Fall 2015 water levels. Spring water level measurements should be used to compare against these criteria to negate the effect of typical seasonal fluctuations.

- No more than 25 percent of the currently verified CASGEM monitoring wells may violate the minimum thresholds during a given year; presently this corresponds to approximately 3 CASGEM monitoring wells. This allows for 1) localized and potentially temporary pumping impacts to influence water levels at various monitoring wells in a given year, 2) time required to assess and address the cause of the decline, and 3) investigation of localized conditions that may not be producing undesirable results at a regional or local scale. This condition permits and encourages local adaptive groundwater management while preserving regional groundwater sustainability.

- *Reduction of Groundwater Storage*: Measureable objectives and minimum thresholds for groundwater storage are directly related to water level monitoring data, and have been set at the same values used for potential chronic lowering of groundwater levels. Given that annual groundwater storage estimates have shown a cumulative increase, if groundwater levels are maintained at sustainable levels, there should be no adverse impacts.

- *Seawater Intrusion:* There are no currently no undesirable results from seawater intrusion. None are considered to be likely in the future given the basin setting.

- *Groundwater quality*: Water quality in the MVGB is generally good with respect to drinking water standards. There are no contaminant plumes identified within the basin, and naturally occurring constituents of concern, such as arsenic and manganese are being managed operationally via blending and pumping adjustments so that no drinking water standards are exceeded. The measurable objective and minimum objective for the MVGB is to produce groundwater for all municipal potable water systems that continue to meet state and federal drinking water standards.

- *Subsidence:* There is no evidence of land surface subsidence in the MVGB. No conditions that would cause subsidence have been identified. Because there is currently no subsidence and it is highly unlikely to occur, compliance with the minimum threshold for groundwater levels, which will limit aquifer depressurization, is the proxy threshold for subsidence.

- *Interconnected Surface Water:* Declines in water levels have not been observed adjacent to the Truckee River or the majority of its tributaries in the MVGB given the historic CASGEM monitoring well data. Groundwater contributes to surface water flows for the majority of surface water reaches in the basin and continued to do so even through the recent drought conditions and severe reduction in flows to the Truckee River at the Lake Tahoe Dam. Sufficient groundwater will continue to be available to feed surface water features in the MVGB from a regional perspective and any localized impacts to interconnected surface water will be detected and monitored via both existing groundwater monitoring wells (shallow and deep wells) and piezometers adjacent to gaining reaches, springs, and associated ecosystems. Measurable objectives and minimum thresholds for depletions of interconnected surface water include criteria to address both regional and local scale impacts. Minimum thresholds and measurable objectives for groundwater levels adjacent to the Truckee River allow for only a 10-foot decrease in spring season water levels from Fall 2015 groundwater levels. Thus, groundwater level measurements will be used as the main proxy for a measurable indicator to prevent both regional and localized impacts. These criteria are intended to allow for some variation due to drought conditions and changes in pumping rates or spatial distribution while also limiting future declines that could decrease groundwater discharges to surface water.

- Overall, the MVGB has been in a sustainable condition for at least 25 years, as demonstrated by groundwater level measurements and water budget analysis. Pumping has historically been well below the calculated sustainable yield, and is estimated to remain at approximately two thirds of this, or less, at buildout. Continued proactive groundwater management coupled with the proposed sustainability criteria will provide a means to preserve sustainable groundwater conditions while encouraging adaptive management for any unforeseen changes.

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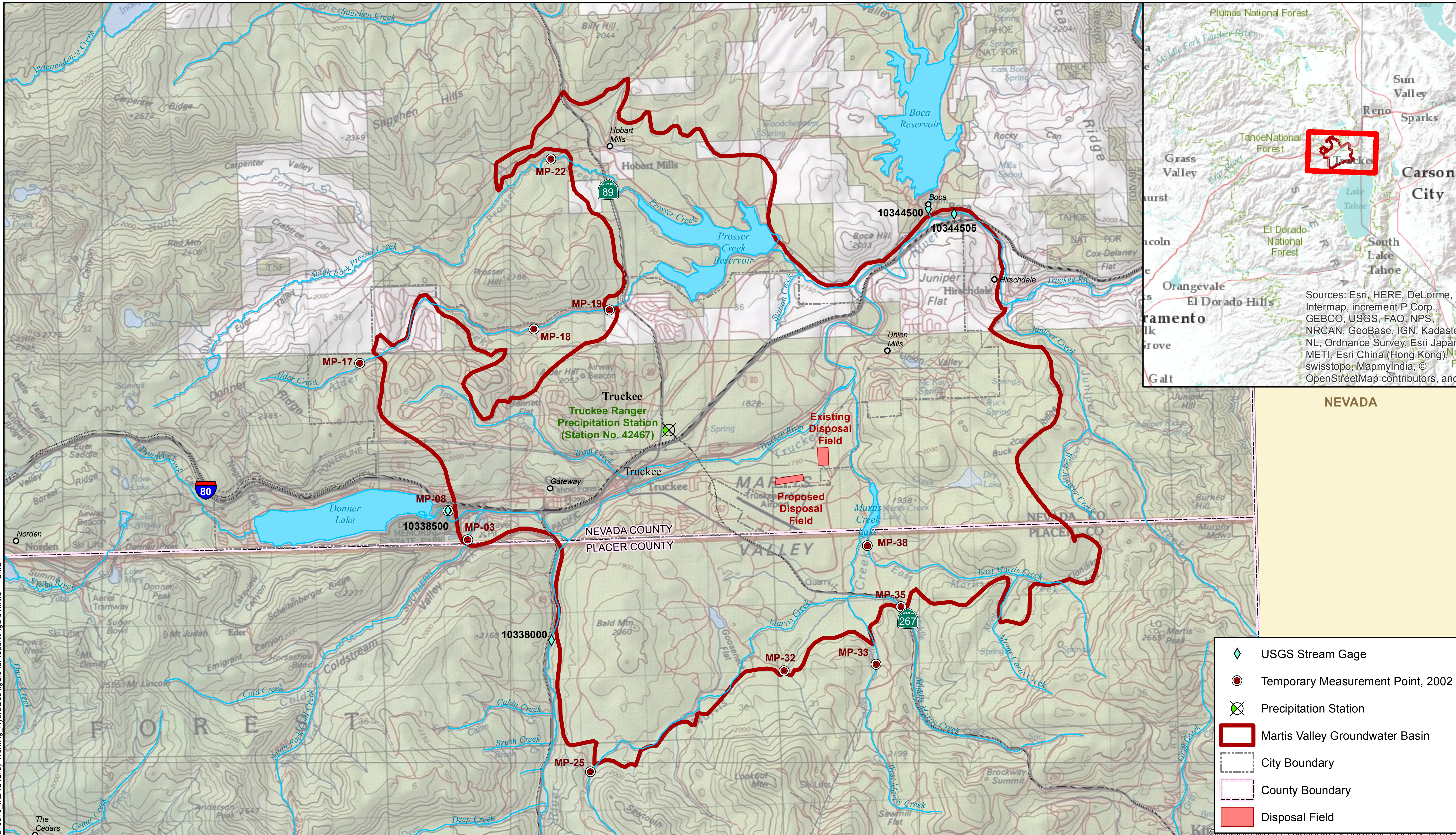
FIGURES

Alternative Submittal
Hydrogeologic Support Study
Martis Valley Groundwater Basin
Nevada and Placer Counties, California



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Martis Valley Alternative Plan
Nevada and Placer Counties, California

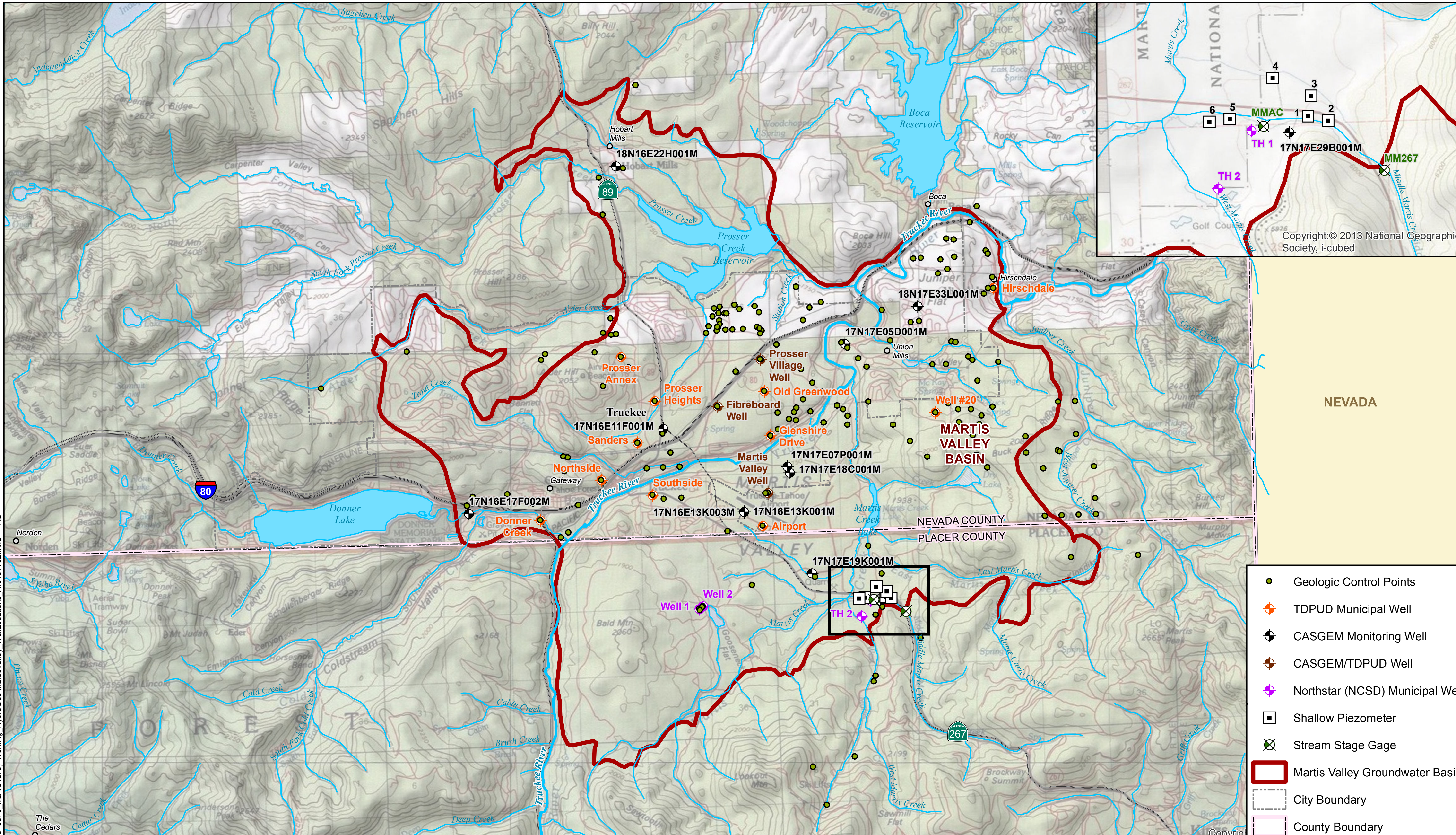
Truckee-Donner Public Utility District

GEI Consultants

MARTIS VALLEY GROUNDWATER BASIN AND PERTINENT FEATURES

NOVEMBER 2016

FIGURE 1



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Nevada and Placer Counties, California

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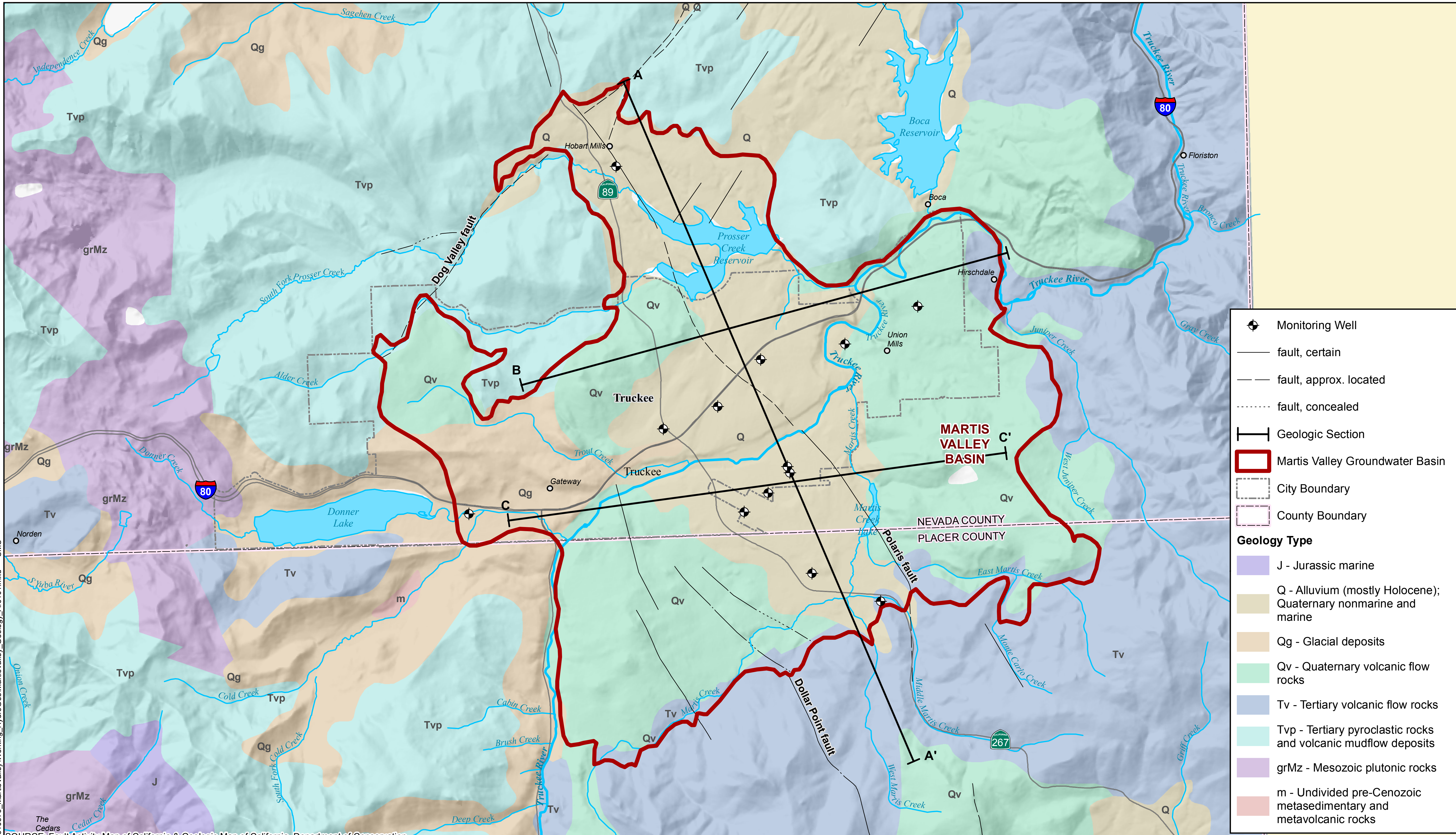
MARTIS VALLEY GROUNDWATER BASIN WELL LOCATIONS

NOVEMBER 2016

FIGURE 2



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MARTIS VALLEY GROUNDWATER BASIN GEOLOGY

NOVEMBER 2016

FIGURE 3

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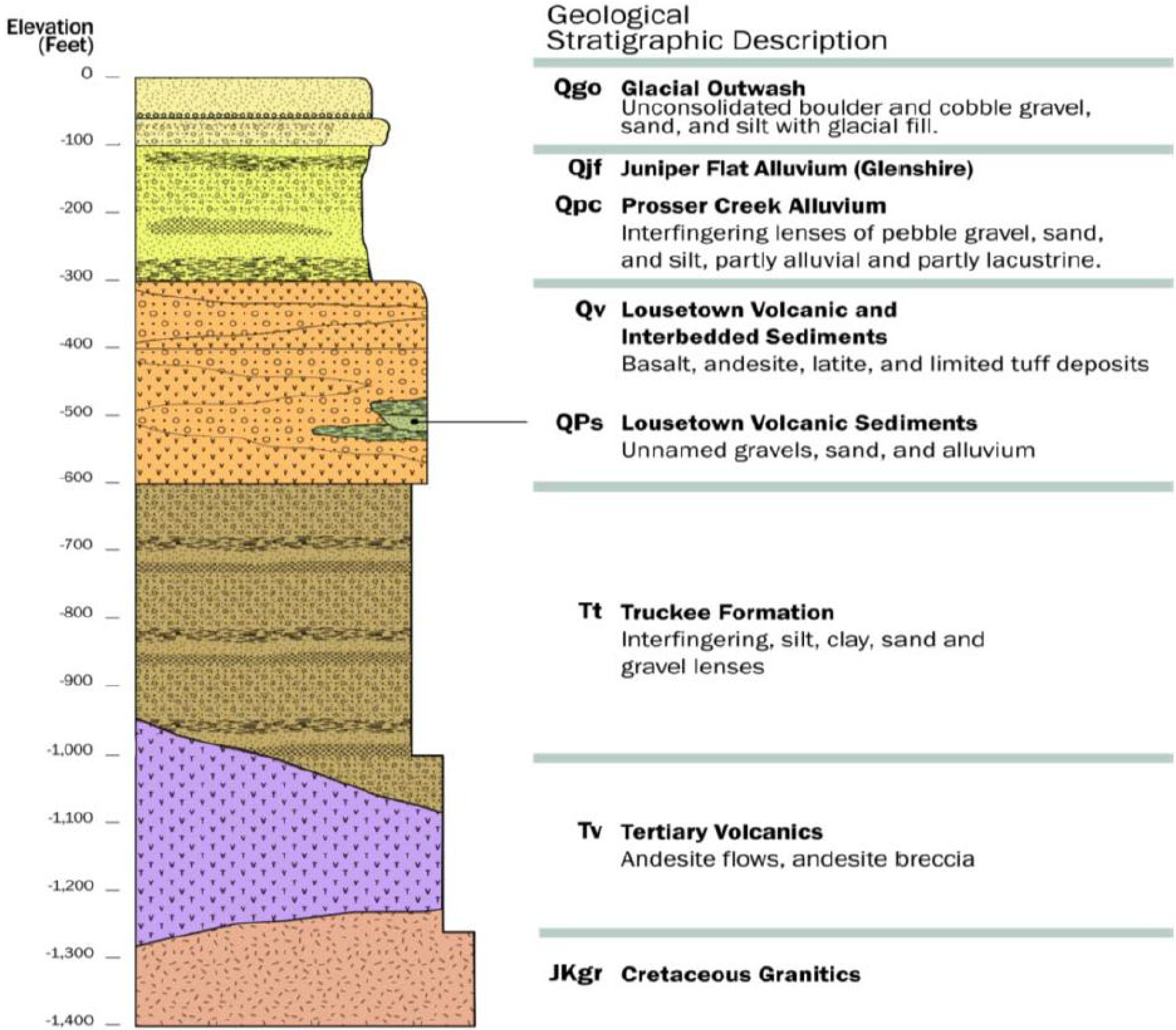
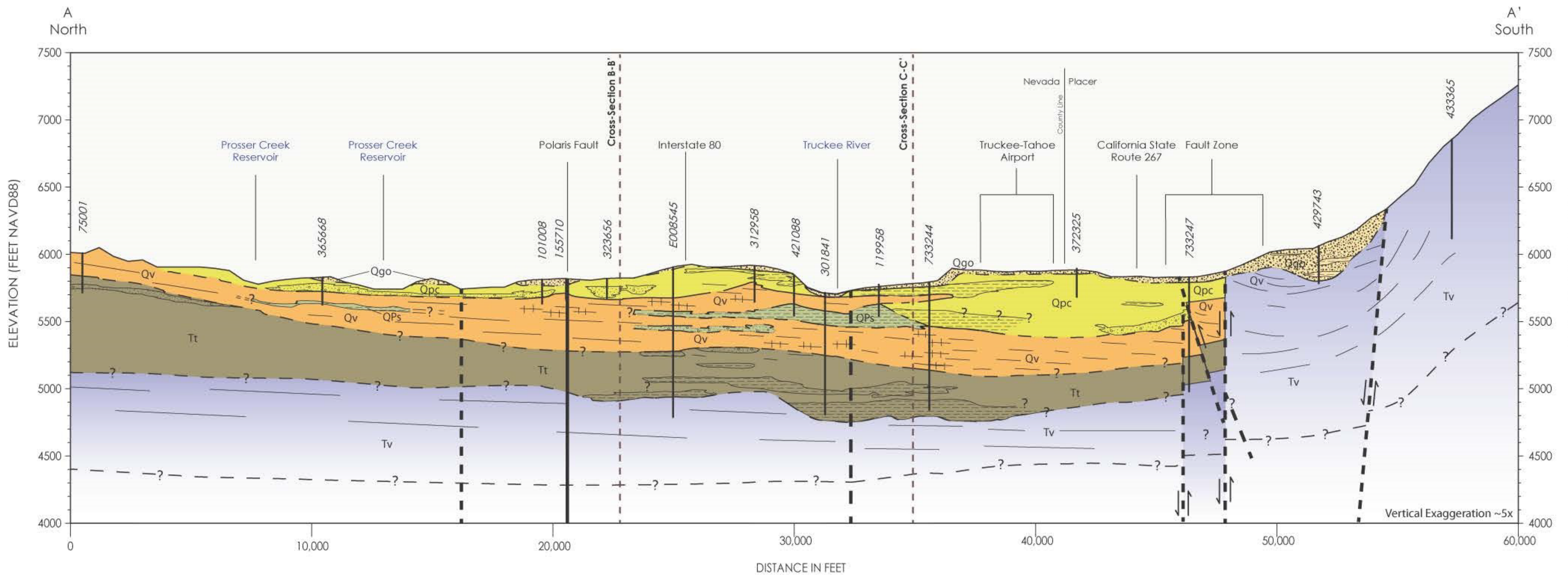

Elevation (Feet)
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1,000
-1,100
-1,200
-1,300
-1,400
Geological Stratigraphic Description
Qgo Glacial Outwash
Unconsolidated boulder and cobble gravel, sand, and silt with glacial fill.
Qjf Juniper Flat Alluvium (Glenshire)
Qpc Prosser Creek Alluvium
Interfingering lenses of pebble gravel, sand, and silt, partly alluvial and partly lacustrine.
Qv Lousetown Volcanic and Interbedded Sediments
Basalt, andesite, latite, and limited tuff deposits
QPs Lousetown Volcanic Sediments
Unnamed gravels, sand, and alluvium
Tt Truckee Formation
Interfingering, silt, clay, sand and gravel lenses
Tv Tertiary Volcanics
Andesite flows, andesite breccia
JKgr Cretaceous Granitics

Figure 4



NOTES:
1. Approximate vertical exaggeration = 5x.
2. Elevation profile developed from 30-meter digital elevation model, downloaded from National Elevation Dataset (http://seamless.usgs.gov/index.php).
3. Well log locations are approximate within 600 feet.
4. Fault locations are approximate, based on Saucedo, "Geologic Map of Lake Tahoe Basin," 2005 and Hunter and others, 2011.
5. Surficial geology inferred from Saucedo, 2005.
6. Significant sand, gravel, and clay beds shown where noted in well logs.
7. Fracture zones shown where noted in well logs.

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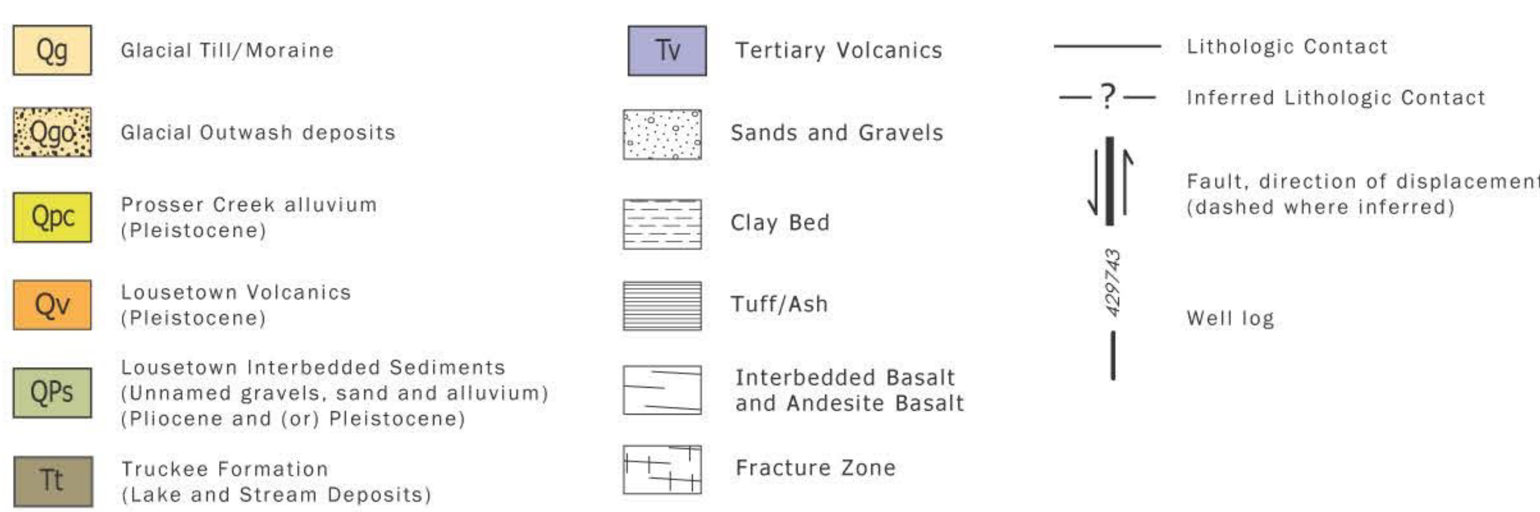
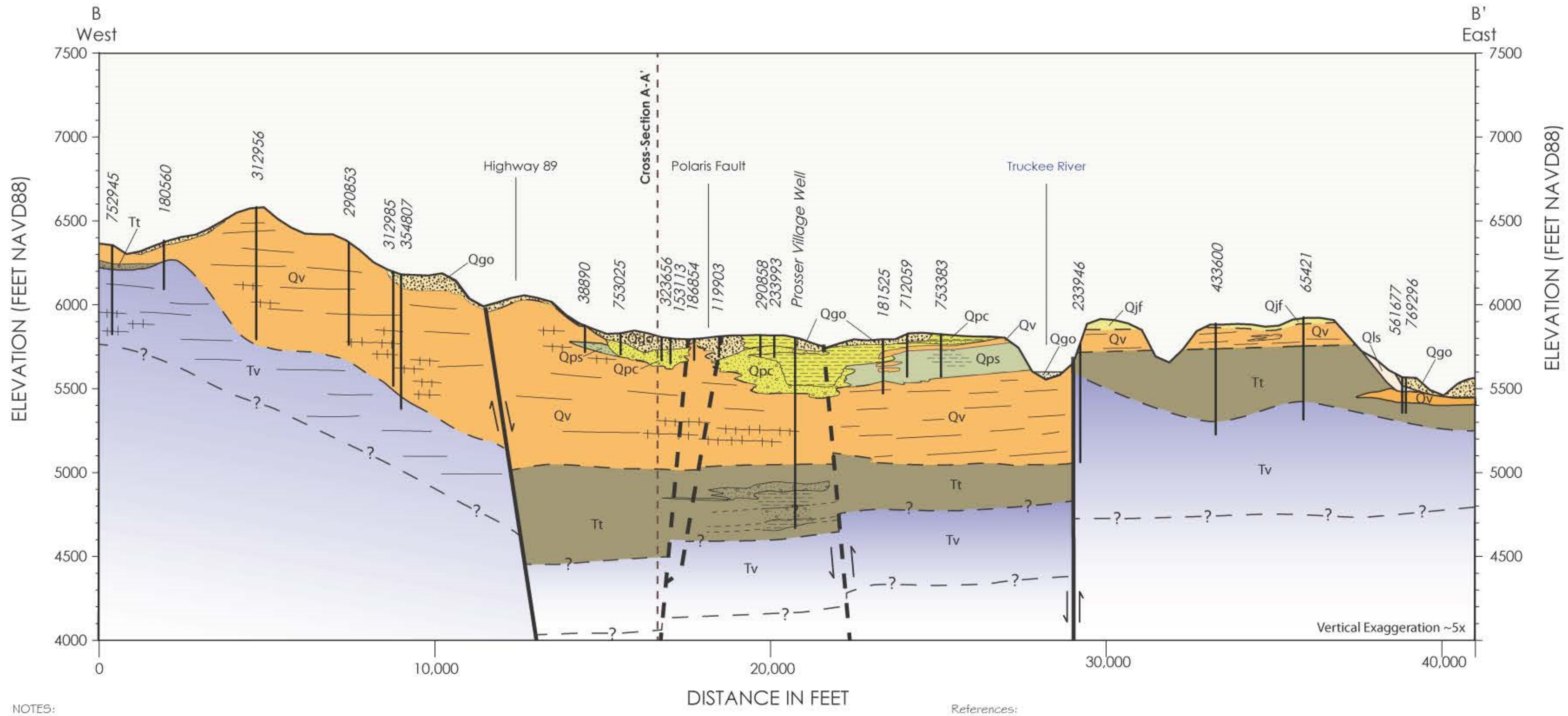
Legend



Source: ©2011 Balance Hydrologics, Inc.

Figure 5



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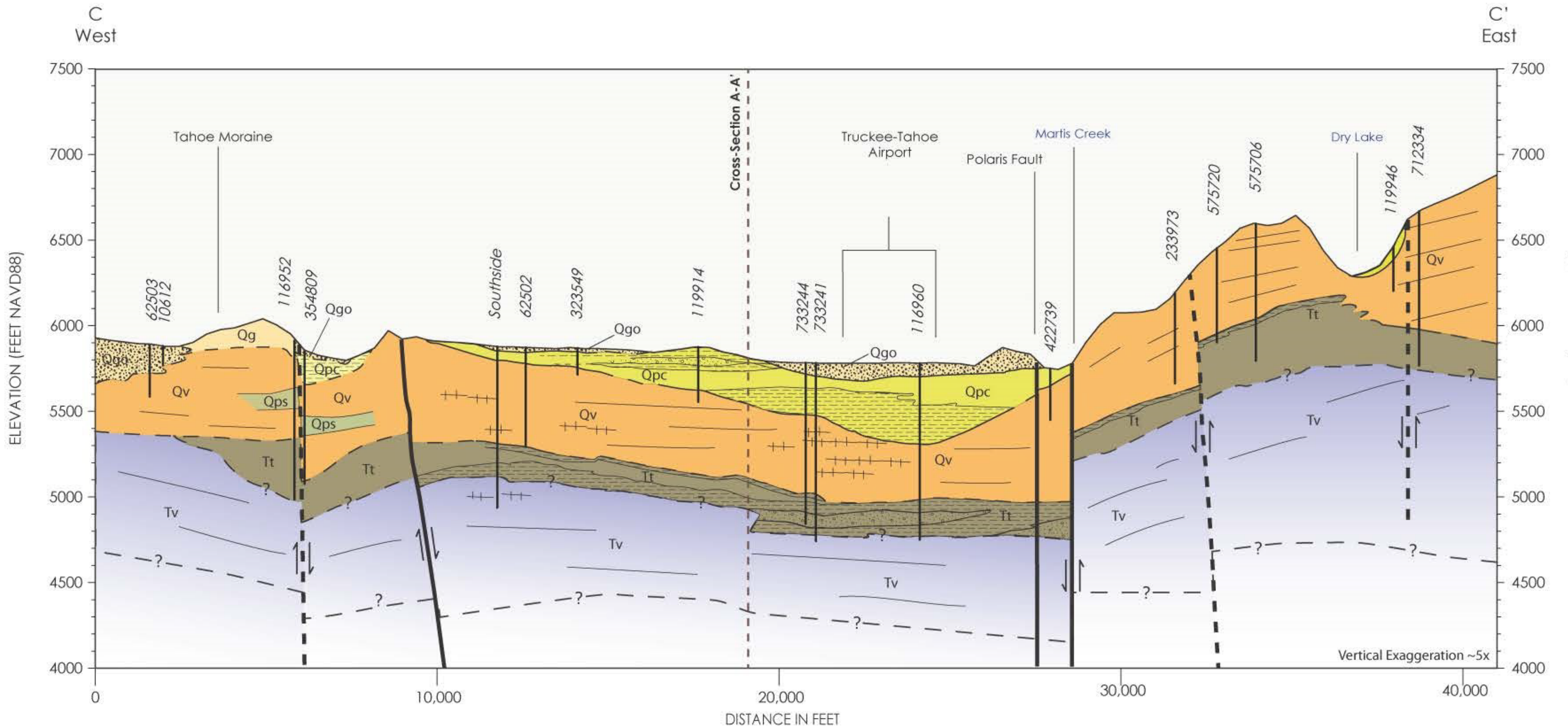
Legend

- Qg — Glacial Till/Moraine
- Qgo — Glacial Outwash deposits
- Qls — Landslide deposits
- Qjf — Juniper Flat alluvium (Pleistocene)
- Qpc — Prosser Creek alluvium (Pleistocene)
- Qv — Lousetown Volcanics (Pleistocene)
- QPs — Lousetown Interbedded Sediments (Unnamed gravels, sand and alluvium) (Pliocene and (or) Pleistocene)
- Tt — Truckee Formation (Lake and Stream Deposits)
- Tv — Tertiary Volcanics
- Sands and Gravels
- Clay Bed
- Tuff/Ash
- Interbedded Basalt and Andesite Basalt
- Fracture Zone
- Lithologic Contact
- —?— Inferred Lithologic Contact
- Fault, direction of displacement (dashed where inferred)
- 429743 Well log

Source: ©2011 Balance Hydrologics, Inc.

Figure 6



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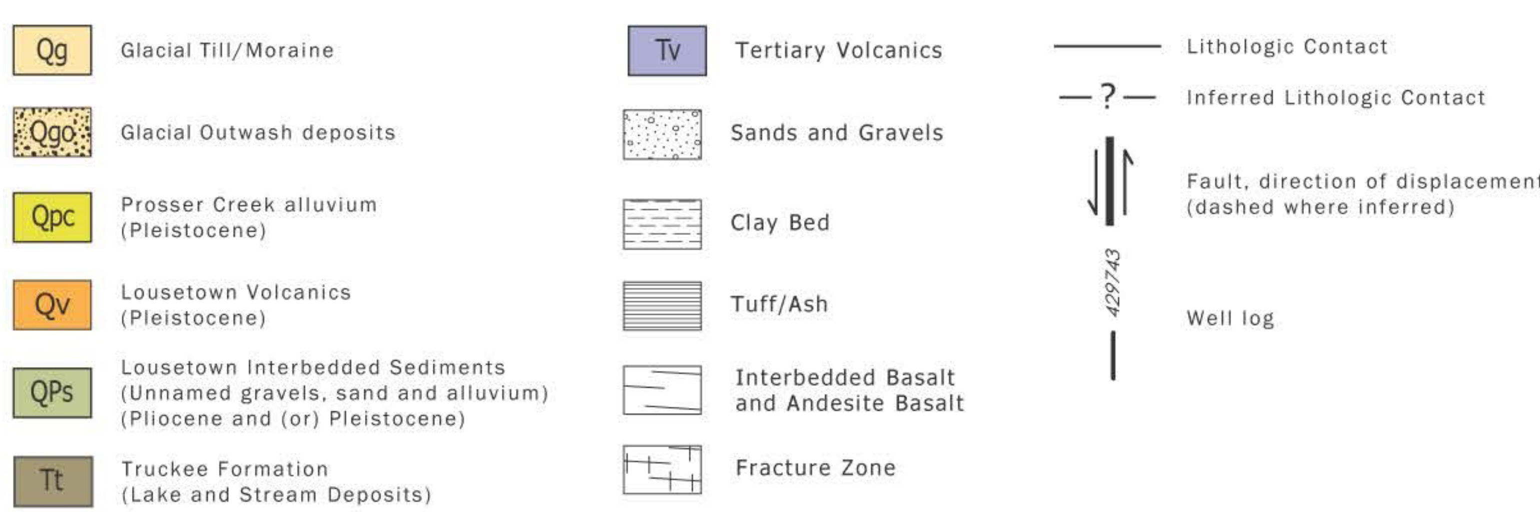
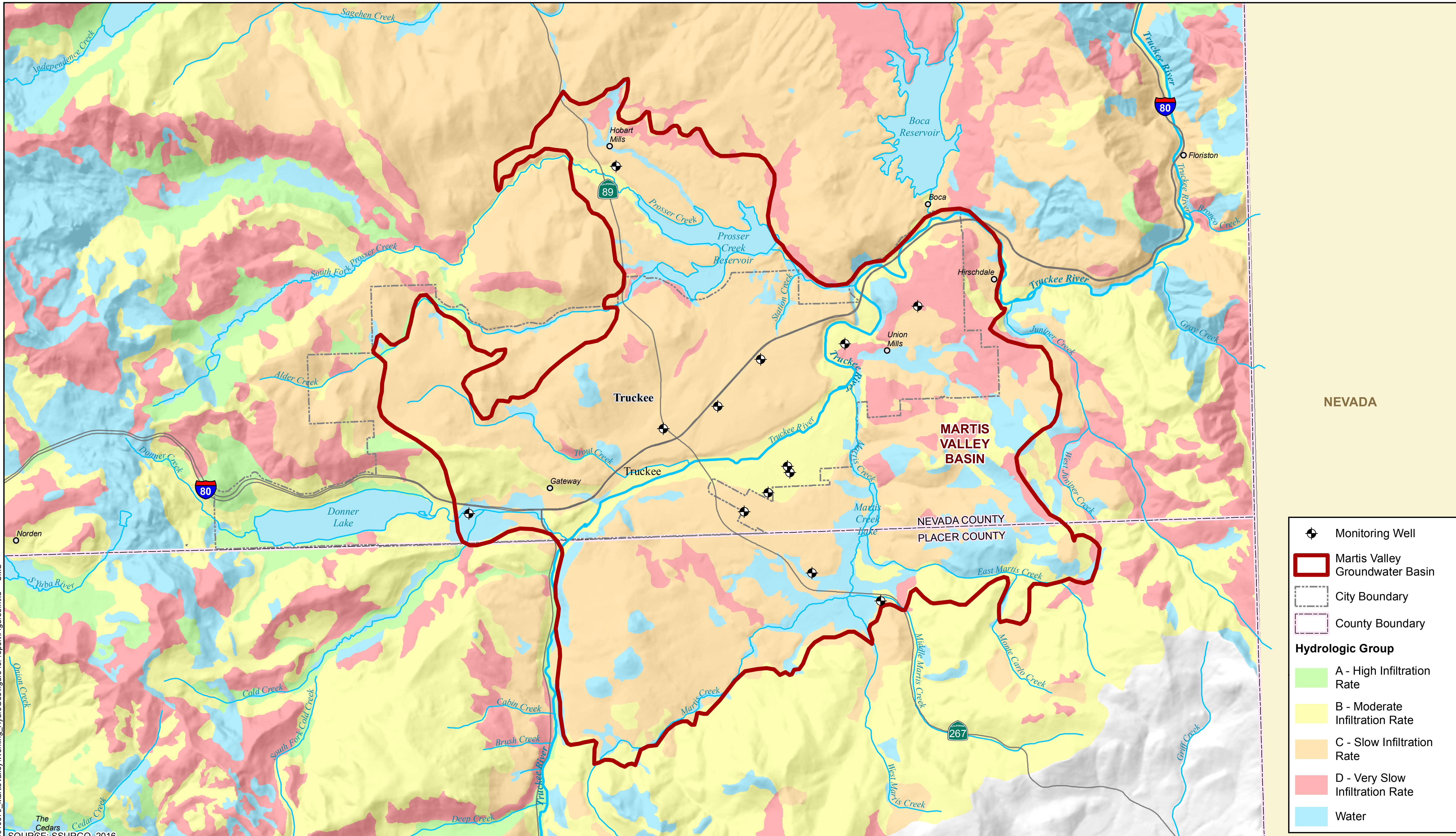


Figure 7



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Martis Valley Alternative Plan
Nevada and Placer Counties, California

Truckee-Donner Public Utility District

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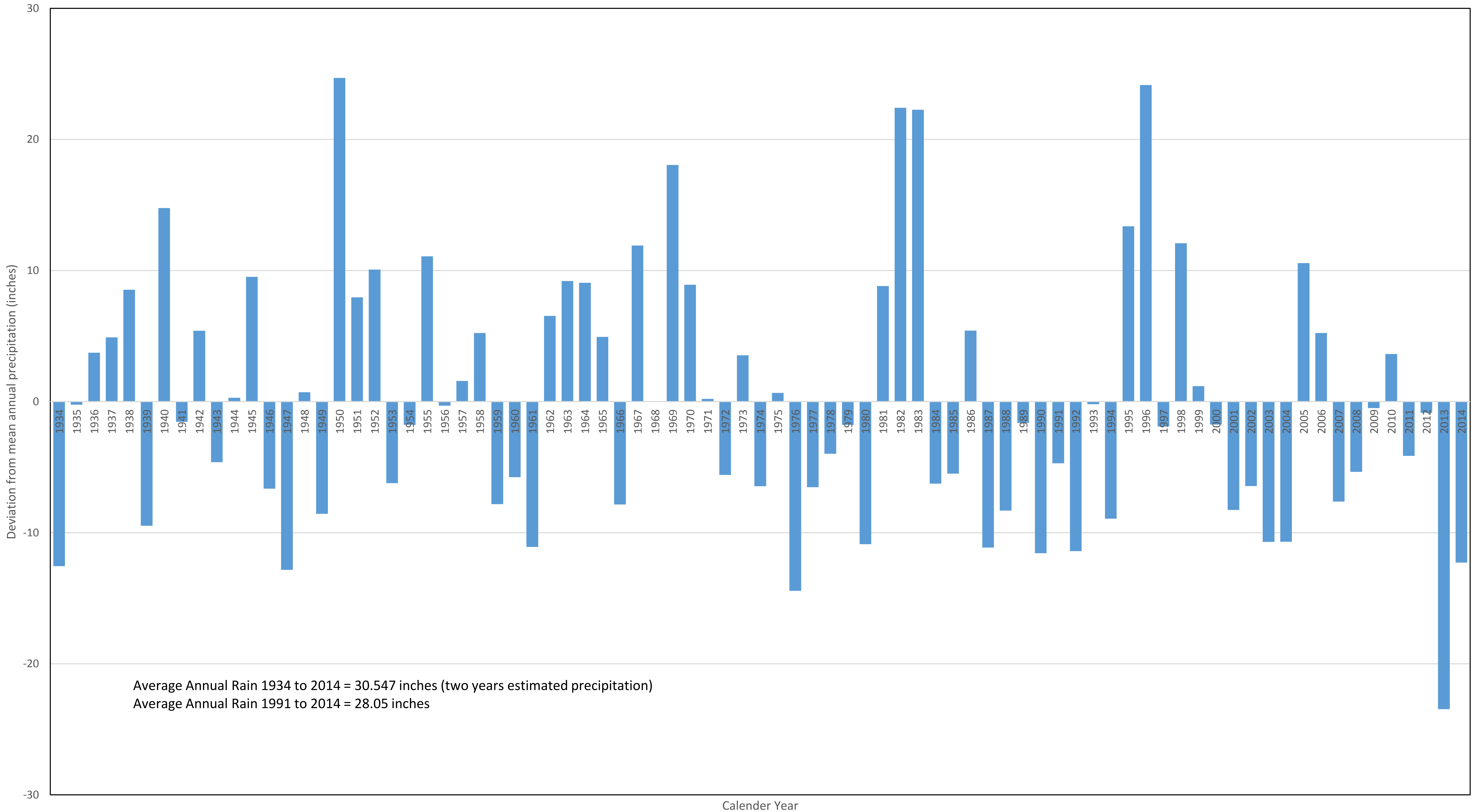
MARTIS VALLEY GROUNDWATER BASIN
SOILS

NOVEMBER 2016

FIGURE 8

Figure 9
Annual Precipitation Deviation from Mean
Truckee Ranger Station No. 049343



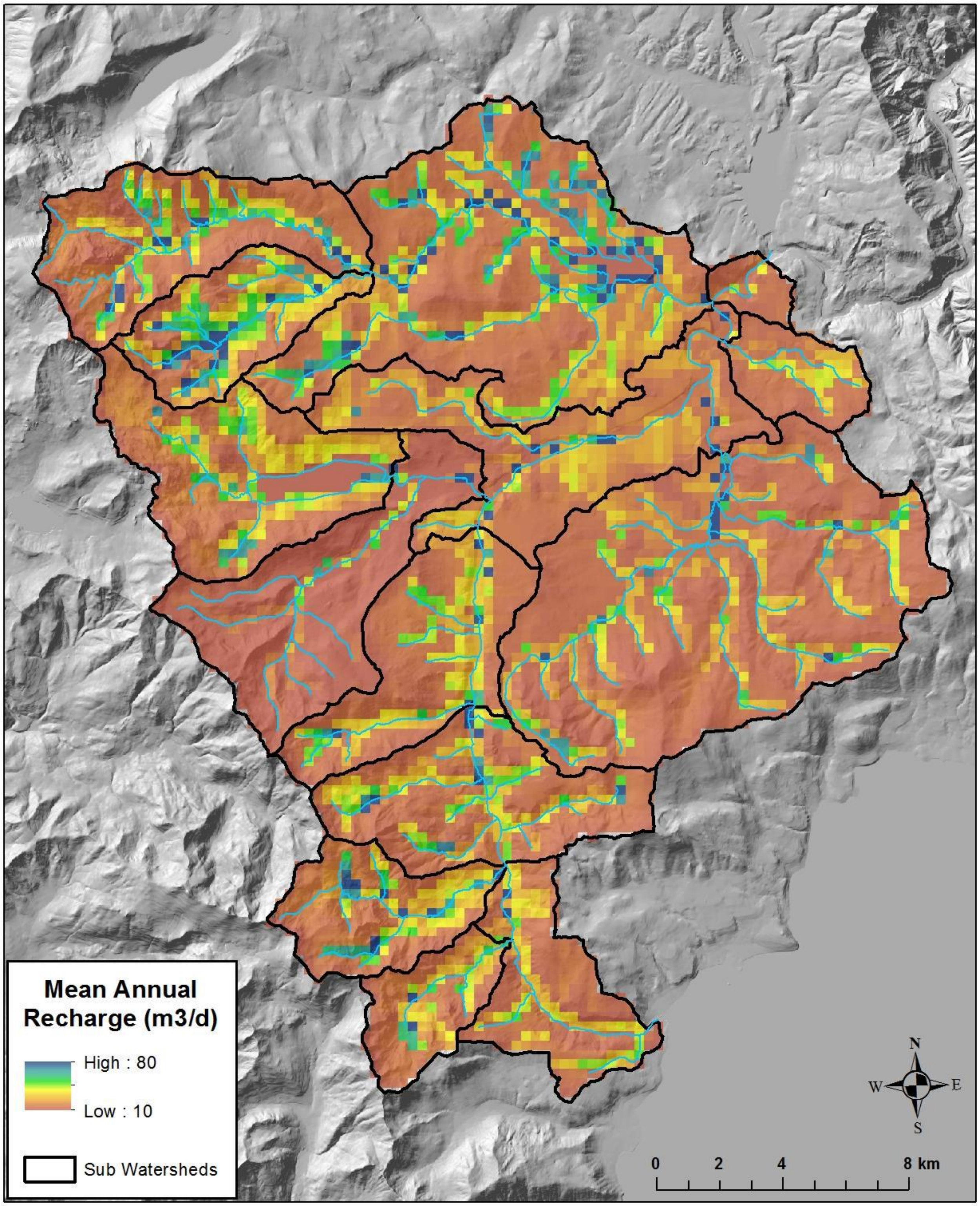
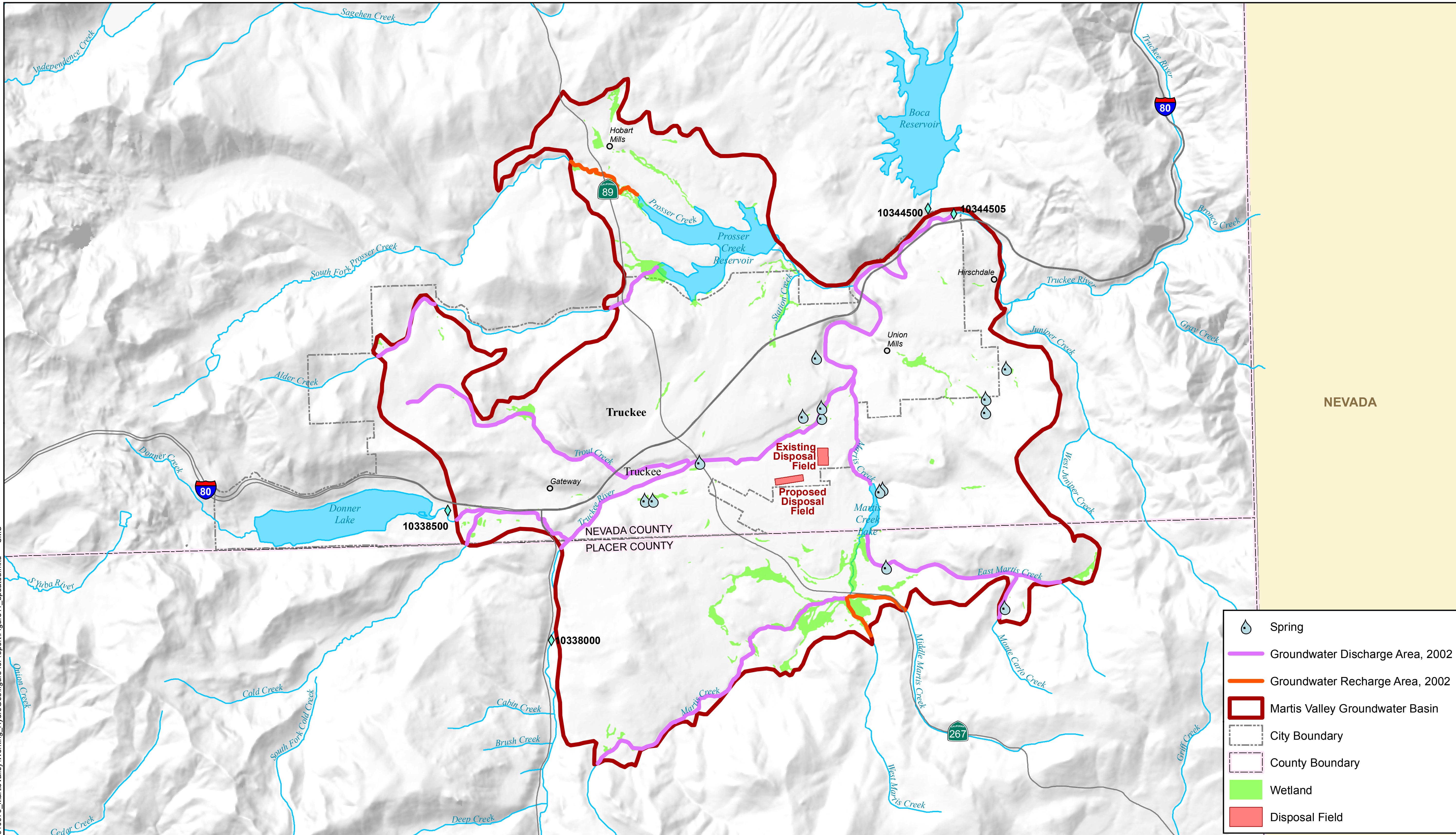


Figure 10: Mean annual recharge (simulated as flux to the saturated zone) over the historical simulation period from 1980 to 2011. (from Ragagopal and others, 2015)



2 1 0 2
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N W E S

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MARTIS VALLEY GROUNDWATER BASIN
WATER BUDGET PERTINENT FEATURES

NOVEMBER 2016

FIGURE 11

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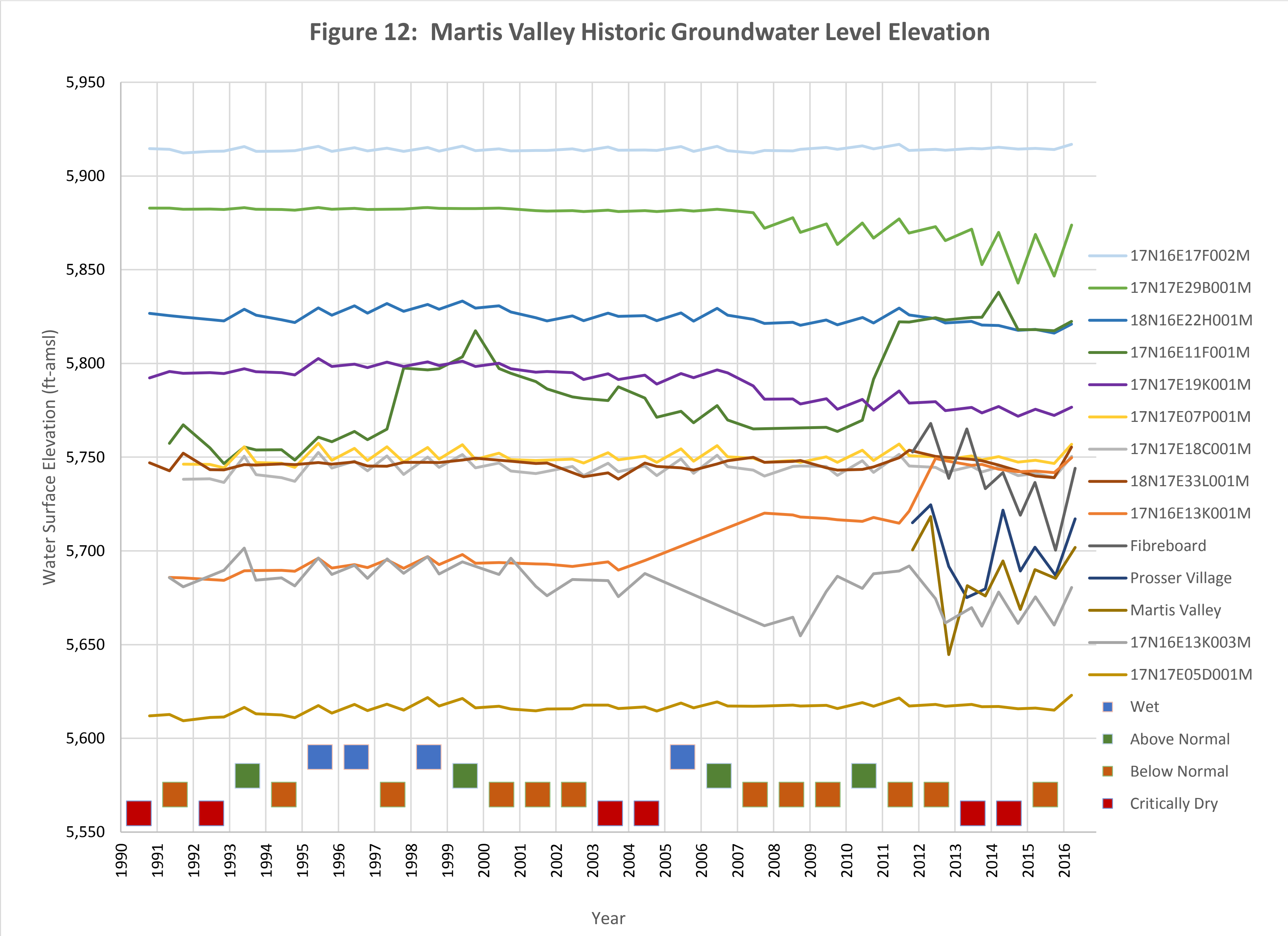
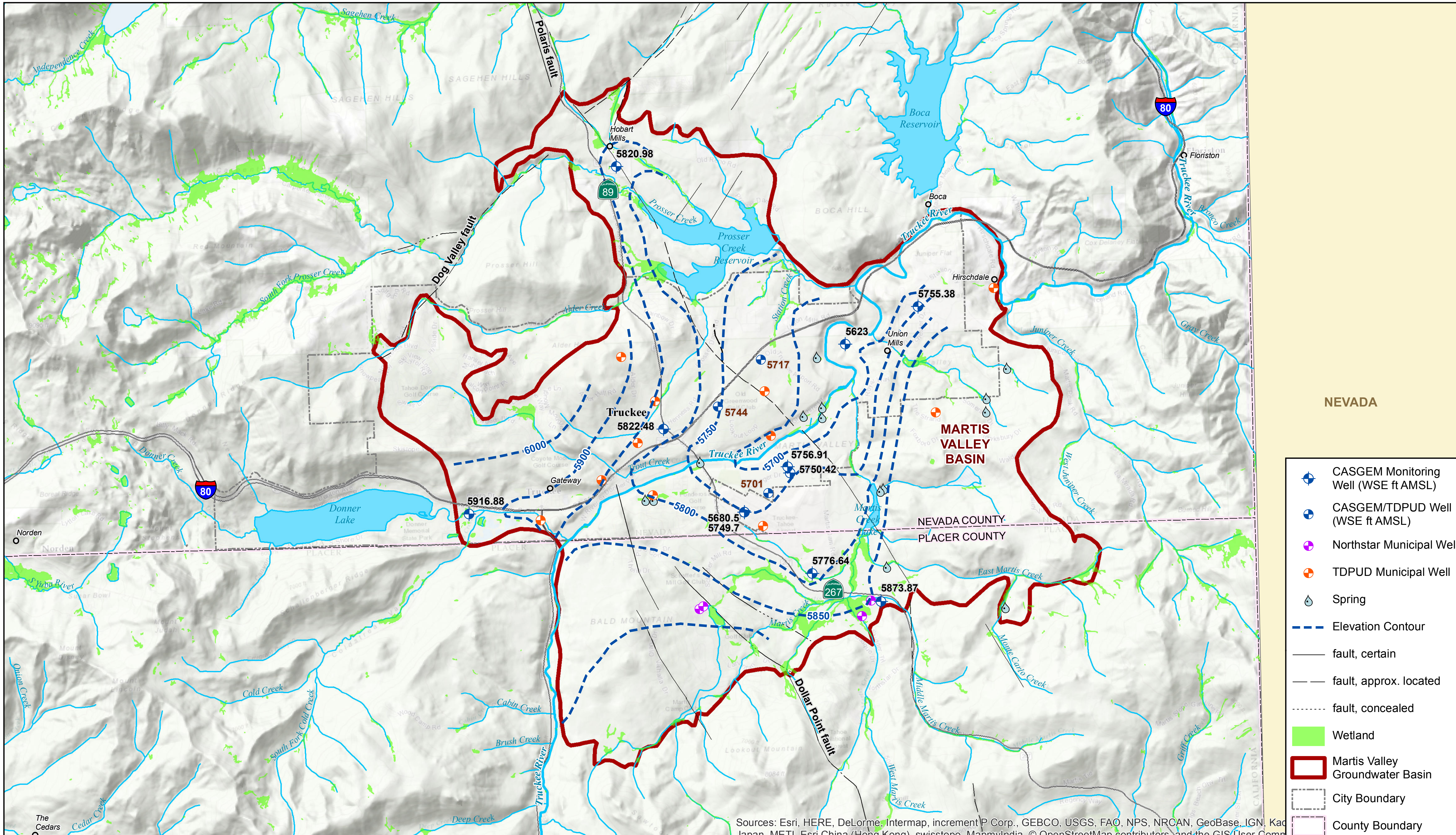


Figure 12: Martis Valley Historic Groundwater Level Elevation
Water Surface Elevation (ft-amsl)
5,950
5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
17N16E17F002M
17N17E29B001M
18N16E22H001M
17N16E11F001M
17N17E19K001M
17N17E07P001M
17N17E18C001M
18N17E33L001M
17N16E13K001M
Fibreboard
Prosser Village
Martis Valley
17N16E13K003M
17N17E05D001M
Wet
Above Normal
Below Normal
Critically Dry



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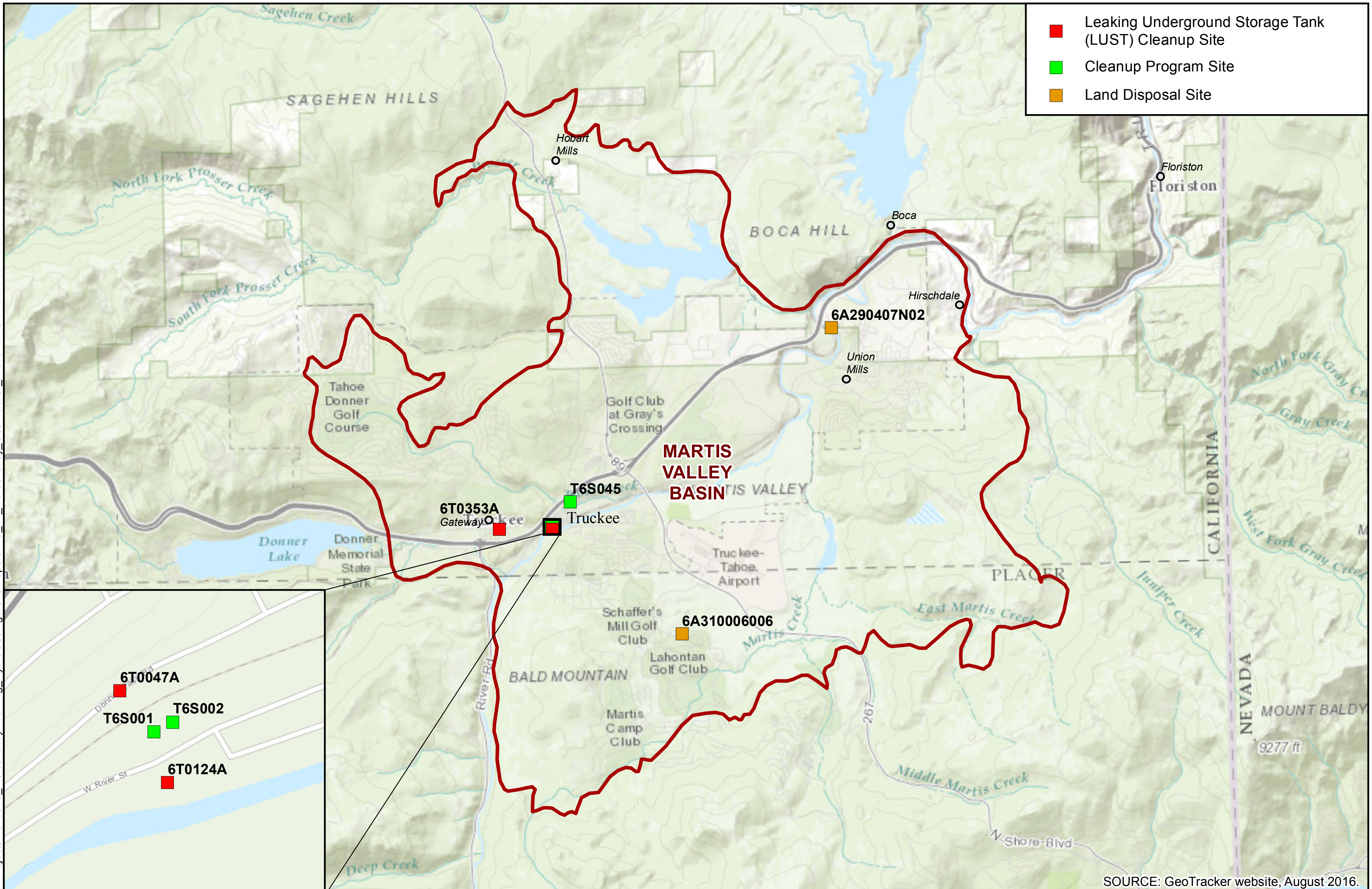
MARTIS VALLEY GROUNDWATER BASIN
GROUNDWATER ELEVATION CONTOURS - SPRING 2016

NOVEMBER 2016

FIGURE 13



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Nevada and Placer Counties, California

Truckee-Donner Public Utility District

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GEOTRACKER SITES
OPEN CASES

NOVERMBER 2016

FIGURE 14

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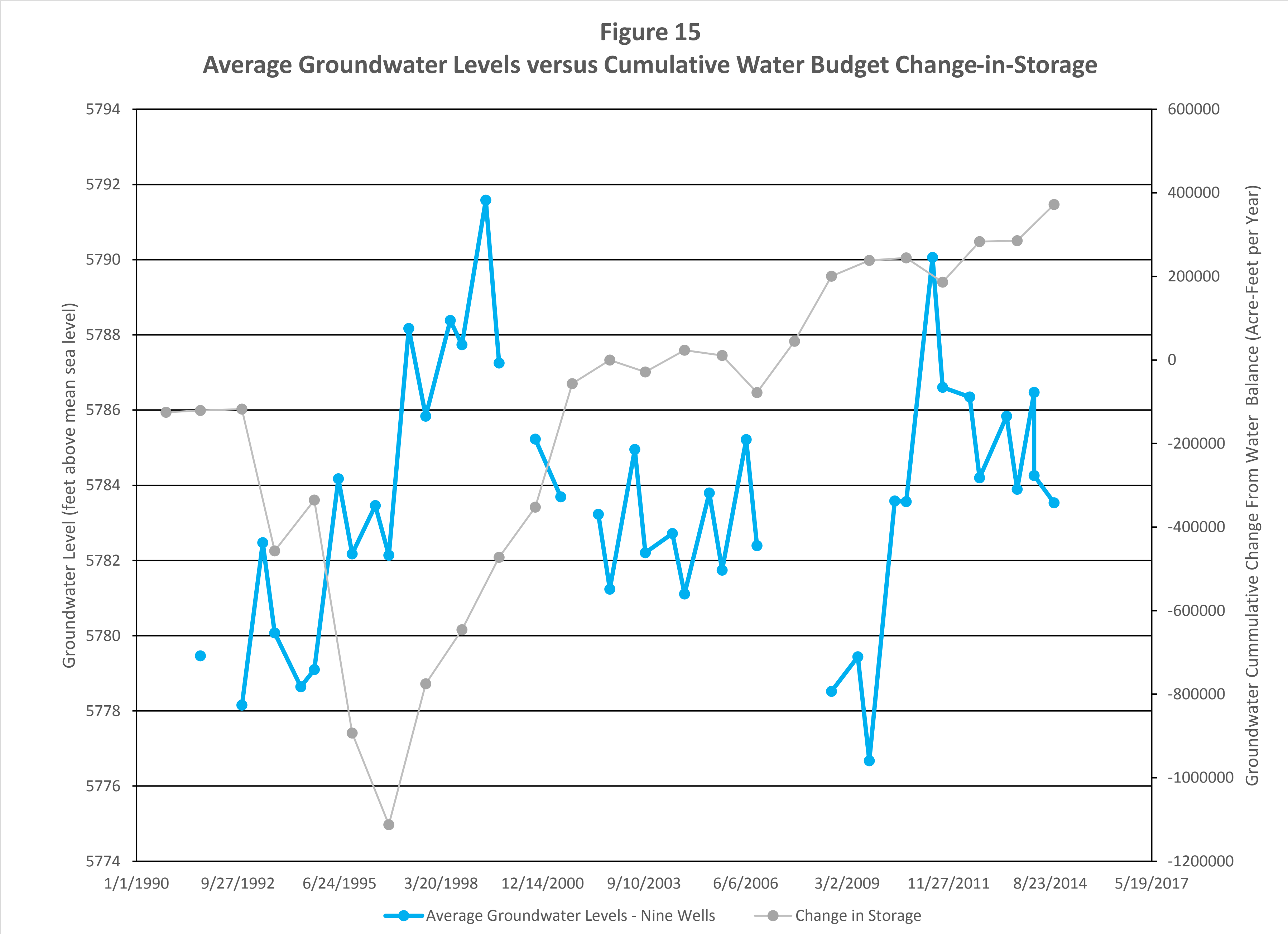
Figure 15
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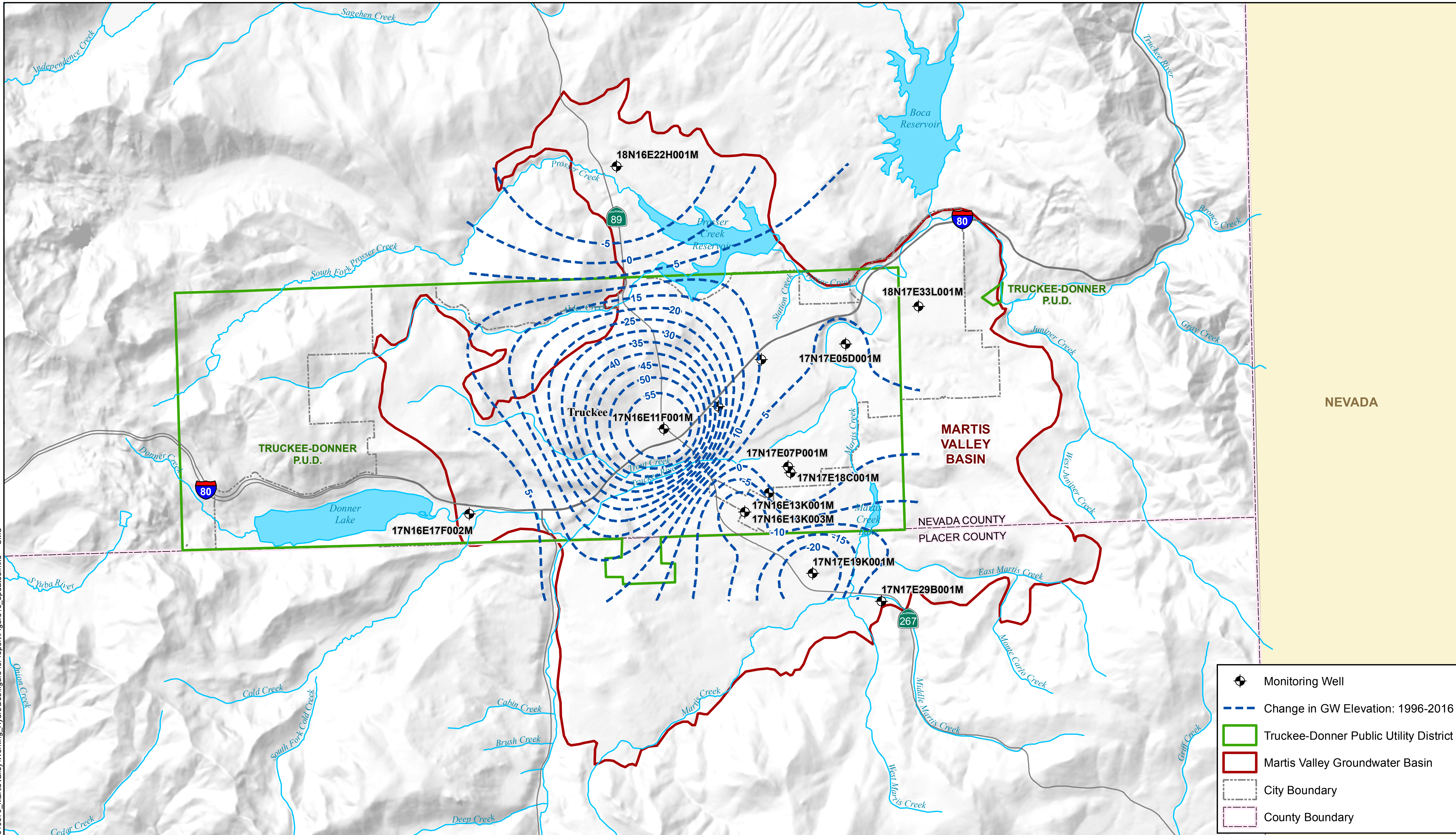
5794
5792
5790
5788
5786
5784
5782
5780
5778
5776
5774
Groundwater Level (feet above mean sea level)
600000
400000
200000
0
-200000
-400000
-600000
-800000
-1000000
-1200000
Groundwater Cummulative Change From Water Balance (Acre-Feet per Year)
1/1/1990
9/27/1992
6/24/1995
3/20/1998
12/14/2000
9/10/2003
6/6/2006
3/2/2009
11/27/2011
8/23/2014
5/19/2017
Average Groundwater Levels - Nine Wells
Change in Storage



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Miles

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Nevada and Placer Counties, California

Truckee-Donner Public Utility District

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MARTIS VALLEY GROUNDWATER BASIN
CHANGE IN GROUNDWATER ELEVATION 1996-2016

NOVEMBER 2016

FIGURE 16

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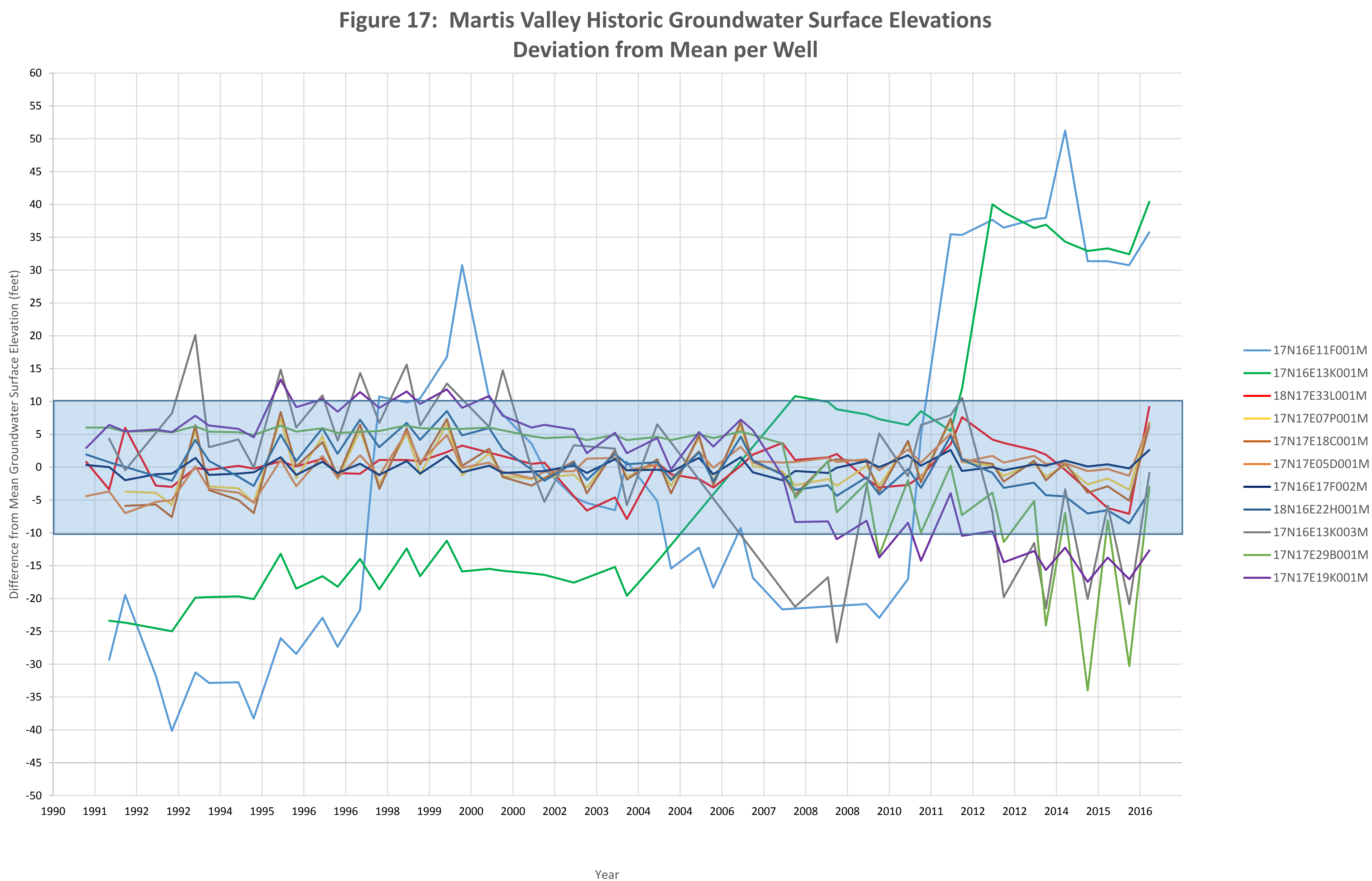


Figure 17: Martis Valley Historic Groundwater Surface Elevations
Deviation from Mean per Well
Difference from Mean Groundwater Surface Elevation (feet)
Year
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
1990
1991
1992
1992
1994
1995
1996
1996
1998
1999
2000
2000
2002
2003
2004
2004
2006
2007
2008
2008
2010
2011
2012
2012
2014
2015
2016
17N16E11F001M
17N16E13K001M
18N17E33L001M
17N17E07P001M
17N17E18C001M
17N17E05D001M
17N16E17F002M
18N16E22H001M
17N16E13K003M
17N17E29B001M
17N17E19K001M

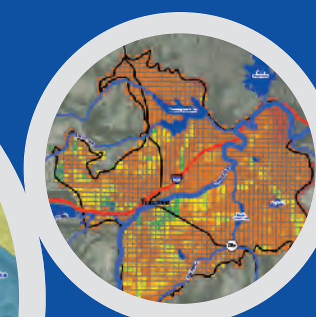

Figure 18: Martis Valley Historic Groundwater Elevations
Deviation from Mean per TDPUD (CASGEM) Well
Difference from Mean Groundwater Surface Elevation (feet)
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
2011
2012
2012
2013
2015
2016
Fibreboard
Martis Valley
Prosser Village

APPENDIX A

2013 Martis Valley Groundwater Management Plan Final

Martis Valley
Groundwater Management Plan

April, 2013



Prepared for

Northstar Community Services District

Placer County Water Agency

Truckee Donner Public Utility District

Northstar Community Services District

PCWA

TRUCKEE DONNER PUBLIC UTILITY DISTRICT

Martis Valley Groundwater Management Plan

Prepared for

Truckee Donner Public Utility District, Truckee, California

Placer County Water Agency, Auburn, California

Northstar Community Services District, Northstar, California

April 18, 2013

140691

MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN
NEVADA AND PLACER COUNTIES, CALIFORNIA

SIGNATURE PAGE

Signatures of principal personnel responsible for the development of the Martis Valley Groundwater Management Plan are exhibited below:

____

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Brown and Caldwell, Project Manager

____

David Shaw, P.G. #8210
Balance Hydrologics, Inc., Project Geologist

____

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Balance Hydrologics, Inc.

This Groundwater Management Plan (GMP) was prepared by Brown and Caldwell under contract to the Placer County Water Agency, Truckee Donner Public Utility District and Northstar Community Services District.

The key staff involved in the preparation of the GMP are listed below.

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Balance Hydrologics, Inc.

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List of Abbreviations

AB 3030	Assembly Bill 3030
ac-ft/yr	acre-feet per year
BMOs	Basin Management Objectives
CASGEM	California
cfs	cubic feet per second
CWC	California Water Code
DPH	Department of Public Health
DRI	Desert Research Institute
DWR	Department of Water Resources
DWSAP	Drinking Water Source Assessment Program
GAMA	Groundwater Ambient Monitoring and Assessment
GCM	general circulation model
GMP	Groundwater Management Plan
gpm	gallons per minute
GSFLOW	Ground-water and Surface-water Flow Model
IRWMP	Integrated Regional Water Management Plan
LGA	Local Groundwater Assistance
LLNL	Lawrence Livermore National Laboratory
LRWQCB	Lahontan Regional Water Quality Control Board
LUST	leaking underground storage tank
MCL	Maximum Contaminant Level
mgd	million gallons per day
MODFLOW	Modular Three-Dimensional Finite-Difference Groundwater Flow Model
msl	mean sea level
MVGB	Martis Valley Groundwater Basin
NCSD	Northstar Community Services District
NOAA	National Oceanic and Atmospheric Association
PCWA	Placer County Water Agency
PRMS	Precipitation Runoff Modeling System
PUC	Public Utilities Commission
SB	Senate Bill
sq mi	square miles
SWG	Stakeholder Working Group
SWRCB	State Water Resources Control Board
TDPUD	Truckee Donner Public Utility District
TDS	Total Dissolved Solids
TROA	Truckee River Operating Agreement
T-TSA	Tahoe-Truckee Sanitation Agency
USACE	United States Army Corps of Engineers
USFS	United State Forest Service
USGS	United States Geologic Survey
UZF	Unsaturated Zone Flow

Section 1

Introduction

In 1992, the State Legislature enacted the California Groundwater Management Act through Assembly Bill 3030 (AB 3030) to encourage local public agencies to adopt plans to manage groundwater resources within their jurisdictions. Provisions were created in the California Water Code (CWC) Sections 10750 et.seq. to manage the safe production, quality, and proper storage of groundwater and AB 3030 codified voluntary components of a Groundwater Management Plan (GMP). In 2002, Senate Bill 1938 (SB 1938) was signed into law which amended the CWC with required components of a GMP for any public agency seeking State funds administered through the California Department of Water Resources (DWR) for groundwater projects. In 2003, DWR published *Bulletin 118 – Update 2003, California's Groundwater* which includes seven recommended components of a GMP.

This GMP includes the following components: the partner agencies' authority, physical setting including groundwater conditions, management goals and Basin Management Objectives (BMOs), and GMP implementation activities.

1.1 Purpose of the Groundwater Management Plan

The Truckee Donner Public Utility District (TDPUD), Northstar Community Services District (NCSD), and Placer County Water Agency (PCWA) have voluntarily partnered to develop the Martis Valley GMP, a collaborative planning tool that assists the partner agencies with efforts to ensure long term quality and availability of shared groundwater resources in the Martis Valley Groundwater Basin (MVGB). This GMP is a "living document" that includes an overall goal, BMOs, and implementation actions that will be periodically updated to reflect changes in groundwater management and progress in meeting its goal and objectives.

The purpose of the Martis Valley GMP is to improve the understanding and management of the groundwater resource in Martis Valley, while providing a framework for the partner agencies to align policy and implement effective and sustainable groundwater management programs.

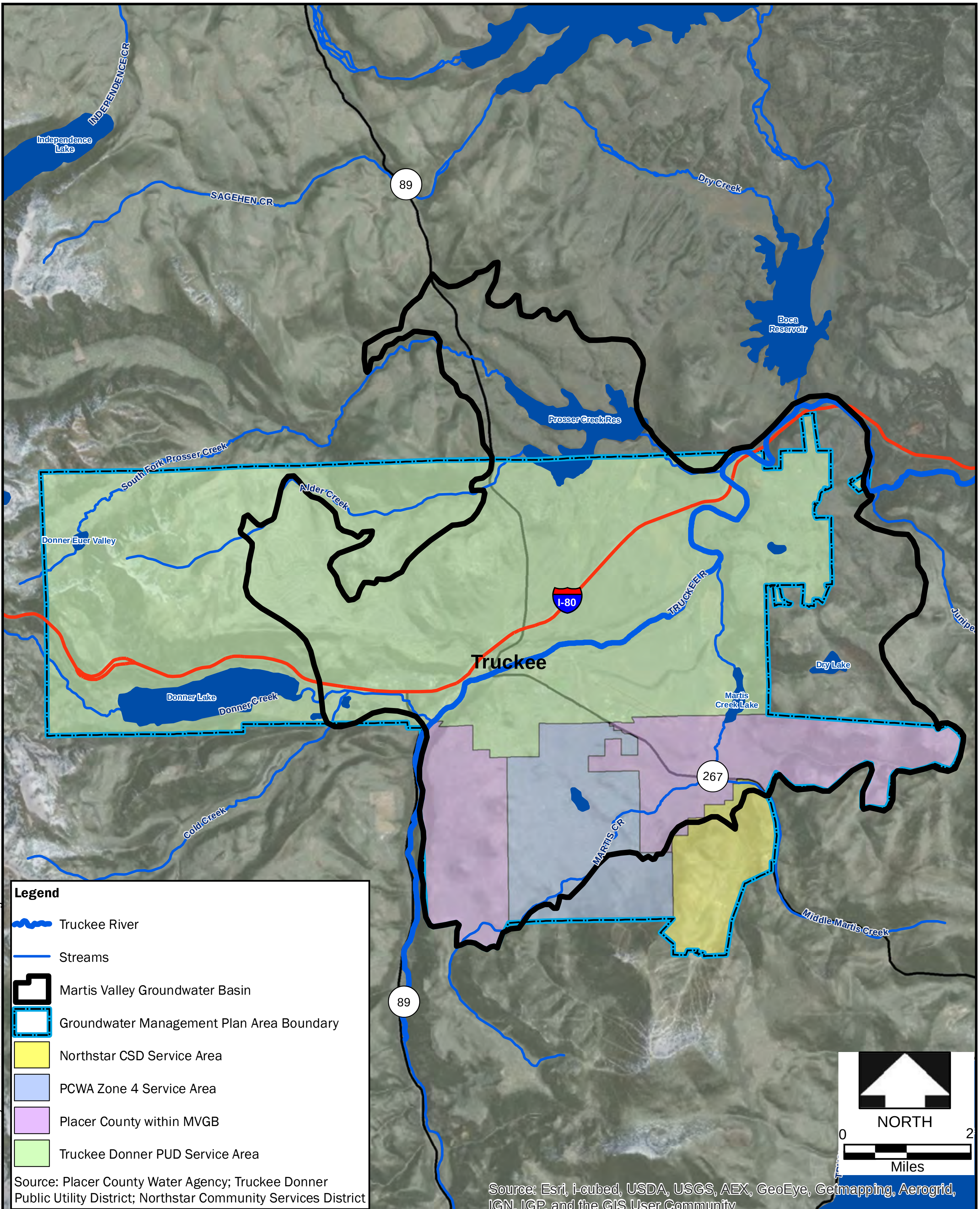
This GMP is not:

- mandatory,
- regulatory,
- an enforcement effort, or
- land use or zoning ordinances.

Older groundwater management plans by TDPUD (1995) and PCWA (1998) are herein updated by this GMP which has been designed to meet the requirements set by SB 1938, addresses the voluntary and recommended components included in AB 3030, as well as address recommendations outlined in Bulletin 118-2003. The area covered by the Martis Valley GMP, as shown in Figure 1-1, includes each partner agencies' jurisdictional boundaries within Nevada and Placer Counties.

1.2 Groundwater Management Plan Authority and Administration

Each partner agency is an authorized groundwater management agency within the meaning of CWC § 10753 (a). In April of 2011, each partner agency adopted respective resolutions of intent to develop a GMP; the resolutions are included as Appendix A.



P:\40000\140691 - PCWA Martis Valley GWP\GIS\MAPDOCS\WORKING\Fig1-1_MV_PlanArea_8x11_20120821.mxd

DATE	PROJECT	SITE	
10/18/2012	140691	Martis Valley, California	Figure 1-1
Brown AND Caldwell		TITLE: Groundwater Management Plan Area	

1.3 Groundwater Management Plan Development Process

During the course of preparing the GMP, various entities were involved in developing, approving, and adopting the GMP. In addition to the partner agencies, a Stakeholder Working Group (SWG) was created to provide local knowledge, data and information, opinions, and review and comment on material prepared by the GMP team. The SWG was comprised of representatives of Federal, State, and local governments, environmental and special interest groups, and local land use interests. Four SWG meetings were held with the partner agencies during GMP development. SWG participants and the agency represented are presented in Table 1-1.

Table 1-1. Stakeholder Working Group Members

Working Group Participant	Representing
Chris Bonds	Department of Water Resources, Central Region Office
Steven Springhorn	Department of Water Resources, Central Region Office
Ron Parr	DMB Highlands Group LLC
Rick Stephens	Lahontan Community Association
John Eaton	Mountain Area Preservation Foundation
Kaitlin Backlund	Mountain Area Preservation Foundation
Michael Johnson	Placer County Community Development
Marcia Beals	Tahoe Truckee Sanitation Agency
Tony Lashbrook	Town of Truckee
Jeff Boyer	Truckee River Operating Agreement
Dave Wathen	Truckee River Operating Agreement
Lisa Wallace	Truckee River Watershed Council
Kenneth Parr	United States Bureau of Reclamation
Tom Scott	United States Bureau of Reclamation
Joanne Roubique	United States Forest Service, Truckee District
Andrew Strain	Heavenly Mountain Resort/Northstar California Resort
Adam Spear	Vail Resorts
Steve Magliscеau	Marlin Atlantis/Schaffer's Mill
Tony Firenzi	Placer County Water Agency
Steven Poncelet	Truckee Donner Public Utility District
Mike Staudenmayer	Northstar Community Services District

There are five main steps in the development of a GMP, as defined under CWC §10753.2 through 10753.6, and the agencies' actions to follow them are shown in Figure 1-2 and are summarized below:

Step 1 – Provide public notification of a hearing on whether or not to adopt a resolution of intention to draft a GMP and subsequently complete a hearing on whether or not to adopt a resolution of intention to draft a GMP. Following the hearing, draft a resolution of intention to draft a GMP. The agencies provided public notification and held their respective hearings in March 2011. Copies of newspaper notifications are included in Appendix A.

Step 2 – Adopt a resolution of intention to draft a GMP and publish the resolution of intention in accordance with public notification. The partner agencies' adopted their respective resolutions of intention to develop a GMP in April 2011. The resolutions are included as Appendix A.

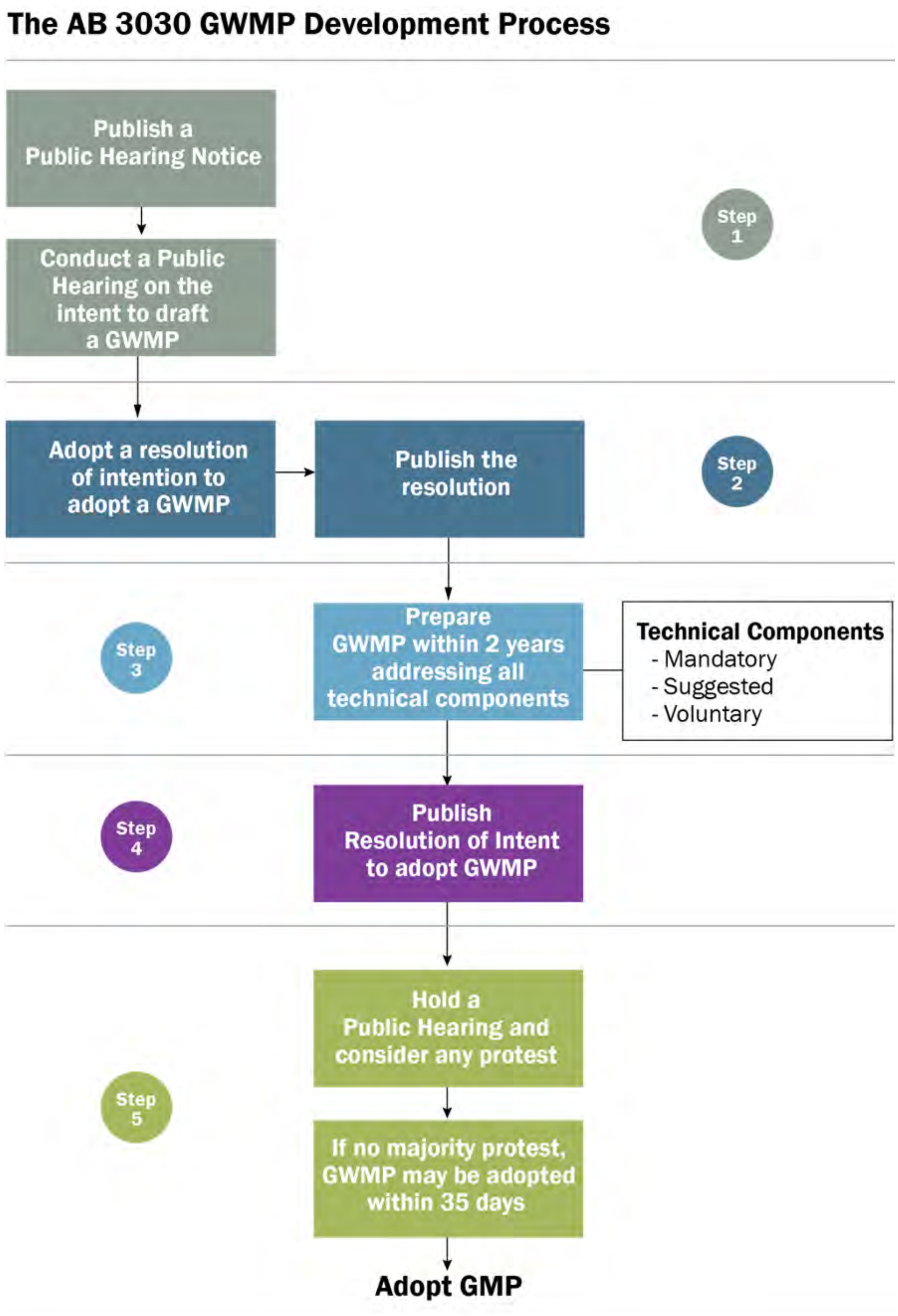


Figure 1-2. GMP Development Process

Step 3 – Prepare a draft GMP within two years of resolution of intention adoption. Provide to the public a written statement describing the manner in which interested parties may participate in developing the GMP. The agencies provided notification and held three SWG meetings where meeting attendees gave input on the GMP goal, BMOs, and implementation actions. The agencies also held a public meeting on July 20, 2011 to receive public input.

Step 4 – Provide public notification of a hearing on whether or not to adopt the GMP, followed by holding a hearing on whether or not to adopt the GMP. Public notices of the scheduled hearings were provided in the Auburn Journal and the Sierra Sun newspapers and proof of publications are included in Appendix B.

Step 5 – The plan may be adopted within 35 days after the completion of Step 4 above if protests are received for less than 50 percent of the assessed value of property in the plan area. If protests are received for greater than 50 percent of the assessed value of the property in the plan area, the plan will not be adopted. No public comments were received during the public comment period. In February 2013 each partner agency adopted the Martis Valley GMP and their respective resolutions are included in Appendix B.

1.4 Groundwater Management Goal

The GMP's goal provides the overarching purpose of the GMP, is used to identify the desired outcome of GMP implementation, is general in nature, and does not include quantitative components:

The goal of the Martis Valley GMP is to ensure long term quality and availability of groundwater in the Martis Valley Groundwater Basin.

1.5 Basin Management Objectives

The BMOs provide more specific direction to the GMP; they are generally protective of the groundwater resource and the environment, and each BMO identifies a distinct portion of the overarching goal which provides specific areas for focus. Summarized below are six primary areas that are emphasized and embodied in the BMO's that support the GMP goal:

1. **Manage groundwater to maintain established and planned uses.**

   Because the MVGB is the primary source of water to multiple users under separate jurisdictions, this objective encourages the partner agencies to pursue management of groundwater that is within their jurisdiction in order to protect existing uses.

2. **Manage groundwater use within the provisions of the Truckee River Operating Agreement.**

   The Truckee-Carson-Pyramid Lake Water Rights Settlement Act (Settlement Act), Public Law 101-618 (1990), established entitlements to the waters of Lake Tahoe, the Truckee River and its tributaries and how the storage reservoirs of the Truckee River are operated. Section 205 of the Settlement Act directs the Secretary of the Department of the Interior to negotiate an operating agreement for the operation of Truckee River reservoirs, between California, Nevada, Sierra Pacific Power Company, Pyramid Tribe, and the United States. The operating agreement is known as the Truckee River Operating Agreement (TROA).

   This objective documents the partner agencies' commitment to continue to comply with provisions of the TROA. Some provisions in TROA apply to groundwater and water wells within the Truckee River Basin (which includes the Martis Valley) to address potential adverse impacts to surface water.

3. **Collaborate and cooperate with groundwater users and stakeholders in the MVGB.**

   Collaborating and sharing information and resources with other groundwater users in the MVGB helps promote GMP goals. This objective encourages the partner agencies to reach out to other groundwater users within the MVGB.

4. **Protect groundwater quantity and quality.**

   Groundwater performs an integral function in a watershed, one of which is satisfying water supply needs. Improving the understanding of the groundwater basin is a critical step in protecting and sustaining the Martis Valley groundwater supply.

5. **Pursue and use the best available science and technology to inform the decision making process.**

   Science and technology continue to develop new tools that may improve the understanding of the MVGB. This objective encourages the partner agencies to take actions that work with the best available science to help make informed agency decisions.

6. **Consider the environment and participate in the stewardship of groundwater resources.**

   The partner agencies are dedicated to stewardship of groundwater resources and this BMO ensures that stewardship is part of the GMP.

1.6 Plan Components

Required GMP components and their location in the GMP are summarized in Table 1-2, Voluntary GMP components and their location in the GMP are summarized in Table 1-3, and recommended GMP components and their location in the GMP are summarized in Table 1-4.

Table 1-2. Required Components and Associated Report Section

Category Required	GMP Components Required Components: (10753.7.)	Report Section
1	Establish Basin Management Objectives (BMOs)	Section 1.5
2	Include components relating to the monitoring and management of: groundwater levels, groundwater quality, and inelastic land subsidence	Section 3.4
3	Include components relating to changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin	Section 3.2
4	Include description of how recharge areas identified in the GMP substantially contribute to the replenishment of the groundwater basin	Section 2.9
5	Prepare a GMP that enables the partner agencies to work cooperatively with other public entities whose service area falls within the plan area and overlies the groundwater basin	Section 3.1 Section 3.4
6	Prepare a map that details the area of the groundwater basin, the area subject to the GMP, and the boundaries of other local agencies that overlie the basin	Section 1.1
7	Prepare a map identifying the recharge areas for the groundwater basin	Section 2.9
8	Adopt monitoring protocols that detect changes in: groundwater levels, groundwater quality, inelastic land subsidence, and surface water flow or quality that affects groundwater or groundwater pumping that affects surface water flow or quality	Section 3.4
9	If the GMP area includes areas outside a groundwater basin as defined in Bulletin 118, the partner agencies will use the required components, and geologic and hydrologic principles appropriate for the area	Throughout GMP

Table 1-3. Voluntary Components and Associated Report Section

Category Voluntary	GMP Components Voluntary Components (10753.8.)	Report Section
1	Control of saline intrusion	Section 3.1
2	Identification and management of wellhead protection	Section 3.4
3	Regulation of the migration of contaminated groundwater	Section 3.1 Section 3.2
4	Administration of a well abandonment and well destruction program	Section 3.1
5	Mitigation of conditions of overdraft	Section 3.1
6	Replenishment of groundwater extracted by water producers	Section 3.1
7	Monitoring of groundwater levels and storage	Section 3.4
8	Facilitating conjunctive use operations	Section 3.1
9	Identification of well construction policies	Section 3.4
10	Construction and operation by the partner agencies of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects	Section 3.1 Section 3.2
11	Development of relationships with state and Federal regulatory agencies	Section 3.1 Section 3.2 Section 3.5
12	Review of land use plans and coordination with land use planning agencies to assess activities that create a reasonable risk of groundwater contamination	Section 3.4

Table 1-4. Recommended Components and Associated Report Section

Category Recommended	GMP Components Recommended Components (From Bulletin 118-2003 Appendix C)	Report Section
1	Document public involvement and ability of the public to participate in development of the GMP, this may include a Technical Advisory Committee (Stakeholder Working Group)	Section 1.3
2	Establish an advisory committee of stakeholders within the plan area that will help guide the development and implementation of the GMP and provide a forum for the resolution of controversial issues	Section 1.3 Section 3.1
3	Describe the area to be managed under the GMP including: • The physical structure of the aquifer system • A summary of available historical data and issues of concern related to groundwater levels, groundwater quality, inelastic land subsidence, and surface water flow or quality that effects groundwater or groundwater pumping that effects surface water flow or quality • A general discussion of historical and projected water demands and supplies	Section 2
4	Establish management objectives (MOs) for the groundwater basin subject to the GMP	Section 1.5
5	Describe the GMP's monitoring program	Section 3.4

Table 1-4. Recommended Components and Associated Report Section		
Category Recommended	GMP Components Recommended Components (From Bulletin 118-2003 Appendix C)	Report Section
6	Describe efforts to coordinate with land use, zoning, or water management planning agencies or activities	Section 3.4
7	Create a summary of monitoring locations with frequency of wells monitored	Appendix D
8	Provide periodic reports summarizing groundwater conditions and management activities including: • A summary of monitoring results, with a discussion of historical trends • A summary of management actions during the period covered by the report • A discussion of whether actions are achieving progress towards meeting BMOs • A summary of proposed management actions for the future • A summary of any GMP changes that occurred during the period covered by the report • A summary of actions taken to coordinate with other water and land agencies and other government agencies	Section 3.1
9	Provide for the periodic re-evaluation of the entire plan by the managing entity	Section 3.1

1.7 Area Covered by the GMP

The Martis Valley GMP includes the service areas of the TDPUD, PCWA, and NCSD that overlay and extend beyond the MVGB boundary, as well as the Placer County portion of the MVGB. It is important to note that at the time of GMP development, there were no other agencies within the Placer County portion of the MVGB that fall within the service area of another local agency, water corporation regulated by the Public Utility Commission (PUC), or mutual water company without the agreement of the overlying agency, as defined in the CWC (CWC § 10750.7(a)). Figure 1-1 shows the Martis Valley GMP area.

1.8 Public Outreach and Education

The partner agencies developed a Public Outreach Plan to guide development of the GMP. Public outreach included the formation of a Stakeholder Working Group to provide input on GMP development, two informative public meetings, and publically noticed public hearings (Appendix A) on the intent to draft and adopt the GMP. The Public Outreach Plan is included in Appendix C.

1.9 Groundwater Model

The partner agencies are currently collaborating with the Bureau of Reclamation (Reclamation) and their subcontractor, Desert Research Institute (DRI), to develop an integrated watershed-groundwater model in conjunction with the Martis Valley GMP. The geologic investigation conducted and documented in Section 2 of this report has been used to develop a geologic framework database, which was used to guide the conceptual and numerical model components for the hydrogeology components (groundwater model) of the integrated watershed model. The integrated watershed model is under development in parallel with the GMP and is not completed at the time of the issuance of the final GMP.

The integrated watershed model is comprised of a Precipitation Runoff Modeling System (PRMS) and Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW) coupled together using an Unsaturated Zone Flow (UZF) package. PRMS is used to model surface water within the watershed, whereas MODFLOW is used to model groundwater within the MVGB. The UZF model package is a kinematic wave vadose zone model used to simulate the interaction between surface water and groundwater. Each model will be calibrated separately, and then calibrated together over a ten year period using a coupled ground-water and surface-water Flow Model (GSFLOW). Predictive model simulations will be performed using multiple general circulation model (GCM) projections of precipitation and temperature to estimate the influence of future climate on water resources within the MVGB. Calibration targets for fully coupled, GSFLOW model will include head values measured from wells, meadow and spring locations, streamflows, measured snow depth, and remotely sensed snow cover.

The integrated model's model domain will cover the entire Martis Valley Watershed, which includes the MVGB, as well as the watersheds that contribute surface water to the region, including Lake Tahoe. The model grid's cells are 300 meters by 300 meters in size. To date, DRI has used the PRMS component of the integrated modeling tool to estimate groundwater recharge across the MVGB, and is discussed in more detail in Section 2.9.

1.10 Document Organization

The Martis Valley GMP is organized into the following sections:

- Section 2 Physical Setting: describes the physical setting of Martis Valley including items such as geologic setting, land use, water sources, and well infrastructure
- Section 3 Plan Implementation: discusses the implementation actions included in the Martis Valley GMP
- Section 4 References
- Appendices

Section 2

Physical Setting

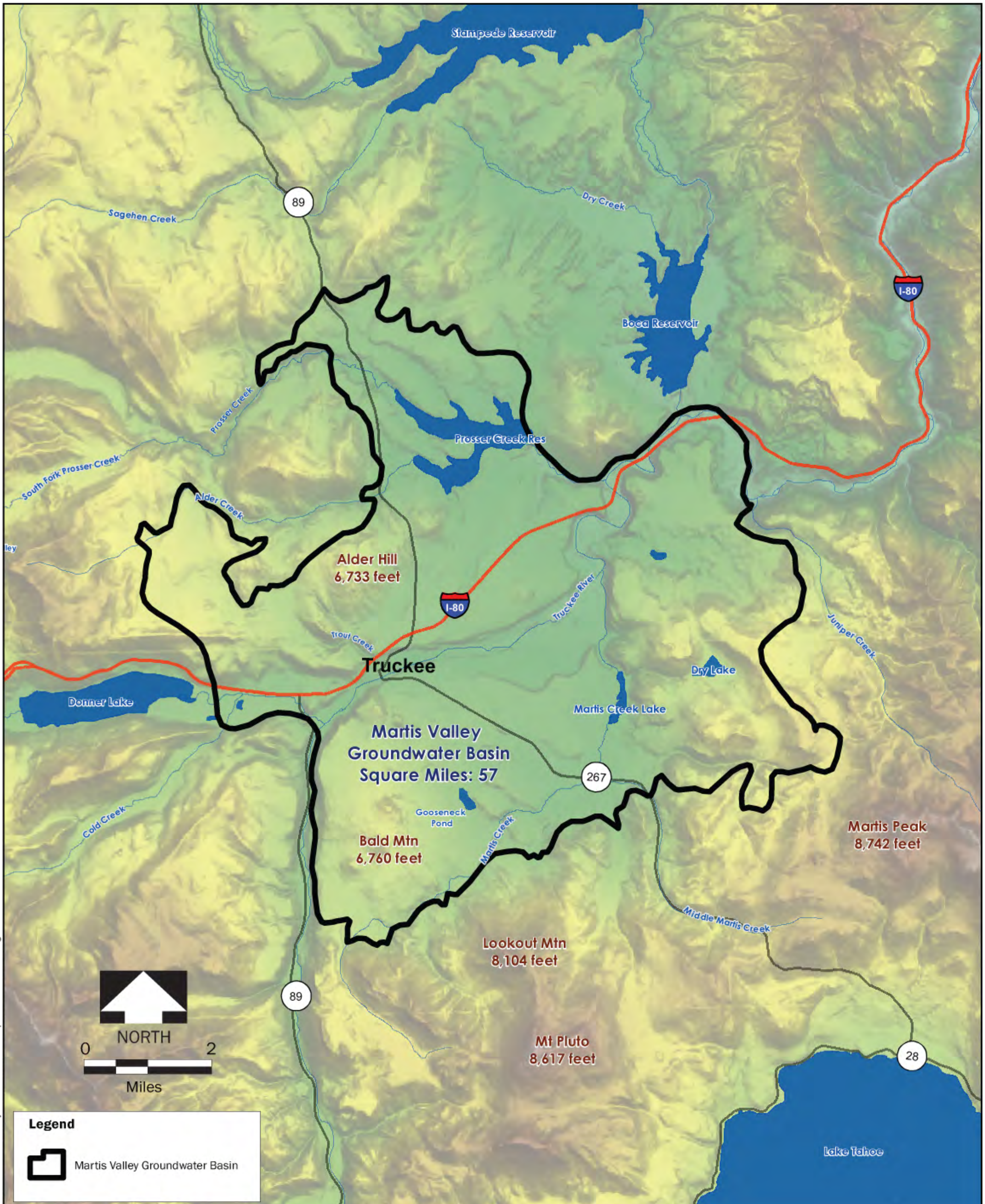
The MVGB is located in the transition zone between the Sierra Nevada and the Basin and Range Geomorphic Provinces, east of the Sierra Nevada crest and part of the larger Tahoe-Truckee River Basin of California and Nevada. Martis Valley is the principal topographic feature within the MVGB. The surrounding landscape is mountainous, underlain by volcanic and, to some extent, granitic bedrock, with apparent faulting and some portions that have been glaciated. A significant portion of the land within the MVGB boundary is privately owned with some areas managed as forest, open space and/or for recreation by special districts or agencies, including the U.S. Forest Service. This section of the GMP characterizes the physical setting of the MVGB, including: topography, climate, surface water hydrology, geology, hydrogeology, and water use.

2.1 Topography

The MVGB encompasses roughly 57 square miles, and lies within the Middle Truckee River Watershed. Elevations of the valley floor range from 5,700 to 5,900 feet above mean sea level (msl). The valley is accented by hills rising above the valley floor and mountains to the south and east of the valley. High points within or immediately adjacent to the MVGB include Bald Mountain at an elevation of 6,760 feet and Alder Hill at 6,733 feet, located on the western margin of the MVGB, and Lookout Mountain at 8,104 feet and Mt. Pluto at 8,617 feet, located on its the southern fringe. Martis Peak, further to the east, is at 8,742 feet. Figure 2-1 illustrates the MVGB location and topography.

2.2 Climate

The Tahoe-Truckee region experiences warm and dry summers, and cold, wet and snowy winters. Elevation and rain shadow play major roles in the spatial distribution of temperature and precipitation. Precipitation is highest at upper elevations in the western portion of the basin, toward the Sierra Crest, and decreases with elevation in the eastern portion of the basin (Figure 2-2). Mean annual precipitation (as snow water equivalent) ranges from approximately 30 inches below 6,500 feet to over 45 inches above 6,500 feet. Precipitation falls mostly as snow between October and April, though runoff and streamflow also responds to periodic mid-winter rain-on-snow events. Annual peak streamflow typically occurs during spring snowmelt in May or June. A small proportion of the total annual precipitation falls during brief thunderstorms in the summer months. Average monthly precipitation is shown in Figure 2-3, as recorded at the United States Forest Service (USFS) Truckee Ranger Station, near the center of the watershed (California Data Exchange Center Station TKE). Average temperatures range from daily lows of 15ºF in December and January to daily highs of 82ºF in July, as recorded at SNOTEL Station Truckee #2.



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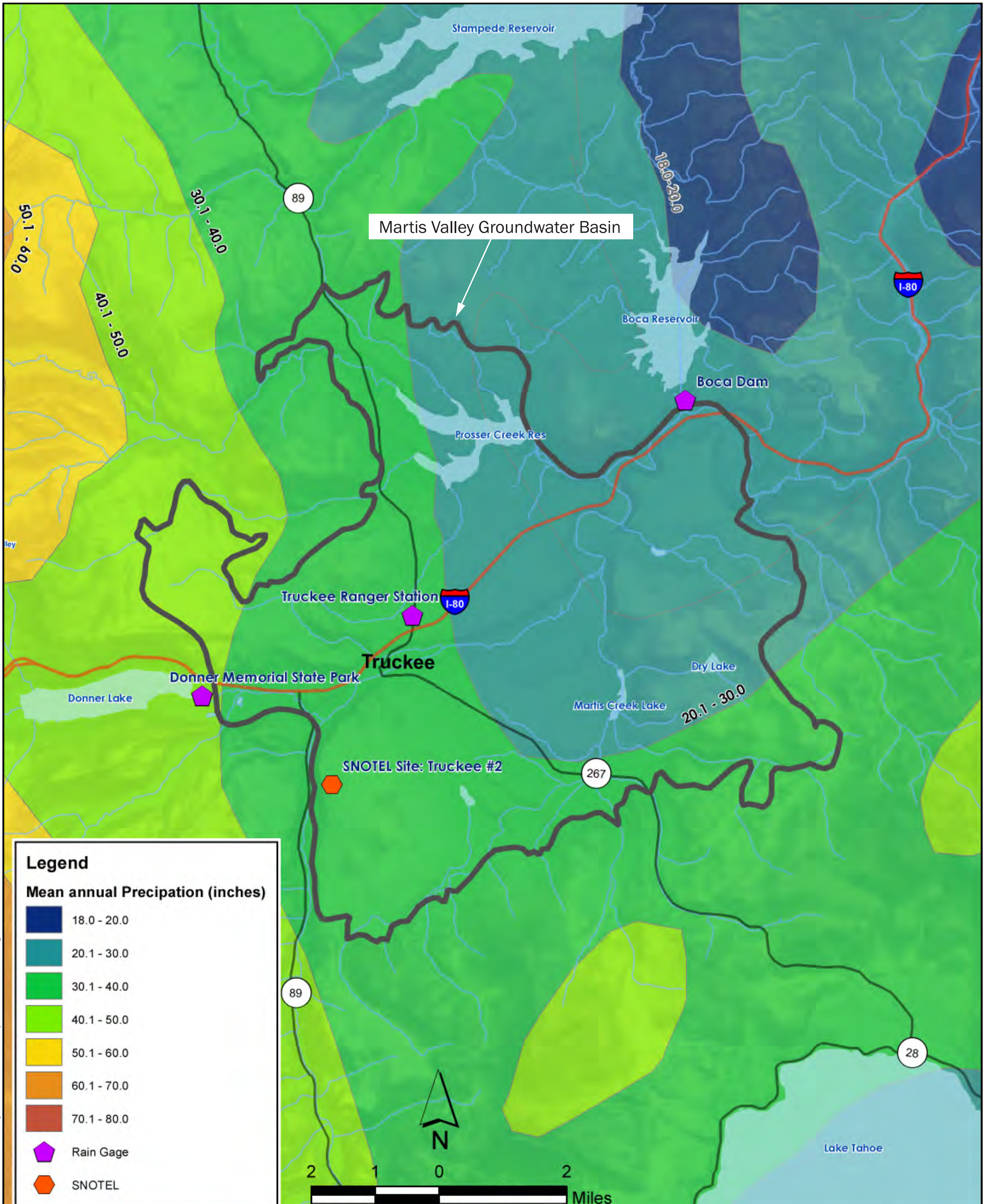
DATE	PROJECT	SITE	
9-7-12	140691	Martis Valley Groundwater Basin, California	Figure 2-1
Brown and Caldwell; Balance Hydrologics, Inc.		TITLE: Groundwater Basin Location and Physiography	



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DATE	PROJECT	SITE
9-7-12	140691	Martis Valley Groundwater Basin, California

Brown AND Caldwell

Balance Hydrologics, Inc.

TITLE

Mean Annual Precipitation

Figure 2-2

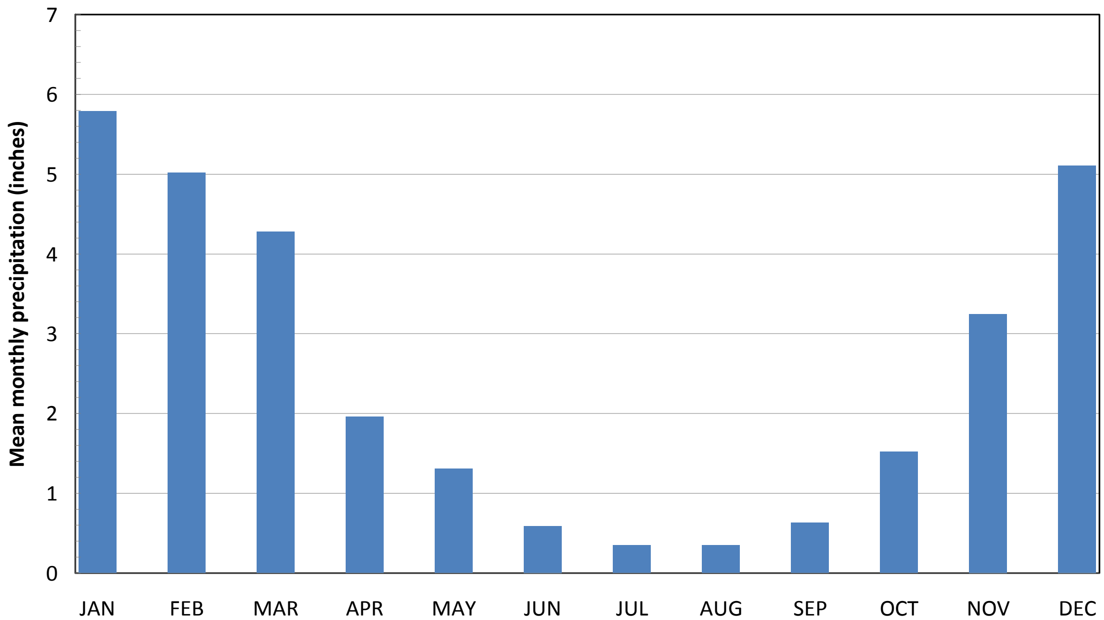


Figure 2-3. Mean Monthly Precipitation, Truckee Ranger Station, from 1904 to 1919 and 1935 to 2009

2.2.1 Climate Variability

The region experiences a wide range in climate variability. Variability is marked by periods of greater than average precipitation ('wet periods') and periods of below average precipitation or drought periods. Droughts have been historically common in the Sierra Nevada; Figure 2-4 illustrates the annual percent deviation from mean annual precipitation in Truckee and annual streamflow recorded at Farad from 1910 to 2009. The data shows that recent dry periods (periods of below average precipitation) generally have longer duration (e.g., 1971-1978, 1987-1994) than wet periods, which are typically short-lived and more extreme (e.g., 1962-1965, 1982-1983). The gray shading shows periods of incomplete annual precipitation data.

The worst drought in the 110 records of recorded streamflows at Farad was from 1987 to 1994. A similar pattern is recorded in tree-ring data since 1600 (Fritts and Gordon, 1980), with longer, more extreme droughts recorded. Lindstrom and others (2000) have described climate changes and details of wet and dry periods over the past 10,000 years, noting evidence of several dry periods when Lake Tahoe, and Donner and Independence Lakes dropped below their natural rims for consecutive years or decades (700 to 500 years ago and 200 to 100 years ago).

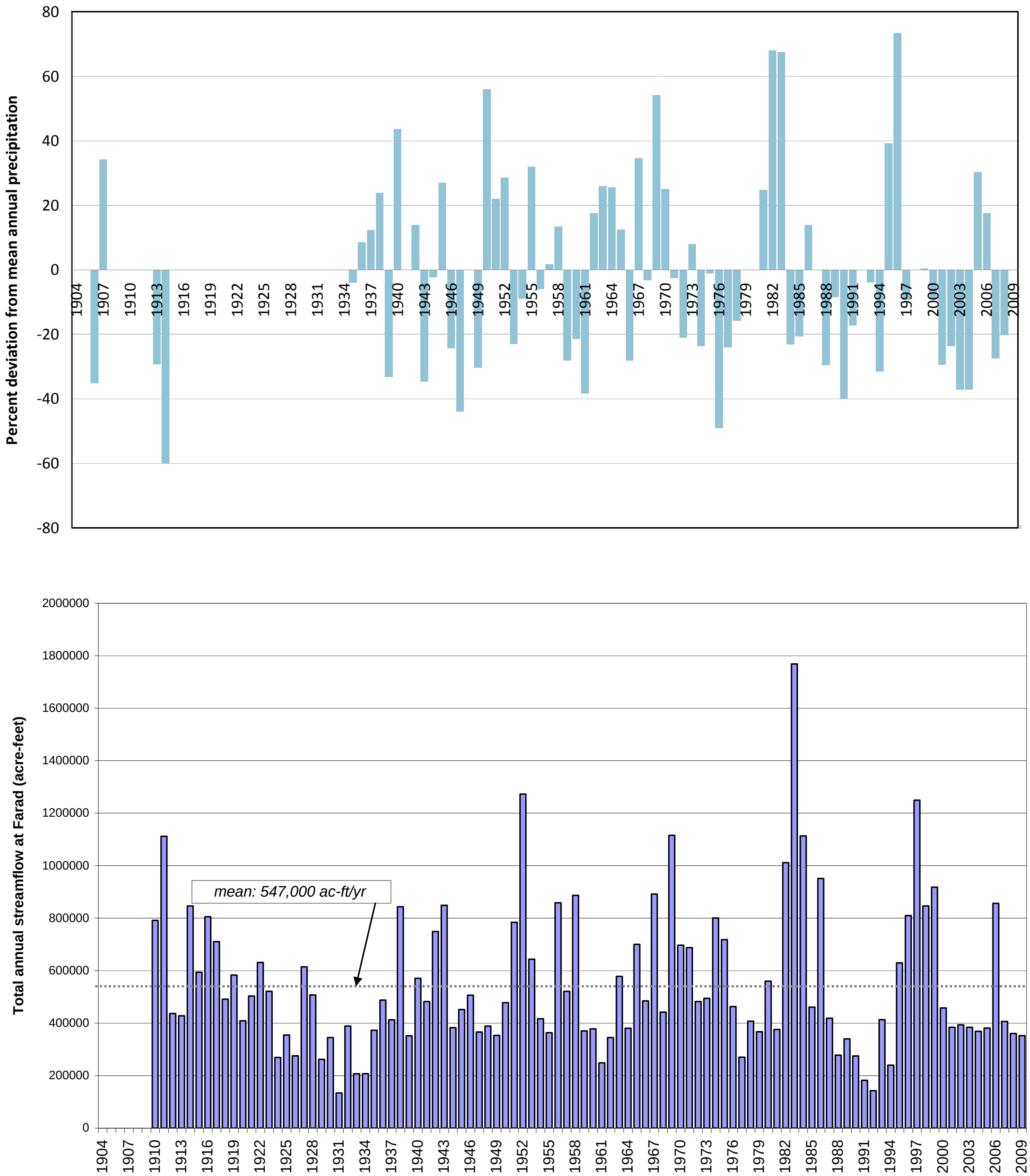


Figure 2-4. Percent Deviation from Mean Annual Precipitation at the Truckee Ranger Station and Total Annual Streamflow at Farad

2.2.2 Climate Change

The National Oceanic and Atmospheric Association (NOAA) and Coats and others (2010) have predicted a future shift from snowfall to rain in the next century in this region as a result of projected increases in average, minimum, and maximum air temperatures. Associated changes in surface water hydrology include potential increases in the frequency and magnitude of major flooding, such that more water may leave the basin as runoff, rather than infiltrating and recharging groundwater resources. NOAA has also predicted that climate change may result in increased drought frequency, and generally reduced water supplies (U.S. Bureau of Reclamation, 2011).

The U.S. Bureau of Reclamation manages water supply in the Truckee River Basin, and is undertaking a number of studies to evaluate the degree to which water supply and demand may be impacted by future changes in climate. This includes the Truckee River Basin Study, as well as funding researchers at DRI to develop an integrated groundwater, surface water, and climate change model of the MVGB.

2.3 Surface Water Hydrology

The Truckee River bisects the MVGB, with several tributaries upstream, within, and downstream of the MVGB. This section provides a brief discussion of the flow regimes of the Truckee River and the primary tributaries within the MVGB. Watershed areas are based on data available from CalAtlas, but subwatersheds shown have been modified in places for consistency with other regional studies, including the Water Quality Assessment and Modeling of the California portion of the Truckee River Basin (McGraw and others, 2001), the Truckee River Water Quality Monitoring Plan (Nichols Engineers, 2008), and the Martis Watershed Assessment (Shaw and others, 2012).

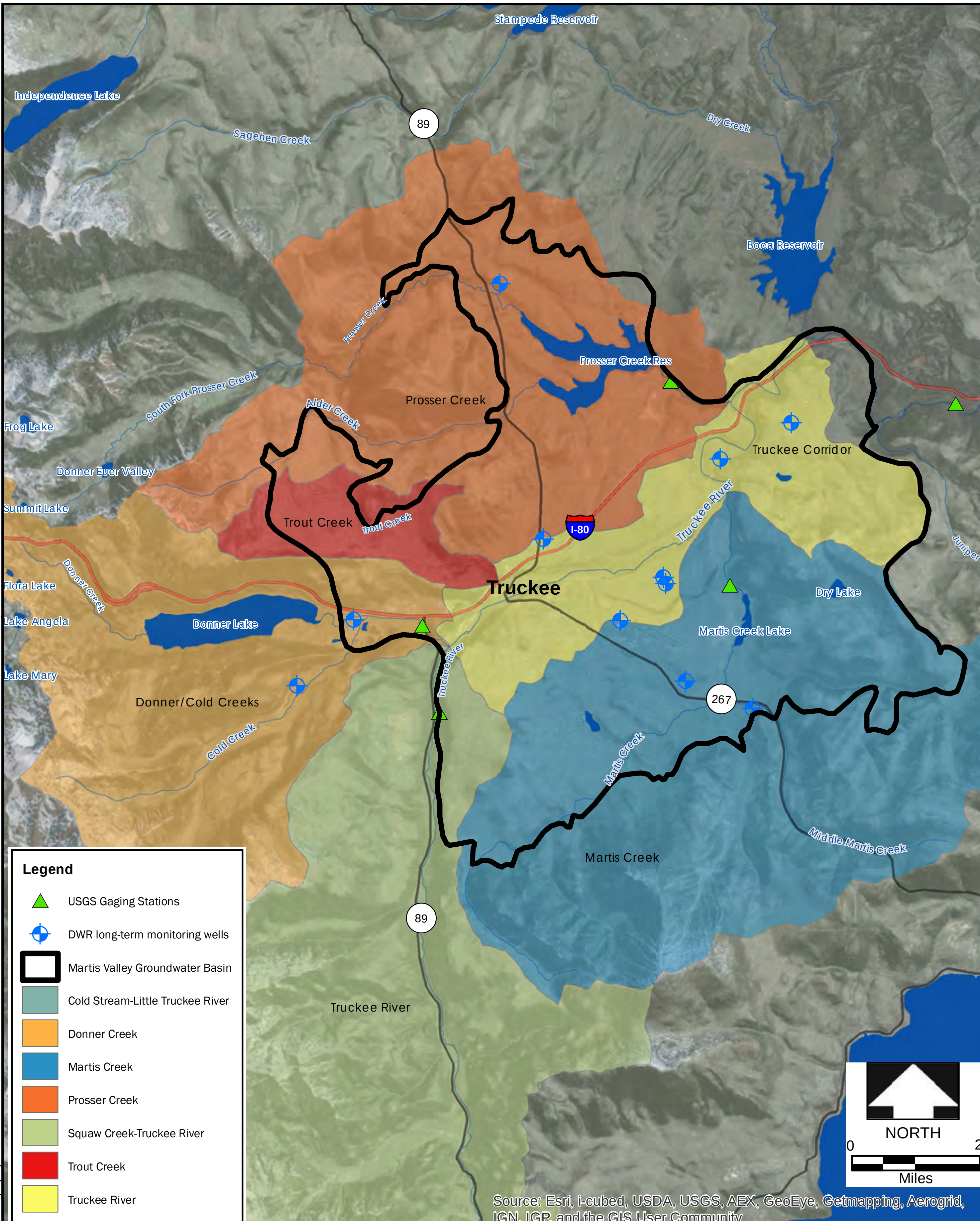
2.3.1 Truckee River

The Middle Truckee River[1] flows out of Lake Tahoe at Tahoe City with a number of tributaries contributing streamflow upstream of Martis Valley, including Bear, Squaw, Deer, Pole, Silver, and Cabin Creeks. The Truckee River then enters the MVGB near the junction of State Highway 89 and Interstate 80, flows west to east across Martis Valley before exiting the basin near Boca, just upstream of its confluence with the Little Truckee River. Main tributaries within Martis Valley are Donner, Cold[2], Trout, Martis and Prosser Creeks (Figure 2-5). Below Boca, the Truckee River descends into the Truckee Canyon before flowing through Reno and Sparks, Nevada, and terminating at Pyramid Lake.

Streamflow from Lake Tahoe, Donner Lake, Martis Creek, and Prosser Creek is controlled by major dams or impoundments, with the timing of releases and streamflows guided by a number of court decrees, agreements, and regulations that govern the flow rate from California to Nevada. These streamflow rates are known as 'Floriston Rates' and measured at Farad, California just upstream of the State line. The Truckee River is currently operated according to the Truckee River and Reservoir Operations Model (Berris and others, 2001). The Truckee River falls under the jurisdiction of TROA, which is further discussed in Section 3.2.

[1] Definitions of the Upper, Middle, and Lower Truckee River vary among numerous published studies. The definition used in this report of the "Middle Truckee River" definition used in this report conforms to nomenclature used by the California Lahontan Regional Water Quality Control Board, but differs from that used by the U.S. Bureau of Reclamation.

[2] Though it is not a direct tributary to the Truckee River, Cold Creek flows into Donner Creek below Donner Lake, approximately 1.5 miles upstream of the confluence with the Truckee River, and therefore accounts for a significant portion of the unregulated flow into the MVGB.



Martis Figure2_5_Hydrography.mxd

DATE 11-2-2012	PROJECT 140691	SITE **Martis Valley Groundwater Basin, California**	**Figure 2-5**
Brown AND Caldwell Balance Hydrologics, Inc.		TITLE **Hydrography and long-term monitoring stations**	

Table 2-1 summarizes historical monthly and average annual flow of the Truckee River and its tributaries, and Figure 2-6 correspondingly shows the average monthly streamflow at a number of gaging stations in the Truckee Basin. This data illustrates how the regulation of streamflows in the Truckee Basin alters the timing of discharge. Unregulated streams in this region tend to experience seasonal low flows in the late summer and early fall, with the bulk of total annual runoff occurring as snowmelt in May and June. This pattern is illustrated by monthly streamflow data collected at Sagehen Creek, an unregulated watershed approximately 5 miles north of the MVGB. In contrast, streams in the MVGB tend to have the total annual streamflow more uniformly distributed during the year, due to timed releases from the various impoundments.

Table 2-1. Average Monthly Streamflow on the Truckee River and Select Tributaries

	Sagehen Creek	Donner Creek below Donner Lake	Truckee River near Truckee	Prosser Creek below Prosser Dam	Martis Creek above Martis Dam	Truckee River at Boca	Truckee River at Farad
USGS Station ID	10343500	10338500	10338000	10340500		10344505	10346000
Watershed Size (sq mi)	10.5	14.3	553.0	52.9	37.2	873	932
Period of record	1953-present	1931-present	1945-present	1964-present	1959-1971; 1973-2007	2002-present	1910-present
(cfs)							
Oct	3	30	175	85	11	382	388
Nov	5	27	179	36	14	277	412
Dec	7	30	256	53	20	341	520
Jan	8	33	293	74	29	390	586
Feb	8	32	315	68	34	348	641
Mar	10	38	305	111	47	540	788
Apr	24	52	372	119	57	835	1240
May	43	86	532	190	52	1190	1680
Jun	25	45	457	112	26	900	1240
Jul	7	11	306	63	14	658	659
Aug	3	7	285	52	10	499	515
Sept	3	27	239	102	11	493	473
Mean annual (cfs)	12	35	310	89	27	571	762
Mean annual (ac-ft)	8,772	25,236	224,068	64,252	19,629	413,445	551,542

Source: U.S. Geological Survey; U.S. Army Corps of Engineers

cfs: cubic feet per second

ac-ft: acre-feet

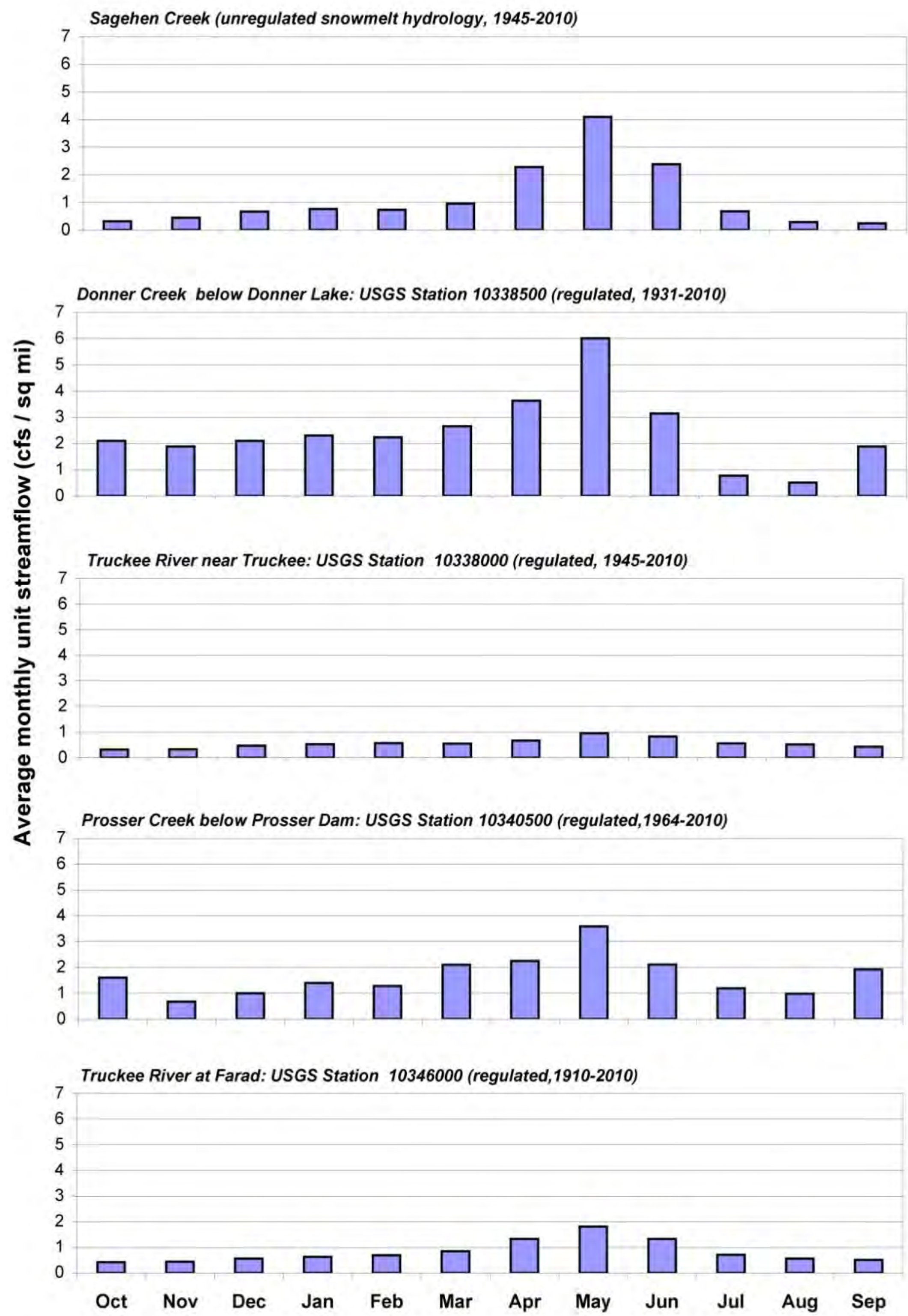


Figure 2-6. Mean Monthly Streamflows in the Middle Truckee River Watershed

2.3.2 Martis Creek

Martis Creek generally flows from south to north in the southern portion of the groundwater basin, with four named tributaries; Martis, West, Middle, and East Martis Creeks comprising the majority of its 42.7 square-mile watershed. Martis Creek Dam was completed in 1972 in order to provide storage for flood control, recreation, and potential water supply (USACE, 1985). Shortly following construction, seepage was observed in the dam face, posing a significant failure risk. As a result, the reservoir has rarely been filled to capacity, and is now maintained at a minimum pool elevation located entirely within the boundaries of the MVGB. The maximum outlet capacity of the dam is 580 cfs prior to spilling and 4,640 cfs at maximum spilling capacity. The United States Army Corps of Engineers (USACE) currently operates the dam in a 'gates wide open' position, such that minimal regulation or disruptions in the timing of streamflow occurs under most circumstances.

The United States Geologic Survey (USGS) maintained a streamflow gaging station on Martis Creek between Martis Dam and the Truckee River from October 1959 through September 2010, and recently transferred the gage to the USACE in October 2010. Since Martis Dam was constructed in 1972, this data has been used by the USACE, along with Martis Reservoir water level data and stage-storage information, to develop a record of inflow to Martis Reservoir. Daily reservoir inflow data is available for water years 1972 to 2008, and indicate average annual runoff into and out of the reservoir to be on the order of 19,629 acre-feet (27.1 cfs).

2.3.3 Donner and Cold Creeks

Donner Lake has a watershed area of approximately 14.3 square miles, all of which lies west of the MVGB boundary. The lake discharges into Donner Creek near the western boundary of the groundwater basin, and then flows toward the east and into the Truckee River (Figure 2-5). A dam was constructed at the lake outlet in 1928 (Berris and others, 2001) allowing for a reservoir capacity of 9,500 ac-ft. The Donner Lake dam is operated by the Nevada Energy (formerly Sierra Pacific Power Company), with a typical release season to provide flood control space from September 1 to November 15. The USGS has maintained a streamflow station on Donner Creek below Donner Lake (Station 10338500) since 1931. Average annual streamflow is 25,794 acre-feet (35.9 cfs), and Figure 2-6 illustrates the effect of dam operations on the timing of streamflow during the year.

2.3.3.1 Cold Creek

Cold Creek has a watershed area of approximately 12.5 square miles and flows from Coldstream Canyon into Donner Creek in the western portion of the groundwater basin. The confluence of these streams historically migrated across the Coldstream Canyon alluvial fan, but now both channels area confined by transportation infrastructure and historical aggregate mining operations. Cold Creek is the largest unregulated watershed that flows into the MVGB; with a runoff regime typical of a snowmelt-dominated system, with peak flows in May and June and low flows in the late summer and early fall.

A streamflow gage was installed on Cold Creek by Balance Hydrologics for the Truckee River Watershed Council in October, 2010. Cold Creek is the only significant tributary to Donner Creek between USGS gaging station 10338000 (Donner Creek at Donner Lake) and 10338700 (Donner Creek at Highway 89), therefore, historical streamflow estimates were inferred by calculating the difference in streamflow between these stations. Based on these data, average annual streamflow from Cold Creek is approximately 26,731 ac-ft (36.9 cfs).

2.3.4 Trout Creek

With a watershed area of approximately 5 square miles, Trout Creek is the only other unregulated stream (besides Cold Creek) which flows into the MVGB. The headwaters of Trout Creek are located within the Tahoe-Donner residential subdivision, part of the Town of Truckee and largely within the boundaries of the MVGB. The runoff regime is predominately snow-melt dominated, but with portions of the watershed covered with impervious surfaces such as roads and rooftops, rainfall events result in slightly more runoff and less infiltration and recharge from this watershed compared to others. A streamflow gage on Trout Creek was installed in January 2011 for the Truckee River Watershed Council so long-term streamflow statistics are not available.

2.3.5 Prosser Creek

Prosser Creek's approximately 32 square-mile watershed area includes Alder Creek and lies largely outside the MVGB. Prosser Creek Reservoir however, is entirely within the groundwater basin and is operated by the U.S. Bureau of Reclamation for water supply and flood control. Reservoir releases for flood control typically occur between September 1 and October 31 (Berris and others, 2001), as reflected in the pattern of average monthly flows depicted in Figure 2-6.

2.3.6 Truckee Corridor

The Truckee Corridor includes intervening areas that do not drain to the tributaries mentioned above. This includes the Union Creek subwatershed, which encompasses much of the Glenshire subdivision in the eastern portion of the MVGB, as well as urban and open space areas within the Town of Truckee.

2.3.7 Other impoundments

A number of small impoundments are located within the boundaries of the MVGB, including Union Mills Pond in the Glenshire subdivision, Dry Lake adjacent to the Waddle Ranch Preserve, and Gooseneck Reservoir, near the Lahontan Golf Club. Though originally constructed for cattle-grazing and/or millpond operations, these impoundments are now managed primarily for open space, recreational/aesthetic, or wildlife purposes.

2.4 Geology

The Martis Valley is located in the Sierra Nevada physiographic region, which is composed primarily of igneous and metamorphic rocks, with sedimentary rocks in its valleys. The MVGB's complex geology is dominated by sedimentary deposits left by glaciations, volcanic rocks, and faulting. A component of the Martis GMP was the development of geologic cross-sections to improve the understanding of MVGB geology and stratigraphy.

2.4.1 Geologic Database Development

Approximately 200 well logs obtained from the DWR, TDPUD, PCWA, NCSD, and the Tahoe-Truckee Sanitation Agency (T-TSA) were interpreted to better understand depths and thicknesses of the various geologic formations comprising the MVGB. The filtered geologic and selected well data were entered into an ESRI ArcGIS Geodatabase, a spatially-referenced database. The benefit of the Geodatabase allowed a visual representation of the geologic data and was also used as the geologic framework for the DRI groundwater model that provides consistency between the GMP geologic interpretation and the groundwater model.

The geochronology and stratigraphic relationships of water-bearing formations was based on Birkeland's (1961; 1963; 1964) work, as well as subsequent investigations by Latham (1985), and Hydro-Search (1995), and mapping published by Saucedo (2005) and Melody (2009). The stratigraphic relationships, lithologies, and formation locations described in these studies, as well as through field observations, formed the basis for the designation of the primary hydrostratigraphic units, as displayed in Figure 2-7. Figure 2-8 shows the approximate locations of wells used to develop the geologic database.

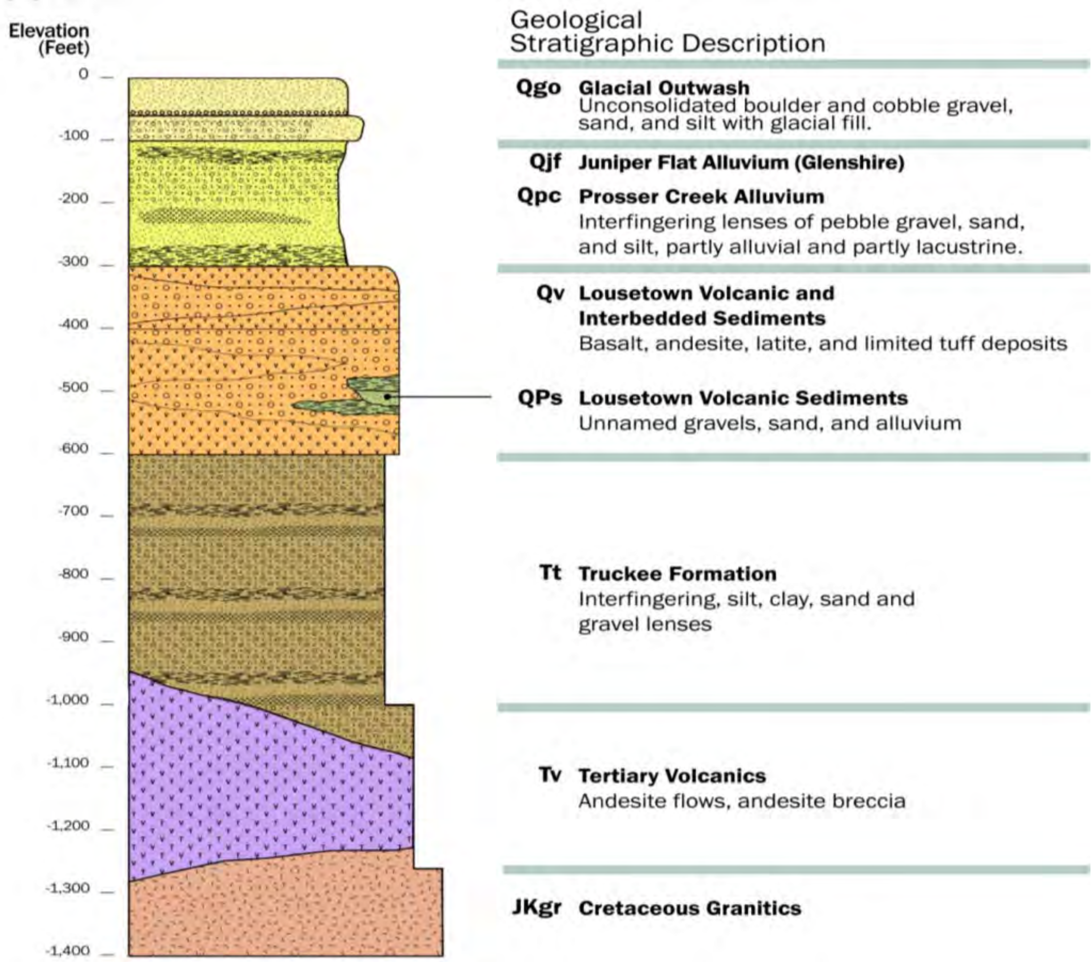
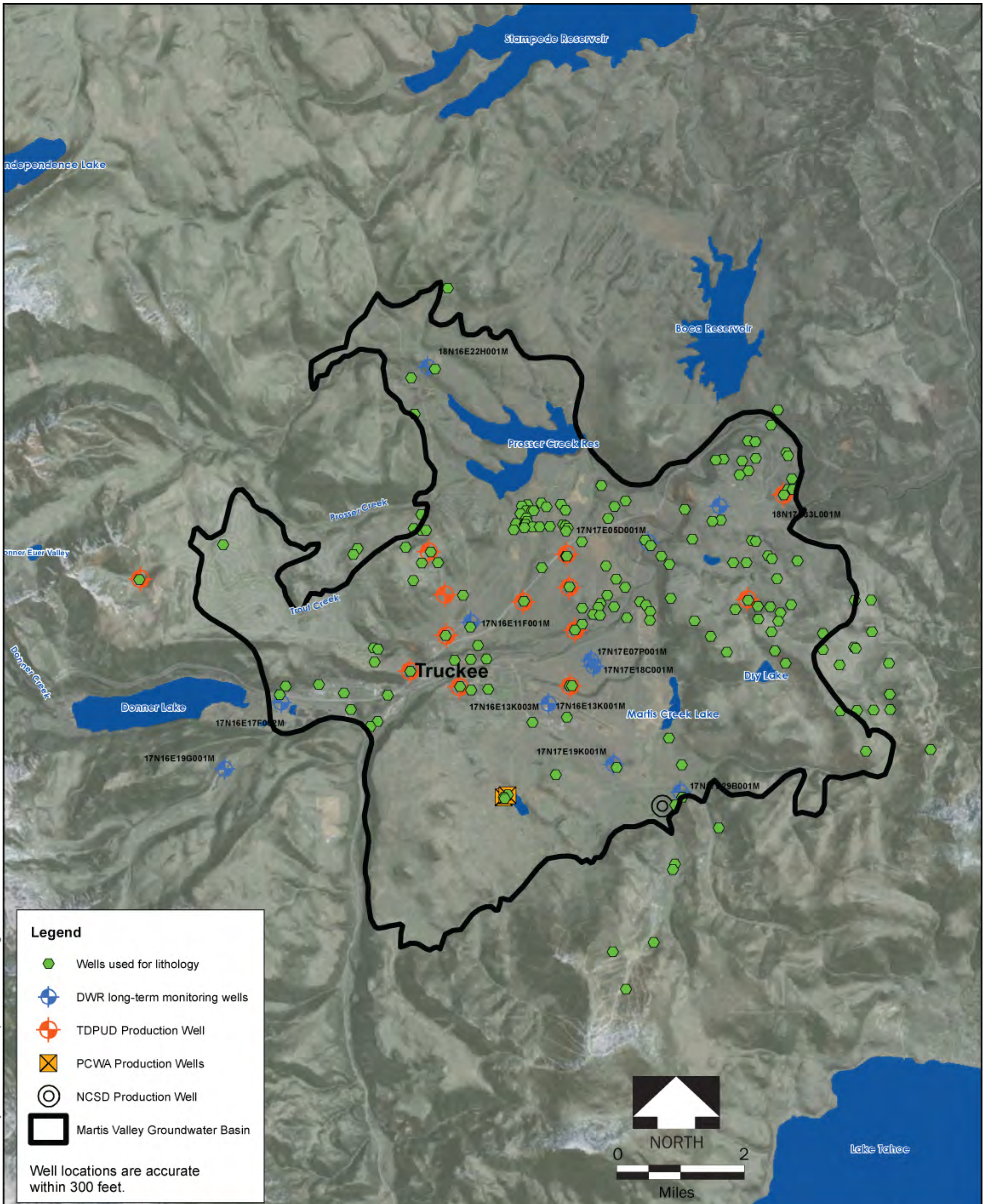


Figure 2-7. Stratigraphic Column showing Primary Hydrostratigraphic Units

Stratigraphic interpretations shown in Figure 2-7 and in Section 2.4.3 (below) are consistent with published geologic maps of the basin (Birkeland, 1961; Birkeland, 1963; Saucedo, 2005; Melody, 2009), and delineate four primary water-bearing stratigraphic units that make up the aquifer, and underlying rocks that are considered to be relatively water-limited (see Figure 2-9). The primary units shown in Figure 2-7 include a number of subunits mapped by previous investigators and shown on Figure 2-9 and noted in parenthesis with the descriptions below. When available, information regarding potentially confining (fine grained) or water-bearing (coarse) subunits are also delineated. Following well log interpretation, three representative geologic cross-sections were located and developed. Figure 2-9 shows the cross-section locations; Figure 2-10 shows cross-section A-A'; Figure 2-11 shows cross-section B-B', and Figure 2-12 shows cross-section C-C'.

It should be noted that Figure 2-9, a geologic map of the MVGB and surrounding areas, is based on published geologic mapping by Saucedo (2005), Melody (2009), and Saucedo and Wagner (1992). The Saucedo and Wagner (2009) mapping was completed at a statewide scale and is therefore, less precise than other portions of the map and geological cross-sections. Accordingly, portions of the geologic map in Figure 2-9 do not correspond to the more detailed geological mapping and cross-sections.



DATE	PROJECT	SITE
9-7-12	140691	Martis Valley Groundwater Basin, California

Brown AND Caldwell

Balance Hydrologics, Inc.

TITLE

Well Locations

Figure 2-8

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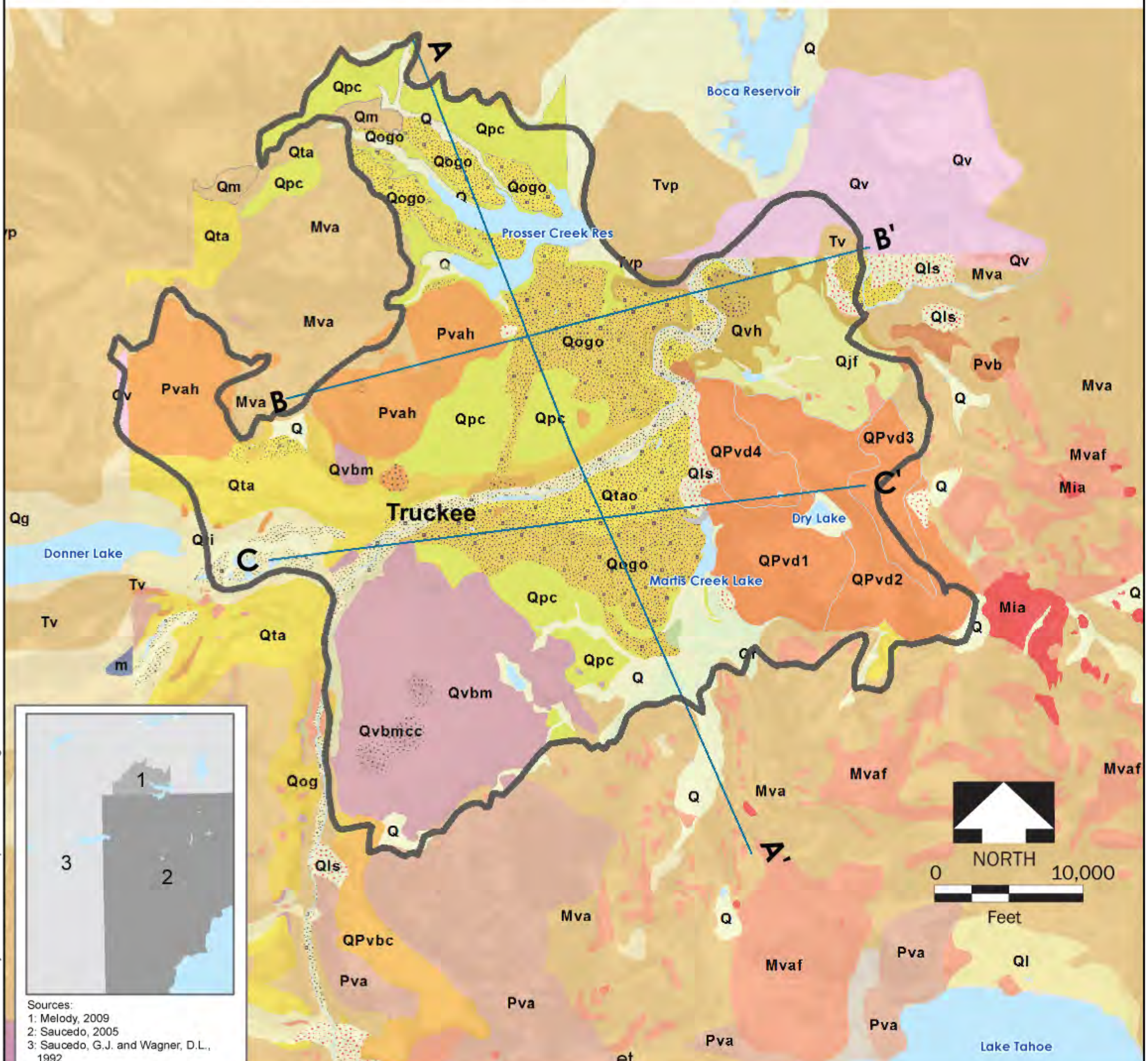
Geology Legend

- Martis Valley Groundwater Basin
- Ql - Lake deposits (Holocene)
- Qls - Landslide deposits (Holocene and Pleistocene)
- Q - Alluvium (Holocene and Pleistocene)
- Qf - Alluvial fan deposits (Holocene and Pleistocene)
- Qm - Mudflow deposits (Holocene and (or) Pleistocene)
- Qti - Tioga outwash?
- Qta - Tahoe outwash?
- Qtao - Outwash deposits
- Qog - Till
- Qogo - Outwash deposits
- Qgo - Outwash deposits
- Qg - Quaternary; nonmarine, glacial till and moraines
- Qv - Undifferentiated volcanic rocks (Quaternary)
- Qvbm - Bald Mountain olivine latite (Pleistocene)
- Qjf - Juniper Flat alluvium (Pleistocene)
- Qpc - Prosser Creek alluvium (Pleistocene)
- Qvh - Hirschdale olivine latite (Pleistocene)
- QPvd - Dry Lake volcanic flows (Pliocene and (or) Pleistocene)
- QPvbc - Big Chief basalt (Pliocene and (or) Pleistocene)
- Pvp - Polaris olivine latite (Pliocene)
- Pvah - Olivine basalt flows (Pliocene)
- Pva - Andesite and basaltic andesite flows (Pliocene)
- Pvb - Basalt flows (Pliocene)
- Mva - Undivided andesitic and dacitic lahars, flows, breccia and volcaniclastic sediments (Miocene)
- Tv - Tertiary; volcanic flow rocks
- Mvaf - Andesite and dacite flows (Miocene)
- Mia - Intrusive rocks (Miocene) andesite, basaltic andesite and latite
- OMvr - Rhyolite tuff (Oligocene and Miocene?)
- grMz - Granite, quartz monzonite (Mesozoic)
- J - Marine sedimentary and metasediment rocks (Jurassic)
- m - Schist (Early Proterozoic to Cretaceous)



Sources:
1: Melody, 2009
2: Saucedo, 2005
3: Saucedo, G.J. and Wagner, D.L., 1992

DATE	PROJECT	SITE	
9-19-12	140691	Martis Valley Groundwater Basin, California	Figure 2-9
Brown AND Caldwell / Balance Hydrologics, Inc.		TITLE: Geology and Cross-section Locations	

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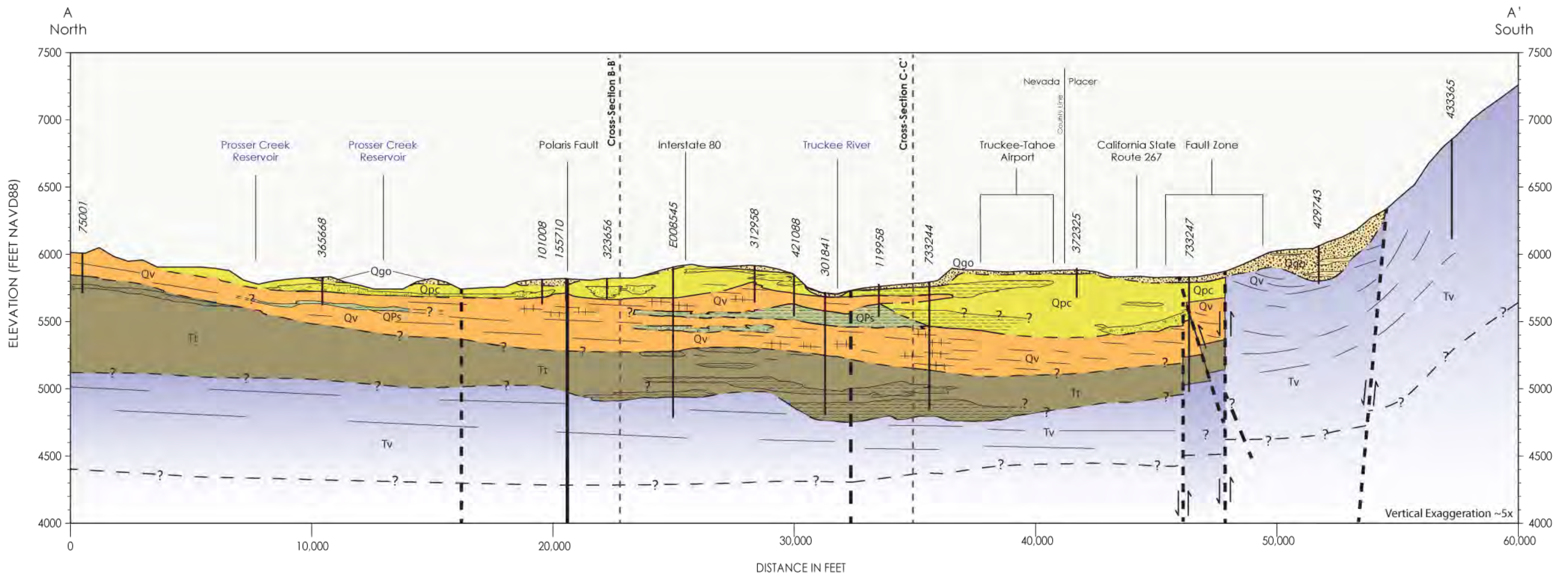

NOTES:
1. Approximate vertical exaggeration = 5x.
2. Elevation profile developed from 30-meter digital elevation model, downloaded from National Elevation Dataset (http://seamless.usgs.gov/index.php).
3. Well log locations are approximate within 600 feet.
4. Fault locations are approximate, based on Saucedo, "Geologic Map of Lake Tahoe Basin," 2005 and Hunter and others, 2011.
5. Surficial geology inferred from Saucedo, 2005.
6. Significant sand, gravel, and clay beds shown where noted in well logs.
7. Fracture zones shown where noted in well logs.

References:
Birkeland, P.W., 1963 Pleistocene History of the Truckee area, north of Lake Tahoe, California, Geological Society of America Bulletin, v. 64, p. 1453-1464.
Hunter, L.E., Howle, J.F., Rose, R.S., and Bawden, G.W., 2011, LiDAR - assisted identification of an active fault near Truckee, California, Bulletin of the Seismological Society of America, v. 101, n. 3, p. 1162-1181.
Latham, T.S., 1985, Stratigraphy, structure, and geochemistry of Plio-Pleistocene volcanic rocks of the western Basin and Range Province, near Truckee, California, unpublished doctoral dissertation, University of California, Davis, 341 p.
Melody, A., 2009, Active faulting and Quaternary paleohydrology of the Truckee Fault Zone north of Truckee, California, MS Thesis, Humboldt State University, Humboldt, CA 71 p.
Saucedo, G.J., 2005, Geologic Map of Lake Tahoe Basin, California and Nevada, California Geological Survey Regional Geologic Map Series, Map No. 4, 1:100,000 scale.

Legend

- Qg — Glacial Till/Moraine
- Qgo — Glacial Outwash deposits
- Qpc — Prosser Creek alluvium (Pleistocene)
- Qv — Lousetown Volcanics (Pleistocene)
- QPs — Lousetown Interbedded Sediments (Unnamed gravels, sand and alluvium) (Pliocene and (or) Pleistocene)
- Tt — Truckee Formation (Lake and Stream Deposits)
- Tv — Tertiary Volcanics
- Sands and Gravels
- Clay Bed
- Tuff/Ash
- Interbedded Basalt and Andesite Basalt
- Fracture Zone
- Lithologic Contact
- — ? — Inferred Lithologic Contact
- Fault, direction of displacement (dashed where inferred)
- 429743 Well log

SITE: **Martis Valley Groundwater Basin, California**

TITLE: **Cross-section A-A'**

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PROJECT: 140691

Figure 2-10

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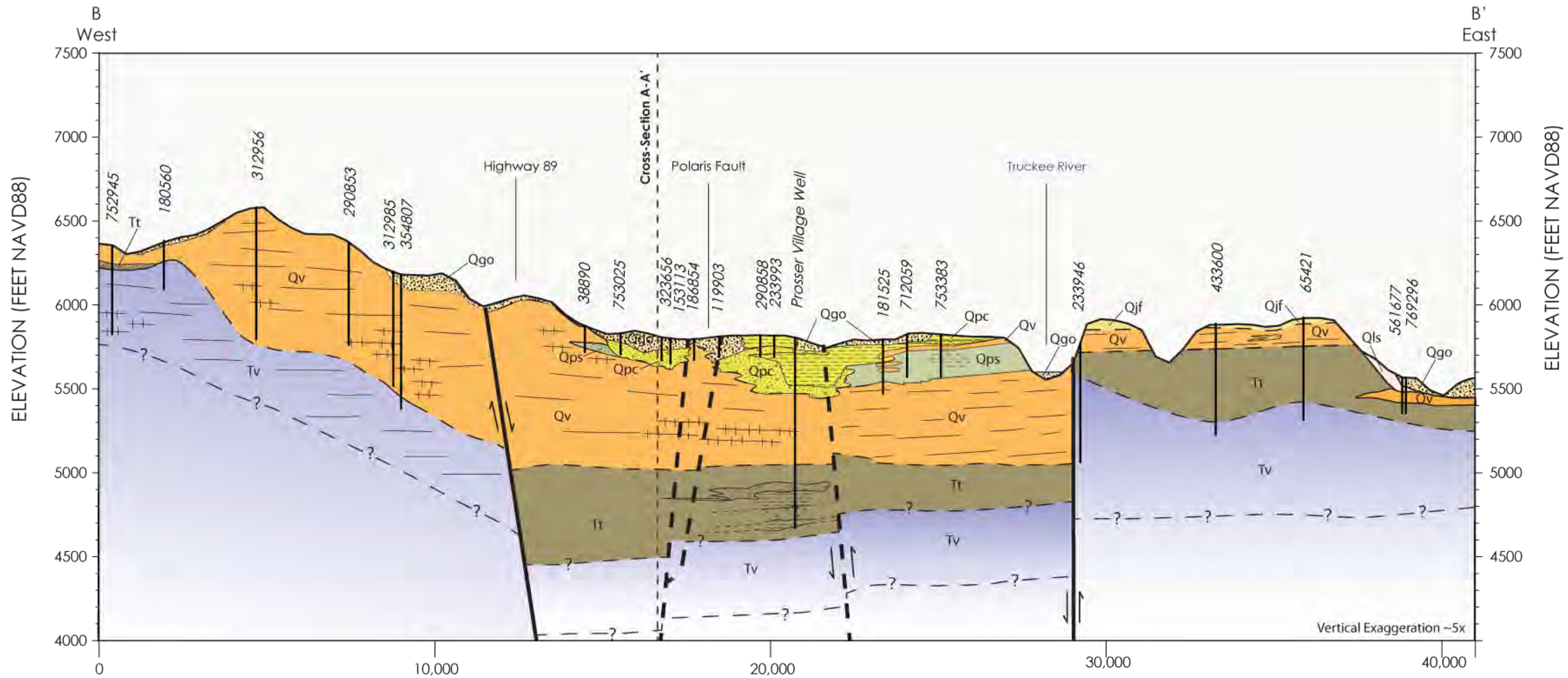
Source: ©2011 Balance Hydrologics, Inc.



NOTES:
1. Approximate vertical exaggeration = 5x.
2. Elevation profile developed from 30-meter digital elevation model, downloaded from National Elevation Dataset (http://seamless.usgs.gov/index.php).
3. Well log locations are approximate within 600 feet.
4. Fault locations are approximate, based on Saucedo, "Geologic Map of Lake Tahoe Basin," 2005 and Hunter and others, 2011.
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6. Significant sand, gravel, and clay beds shown where noted in well logs.
7. Fracture zones shown where noted in well logs.

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Latham, T.S., 1985, Stratigraphy, structure, and geochemistry of Plio-Pleistocene volcanic rocks of the western Basin and Range Province, near Truckee, California, unpublished doctoral dissertation, University of California, Davis, 341 p.
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Legend

- Qg — Glacial Till/Moraine
- Qgo — Glacial Outwash deposits
- Qls — Landslide deposits
- Qjf — Juniper Flat alluvium (Pleistocene)
- Qpc — Prosser Creek alluvium (Pleistocene)
- Qv — Lousetown Volcanics (Pleistocene)
- QPs — Lousetown Interbedded Sediments (Unnamed gravels, sand and alluvium) (Pliocene and (or) Pleistocene)
- Tt — Truckee Formation (Lake and Stream Deposits)
- Tv — Tertiary Volcanics
- Sands and Gravels
- Clay Bed
- Tuff/Ash
- Interbedded Basalt and Andesite Basalt
- Fracture Zone
- Lithologic Contact
- —?— Inferred Lithologic Contact
- Fault, direction of displacement (dashed where inferred)
- 429743 — Well log

SITE: Martis Valley Groundwater Basin, California

TITLE: Cross-section B-B'

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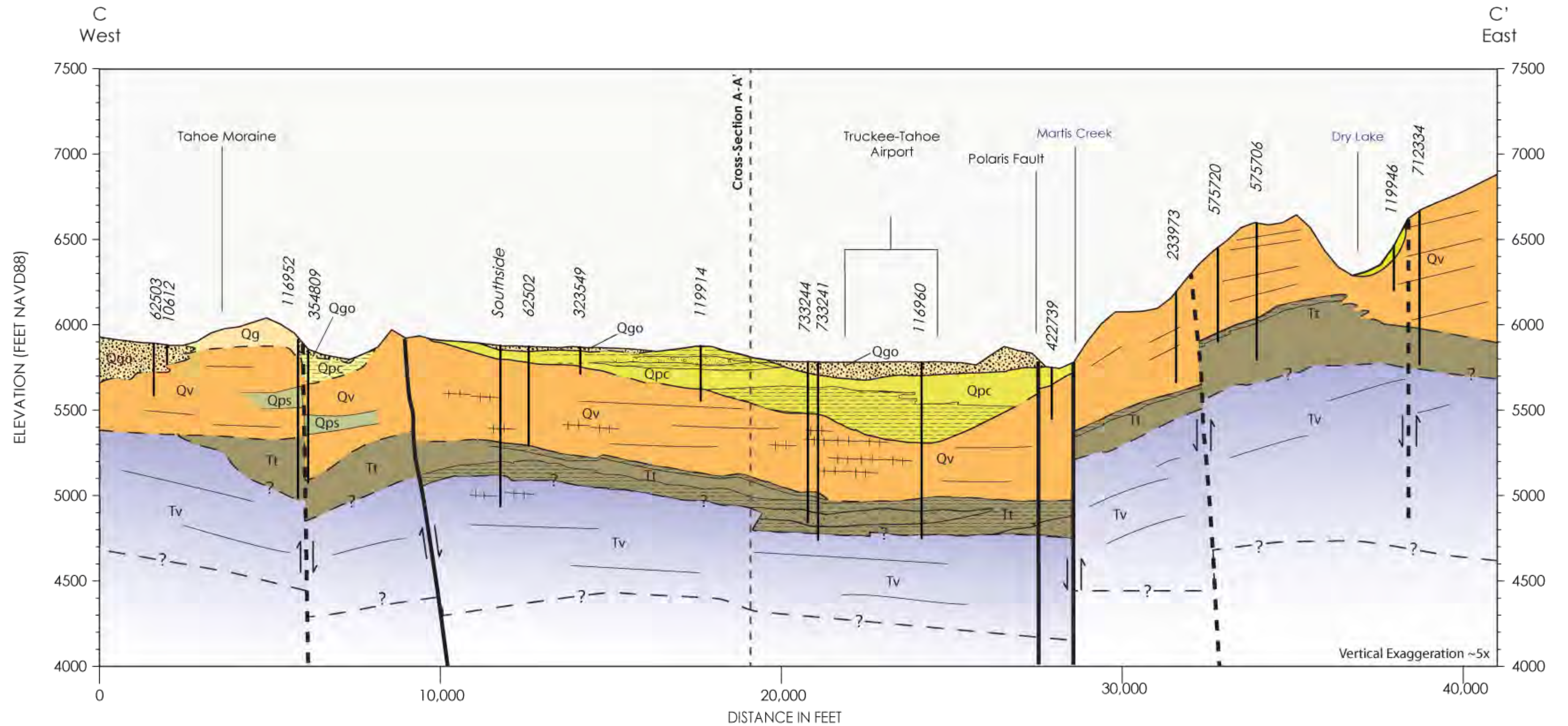
DATE: 9-7-12

PROJECT: 140691

Figure 2-11



NOTES:
1. Approximate vertical exaggeration = 5x.
2. Elevation profile developed from 30-meter digital elevation model, downloaded from National Elevation Dataset (http://seamless.usgs.gov/index.php).
3. Well log locations are approximate within 600 feet.
4. Fault locations are approximate, based on Saucedo, "Geologic Map of Lake Tahoe Basin," 2005 and Hunter and others, 2011.
5. Surficial geology contacts inferred from Saucedo, 2005.
6. Significant sand, gravel, and clay beds shown where noted in well logs.
7. Fracture zones shown where noted in well logs.

References:
Birkeland, P.W., 1963 Pleistocene History of the Truckee area, north of Lake Tahoe, California, Geological Society of America Bulletin, v. 64, p. 1453-1464.
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Legend

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- Tt — Truckee Formation (Lake and Stream Deposits)
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- Sands and Gravels
- Clay Bed
- Tuff/Ash
- Interbedded Basalt and Andesite Basalt
- Fracture Zone
- Lithologic Contact
- — ? — Inferred Lithologic Contact
- Fault, direction of displacement (dashed where inferred)
- 429743 Well log

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SITE
Martis Valley Groundwater Basin, California

TITLE
Cross-section C-C'

Brown AND Caldwell
Balance Hydrologics, Inc.

DATE 9-7-12
PROJECT 140691

Figure 2-12

2.4.2 Stratigraphy

The uplift along the faults that created the MVGB probably began during the late Pliocene and into the early Pleistocene, with relatively low-permeability Tertiary volcanics forming the bottom of the basin (considered basement rocks in this report). Prior to and throughout the middle Pliocene, the sedimentary material of the Truckee Formation was deposited in the MVGB, directly overlying andesite tuff breccias, andesite flows, and intrusive rocks of Tertiary age. Following deformation, the general topography of the Martis Valley was probably somewhat similar to today's topography (Birkeland, 1963), with the Truckee River flowing out of the MVGB near where it does today, cutting a canyon through the pre-Pleistocene rocks of the Carson Range.

During the Pleistocene, a series of volcanic flows occurred in the regional Truckee area. At least 20 distinct flows have been recognized (Birkeland, 1961), mostly (but not exclusively) consisting of fine-grained latites and basalts, and are noted as being fairly local in extent. Flows found in the MVGB include the Dry Lake Flows (QPvd), the Bald Mountain olivine latite (Qvbm), Alder Hill Basalt, Polaris olivine latite, and Hirschdale olivine latite. Collectively, these units are referred to as Lousetown volcanics (Qv) based on Birkeland's (1963) correlation to other Lousetown flows in the Carson Range. Also included within the in the Lousetown Formation are interbedded Lousetown sediments (Qps); fluvial (stream) and lacustrine (lake) deposits accumulating, and thereby raising land surface elevation, in the valley between flow events.

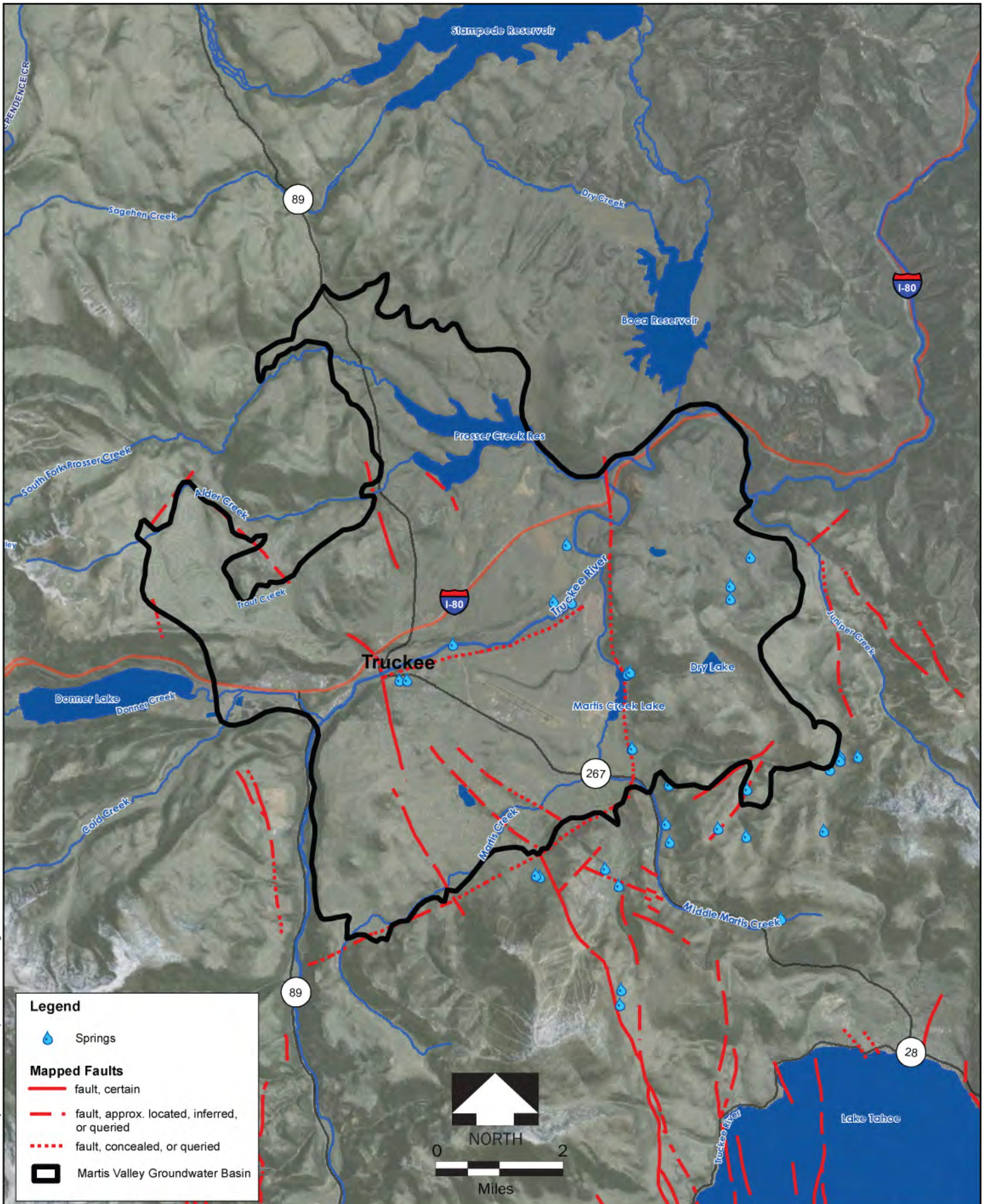
As volcanic activity waned, one of the last flows, the Hirschdale Olivine Latite, flowed across the Truckee River Canyon, damming the basin and causing widespread sediment accumulation and deposition of the Prosser Formation (Qpc), a partly-lacustrine and partly fluvial sedimentary unit (Birkeland, 1963). Brown (2010) has subdivided the Prosser Formation into Upper, Middle, and Lower Members. For geodatabase development purposes, interbedded Lousetown sediments are defined as being capped by volcanics, while the Prosser Formation is not. It is recognized however, that the lower Prosser Formation may have been deposited concurrently with the interbedded Lousetown sediments, and in some cases, may be correlated to these upper sediments where capping volcanics pinch out laterally.

During this same period, Juniper Flat alluvium was being deposited in the Glenshire area with sediment derived from the paleo-Juniper Creek watershed and alluvium derived from the west.

The Prosser Formation and volcanics in other areas are capped by glacial deposits, derived from glacial advances and retreats during a number of glacial episodes (Birkeland, 1961). In the MVGB, most of the deposits consist of glacial outwash deposits of varying age (Qgo). The outwash deposits consist of loose and unconsolidated boulder, cobble, gravel, and sand. In the vicinity of the Truckee River, three distinct outwash deposits (Qogo, Qtao, and Qti) are apparent and form terraces along the course of the river (Birkeland, 1961). A number of glacial moraines were also deposited, and are visible today in the vicinity of Donner Lake, the Tahoe-Donner residential neighborhood, and the Gateway Neighborhood of Truckee.

2.4.3 Structure

The MVGB lies within the Truckee Basin, a structural trough formed at the boundary of the Sierra Nevada and Basin and Range Geomorphic Provinces. Tectonics in this zone are complex and include active right-lateral (strike-slip) shear associated with the Pacific-North American Plate boundary and North Walker Lane Belt, as well as extensional (normal) faulting associated with the Basin and Range Province. The uplift along the faults that created the basin probably began during the late Pliocene and into the early Pleistocene (Birkeland, 1963), while right-lateral faulting is inferred to have occurred into the Holocene (Melody, 2009; Brown, 2010; Hunter and others, 2011). Most recently, the Polaris Fault has been mapped as an active North-South Holocene fault across the center of the MVGB. Identified faults are shown in Figure 2-13.



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DATE	PROJECT	SITE	
9-7-12	140691	Martis Valley Groundwater Basin, California	Figure 2-13
Brown and Caldwell; Balance Hydrologics, Inc.		TITLE: Locations of Springs and Mapped Faults (active and inferred)	

2.5 Groundwater Occurrence and Movement

The geologic units described above are interlayered, with complex spatial relationships, and as such, the occurrence and movement of groundwater within and between these units is variable. For this report, the low-permeability Miocene (Tertiary) volcanic rocks are considered the bottom of the MVGB. This section discusses where groundwater occurs, groundwater and surface water interaction, and water levels over time.

2.5.1 Water-bearing Units and Properties

The Truckee Formation (Tt) is composed of interlayered silts, sands, and clays, and therefore has variable groundwater availability. Well driller's logs document sands and gravels within the Truckee Formation in the center of the basin, near the Truckee Tahoe Airport, at depths of approximately 900 to 1,000 feet, and from 200 to 700 feet in the southern portion of the basin near Shaffer's Mill and Lahontan Golf Clubs. Well yields in the Truckee Formation range from 280 gallons per minute (gpm) in the eastern portion of the basin (Hydro-Search, 1995) to more than 1,000 gpm in faulted areas underlying the Bald Mountain volcanics in the southwestern portions of the MVGB (Herzog, 2001).

Water is found along faults and fractures within the Lousetown volcanics (Qv), though portions of the volcanic flows are massive and unfractured. Figure 2-14a is a photo of a Lousetown volcanic outcrop and illustrates the range of fracture concentrations that can occur in this unit. In most cases, water encountered in this fractured system is pressurized, rising to a static level several hundred feet higher than where initially encountered, suggesting the presence of confining units above these fracture zones.

Wells located in the southern portion of the groundwater basin have been found to be artesian, or flowing, along fractures interpreted as faults (Herzog and Whitford, 2001), with yields ranging from approximately 250 to 1,000 gpm. A number of distinct fault blocks are present in this area, with unique and heterogeneous aquifer properties where faults serve as barriers to groundwater flow (ECO:LOGIC, 2006; ECO:LOGIC, 2007; Bugenig, 2007; Bugenig, 2006; Peck and Herzog, 2008). Groundwater discharge areas in the form of seeps and springs are also found within these areas and along the periphery of the MVGB (Figure 2-13), including thermal springs in the vicinity of the recently-mapped Polaris Fault (Hunter and others, 2011).

The Prosser Formation (Qpc) includes interlayered silts, sands, and clays and has variable water bearing capacity. Figure 2-14b shows an outcrop of the Prosser Formation, where coarser materials such as sand and gravel are present, and moderate groundwater yields may be encountered. Water-bearing portions of the Prosser Formation may also be hydrologically connected to overlying glacial outwash and potentially surface water bodies as well. Well yields in these alluvial formations typically range from 12 to 100 gpm, though larger-diameter production wells have estimated yields as high as 500 gpm according to State well driller's logs.

Hydraulic properties of the glacial moraines contrast sharply with those of the glacial outwash deposits; the moraines consist of poorly-sorted clay to boulder-size materials, while the glacial outwash deposits are primarily well-sorted sands and gravels. As a result, the glacial outwash tends to transmit water relatively easily, while moraines are typically water-limited.

Figure 2-14a. Lousetown Volcanic Outcrop

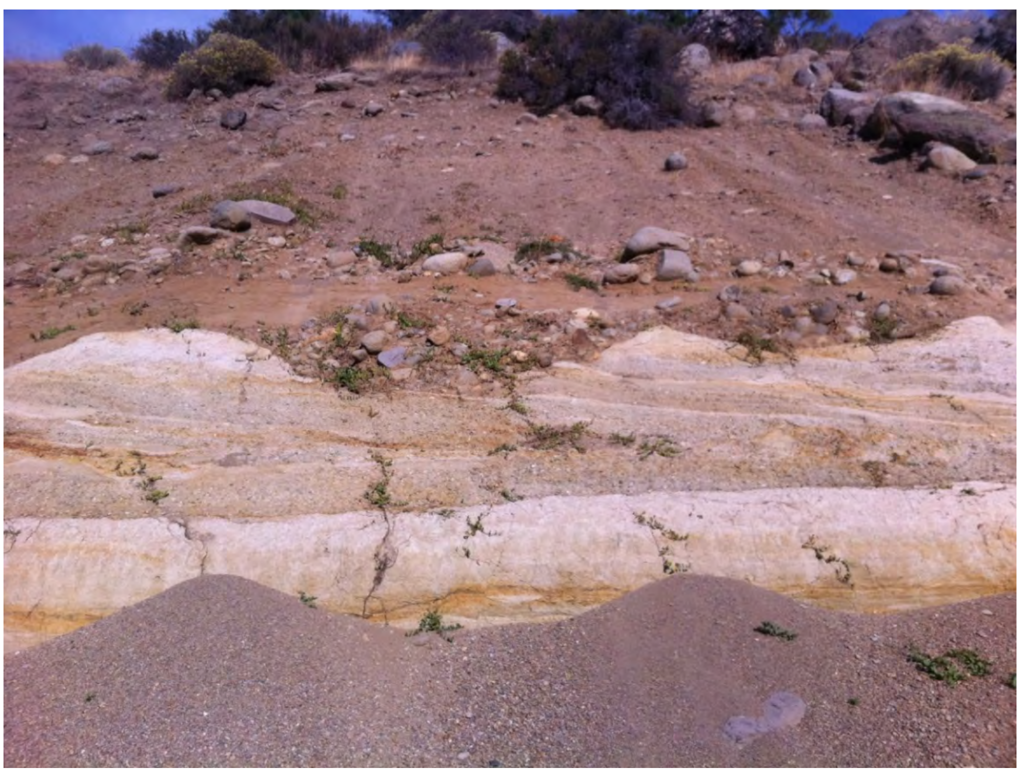


Figure 2-14b. Prosser Formation Outcrop Underlying Glacial Outwash

2.5.2 Surface-groundwater interaction

Generalized groundwater flow directions were inferred by Hydro-Search (1995) and were based on static water levels reported in State well drillers reports and DWR's long-term well monitoring data, and indicated groundwater flow directions toward the Truckee River.

A more detailed surface water and groundwater interaction study (Interflow Hydrology, 2003) was completed for the TDPUD. The Interflow Hydrology study provides estimates of the magnitude of stream losses and gains to and from groundwater across the Martis Valley during summer 2002, in the middle of a multi-year dry period. Observations made during the course of the study showed Martis Creek to be a 'gaining stream' (receiving groundwater discharge) across the Lahontan Golf Club, upstream of Martis Valley; West Martis Creek was found to be a 'losing stream' as it enters Martis Valley, recharging groundwater between the Northstar Golf Course and its confluence with Martis Creek; and Middle Martis Creek showed no loss or gain across the valley floor. Groundwater discharge in the form of springs generally support perennial flows in Lower East Martis and Dry Lake Creeks, as well as from the hillside adjacent to Martis Reservoir.

Interflow Hydrology (2003) computed a basic water balance based on late season low flow measurements in the watershed and found that in October 2002, total streamflow losses across the Martis Valley floor were on the order of 0.65 cfs (approximately 9 percent of the total baseflow into the MVGB from Martis Creek), while losses at Martis Creek Lake were on the order of 1.55 cfs (approximately 29 percent of the total flow at that point). Evaporation and evapotranspiration by plants were not measured as part of the study; however, these data suggest that the Martis Valley floor potentially serves as a groundwater recharge area during the late summer and fall months.

In addition, Interflow Hydrology (2003) identified groundwater recharge occurring where Prosser Creek enters the MVGB, just upstream of Prosser Reservoir. All other tributaries, including Cold, Donner, and Trout Creeks were concluded to be supported by groundwater discharge.

2.5.3 Groundwater levels and Land Subsidence

Groundwater levels have been generally stable in the Martis Valley with some declines occurring in specific regions. Figure 2-15 presents groundwater level monitoring data throughout much of the MVGB as measured by DWR since 1990 in a single set of hydrographs. This graph shows that overall groundwater levels have been stable in the MVGB, including during the drought of the early 1990s, and the wet years of the late 1990s.

Figure 2-16 shows the locations of the 16 DWR monitoring wells and selected respective hydrographs. The hydrographs indicate that groundwater is locally variable in the MVGB, as levels may decline in some wells and rise in other wells over the same period of time. These data suggest that there may be several water-bearing zones in the MVGB that may or not be hydraulically connected. The hydrographs also provides the following well specific information:

- Well 17N16E11F001M (northeast of downtown Truckee) experienced a nearly 50-foot rise in water level in the late 1990s, and then declined steadily over the following decade. This rise coincides with above-average precipitation and streamflow (Figure 2-4).
- Levels in Well 17N17E29B001M (Northstar) and 17N17E19K001M (Truckee Airport) were relatively steady throughout the monitoring period until summer 2007, when seasonal fluctuations began to occur. Water levels have declined seven feet between 2007 and 2012.
- Groundwater levels in well 17N17E05D001M (Truckee River east of Truckee) have increased steadily over the period of record, rising over 10 feet from 1990 to 2012.
- In well 17N1E17F002M (Donner Creek area), groundwater levels fluctuated seasonally but generally remained constant year to year).

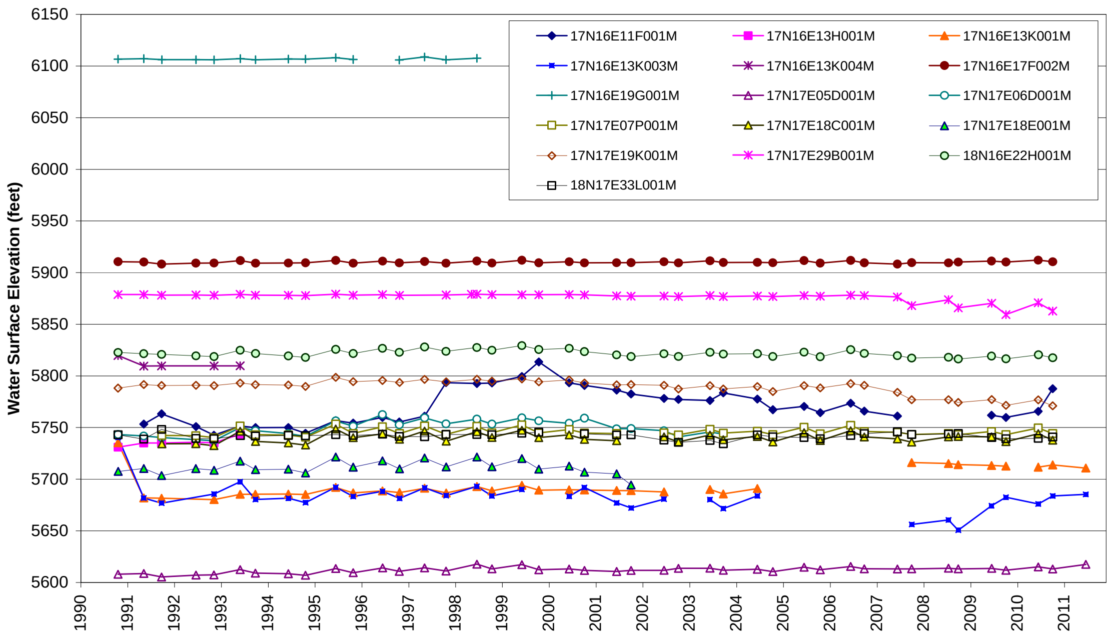


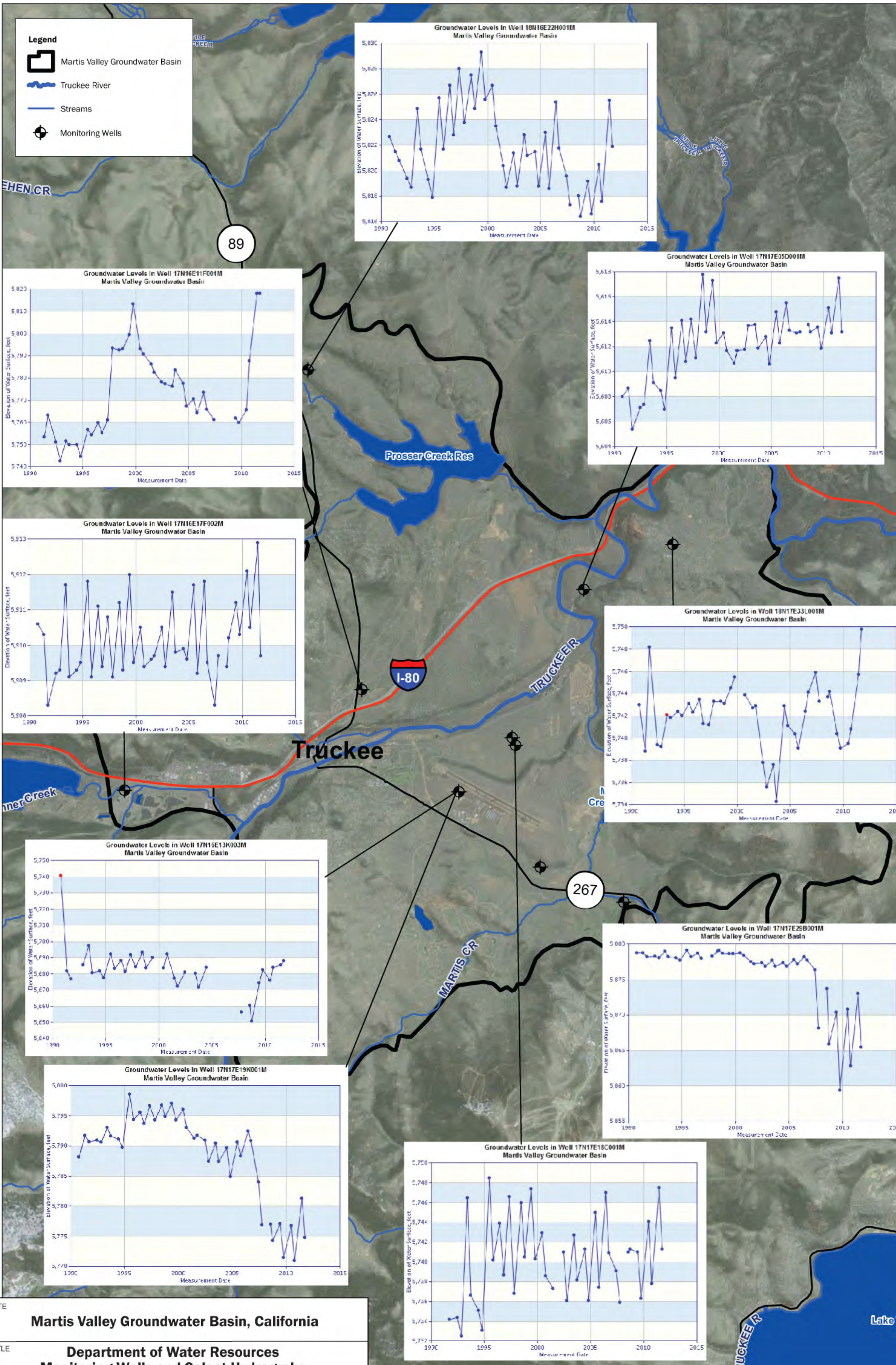
Figure 2-15. Water Levels in DWR Long-term Groundwater Monitoring Wells

2.5.3.1 Land Subsidence

Permanent land subsidence can occur when groundwater is removed by pumpage or drainage due to irreversible compression of aquitard materials. Limited data on land subsidence within the MVGB is available, but no indications of land subsidence have been reported in the documents reviewed as part of this evaluation.

2.6 Groundwater Well Infrastructure

The three partner agencies, hundreds of domestic pumpers, and a number of golf courses rely on the MVGB for drinking water and irrigation supplies. The TDPUD provides water service to portions of the Town of Truckee and adjacent unincorporated areas of Nevada and Placer Counties. The TDPUD currently has 13 active production wells for potable water service, plus 3 wells to serve non-potable water demands. PCWA's Eastern Water System (Zone 4) currently includes two production wells, Lahontan Well #1 and Lahontan Well #2, to serve the Lahontan Golf Club, Shaffer's Mill Golf Club, Hopkins Ranch, and Martis Camp Residences. PCWA is planning to develop a third permanent groundwater production well to serve planned development in and around the existing communities, including Shaffer's Mill Golf Club (Tully and Young, 2011). NCSD supplies water to residents and guests in the Northstar community, producing water from one production well (TH-2) with an estimated yield of 800 gpm. NCSD is currently working to bring a second well (TH-1) online during summer 2012 with a similar anticipated yield. Table 2-2 summarizes the estimated yields and production rates associated with these wells.



SITE

Martis Valley Groundwater Basin, California

TITLE

Department of Water Resources Monitoring Wells and Select Hydrogrphs

Brown AND Caldwell

DATE 9-7-12

PROJECT 140691

Figure 2-16

Source:?

Table 2-2. Estimated Yield of Public Agency Production Wells[a]	
Well Name	Estimated Maximum Yield (gpm)
NCSD	
TH-2	800
TH-1 (anticipated in 2012)	800 (estimated)
PCWA	
Lahontan Well 1	1,400
Lahontan Well 2	1,400
TDPUD	
A Well	160
Airport	2,140
Prosser Annex	460
Glenshire Drive	1,725
Martis Valley No. 1	1,585
Northside	575
Southside No. 2	200
Southside No. 1 (non-potable)	N/A
Sanders	290
Old Greenwood	870
Hirschdale	35
Prosser Heights	360
Prosser Village	800
Well No. 20	540
Fibreboard (non-potable)	N/A
Donner Creek (non-potable)	N/A

[a] *Well Yield information provided by NCSD, PCWA (Tully and Young, 2011), and TDPUD (Kaufman, 2011)*

A number of private wells are distributed across the basin, and a number of residential neighborhoods or tracts have relatively higher concentrations of wells. Martis Camp operates 2 irrigation wells for their own use and provides Northstar with water from these wells for snowmaking and irrigation purposes as well (Josh Detweiller, NCSD, pers. comm.). At higher elevations in the eastern portion of the basin, the Juniper Hills area includes a number of estates, most of which rely on private wells drilled deep (typically 500 to 800 feet) into uplifted Lousetown volcanics and/or deeper volcanics. In the center of the MVGB, a high density of relatively shallow (200 to 300 feet deep) private wells have been drilled and are in use along Prosser Dam Road. Many of these are drilled into shallow Lousetown volcanics, while others are drilled into glacial outwash and the Prosser Formation. In the northwestern portion of the MVGB a number of homes located on Alder Hill have domestic wells drilled primarily into uplifted Lousetown volcanics and range in depth from 300 to 800 feet.

Figure 2-17 is a cumulative frequency plot derived from DWR data, and shows the number of public and domestic wells drilled at various depths in the MVGB. These data show that the vast majority of domestic wells drilled in the area are relatively shallow, with 50% of domestic wells being installed at depths of 300 feet below ground surface or less, while the public production wells range widely in depth.

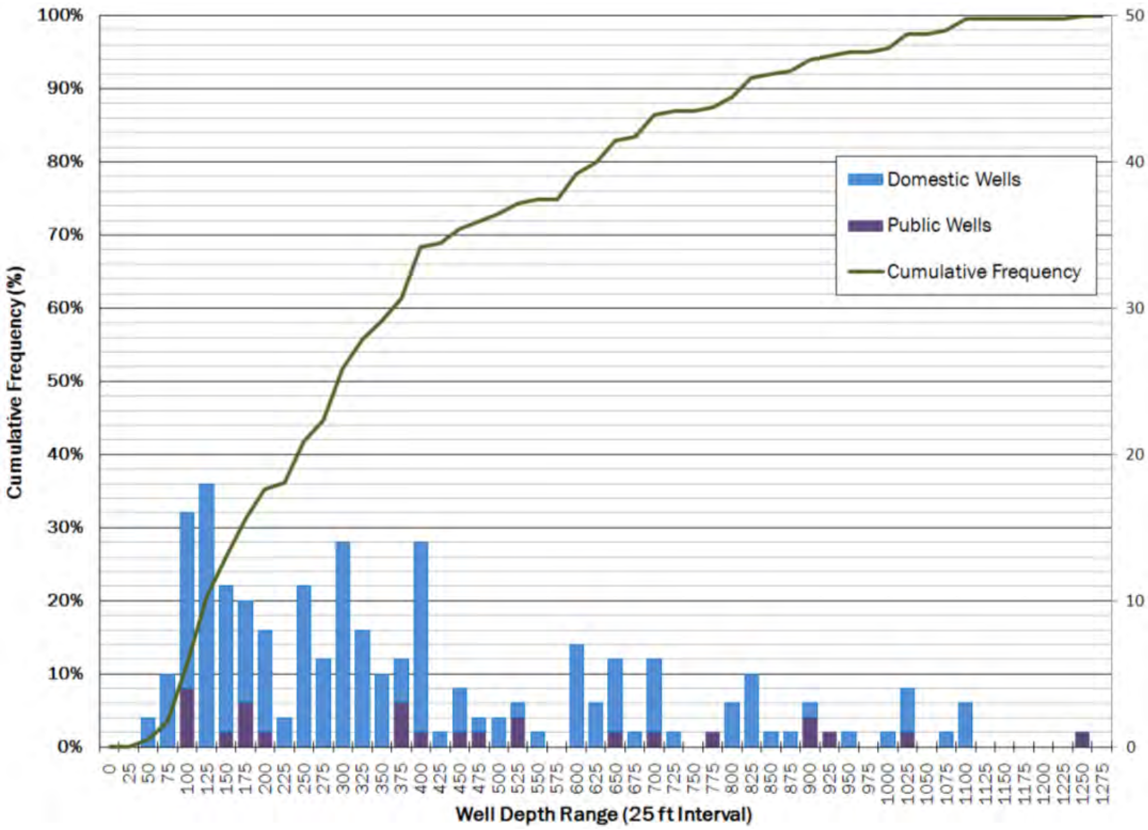


Figure 2-17. Depth Distribution of Wells in the Martis Valley Groundwater Basin

2.7 Groundwater Quality

Groundwater quality in the MVGB is generally of good quality and is currently monitored as part of the agencies' agreements with DPH. Each agency releases an annual water quality report for their service areas in the MVGB; the 2011 annual reports are included in Appendix E. The USGS carried out groundwater monitoring activities in the MVGB in cooperation with the California State Water Resources Control Board (SWRCB) as part of the California Groundwater Ambient Monitoring and Assessment (GAMA) Program (Fram and others, 2007), and sampled 14 wells in the MVGB for a wide range of constituents during summer 2007. The concentrations of most constituents detected in these samples were below drinking-water thresholds, with some exceptions: a) concentrations of arsenic were above the Maximum Contaminant Level (MCL) in 4 of the 14 wells sampled, and b) manganese concentrations were elevated above the MCL in one well. Arsenic levels above the MCL have also been reported by the TDPUD.

The T-TSA operates a water reclamation plant which includes the discharge of tertiary-treated effluent into glacial outwash and Prosser Formation alluvium downstream of the Town of Truckee on the south side of the Truckee River. Hydrogeologic investigations in the vicinity of the plant indicate that effluent flows laterally toward the Truckee River and Martis Creek, discharging to these water bodies after a minimum 50 day travel time (CH2MHill, 1974). DWR (2003) noted that a water quality monitoring program is in place to evaluate potential changes to ground- and surface-water quality.

Sixty-three leaking underground storage tank (LUST) cleanup sites have been identified by the SWRCB's GeoTracker database in the MVGB. Of these 63 sites, cleanup actions for 49 are documented as "completed", while 14 are listed as "open" or "active." All the sites are located in the Town of Truckee, except for one active site in Hirschdale.

2.8 Land Use

Prior to the 1950s, land use in Martis Valley and the Truckee area was primarily ranching and timber related (Shaw and others, 2012). During the 1950s, 60s, and 70s, the rural ranching- and timber-based economy began shifting to more recreational and community development. Today, the primary land uses in the MVGB are residential and ski and/or golf resort related communities with commercial centers in and near downtown Truckee and at the Truckee Airport. Timber and sand and gravel mining operations still continue to operate on a seasonal basis (Shaw and others, 2012).

2.9 Groundwater Recharge

Several previous studies estimated groundwater recharge within the MVGB using water balance and empirical data, resulting in a range from 18,000 to 34,560 acre-feet per year. Recently, DRI has developed annual groundwater recharge estimates using the physically-based PRMS. Table 2-3 summarizes previous and current studies including the study's author, year, and average annual groundwater recharge estimates.

Table 2-3. Summary of Average Annual Groundwater Recharge Estimates for the MVGB

Author	Year	Recharge (ac-ft/yr)
Hydro-Search	1974, 1980, 1995	18,000
Nimbus Engineers	2001	24,700
Kennedy/Jenks Consultants	2001	none
Interflow Hydrology, Inc. and Cordilleran Hydrology, Inc	2003	34,560
DRI, PRMS estimate DRI, modified Maxey-Eakin method	2012	32,745 35,168

DRI outlines its scientific and technical methods, including the climate data used, the PRMS method, and total recharge estimates in a Technical Note, which is included in Appendix F. PRMS simulates land surface hydrologic processes of evapotranspiration, runoff, infiltration, and interflow by balancing energy and mass budgets of the plant canopy, snowpack, and soil zone on the basis of distributed climate information. The PRMS computed recharge consists of the sum of shallow infiltrated water that discharges into the Truckee River and its tributaries as well as deep percolation of ground water to deeper aquifers with water supply wells (Rajagopal and others, 2012). DRI's study "…also applied a modified Maxey-Eakin (1949) method to estimate recharge which relates mean annual precipitation to recharge using recharge coefficients applied to precipitation amounts."

The PRMS is modeled for the years 1983 to 2011 with annual recharge estimates ranging from 12,143 ac-ft/yr (dry year) to 56,792 ac-ft/yr (wet year), with an average annual recharge estimate of 32,745 ac-ft/yr. Because annual precipitation drives recharge, the PRMS simulated recharge varies from year to year. DRI included in its Technical Note annual recharge efficiency, or the ratio of annual recharge to annual precipitation. For the MVGB, the calculated annual recharge efficiency is 18-26%. Figure 2-18 shows the average annual groundwater recharge as simulated by the PRMS model, for a period of record from 1983 to 2011. Figure 2-19 shows the annual recharge for the year 1988, a dry year. Figure 2-20 shows the annual recharge for the year 1995, a wet year.

2.10 Water Use

Groundwater use in the MVGB is primarily for municipal, domestic, and recreational uses. The TDPUD and PCWA have summarized water supply and demand as part of Urban Water Management Plans completed for their respective service areas (Tully and Young, 2011; Kaufman, 2011). Average potable day demand served by the TDPUD in 2010 was reported to be 4.53 million gallons per day (mgd); 5,073 acre-feet per year (ac-ft/yr)). From 2005 to 2009, production from PCWA wells has increased from an average day demand of 0.04 to 0.13 mgd (44 to 141 ac-ft/yr).

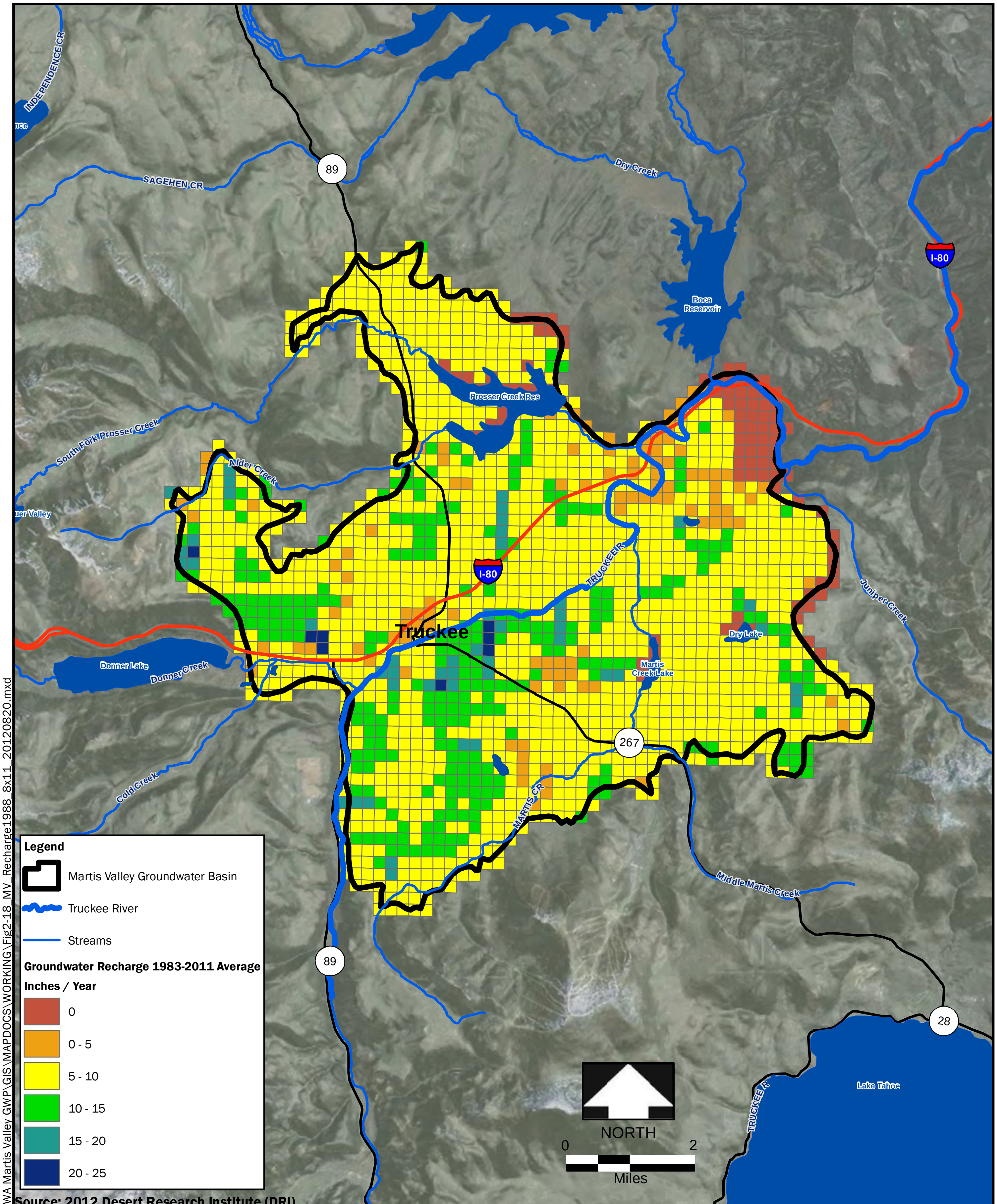
NCSD meets demand primarily from its Big Springs collection system, outside of the MVGB, and uses water pumped from TH-2 (and in the future, TH-1) to augment this supply (J. Detwiler, pers. comm.). Demand on the MVGB imposed by NCSD operations is best represented by pumping records from Well TH-2. Annual water volumes pumped by NCSD averaged 0.18, 0.36, and 0.29 mgd (200, 398, and 320 ac-ft/yr) in water years 2008, 2009, and 2010, respectively.

Nine golf courses depend on the MVGB for irrigation supply; four are supplied by TDPUD (one uses a potable supply and 3 are non-potable), 1 is supplied by NCSD (potable), and 4 are supplied privately and assumed to be all non-potable. Using the partner agencies records of non-potable water pumped and supplied to the majority of the courses, the average non-potable demands range from 0.19 ac-ft/yr to 0.25 ac-ft/yr (210 ac-ft/yr to 279 ac-ft/yr), with an average of 0.24 mgd (272 ac-ft/yr). This average demand rate of 0.24 mgd is applied to the four privately-supplied courses for an estimated production of 993 ac-ft/yr.

Based on the available data and summarized in Table 2-4, current annual production from the MVGB is estimated to be approximately 9,341 ac-ft/yr. Kaufman (2011) estimates buildout water demand for all users in the MVGB to be approximately 21,000 ac-ft/yr.

Table 2-4. Estimated Current Groundwater Production

	mgd	ac-ft/yr
TDPUD		
Potable - Average (2007-2010)	5.78	6,475
Golf Course non-potable – Average (2001-2011)	0.75	837
PCWA		
Potable – Average (2009)	0.10	141
NCSD		
Potable - Average (2008-2010)	0.08	96
Golf Course (potable) – Average (2009-2011)	0.19	210
Snowmaking (Water Year 2011)	0.53	589
Privately Supplied Golf Courses		
Total estimated non-potable production	0.96	993
Estimated Total Demand	8.39	9,341



Source: 2012 Desert Research Institute (DRI)

DATE	PROJECT	SITE
9-17-12	140691	**Martis Valley Groundwater Basin, California**

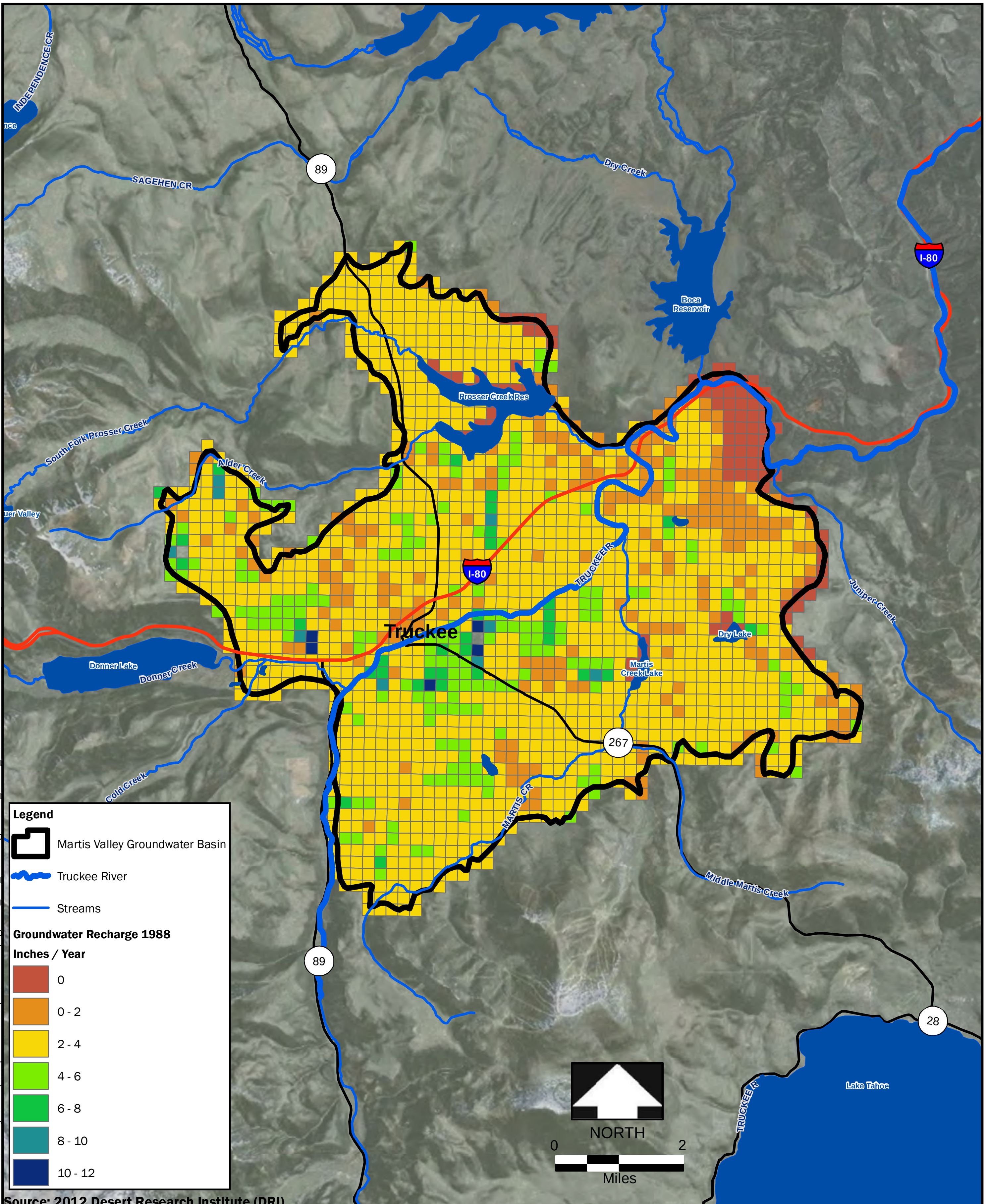
Brown AND Caldwell

TITLE

Average Annual Groundwater Recharge 1983-2011

Figure 2-18

P:\40000\140691 - PCWA Martis Valley GWP\GIS\MAPDOCS\WORKING\Fig2-18_MV_Recharge1988_8x11_20120820.mxd



Source: 2012 Desert Research Institute (DRI)

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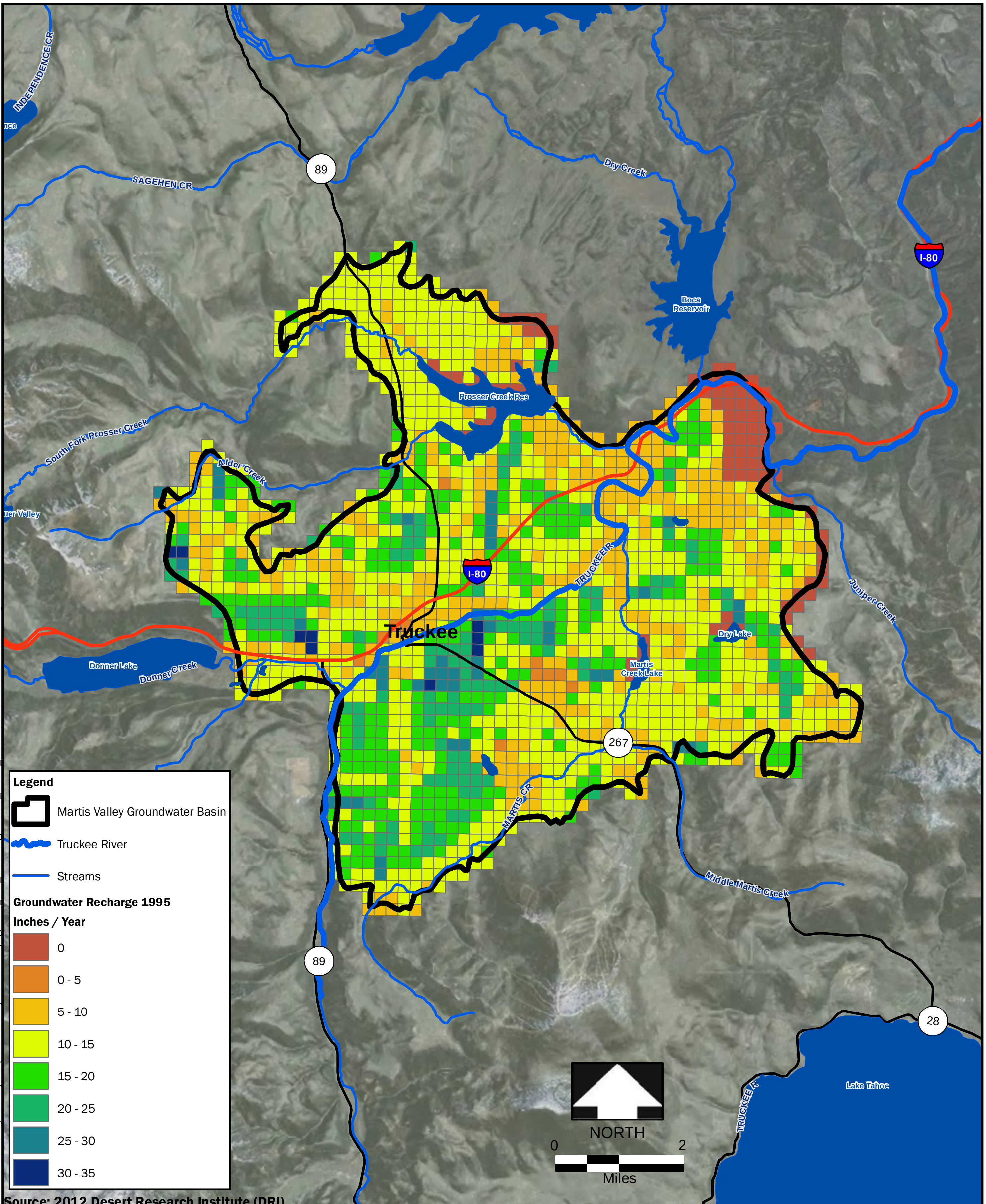
DATE	PROJECT	SITE
9-17-12	140691	Martis Valley Groundwater Basin, California

Brown AND Caldwell

TITLE

Annual Groundwater Recharge 1988

Figure 2-19



Source: 2012 Desert Research Institute (DRI)

P:\40000\140691 - PCWA Martis Valley GWP\GIS\MAPDOCS\WORKING\Fig2-20_MV_Recharge1995_8x11_20120820.mxd

DATE	PROJECT	SITE
9-7-12	140691	Martis Valley Groundwater Basin, California

Brown AND Caldwell

TITLE

Annual Groundwater Recharge 1995

Figure 2-20

Section 3

Plan Implementation

The partner agencies are already performing many of the groundwater management activities associated with an AB 3030 GMP. Through GMP implementation, the partner agencies formalize their groundwater management goal, BMOs, and implementation actions that elaborate on both current actions and planned future actions under the GMP. As discussed in Section 1.6 and shown on Tables 1-2, 1-3, and 1-4, a number of required, voluntary, and suggested components constitute a GMP.

This chapter discusses implementation actions that are grouped under each BMO. The BMOs are fully described in Section 1.5, and are listed below:

1. Manage groundwater to maintain established and planned uses.
2. Manage groundwater use within the provisions of the Truckee River Operating Agreement.
3. Collaborate and cooperate with groundwater users and stakeholders in the Martis Groundwater Basin.
4. Protect groundwater quantity and quality.
5. Pursue and use the best available science and technology to inform the decision making process.
6. Consider the environment and participate in the stewardship of groundwater resources.

3.1 Implementation Actions that Support BMO #1 - Manage Groundwater to Maintain Established and Planned Uses

The MVGB is the primary source of water to multiple users under separate jurisdictions. BMO #1 encourages the partner agencies to pursue management of groundwater that is within their jurisdiction in order to protect existing uses.

Implementation actions identified as falling under BMO #1 facilitate the management of groundwater in the MVGB. These implementation actions are focused on regular communication and consideration of future programs intended to protect the groundwater resource from degradation and depletion.

3.1.1 Develop and implement a summary report every five years

This action is intended to concentrate and document GMP activity, data, and management decisions into periodic reports for use by partner agencies, Stakeholders, and local planning agencies for continual groundwater management decisions and maintenance.

This implementation action provides a report every five years that summarizes groundwater conditions and management activities, and presents an opportunity to update and improve the GMP. The summary report will include:

- A summary of monitoring results with a discussion of historical trends.
- A summary of management actions during the period covered by the report.
- A discussion of whether actions are achieving progress towards meeting BMOs.
- A summary of proposed management actions for the future.
- A summary of any GMP changes that occurred during the period covered by the report.
- A summary of actions taken to coordinate with other water and land agencies and other government agencies.

- Recommendation of updates and changes to the GMP.

3.1.2 Compile an annual summary of groundwater monitoring data

This action will compile, organize and evaluate groundwater level elevation and groundwater quality monitoring data collected during the previous year. The annual summary of monitoring data will include groundwater level monitoring information from the partner agencies water level monitoring efforts, and water quality data collected by the partner agencies from production wells. The annual summary of groundwater monitoring data will be used by the agencies at the annual GMP implementation meeting described in Section 3.1.3 to evaluate the need to implement other portions of the GMP that are contingent on monitoring data. The annual summary of groundwater monitoring data will also be included in the five year summary report.

3.1.3 Partner agencies to meet annually to discuss GMP implementation

This action will require the partnership agencies to meet at least once annually to discuss GMP implementation. Currently, the partner agencies meet in the Truckee area annually and GMP implementation will be added as an agenda item during this annual meeting.

3.1.4 Support TROA provisions associated with well construction, repair, modification, and destruction

The Settlement Act may eventually establish additional requirements for the siting and construction of wells drilled in the Truckee River Basin, which includes the MVGB. Section 6.E of TROA outlines Truckee River basin allocation procedures including well construction, repair, modification and destruction to address groundwater-surface water interactions within the Truckee River Basin including areas of Martis Valley. Section 204(c)(1)(B) of the Settlement Act provides that, "…all new wells drilled after the date of enactment of this title shall be designed to minimize any short-term reductions of surface streamflows to the maximum extent feasible." This implementation action supports the implementation of TROA's well construction guidelines.

3.1.5 Evaluate and consider taking a position on relevant water resources-related policies, programs, and projects under consideration by local, State and Federal agencies

Throughout the state, surface water and groundwater resource management are becoming critical components of meeting growing water supply demands. As part of this implementation action, the partner agencies will actively evaluate and consider policies, programs and projects that may impact water resources quality and/or quantity within the Martis Valley.

3.1.6 Pursue opportunities for improved groundwater basin monitoring and reporting with local, State, and Federal agencies

This implementation action prompts the partner agencies to continuously pursue opportunities and funding that may provide additional groundwater data collection and/or reporting. Groundwater monitoring is a critical component in understanding the physical condition of the groundwater basin and is further described in Section 3.3.1.

3.1.7 Evaluate the need for programs to facilitate saline intrusion control, mitigate the migration of contaminated groundwater, facilitate conjunctive use, and to mitigate overdraft

This implementation action includes evaluation of a variety of potential programs to manage groundwater within the jurisdiction of the partner agencies. As part of this action, the agencies will evaluate the need for saline intrusion controls, mitigation of the migration of contaminated groundwater, conjunctive use programs, and overdraft mitigation.

Currently, the groundwater supply in Martis Valley is not threatened by saline intrusion, contaminant plumes, or in a state of overdraft that would warrant immediate steps for mitigation. Saline intrusion is a primary concern along coastal areas with intruding sea water, which is high in Total Dissolved Solids (TDS) that may threaten fresh groundwater supplies. Saline conditions may also occur in interior basins. In the Martis Valley, groundwater monitoring (discussed under Section 3.4), will assist in identifying saline issues. Should future monitoring indicate that saline intrusion is a potential problem in the MVGB, the partner agencies will evaluate development of a saline intrusion control program.

Groundwater contamination in the MVGB falls under the jurisdiction of the Lahontan Regional Water Quality Control Board (LRWQCB). Should monitoring indicate a large scale groundwater contamination issue, the partner agencies will share knowledge of the issue and collaborate with the LRWQCB. If monitoring indicates that contaminated groundwater is migrating, the partner agencies will further collaborate with the LRWQCB to mitigate the migration.

Conjunctive use is the management of surface water and groundwater to optimize the yield of the overall water resource. One method would be to rely primarily on surface water in wet years and groundwater in dry years. Other methods employ artificial recharge, where surface water is intentionally stored into aquifers for later use. NCSD currently manages both its springwater and groundwater supply and TDPUD currently relies solely on groundwater but maintains water rights to several springs. Groundwater is PCWA's only supply source. The partner agencies will evaluate opportunities to increase the use of conjunctive management as they arise within the MVGB.

Groundwater overdraft occurs when pumping exceeds recharge to a groundwater basin. If monitoring indicates through declining groundwater levels that groundwater overdraft is occurring, the partner agencies will consider development of programs to mitigate the groundwater overdraft.

3.1.8 Consider development of contamination cleanup, recharge, storage, conservation and water recycling projects

This implementation action includes evaluation of a variety of potential programs to manage groundwater within the jurisdiction of the partner agencies. As part of this action, the partner agencies will consider development of projects that cleanup contamination, increase groundwater recharge and storage, or increase conservation and water recycling.

The LRWQCB is responsible for developing and enforcing water quality objectives and plans that best protect the State's waters within its hydrologic area. Should monitoring indicate that contaminated groundwater is a threat to groundwater supplies, the partner agencies will consider collaborating with the LRWQCB.

During GMP implementation, opportunities may arise for the partner agencies to engage in activities related to groundwater recharge, storage, conservation and recycling. As those opportunities arise, the agencies will consider participating in projects to improve groundwater recharge, storage, conservation and recycling efforts.

3.1.9 Pursue funding sources for implementation of plan policies, programs, reporting and projects

This implementation action directs the partner agencies to pursue funds from Federal, State and other sources as they become available and are beneficial to pursue. Funding sources may include Local Groundwater Assistance (LGA) grants and Integrated Regional Water Management Planning (IRWMP) grants from DWR, grants from the California Department of Public Health (DPH), various funds available through collaboration with the U.S. Bureau of the Interior, and other agencies.

3.1.10 Participate in the evaluation of relevant local projects to maintain groundwater quantity and quality

Local groups and local, State or Federal agencies may develop opportunities that seek support or assistance for projects that affect groundwater quantity and/or quality in the Martis Valley. This action directs the partner agencies to participate in relevant local projects as appropriate and reasonable.

3.1.11 Summary of BMO #1 Actions

Table 3-1 presents a summary of implementation actions to be undertaken by the partner agencies that support BMO #1 including the anticipated schedule of implementation.

Table 3-1. Summary BMO#1 Supporting Implementation Actions

	Description of Action	Implementation Schedule
1-1	Develop and implement a summary report every five years that includes: A summary of monitoring results, with a discussion of historical trends A summary of management actions during the period covered by the report A discussion of whether actions are achieving progress towards meeting BMOs A summary of proposed management actions for the future A summary of any GMP changes that occurred during the period covered by the report A summary of actions taken to coordinate with other water and land agencies and other government agencies Review of the GMP and consider updates to the GMP	Once every five years, first summary report to be completed in 2018
1-2	Compile an annual summary of groundwater monitoring data	Annually
1-3	Partner agencies to meet annually to discuss GMP implementation	Annually
1-4	Support TROA provisions associated with well construction, repair, modification, and destruction	As Needed
1-5	Evaluate and consider taking a position on relevant water resource-related policies, programs, and projects under consideration by local, State and Federal agencies	As Needed
1-6	Pursue opportunities for improved groundwater basin monitoring and reporting with local, State, and Federal agencies	As Needed
1-7	Evaluate the need for programs to facilitate saline intrusion control, mitigate the migration of contaminated groundwater, facilitate conjunctive use, and to mitigate overdraft	As Needed
1-8	Consider development of contamination cleanup, recharge, storage, conservation and water recycling projects	As Needed
1-9	Pursue funding sources for implementation of plan policies, programs, reporting and projects	Ongoing
1-10	Participate in the evaluation of relevant local projects to maintain groundwater quantity and quality	As Needed

3.2 Implementation Actions that Support BMO #2 - Manage Groundwater within the Provisions of TROA

The Settlement Act, Public Law 101-618 (1990), established entitlements to the waters of Lake Tahoe, the Truckee River and its tributaries, and how the storage reservoirs of the Truckee River are operated. Section 205 of the Settlement Act directs the Secretary of the Department of the Interior to negotiate an operating agreement for the operation of Truckee River reservoirs, between DWR, Nevada, Nevada

Energy (formerly Sierra Pacific Power Company), Pyramid Tribe, and the United States Bureau of Reclamation. The operating agreement is known as TROA.

Section 204(c)(1) of the Settlement Act outlines the allocation of 32,000 acre-feet of water (both surface and groundwater) to the State of California from within the Truckee River Basin. The Settlement Act may eventually establish additional requirements for the siting and construction of wells drilled in the Truckee River Basin, which includes the MVGB. Section 6.E of TROA outlines Truckee River Basin allocation procedures including surface water diversions and water accounting procedures. Article 10 of TROA identifies well construction, repair, modification and destruction to address groundwater-surface water interactions within the Truckee River Basin including areas of Martis Valley. Section 204(c)(1)(B) of the Settlement Act provides that, "…all new wells drilled after the date of enactment of this title shall be designed to minimize any short-term reductions of surface streamflows to the maximum extent feasible." Article 10 of TROA requires that new water supply wells be designed to minimize impacts to surface water and outlines siting and design processes. Wells drilled or under construction before May 1, 1996 are presumed to comply with the Settlement Act.

This BMO documents the partner agencies' commitment to continue to comply with provisions of TROA. There are provisions in TROA that apply to groundwater and water wells within the Truckee River Basin (which includes the Martis Valley) to address potential adverse impacts to surface water.

3.2.1 Continue coordination and collaboration with TROA agencies on groundwater management issues and source well development

This implementation action directs the partner agencies to coordinate and collaborate with TROA agencies as necessary to be compliant with the Settlement Act. To meet this implementation action, the agencies will continue regular contact with TROA agencies as appropriate.

3.2.2 Summary of BMO #2 Actions

Table 3-2 presents a summary of implementation actions to be undertaken by the partner agencies that support BMO #2 including the anticipated schedule of implementation.

Table 3-2. Summary BMO#2 Supporting Implementation Actions

Description of Action		Implementation Schedule
2-1	Continue coordination and collaboration with TROA agencies on groundwater management issues and source well development	Ongoing

3.3 Implementation Actions that Support BMO #3 - Collaborate and Cooperate with Groundwater Users and Stakeholders in the Martis Valley Groundwater Basin

With one common groundwater supply it makes sense to share information and resources toward similar goals. This objective encourages the partner agencies to reach out to other agencies and groundwater users within the MVGB.

3.3.1 Formalize and institute a Stakeholder Working Group to meet at least annually or as needed on GMP implementation activities and updates

The SWG has been a key component of the GMP development process and will be continued into the implementation phase. This implementation action directs the partner agencies to continue using a

SWG during implementation of the GMP. The SWG will continue to work cooperatively with the partner agencies and will meet at least once a year to discuss GMP implementation.

3.3.2 Collaborate with the LRWQCB to limit the migration of contaminated groundwater and in development of large scale contamination clean up programs

This implementation action directs the partner agencies to communicate, collaborate, and coordinate with the LRWQCB on groundwater contamination issues. There are no currently identified large scale groundwater contamination issues in the Martis Valley at this time. Communication with the LRWQCB allows for collaboration in the event of the identification of groundwater contamination and collaboration with the LRWQCB on the prevention of contaminant migration.

3.3.3 Work cooperatively with local stakeholders and local, State and Federal agencies on groundwater management activities, projects, and studies

Strong relationships with Federal, State, and local agencies and stakeholders are critical in developing and implementing many of the GMP's implementation actions. The partner agencies are already working cooperatively with local stakeholders and agencies on groundwater management, as evidenced by the use of the SWG during GMP development. This implementation action directs the partner agencies to communicate and work cooperatively with local groundwater interests, and includes outreach activities aimed to educate agencies and stakeholders on groundwater management opportunities and activities in the MVGB.

3.3.4 Identify opportunities for public involvement during GMP implementation

Informing the public of GMP implementation activities increases local understanding and support of GMP activities. This implementation action encourages the partner agencies to inform and invite the public to participate in GMP implementation activities. Public information and involvement may take place in the form of a specific webpage designed to communicate GMP implementation actions, public meetings, and at agency board meetings, as well as other activities.

3.3.5 Summary of BMO #3 Actions

Table 3-3 presents a summary of implementation actions to be undertaken by the partner agencies that support BMO #3 including the anticipated schedule of implementation.

Table 3-3. Summary BMO#3 Supporting Implementation Actions

	Description of Action	Implementation Schedule
3-1	Formalize and institute a Stakeholder Working Group to meet at least annually or as needed on GMP implementation activities and updates.	Annually
3-2	Collaborate with the LRWQCB to limit the migration of contaminated groundwater and in development of large scale contamination clean up programs	As Needed
3-3	Work cooperatively with local stakeholders and local, State and Federal agencies on groundwater management activities, projects and studies	Ongoing
3-4	Identify opportunities for public involvement during plan implementation	Ongoing

3.4 Implementation Actions that Support BMO #4 - Protect Groundwater Quantity and Quality

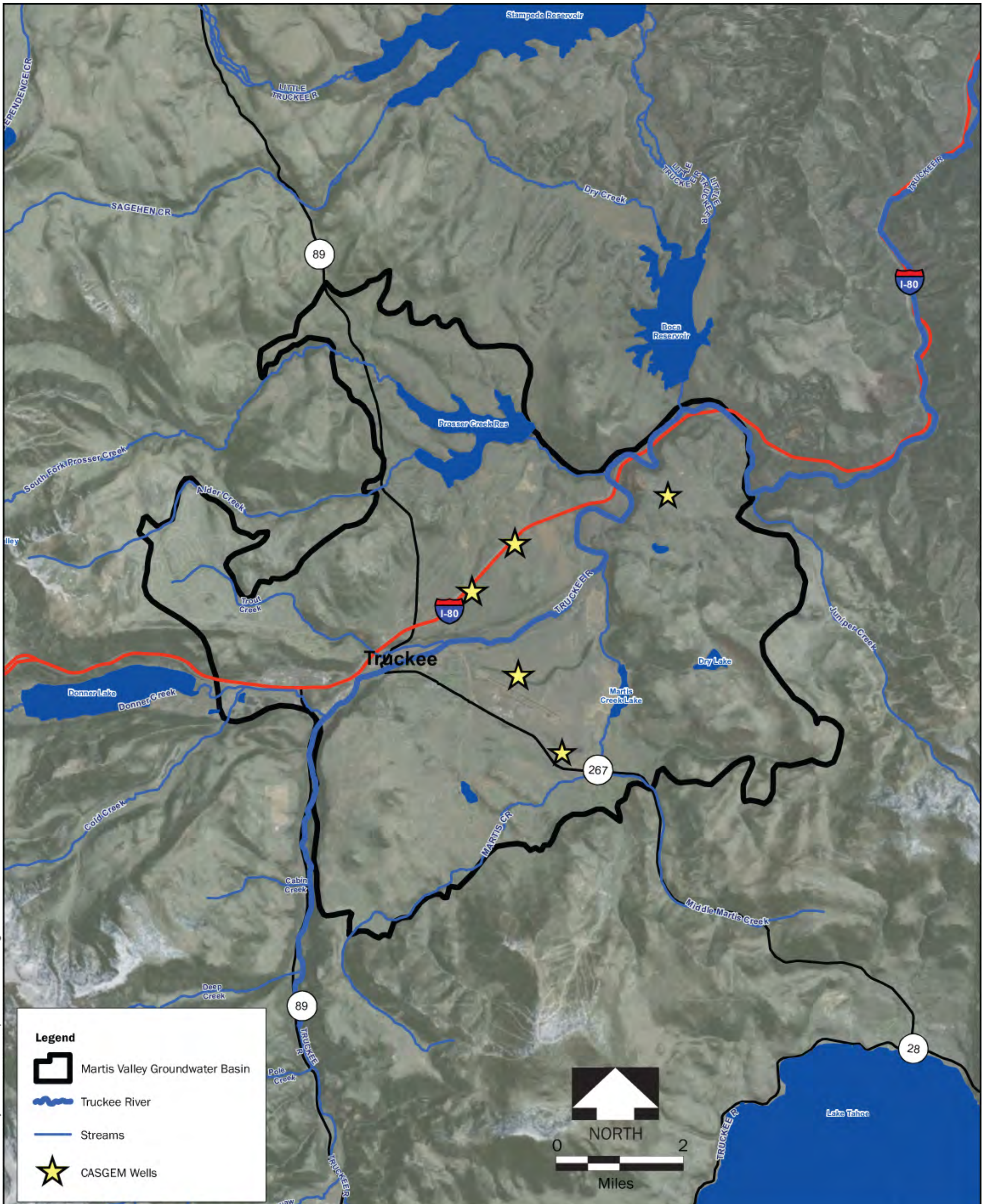
Groundwater performs an integral function in a watershed, one of which is satisfying water supply needs. Improving the understanding of the regional supplies is a critical step in protecting and sustaining the Martis Valley groundwater supply.

The collection, evaluation and analysis of groundwater monitoring data including water quality and water levels on a regular basis is the cornerstone in understanding the MVGB's groundwater resources and provides critical information for management decisions. Groundwater level monitoring can identify areas of overdraft, enabling appropriate management decisions and responses. Groundwater quality monitoring can help identify areas of degrading water quality, potentially identifying specific water quality issues. Ongoing groundwater monitoring provides information needed to document current conditions, assess long-term trends, and to support development and implementation of GMP components.

Groundwater data is collected by both DWR and the partner agencies on a regular basis; and by the USGS on a less regular basis. Accumulating, processing, evaluating, summarizing and reporting the available data for discussion and distribution will be required to make informed decisions regarding continued groundwater supply and demand. Additionally, surface water data is collected by local, State, and Federal agencies and is evaluated by the appropriate agency for their own purpose. These data are critical and can be used in conjunction with the accumulated groundwater data to help improve the understanding of surface water-groundwater relationships.

3.4.1 Establish and maintain a California Statewide Groundwater Elevation Monitoring compliant monitoring program

This implementation action directs the partner agencies to continue their California Statewide Groundwater Elevation Monitoring (CASGEM) compliant monitoring program (included as Appendix D). Figure 3-1 shows the locations of CASGEM monitoring wells in the MVGB. CASGEM monitoring results will be used in the annual groundwater monitoring summary prepared under implementation action 1-2.



P:\40000\140691 - PCWA Martis Valley GWP\GMP\Report\1st Draft\Figures

DATE	PROJECT	SITE	
9-7-12	140691	Martis Valley Groundwater Basin, California	Figure 3-1
Brown AND Caldwell		TITLE: CASGEM and DWR Groundwater Monitoring Wells	

3.4.2 Continue and Encourage Water Conservation Activities and Public Education

The partner agencies currently implement significant water conservation and public outreach programs per State requirements. All three agencies hold public board meetings and maintain informative websites for public outreach purposes at the following web addresses:

- www.tdpud.org
- www.pcwa.net
- www.northstarcsd.org

This implementation action encourages the partner agencies to continue to implement conservation activities and continue public outreach activities as opportunities become available.

3.4.3 Work with local stakeholders and DWR to identify areas that may need additional groundwater level and groundwater quality monitoring based on identified data gaps or negative performance trends

Currently, groundwater is monitored by the partner agencies under CASGEM, and by DWR, who monitors a number of wells in the MVGB. DWR monitoring wells are shown in Figure 3-1. This implementation action requires the partner agencies to work with local stakeholders and DWR to identify areas in need of additional monitoring. The SWG included two DWR North Central Region office staff and future members of the SWG should continue to include DWR staff. Through the SWG, the partner agencies will be working with local stakeholders and DWR, and will discuss identification of additional monitoring areas at the SWG annual meetings.

3.4.4 Coordinate with other agencies, including DWR and the USGS to identify opportunities for land subsidence monitoring

Inelastic land subsidence is caused by dewatering of aquifers and the compressing of clays. As water is removed from the aquifer, it is transported through interconnected pore spaces between grains of sand and gravel. If an aquifer has intervals of clay or silt within it, the lowered water pressure in the sand and gravel results in the slow drainage of water from the clay and silt beds. The decreased water pressure reduces the support for the clay and silt beds. Because these beds are compressible, they compact (become thinner) and the effects are seen as a lowering of the land surface. The lowering of the land surface elevation from this process is often permanent (inelastic). Recharge of the aquifer will not result in an appreciable recovery of the land-surface elevation.

The partner agencies have not developed a network of extensometers to measure inelastic land subsidence. Groundwater level monitoring indicates that groundwater levels have not been significantly lowered, a condition required for land subsidence due to groundwater extraction to occur. Additionally, the geology (Section 2.4) in the MVGB does not consist of large layers of clay to be compressed, and is unlikely to experience inelastic land subsidence even if groundwater levels begin to decline. Based on a review of groundwater elevation trends over time, it can reasonably be assumed that significant land subsidence has not occurred on a regional scale due to groundwater extraction within the MVGB.

Under this implementation action, the partner agencies will coordinate with DWR and the USGS to identify opportunities for collaboration to detect land subsidence. Because inelastic land subsidence is tied to groundwater levels, the primary means for early detection include:

- Monitor and analyze groundwater levels, watching for significant declines
- Inspect wells for anecdotal evidence of subsidence during groundwater level monitoring

Monitoring groundwater levels with concurrent inspections for anecdotal evidence of subsidence is the least expensive, and least reliable, method to monitor for land subsidence. Declines in groundwater levels can be a precursor to land subsidence. Staff performing water level monitoring can inspect the monitoring well for indicators of subsidence. Anecdotal subsidence indicators include cracks in the well pad, elevation of the well casing in comparison to the ground surface, and cracks in the ground surface.

3.4.5 Evaluate the need for, and advocate for, as necessary, a wellhead protection, groundwater recharge area protection, and other programs as necessary in MVGB

Wellhead protection is a component of the Drinking Water Source Assessment and Protection (DWSAP) program administered by the DPH. The purpose of the DWSAP program is to protect groundwater sources of public drinking water supplies from contamination, thereby eliminating the need for costly treatment to meet drinking water standards. There are three major components to the DWSAP program, including: Delineation of capture zones around source wells, inventory of potential contaminating activities within protection areas, and analysis of vulnerabilities.

The partner agencies are in compliance with the DWSAP program, will work to comply with the DWSAP program into the future, and will consider supporting programs that will protect groundwater quality in the MVGB.

3.4.6 Map and share groundwater recharge zones

This GMP identifies preliminary areas of groundwater recharge in the MVGB in Section 2.9. Once the groundwater model is calibrated and finalized, groundwater recharge zones will be updated during the scheduled plan update identified in Section 3.1.1. This implementation action encourages the partner agencies to share the recharge zone maps developed in this GMP with local land use agencies to consider in land use decisions.

3.4.7 Provide relevant information to land use agencies regarding groundwater availability

Through GMP implementation activities, such as CASGEM monitoring, groundwater monitoring summary reports and annual meetings of the SWG, the partner agencies will develop water resources information about the MVGB. As development increases in the MVGB, local land use agencies will be faced with decisions regarding zoning and permitting. In Placer County, the Community Development Resource Agency leads development of the County's general plan and land development activities. The Nevada County Community Development Agency is responsible for the Nevada County General Plan and zoning, and the Town of Truckee has developed its own general plan and zoning. This implementation action directs the partner agencies to communicate relevant groundwater information to the appropriate planning agencies to assist them in making informed land use decisions.

3.4.8 Summary of BMO #4 Actions

Table 3-4 presents a summary of implementation actions to be undertaken by the partner agencies that support BMO #3 including the anticipated schedule of implementation.

Table 3-4. Summary BMO#4 Supporting Implementation Actions

	Description of Action	Implementation Schedule
4-1	Establish and maintain a CASGEM compliant monitoring program	Ongoing
4-2	Continue and encourage water conservation activities and public education	Ongoing
4-3	Work with local stakeholders and DWR to identify areas that may need additional groundwater level and groundwater quality monitoring based on identified data gaps or negative performance trends	Annually

Table 3-4. Summary BMO#4 Supporting Implementation Actions		
Description of Action		Implementation Schedule
4-4	Coordinate with other agencies, including DWR and the USGS to identify opportunities for land subsidence monitoring	As Needed
4-5	Evaluate the need for, and advocate for, as necessary, a wellhead protection, groundwater recharge area protection, and other programs as necessary in MVGB	As Needed
4-6	Map and share groundwater recharge zones	Ongoing
4-6	Provide relevant information to land use agencies regarding groundwater availability	As Needed

3.5 BMO #5 - Pursue and use the best available science and technology to inform the decision making process.

Science and technology continue to develop new tools that may improve our understanding of the MVGB. This objective encourages the partner agencies to take actions that work with the best available science to help make informed agency decisions.

The partner agencies are currently working to develop the best groundwater science available by collaborating with the Bureau of Reclamation (Reclamation) and DRI to develop an integrated watershed-groundwater model in conjunction with the Martis Valley GMP. The geologic investigation conducted and documented in Section 2 of this report has been used to shape a bi-modal geologic framework which was used to develop the conceptual model for the hydrogeology of the subsurface components of the integrated watershed model. The integrated model is under development in parallel with the GMP and is not completed at the time of the issuance of the draft GMP.

The integrated watershed model is comprised of a PRMS and MODFLOW coupled together using an UZF package. The PRMS is used to model surface water within the watershed, the MODFLOW is used to model groundwater within the MVGB, and UZF is a kinematic wave vadose zone model used to model the interaction between surface water and groundwater. Each model will be calibrated separately, and then calibrated together over a ten year period using a coupled GSFLOW. Calibrations will be conducted using multiple GCM projections of precipitation and temperature to investigate the influence of future climate on water resources. Calibration targets for GSFLOW will include head values measured from wells, meadow and spring locations, streamflows, measured snow depth, and remotely sensed snow cover.

The integrated model's model domain will cover the entire MVGB, and the watersheds that contribute surface water to the region up to Lake Tahoe. The model grid's cells are 300 meters by 300 meters in size.

The partner agencies will obtain a copy of the groundwater model component for future use.

3.5.1 Work with State and Federal agencies to attempt to secure funding for expansion of the partner agencies' monitoring grid

Increasing the number of monitoring points and frequency of monitoring provides for better long term understanding of groundwater trends in the MVGB. Monitoring locations can be added by drilling new, dedicated monitoring wells, and by reaching agreements with well owners that have wells suitable for monitoring activities. Suitable wells will have a driller's log that describes well construction and sediments encountered, a short screened interval, a sanitary seal to prevent surface water from entering the well, and cannot be municipal supply wells.

The partner agencies are currently working with DWR to expand the monitoring grid by submitting a competitive grant application under DWR's LGA program. The agencies' application includes plans to drill and install three monitoring wells located across the Martis Valley.

This implementation action directs the partner agencies to collaborate with State agencies such as DWR, DPH, and others, as well as Federal agencies such as Reclamation, to acquire funding for improvements to the groundwater monitoring grid in the MVGB.

3.5.2 Maintain relationship with DWR for groundwater monitoring and database management activities

The partner agencies are a designated monitoring entity under DWR's CASGEM program. DWR staff have been an integral part of the SWG during GMP development and their contribution in the SWG is anticipated during GMP implementation.

This implementation action directs the partner agencies to continue to maintain a collaborative relationship with DWR for monitoring and database management activities in the MVGB. A continued relationship with DWR benefits the GMP by continuing the monitoring of long-term monitoring wells (especially those with long periods of records), and ensures that DWR groundwater expertise is involved during plan implementation activities through the SWG.

3.5.3 Identify opportunities for collecting water quality monitoring data

The purpose of water quality monitoring as a GMP implementation action is to assess regional trends in water quality that may be caused by changes in groundwater-related activities. For example, groundwater pumping may induce groundwater flow from deeper aquifers or hard rock areas that are less desirable, such as water with a high mineral content or arsenic. Groundwater quality monitoring from a basin-wide perspective is focused on information that is indicative of overall groundwater basin conditions and not focused on individual anthropogenic contaminants. Localized anthropogenic groundwater quality contaminants fall under the jurisdiction of the LRWCQB.

Groundwater quality is currently monitored as part of the agencies' agreements with DPH. Each agency releases an annual water quality report for their service areas in the MVGB, and maintains databases of water quality information. Partner agency annual water quality reports are included in Appendix E.

Additional opportunities exist to collect groundwater quality information by collaborating with other State and Federal programs, such as the USGS funded California Groundwater Ambient Monitoring and Assessment Special Studies Program (GAMA). The 2007 GAMA study collected water quality data in the MVGB from 52 groundwater wells. The GAMA fact sheet for the MVGB is included in Appendix E.

Another example of how the partner agencies optimize collaboration opportunities occurred in February, 2012. The partner agencies teamed with Lawrence Livermore National Laboratory (LLNL) to conduct a water aging study that will help improve the understanding of how the MVGB functions. The LLNL study is funded by the GAMA Special Studies Program. Results of the LLNL study will supplement and validate the DRI integrated Martis Valley surface-groundwater model.

This implementation action encourages the partner agencies to continue to identify opportunities, both within the agencies' operations and by collaborating with State and Federal agencies to improve groundwater quality data collection in the MVGB. Data collected for GMP implementation will be focused on identifying long-term water quality trends as they are related to groundwater use.

3.5.4 Use and consider updating the hydrologic model to improve understanding of groundwater in the MVGB

The implementation action directs the partner agencies to use the groundwater model component of the integrated watershed model (when completed) to improve local hydrogeologic understanding within the MVGB. This may be achieved by revising the future regional groundwater model to include the following:

- Development of a focused MVGB hydrogeologic conceptual model;
- Refinement of the numerical groundwater model grid size and model extent;
- Revisions to numerical groundwater model layering and parameterization to reflect updates in the conceptual model; and,
- Establishment of appropriate stress periods and time scales for transient model simulations.

Incorporation of these revisions to the DRI-developed groundwater model will improve the tool so that it can be used to characterize groundwater flow patterns originating from key recharge zones; to quantify potential impacts on groundwater resources resulting from localized extractions; and to evaluate current and future impacts on base flows within the Truckee River as a result of groundwater pumping within the MVGB.

3.5.5 Seek new tools, technology, and information that may improve the understanding of the water resources in the MVGB and watershed

The partner agencies strive to have the best possible understanding of water resources in the MVGB, and prepare reports on water resources such as urban water management plans, water supply analyses, and water master plans in accordance to State requirements.

This implementation action directs the partner agencies to actively seek out tools, technology, and compiled information in order to improve the understanding of water resources in the MVGB. The agencies will share and compare their water resources planning documents to identify similarities and differences. Additionally the agencies will continue to be proactive in looking for methods, approaches, and analysis that improves understanding of water in the MVGB.

3.5.6 Summary of BMO #5 Actions

Table 3-5 presents a summary of implementation actions to be undertaken by the partner agencies that support BMO #5 including the anticipated schedule of implementation.

Table 3-5. Summary BMO#5 Supporting Implementation Actions

	Description of Action	Implementation Schedule
5-1	Work with State and Federal agencies to attempt to secure funding for expansion of the Partner Agencies monitoring grid	Ongoing
5-2	Maintain relationship with DWR for groundwater monitoring and database management activities	Ongoing
5-3	Identify opportunities for collecting water quality monitoring data	As Available
5-4	Use and consider updating the hydrologic model to improve understanding of groundwater in the MVGB	Ongoing
5-5	Seek new tools, technology, and information that may improve the understanding of the water resources in the MVGB and watershed	Ongoing
5-6	Use the best available data to inform and link agency interdependent planning documents (i.e. urban water management plans, water supply analyses, and water master plans)	Ongoing

3.6 Implementation Actions that Support BMO #6 - Consider the environment and participate in the stewardship of groundwater resources

The partner agencies are dedicated stewards of the Martis Valley groundwater resources. The partner agencies' mission statements reflect the importance of managing their respective agencies in an environmentally sound manner, such as minimizing negative impacts of operations on the environment. This BMO directs the partner agencies to continue their leadership in the stewardship of the groundwater, watershed and natural infrastructure.

3.6.1 Consider local, State, or Federal riparian, surface water, or surface water-groundwater interaction investigations, studies or programs in the MVGB

This implementation action directs the partner agencies to consider existing and future studies and investigations of riparian habitat, surface water, and surface- groundwater interaction investigations. Wetlands and riparian areas play an important role in protecting water quality and reducing adverse water quality impacts (EPA, 2005). This implementation action, while not solely focused on pollution prevention, may address issues with such through traditional point sources and non-point sources. Many pollutants are delivered to surface waters and to groundwater from diffuse sources, such as urban runoff, agricultural runoff, and atmospheric deposition of contaminants. Pollution of surface water can impact groundwater quality and conversely pollution of groundwater can impact surface water. The agencies will evaluate the need to consider studies, guidance documents, and programs that investigate the linkages between ground and surface waters.

3.6.2 Continue support and collaboration with local groups that identify, coordinate, or implement projects that support the overall sustainability of the MVGB

This implementation action directs the partner agencies to support and collaborate with local groups that improve sustainability in the MVGB.

The partner agencies will continue support and collaboration with groups and agency members of the SWG, and through public involvement and outreach, identify additional groups to include in GMP implementation.

3.6.3 Summary of BMO #6 Actions

Table 3-6 presents a summary of implementation actions to be undertaken by the partner agencies that support BMO #3 including the anticipated schedule of implementation.

Table 3-6. Summary BMO#6 Supporting Implementation Actions

Description of Action		Implementation Schedule
6-1	Consider local, State, or Federal riparian, surface water, or surface water-groundwater interaction investigations, studies or programs in the MVGB.	As Needed
6-2	Continue support and collaboration with local groups that identify, coordinate, or implement projects that support the overall sustainability of the MVGB.	Ongoing

Section 4

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Appendix A: Resolutions of Intent to Adopt a Groundwater Management Plan

RESOLUTION NO. 11 - 13 OF THE BOARD OF DIRECTORS OF THE PLACER COUNTY WATER AGENCY DECLARING ITS INTENT TO UPDATE ITS MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN AND ADOPT A STATEMENT OF PUBLIC PARTICIPATION

WHEREAS, one of the responsibilities of Placer County Water Agency (Agency) is to provide for sustainable use of groundwater resources within Placer County; and

WHEREAS, The Agency uses groundwater to serve customers in its Martis Valley water system located near Truckee, California; and

WHEREAS, the Agency adopted its current Martis Valley Groundwater Management Plan on October 6, 1998; and

WHEREAS, the current groundwater management plan allows for periodic updates and advocates working collaboratively with others in Martis Valley; and

WHEREAS, the Agency has established a partnership with Truckee Donner Public Utilities District and Northstar Community Services District to prepare an updated groundwater management plan and develop a groundwater model to reflect current water resources planning in Martis Valley and enhance understanding of the underlying groundwater basin; and

WHEREAS, the Agency intends to prepare, adopt, and implement this updated groundwater management plan in cooperation with the general public and stakeholders;

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of the Placer County Water Agency that:

1. The Board intends to prepare, adopt, and implement an updated Martis Valley Groundwater Management Plan. Among other content, the updated groundwater management plan will include basin management objectives, plan components, and management actions.

2. The Agency further intends to provide for and encourage public/stakeholder involvement in the preparation of this updated groundwater management plan.

The foregoing resolution was duly passed at meeting of the Board of Directors of the Placer County Water Agency held on April 7, 2011, by the following on roll call:

AYES DIRECTORS: Gray Allen, Alex Ferreira, Mike Lee, Ben Mavy, Chairman Lowell Jarvis

NOES DIRECTORS: None

ABSENT DIRECTORS: None

Signed and approved by me after its passage this 7th day of April, 2011.

Lowell M. Jarvis

Chair, Board of Directors
Placer County Water Agency

ATTEST:

Chri Sprunck

Clerk, Board of Directors
Placer County Water Agency

z:/ns.martis valley.resolution.vf

N·C·S·D
Northstar Community Services District
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BOARD OF DIRECTORS

NORTHSTAR COMMUNITY SERVICES DISTRICT

RESOLUTION NO. 11 - 05

**RESOLUTION OF INTENTION
TO COOPERATE IN THE PREPARATION OF THE UPDATED
MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN
WITH THE PLACER COUNTY WATER AGENCY AND
THE TRUCKEE DONNER PUBLIC UTILITY DISTRICT**

AS A BASIS AND PREMISE for this Resolution, the Board of Directors of NORTHSTAR COMMUNITY SERVICES DISTRICT ("District") finds and states as follows:

The District is a "local agency" as that term is defined in the provisions of the California Water Code relating to adoption of a Groundwater Management Plan ("Plan").

The District uses groundwater resources available in the Martis Valley.

The Placer County Water Agency ("Agency") and Truckee Donner Public Utilities District ("TDPUD") also use water from the same or adjoining groundwater aquifers.

The Agency adopted its current Martis Valley Groundwater Management Plan ("Plan") on October 6, 1998, and the Plan allows for periodic updates and advocates working collaboratively with others with an interest in groundwater resources in the Martis Valley.

The Agency, the District and TDPUD have determined it is in their best interests to, and have established a partnership (1) to develop a groundwater model to reflect current water resources planning and operations in the Martis Valley, (2) to enhance understanding of the underlying groundwater basin, and (3) to prepare an updated Plan and propose it for adoption by all three entities as a joint Plan.

On March 16, 2011 this Board directed that notice be given of its desire to adopt this Resolution of Intention, and such notice has been given as provided by law.

NOW, THEREFORE, the BOARD OF DIRECTORS of the NORTHSTAR COMMUNITY SERVICES DISTRICT does hereby RESOLVE, DETERMINE, and ORDER as follows:

1. The District intends to cooperate with the Agency and TDPUD in the development a groundwater model to reflect current water resources planning and operations in the Martis Valley and an updated Martis Valley Groundwater Management Plan, and to propose the Plan for adoption as a joint Plan within the time provided by law.

2. Among other content, the updated Plan will consider inclusion of basin management objectives, plan components, and management actions.

Together with the Agency and TDPUD, the District further intends to provide for and encourage public involvement in the preparation of the updated Plan.

PASSED AND ADOPTED at a regular meeting of the Board of Directors on April 20, 2011 by the following vote:

AYES:	Evans, Green, Ives, Moll, Seelig
NOES:	None
ABSTAIN:	None
ABSENT:	None

Duane E. Evans, President of the Board

ATTEST:

James Bowling, Assistant Secretary of the Board

Resolution No. 2011 - 01

TRUCKEE DONNER PUBLIC UTILITY DISTRICT DECLARING ITS INTENT TO UPDATE ITS MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN AND ADOPT A STATEMENT OF PUBLIC PARTICIPATION

WHEREAS, groundwater is a valuable natural resource in California and should be managed to ensure both its safe production and its quality; and,

WHEREAS, one of the responsibilities of Truckee Donner Public Utility District (District) is to provide for sustainable use of groundwater resources; and

WHEREAS, the District uses groundwater to serve customers from the Martis Valley water system located near Truckee, California; and

WHEREAS, the District adopted its current Martis Valley Groundwater Management Plan on January 3, 1995; and

WHEREAS, the current groundwater management plan allows for periodic updates and advocates working collaboratively with others in Martis Valley; and

WHEREAS, the District has established a partnership with Northstar Community Services District and Placer County Water Agency to prepare an updated groundwater management plan and develop a groundwater model to reflect current water resources planning in Martis Valley and enhance understanding of the underlying groundwater basin; and

WHEREAS, the District intends to prepare, adopt, and implement this updated groundwater management plan in cooperation with the general public and stakeholders;

WHEREAS, prior to adoption of this resolution, the District has held a public hearing, after publication of notice pursuant to Section 6066 of the Government Code, on whether or not to adopt a resolution for intention to update a groundwater management plan;

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of the Truckee Donner Public Utility District that:

1. The Board intends to prepare, adopt, and implement an updated Martis Valley Groundwater Management Plan. Among other content, the updated groundwater management plan will include basin management objectives, plan components, and management actions.

2. The District further intends to provide for and encourage public/stakeholder involvement in the preparation of this updated groundwater management plan.

PASSED AND ADOPTED by the Board of Directors of the Truckee Donner Public Utility District in a meeting duly called and held within said District on the 6th day of April, 2011.

AYES: Directors Aguera, Bender, Hemig, Hillstrom and Laliotis

NOES: None

ABSTAIN: None

ABSENT: None

TRUCKEE DONNER PUBLIC UTILITY DISTRICT

____
Jeff Bender, President

ATTEST:

____
Michael D. Holley, P.E. Clerk of the Board

Agenda Item # 11

TRUCKEE DONNER
Public Utility District

ACTION

To: Board of Directors
From: Steven Poncelet
Date: March 16, 2011
Subject: Consideration of Setting a Public Hearing Date to Begin the Martis Valley Groundwater Management Plan Process

---

1. WHY THIS MATTER IS BEFORE THE BOARD

The Board is responsible for the long-term stewardship of our water supply. Studying the Martis Valley aquifer and having an up-to-date Groundwater Management Plan are important tools for effective stewardship of our water supply.

2. HISTORY

The District has always been concerned with maintaining long-term water supply and water quality for our community. The Board last adopted a Groundwater Management Plan in 1995. The opportunity exists to both update this document and to greatly improve our understanding of how the aquifer functions. This includes better information on the sustainable yield of the aquifer, how changes in the built environment may be impacting water quality, and how climate change may be impacting our long term water supply and quality.

The Board approved the FY09 budget which included $150,000 for a study of the Martis Valley aquifer and an update of our Groundwater Management Plan. The District was able to partner with Placer County Water Agency (PCWA) and Northstar Community Services District (Northstar CSD) to expand the funding for this effort to a total of $250,000. The Board adopted a Memorandum of Agreement for development of the Martis Valley Groundwater Management Plan and groundwater model with PCWA and Northstar CSD at the July 21, 2010 Board meeting. The agency partners secured an additional approximately $500,000 in grant funding from the Bureau of Reclamation for Desert Research Institute (DRI) modeling services and integration of a climate change model. The total project funding is now approximately $750,000.

In late 2010, PCWA, the lead agency, issued a Request for Proposal to hire a consultant to manage the development of the Martis Valley aquifer model and to develop a Groundwater Management Plan and associated public outreach. At their February 7, 2011 Board meeting, a contract was awarded to Brown and Caldwell, with local Truckee sub-contractor Balanced Hydrologics.

3. NEW INFORMATION

Brown and Caldwell has begun work on the Groundwater Management Plan and associated public outreach. The State of California has specific requirements for the development of Groundwater Management Plans. Included in the State requirements is that the District must hold a public hearing, and adopt a Board Resolution to announce the intention to update the Groundwater Management Plan. The District must also hold a second public hearing, and a Board Resolution to adopt the final Groundwater Management Plan. Staff is recommending that we hold the initial public hearing and that the Board consider adopting a Resolution for the intention to update the Groundwater Management Plan at the April 6, 2011 Board meeting.

Brown and Caldwell is developing a final project workplan and schedule. The development of the Martis Valley aquifer model and Groundwater Management Plan and associated public outreach is expected to take approximately two years. Key next steps include:

- Agency partner kick-off meeting with Brown and Caldwell and DRI on March 21, 2011
- Public notice and hearing on the District's intention to update our Groundwater Management Plan
- Creation of a Stakeholder Working Group which would include a technical advisory committee
- Development of a project website available to the public
- Kick-off of the Martis Valley aquifer modeling effort by DRI

4. FISCAL IMPACT

Sufficient funds exist within the approved FY11 budget for the project.

5. RECOMMENDATION

Authorize staff to:

- Schedule a public hearing for the April 6, 2011 Board meeting
- Advertise a public notice for the public hearing

Steven Poncelet
Public Information & Conservation Manager

Michael D. Holley
General Manager

SIERRA SUN

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Nicole

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Proof and Statement of Publication

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Account Number: 1066693

Legal Account
Placer County Water Agency
P.O. Box 6570
Auburn, CA 95604
Attn: Nicole Snyder

Rachel Renaud says:
That (s)he is a legal clerk of the **SIERRA SUN**, a newspaper published Wednesday, Friday, Saturday at Truckee, in the State of California.

Martis Valley Groundwater Plan

Ad # 6289415

of which a copy is hereto attached, was published in said newspaper for the full required period of **2 times** commencing on **March 16, 2011,** and ending on **March 23, 2011,** all days inclusive.

Signed: Rachel Renaud

STATEMENT:

DATE	AMOUNT	CREDIT	BALANCE
3/23/11	$135.26	$ 0.00	$135.26

NOTICE OF PLACER COUNTY WATER AGENCY BOARD OF DIRECTORS MEETING AGENDA ITEM FOR RESOLUTION OF INTENT TO UPDATE ITS MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN

NOTICE IS HEREBY GIVEN that the Placer County Water Agency (PCWA) will hold a public hearing in accordance with California Water Code Section 10753.2 to review and consider a Resolution of Intent to update its Martis Valley Groundwater Management Plan. The public hearing will be held April 7, 2011 at 2:00 p.m. at the regularly scheduled meeting of the PCWA Board of Directors which is held in the American River Room at its Business Center, 144 Ferguson Road, Auburn, California. The public is invited to comment on PCWA's intent as described.

The reasons for updating the Martis Valley Groundwater Management Plan are to reflect current water resources planning in the region, to reflect the latest information and understandings of the underlying groundwater basin, and to update the plan in partnership with adjacent water purveyors in an effort to work collaboratively and align policy. The plan will be updated in partnership with Truckee Donner Public Utilities District and Northstar Community Services District. In addition to updating the groundwater management plan, a computer model of the groundwater basin will be developed, which will assimilate available data and enhance understanding of the basin.

PCWA and its partners intend to prepare, adopt, and implement this updated groundwater management plan in cooperation with the general public and stakeholders. For more information please contact Tony Firenzi at (530) 823-4886 or tfirenzi@pcwa.net.

Pub: March 16, 23, 2011 Ad#6289415

SIERRA SUN

Serving the Truckee Community since 1869

PCWA FINANCE

Proof and RECEIVED 4/28/11

Statement of Publication

P.O. Box 1888 Carson City, NV 89702 2011 APR 25 PM 1 16
Phone (775) 881-1201
Fax (775) 887-2408

Account Number: 1066693

Legal Account
Placer County Water Agency
P.O. Box 6570
Auburn, CA 95604
Attn: Nicole Snyder

Rachel Renaud says:
That (s)he is a legal clerk of the **SIERRA SUN**, a newspaper published Wednesday, Friday, Saturday at Truckee, in the State of California.

Martis Valley Groundwater Management Plan

Ad # 6400246

of which a copy is hereto attached, was published in said newspaper for the full required period of **2 times** commencing on **April 13, 2011,** and ending on **April 20, 2011,** all days inclusive.

Signed: Rachel Renaud

STATEMENT:

DATE	AMOUNT	CREDIT	BALANCE
4/20/11	$226.63	$ 0.00	$226.63

RESOLUTION NO. 11-13 OF THE BOARD OF DIRECTORS OF THE PLACER COUNTY WATER AGENCY DECLARING ITS INTENT TO UPDATE ITS MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN AND ADOPT A STATEMENT OF PUBLIC PARTICIPATION

WHEREAS, one of the responsibilities of Placer County Water Agency (Agency) is to provide for sustainable use of groundwater resources within Placer County; and

WHEREAS, The Agency uses groundwater to serve customers in its Martis Valley water system located near Truckee, California; and

WHEREAS, the Agency adopted its current Martis Valley Groundwater Management Plan on October 6, 1998; and

WHEREAS, the current groundwater management plan allows for periodic updates and advocates working collaboratively with others in Martis Valley; and

WHEREAS, the Agency has established a partnership with Truckee Donner Public Utilities District and Northstar Community Services District to prepare an updated groundwater management plan and develop a groundwater model to reflect current water resources planning in Martis Valley and enhance understanding of the underlying groundwater basin; and

WHEREAS, the Agency intends to prepare, adopt, and implement this updated groundwater management plan in cooperation with the general public and stakeholders;

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of the Placer County Water Agency that:

1. The Board intends to prepare, adopt, and implement an updated Martis Valley Groundwater Management Plan. Among other content, the updated groundwater management plan will include basin management objectives, plan components, and management actions.
2. The Agency further intends to provide for and encourage public/stakeholder involvement in the preparation of this updated groundwater management plan.

The foregoing resolution was duly passed at meeting of the Board of Directors of the Placer County Water Agency held on April 7, 2011, by the following on roll call:

AYES DIRECTORS: Gray Allen, Alex Ferreira, Mike Lee, Ben Mavy, Chairman Lowell Jarvis

NOES DIRECTORS: None

ABSENT DIRECTORS: None

Signed and approved by me after it passage this 7th day of April, 2011

/s/ Lowell M. Jarvis
Chair, Board of Directors
Placer County Water Agency

ATTEST:
/s/ Cheri Sprunck
Clerk, Board of Directors
Placer County Water Agency

Pub: April 13, 20, 2011 Ad#6400246

16391896

PUBLIC NOTICE

16391896

PUBLIC NOTICE

NOTICE OF PLACER COUNTY WATER AGENCY BOARD OF DIRECTORS MEETING AGENDA ITEM FOR RESOLUTION OF INTENT TO UPDATE ITS MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN

NOTICE IS HEREBY GIVEN that the Placer County Water Agency (PCWA) will hold a public hearing in accordance with California Water Code Section 10753.2 to review and consider a Resolution of Intent to update its Martis Valley Groundwater Management Plan. The public hearing will be held April 7, 2011 at 2:00 p.m. at the regularly scheduled meeting of the PCWA Board of Directors which is held in the American River Room at its Business Center, 144 Ferguson Road, Auburn, California. The public is invited to comment on PCWA's intent as described.

The reasons for updating the Martis Valley Groundwater Management Plan are to reflect current water resources planning in the region, to reflect the latest information and understandings of the underlying groundwater basin, and to update the plan in partnership with adjacent water purveyors in an effort to work collaboratively and align policy. The plan will be updated in partnership with Truckee Donner Public Utilities District and Northstar Community Services District. In addition to updating the groundwater management plan, a computer model of the groundwater basin will be developed, which will assimilate available data and enhance understanding of the basin.

PCWA and its partners intend to prepare, adopt, and implement this updated groundwater management plan in cooperation with the general public and stakeholders. For more information please contact Tony Firenzi at (530) 823-4886 or tfirenzi@pcwa.net.

PUBLISHED IN AUBURN JOURNAL: MARCH 16, 23, 2011

The above space is reserved for Court/County Filed Date Stamp

PROOF OF PUBLICATION
(2015.5 C.C.P.)

STATE OF CALIFORNIA
County of Placer

I am a citizen of the United States and employed by a publication in the County aforesaid. I am over the age of eighteen years, and not a party to the mentioned matter. I am the principal clerk of **The Auburn Journal**, a newspaper of general circulation, in the **City of Auburn**, which is printed and published in the **County of Placer**. This newspaper has been judged a newspaper of general circulation by the Superior Court of the State of California, in and for the **County of Placer**, on the date of May 26, 1952 (Case Number 17407). The notice, of which the attached is a printed copy (set in type not smaller than nonpareil) has been published in each regular and entire issue of said newspaper and not in any supplement thereof on the following dates, to-wit:

MARCH 16, 23

I certify, under penalty of perjury, that the foregoing is true and correct.

Terry Clark

Dated in Auburn, California

MARCH 23, 2011

PROOF OF PUBLICATION
THE AUBURN JOURNAL
1030 High Street
Auburn, CA 95604-5910

16395813

PUBLIC NOTICE

16395813

PUBLIC NOTICE

RESOLUTION NO. 11 - 13 OF THE BOARD OF DIRECTORS OF THE PLACER COUNTY WATER AGENCY DECLARING ITS INTENT TO UPDATE ITS MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN AND ADOPT A STATEMENT OF PUBLIC PARTICIPATION

WHEREAS, one of the responsibilities of Placer County Water Agency (Agency) is to provide for sustainable use of groundwater resources within Placer County; and

WHEREAS, The Agency uses groundwater to serve customers in its Martis Valley water system located near Truckee, California; and

WHEREAS, the Agency adopted its current Martis Valley Groundwater Management Plan on October 6, 1998; and

WHEREAS, the current groundwater management plan allows for periodic updates and advocates working collaboratively with others in Martis Valley; and

WHEREAS, the Agency has established a partnership with Truckee Donner Public Utilities District and Northstar Community Services District to prepare an updated groundwater management plan and develop a groundwater model to reflect current water resources planning in Martis Valley and enhance understanding of the underlying groundwater basin; and

WHEREAS, the Agency intends to prepare, adopt, and implement this updated groundwater management plan in cooperation with the general public and stakeholders;

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of the Placer County Water Agency that:

1.The Board intends to prepare, adopt, and implement an updated Martis Valley Groundwater Management Plan. Among other content, the updated groundwater management plan will include basin management objectives, plan components, and management actions.

2. The Agency further intends to provide for and encourage public/stakeholder involvement in the preparation of this updated groundwater management plan.

The foregoing resolution was duly passed at meeting of the Board of Directors of the, Placer County Water Agency held on April 7, 2011, by the following on roll call:

AYES DIRECTORS: Gray Allen, Alex Ferreira, Mike Lee, Ben Mavy, Chairman Lowell Jarvis

NOES DIRECTORS: None

ABSENT DIRECTORS: None

Signed and approved by me after its passage this 7th day of April, 2011.

PUBLISHED IN AUBURN JOURNAL: APRIL 13, 20, 2011

A/P Has Original

The above space is reserved for Court/County Filed Date Stamp

PROOF OF PUBLICATION (2015.5 C.C.P.)

STATE OF CALIFORNIA
County of Placer

I am a citizen of the United States and employed by a publication in the County aforesaid. I am over the age of eighteen years, and not a party to the mentioned matter. I am the principal clerk of **The Lincoln News Messenger**, a newspaper of general circulation, in the **City of Lincoln**, which is printed and published in the **County of Placer.** This newspaper has been judged a newspaper of general circulation by the Superior Court of the State of California, in and for the **County of Placer**, on the date of April 3, 1952, Superior Court Order Number 89429. The notice, of which the attached is a printed copy (set in type not smaller than nonpareil) has been published in each regular and entire issue of said newspaper and not in any supplement thereof on the following dates, to-wit:

APRIL 13, 20

I certify, under penalty of perjury, that the foregoing is true and correct.

Terry Clark

Dated in Lincoln, California

APRIL 20, 2011

PROOF OF PUBLICATION
THE LINCOLN NEWS MESSENGER
553 F Street
Lincoln, CA 95648

N·C·S·D
Northstar Community Services District
908 Northstar Drive, Northstar, CA 96161
P: 530.562.0747 • F: 530.562.1505 • www.northstarcsd.com

NORTHSTAR COMMUNITY SERVICES DISTRICT
NOTICE OF THE REGULAR MEETING
OF THE BOARD OF DIRECTORS

DATE: **MARCH 16, 2011**
TIME: **9 A.M.**
PLACE: **NORTHSTAR FIRE STATION, 910 NORTHSTAR DRIVE**

I. CALL TO ORDER, PLEDGE OF ALLEGIANCE, ROLL CALL

II. PUBLIC COMMENTS

Any member of the public may address the Board after roll call on any topic related to the District that is not on the agenda. Public comment will be taken on agenda action items immediately prior to Board action.

III. RECURRING BUSINESS

1. Approval and Discussion of the minutes of the February 15, 2011 Finance Committee Meeting and the February 16, 2011 Regular Meeting.
2. Meetings attended by NCSD Board Members – Discussion.

IV. NEW BUSINESS

3. East West Partners – Update.
4. Northstar Property Owners Association – Update.
5. CAMCO – Update.
6. Northstar-at-Tahoe/Vail – Update.
7. Martis Valley Groundwater Management Plan – Action to set Public Hearing on Resolution of Intention to cooperate in the preparation of the Martis Valley Groundwater Management Plan – Discussion – Action.
8. Resolution 11-03 "Resolution Approving the Department of Forestry and Fire Protection Agreement for Services from July 1, 2010 to June 30, 2013" – Discussion – Action.
9. Approval of Shift Proposal for Strategic Communications and Community Engagement Strategies – Martis Valley Regional Trail – Discussion – Action.
10. Approval of Memorandum of Agreement Between the North Lake Tahoe Resort Association and the Northstar Community Services District for use of Transient Occupancy Tax (TOT) Infrastructure Funds – Discussion – Action.
11. Approval of Exempt Employee Flexible Work Schedule Policy – Discussion – Action.

V. ATTORNEYS REPORT

VI. CLOSED SESSION

12. Conference with Legal Counsel – Existing Litigation [California Government Code Section 54956.9(a)]; Two cases: 1) Name of Case: *Community Facilities District #1 of the Northstar Community Services District vs. Highlands Hotel Residences Company, LLC, Bank of America, et al*, Placer County, California Superior Court #SCV0027907. 2) Name of Case: *Bank of America & Thomas Morone, as Receiver for Highlands Hotel Company vs. NCSD & Community Facilities District No. 1 of NCSD*, Placer County, California Superior Court #SCV0028495.

13. Public Employee Performance Evaluation (Government Code Section 54957) – Titles: Engineering and Mapping Department: Information Systems Supervisor, Director of Public Works, Associate Engineer, GIS Analyst – Administration Department: Controller, Administrative Manager, Administrative Assistant, Human Resource Director
14. Conference with Labor Negotiators (Government Code §54957.6) – Agency designated representatives: Jim Bowling, Mark Shadowens. Employee organization: Employee Representation – Fire Department employees.

VII. DIRECTOR REPORTS

Individual directors may give brief reports on miscellaneous items for the information of the other members of the board and NCSD staff. No action will be taken.

VIII. OPERATION REPORTS

15. General Managers Report – Staudenmayer – Discussion.
16. Fire Department Report – Shadowens – Discussion.
17. Director of Public Works Report – Geary – Discussion.
18. Utilities Department Report – Ryan – Discussion.
19. Administration Department Report – Tanner/Lewis/Bowling – Discussion.

IX. WARRANT REGISTER & MELLO-ROOS REQUISITIONS

20. Approval of the Warrant Register.
21. Ratification of Mello-Roos Requisitions in the amount of $15,353.42.

X. ADJOURNMENT

Items may not be taken in the order listed above.

In compliance with the Americans with Disabilities Act, if you are a disabled person and you need a disability-related modification or accommodation to participate in this meeting, then please contact Myra Tanner at (530) 562-0747 or (530) 562-1505 (fax). Requests must be made as early as possible and at least one-full business day before the start of the meeting.

Appendix B: Resolutions Adopting the Groundwater Management Plan

SIERRA SUN

P.O. Box 1888 Carson City, NV 89702
(775) 881-1201 FAX: (775) 887-2408

Proof and Statement of Publication

Ad #: 8823943D

Customer Account: # 1073085

Legal Account
Placer County Water Agency
P.O. Box 6570
AUBURN, CA 95604
Attn: Vibeke Figueroa

Victoria Lopez says:
That (s)he is a legal clerk of the **SIERRA SUN**, a newspaper published Wednesday and Friday at Truckee, in the State of California.

Copy Line
Joint Martis Valley

PO#:

Ad #: 8823943D
of which a copy is hereto attached, was published in said newspaper for the full required period of **2** time(s) commencing on **1/23/2013**, and ending on **1/30/2013**, all days inclusive.

Signed: ______________________

Date: 01/31/2013 State of Nevada, Carson City

Price: $ 235.980

Subscribed and sworn to before me this ____ day of ______

____
Notary Public

PUBLIC HEARINGS

NOTICE OF TRUCKEE DONNER PUBLIC UTILITIES DISTRICT BOARD OF DIRECTORS
NOTICE OF NORTHSTAR COMMUNITY SERVICES DISTRICT BOARD OF DIRECTORS
NOTICE OF PLACER COUNTY WATER AGENCY BOARD OF DIRECTORS
MEETING AGENDA ITEMS TO ADOPT THE MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN

Truckee Donner Public Utility District (TDPUD), Northstar Community Services District (NCSD) and Placer County Water Agency (PCWA) will hold their individual public hearings in accordance with California Water Code Section 10753.2 to review and consider adoption of the Martis Valley Groundwater Management Plan. The respective public hearings are scheduled accordingly:

- The TDPUD public hearing will be held February 20, 2013 at 6:00 PM at the regularly scheduled meeting of the TDPUD Board of Directors located at 11570 Donner Pass Road, Truckee, California.
- The NCSD public hearing will be held February 20, 2013 at 9:00 AM at the regularly scheduled meeting of the NCSD Board of Directors located at the Northstar Fire Station located at 910 Northstar Drive, Northstar, California.
- The PCWA public hearing will be held February 21, 2013 at 2:00 PM, at the regularly scheduled meeting of the PCWA Board of Directors, which is held in the American River Room at its Business Center, 144 Ferguson Road, Auburn, California.

The public is invited to comment on the partner Agencies' intent as described.

The reasons for updating the Martis Valley Groundwater Management Plan are to reflect current water resources planning in the region, to reflect the latest information and understandings of the underlying groundwater basin, and to update the plan in partnership with TDPUD, NCSD and PCWA in an effort to promote regional water management, work collaboratively, and align policy. The plan document includes management objectives and actions that support long term quality and availability of groundwater in the Martis Valley Groundwater Basin. In addition to updating the groundwater management plan, a Bureau of Reclamation-sponsored computer model of the Martis Valley groundwater basin and watershed is currently being developed by the Desert Research Institute, which provided preliminary groundwater recharge estimates of the Martis Valley groundwater basin and will ultimately enhance understanding of basin groundwater resources.

Copies of the draft Martis Valley Groundwater Management Plan are available for public review and comment at the respective agency offices or at www.MartisValleyGMP.org. Printed copies may be obtained for the cost of reproduction. The three partners intend to adopt and implement this updated groundwater management plan in cooperation with the general public and stakeholders. For more information please contact Barbara Cahill at (530) 582-3909 or barbaracahill@tdpud.org ; Mike Staudenmayer (NCSD) at (530) 562-0747 or mikes@northstarcsd.com ; or Tony Firenzi (PCWA) at (530) 823-4886 or tfirenzi@pcwa.net. Any comments or protests by landowners in the plan area must be submitted prior to the close of public comment at any of the three hearings listed above.

Pub: January 23, 30, 2013 **Ad#8823943**

16489006

PUBLIC HEARINGS

16489006

PUBLIC HEARINGS

NOTICE OF TRUCKEE DONNER PUBLIC UTILITIES DISTRICT BOARD OF DIRECTORS NOTICE OF NORTHSTAR COMMUNITY SERVICES DISTRICT BOARD OF DIRECTORS NOTICE OF PLACER COUNTY WATER AGENCY BOARD OF DIRECTORS MEETING AGENDA ITEMS TO ADOPT THE MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN

Truckee Donner Public Utility District (TDPUD), Northstar Community Services District (NCSD) and Placer County Water Agency (PCWA) will hold their individual public hearings in accordance with California Water Code Section 10753.2 to review and consider adoption of the Martis Valley Groundwater Management Plan. The respective public hearings are scheduled accordingly:

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- The NCSD public hearing will be held February 20, 2013 at 9:00 AM at the regularly scheduled meeting of the NCSD Board of Directors located at the Northstar Fire Station located at 910 Northstar Drive, Northstar, California.
- The PCWA public hearing will be held February 21, 2013 at 2:00 PM, at the regularly scheduled meeting of the PCWA Board of Directors, which is held in the American River Room at its Business Center, 144 Ferguson Road, Auburn, California.

The public is invited to comment on the partner Agencies' intent as described.

The reasons for updating the Martis Valley Groundwater Management Plan are to reflect current water resources planning in the region, to reflect the latest information and understandings of the underlying groundwater basin, and to update the plan in partnership with TDPUD, NCSD and PCWA in an effort to promote regional water management, work collaboratively, and align policy. The plan document includes management objectives and actions that support long term quality and availability of groundwater in the Martis Valley Groundwater Basin. In addition to updating the groundwater management plan, a Bureau of Reclamation-sponsored computer model of the Martis Valley groundwater basin and watershed is currently being developed by the Desert Research Institute, which provided preliminary groundwater recharge estimates of the Martis Valley groundwater basin and will ultimately enhance understanding of basin groundwater resources.

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PUBLISHED IN AUBURN JOURNAL: JANUARY 23, 30, 2013

The above space is reserved for Court/County Filed Date Stamp

PROOF OF PUBLICATION (2015.5 C.C.P.)

STATE OF CALIFORNIA
County of Placer

I am a citizen of the United States and employed by a publication in the County aforesaid. I am over the age of eighteen years, and not a party to the mentioned matter. I am the principal clerk of **The Auburn Journal**, a newspaper of general circulation, in the **City of Auburn**, which is printed and published in the **County of Placer**. This newspaper has been judged a newspaper of general circulation by the Superior Court of the State of California, in and for the **County of Placer**, on the date of May 26, 1952 (Case Number 17407). The notice, of which the attached is a printed copy (set in type not smaller than nonpareil) has been published in each regular and entire issue of said newspaper and not in any supplement thereof on the following dates, to-wit:

JANUARY 23, 30

I certify, under penalty of perjury, that the foregoing is true and correct.

Terry Clark

Dated in Auburn, California

JANUARAY 30, 2013

PROOF OF PUBLICATION
THE AUBURN JOURNAL
1030 High Street
Auburn, CA 95604-5910

N·C·S·D
Northstar Community Services District
908 Northstar Drive, Northstar, CA 96161
P: 530.562.0747 • F: 530.562.1505 • www.northstarcsd.org

BOARD OF DIRECTORS
NORTHSTAR COMMUNITY SERVICES DISTRICT

RESOLUTION 13-01

RESOLUTION OF THE BOARD OF DIRECTORS OF THE NORTHSTAR COMMUNITY SERVICES DISTRICT ADOPTING THE MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN

WHEREAS, On April 20, 2011 the Board of Directors passed Resolution 11-05 "Resolution of Intention to Cooperate in the Preparation of the Updated Martis Valley Groundwater Management Plan with the Placer County Water Agency and the Truckee Donner Public Utility District and adopt a statement of public involvement; and

WHEREAS, the District prepared an updated plan in partnership with the Truckee Donner Public Utilities District and the Placer County Water Agency (PCWA) in an effort to work collaboratively and align policy; and

WHEREAS, the updated Martis Valley Groundwater Management Plan was prepared in accordance with the California Groundwater Management Act, Assembly Bill 3030, and Senate Bill 1938; and

NOW, THEREFORE, BE IT RESOLVED that the Board of Directors of the Northstar Community Services District hereby adopts the updated Martis Valley Groundwater Management Plan.

PASSED AND ADOPTED by the Northstar Community Services District this 20th day of February, 2013, by the following vote on call:

AYES:	**Green, Ives, Seelig, Smith**
NOES:	**None**
ABSENT:	**None**
ABSTAIN:	**Evans**

Nancy P. Ives
President of the Board

ATTEST:

James Bowling
Secretary of the Board

RESOLUTION NO. 13-03 OF THE BOARD OF DIRECTORS OF THE PLACER COUNTY WATER AGENCY ADOPTING THE UPDATED MARTIS VALLEY GROUNDWATER MANAGEMENT PLAN

WHEREAS, On April 7, 2011 the Board of Directors passed Resolution 11-13 declaring its intent to update its Martis Valley Groundwater Management Plan and adopt a statement of public involvement; and

WHEREAS, the Agency prepared an updated plan in partnership with the Truckee Donner Public Utilities District and the Northstar Community Services District in an effort to work collaboratively and align policy; and

WHEREAS, the updated Martis Valley Groundwater Management Plan was prepared in accordance with the California Groundwater Management Act, Assembly Bill 3030, and Senate Bill 1938; and

NOW, THEREFORE, BE IT RESOLVED that the Board of Directors of the Placer County Water Agency hereby adopts the updated Martis Valley Groundwater Management Plan.

The foregoing resolution was duly passed at meeting of the Board of Directors of the Placer County Water Agency held on February 21, 2013, by the following on roll call:

AYES DIRECTORS: Joshua Alpine, Robert Dugan, Alex Ferreira, Mike Lee, Chair Gray Allen

NOES DIRECTORS: None

ABSENT DIRECTORS: None

Signed and approved by me after its passage this 21st day of February, 2013.

Chair, Board of Directors
Placer County Water Agency

ATTEST:

Clerk, Board of Directors
Placer County Water Agency

Resolution No. 2013 – 04

Adopt the Martis Valley Groundwater Management Plan

WHEREAS, groundwater is a valuable natural resource in California and should be managed to ensure both its safe production and its quality; and,

WHEREAS, one of the responsibilities of Truckee Donner Public Utility District (District) is to provide for sustainable use of groundwater resources; and

WHEREAS, the District uses groundwater to serve customers from the Martis Valley water system located near Truckee, California; and

WHEREAS, the District adopted its current Martis Valley Groundwater Management Plan on January 3, 1995; and

WHEREAS, on April 8, 2011, the Board of Directors passed Resolution 2011-01 declaring its intent to update its Martis Valley Groundwater Management Plan and adopt a statement of public involvement; and

WHEREAS, the District prepared an updated plan in partnership with the Placer County Water Agency and the Northstar Community Services District in an effort to work collaboratively and align policy; and

WHEREAS, the updated Martis Valley Groundwater Management Plan was prepared in accordance with the California Groundwater Management Act, Assembly Bill 3030, and Senate Bill 1938.

NOW, THEREFORE, BE IT RESOLVED that the Board of Directors of the Truckee Donner Public Utility District hereby adopts the updated Martis Valley Groundwater Management Plan.

The foregoing resolution was duly passed at a meeting of the Board of Directors of Truckee Donner Public Utility District held on February 20, 2013, by the following roll call:

AYES: Directors Bender, Ellis, Hemig and Laliotis
NOES: None
ABSTAIN: None
ABSENT: Director Aguera

TRUCKEE DONNER PUBLIC UTILITY DISTRICT

Jeff Bender, President

ATTEST:

Michael D. Holley, District Clerk

Appendix C: Public Outreach Plan

Brown AND Caldwell

10540 White Rock Road, Suite 180
Rancho Cordova, CA 95670
Tel: 916-444-0123
Fax: 916-635-8805

Technical Memorandum

Project Title: Martis Valley Groundwater Management Plan

Project No: 140691

Public Outreach Plan Technical Memorandum (Deliverable Task 1.2)

Date: May 25, 2011

To: Tony Firenzi, Brian Martin, Michael Holley, Steven Poncelet, and Mike Staudenmayer

From: Tina Bauer, Project Manager

Prepared by: ________________________________

John Ayres, Task One Manager

Reviewed by: ________________________________

Tina M. Bauer, Project Manager

Introduction

The partnership of Placer County Water Agency (PCWA), Truckee Donner Public Utilities District (TDPUD), and Northstar Community Services District (NCSD), herein referred to as the partnership agencies, are working together to update a Groundwater Management Plan (GMP) for the Martis Valley in accordance with the California Water Code, Article 107050. The overall goal of the GMP is to develop a framework that maintains groundwater quantity and quality, thereby providing a sustainable, high-quality supply for beneficial use in the Martis Valley. Brown and Caldwell (BC) has been contracted by the partnership to prepare the GMP and perform public outreach activities.

The reasons for updating the Martis Valley GMP are to:

- Reflect current water resources planning in the region,
- Update the understanding of the underlying groundwater basin, and
- Prepare the plan in partnership with basin water purveyors in an effort to work collaboratively and align policy.

In addition to updating the GMP a computer model of the groundwater basin will be developed by the Desert Research Institute (through a grant from the Bureau of Reclamation) which will assimilate available data and enhance the understanding of the basin. This groundwater model will be used as a tool to improve basin understanding during GMP development.

Public outreach as described herein is a key component of the process in preparing the GMP.

Public Outreach Objectives

This plan's outreach activities are designed to meet the following outreach objectives:

- Inform the public regarding the development of the GMP.
- Provide meaningful opportunities for stakeholders and the general public to contribute to the development of the GMP.
- Incorporate stakeholder input regarding the GMP.
- Document stakeholder recommendations in a clear, complete manner.
- Develop public understanding and support of the GMP.

To pursue these objectives effectively, various outreach methods will be necessary to reach the groups targeted for inclusion in the planning process.

Groundwater Management Plan Preparation

During the course of preparing the GMP, various entities will be involved in developing, approving, and adopting the GMP. Their roles and responsibilities are as follows:

Partnership Agencies – Each individual agency will follow the GMP adoption process. As such, each agency will conduct two public hearings. The first hearing will be to adopt a resolution of intent to prepare a GMP and the second hearing will be to determine whether or not to adopt the GMP. These hearings will be conducted in compliance with the California Water Code, Article 10753.2 through Article 10753.6. Hearings were held by each agency in April 2011 to indicate to the public the intent of the agencies to develop a GMP. The public was notified in advance in accordance with the California Water Code.

Groundwater Management Plan Team – The GMP team consists of the partnership agencies, BC, and BC's subcontractor, Balance Hydrologics, Inc of Truckee, Ca. Brown and Caldwell will perform the majority of the technical work and analyses, conduct and document the public outreach effort, conduct public meetings and SWG meetings, develop and maintain a website so that information on the project is available to interested parties, and prepare newsletters and notifications of meetings and events. The partnership agencies will provide available resource data, GIS information, and review BC's work. The partnership agencies will provide the names and addresses of special interest groups and interested public members, and assist in distributing newsletters and notifications of meetings and events through the media. The Partnership Agencies will also provide available data and information related to land and water use policies and ordinances affecting water management in Martis Valley.

Stakeholder Working Group – The Stakeholder Working Group (SWG) will be comprised of representatives of federal, state, and local governments, environmental and special interest groups, local land use interests, and the general public selected by the partnership agencies. The SWG will provide local knowledge, data and information, opinions, and review and comment on material prepared by the GMP team. Five meetings with the SWG are anticipated to occur at strategic times for addressing particular items, as appropriate.

General Public – The public will be invited to participate in two public hearings for each partnership agency and two public workshops. The first workshop will explain the process of GMP development and present groundwater model concepts (July 2011). The second workshop will be conducted near project completion and will provide an overview of GMP content. The first agency public hearings have been completed. The second agency public hearings will be conducted at project completion (anticipated November 2012). All agency public hearings will be in compliance with the California Water Code, Article 107050.

Communications and Notifications

Communication and notification is an important aspect of effective outreach. Various means of communication and notification will be utilized to implement this Public Outreach Plan including the following:

Notifications - Notifications are the primary method of outreach used to inform the public of upcoming meetings and hearings. Notifications will be published in the Sierra Sun and the Auburn Journal and will be prepared and submitted to the review group approximately one week prior to the planned publication date.

Website - During project implementation, a public website will be developed and hosted. The website will also contain basic information about the project, including project goals, sponsoring agencies, and who to contact for more information. The website will be updated monthly to supply regular information updates to the public about project progress, data gathered, and decisions made. The website will have pages dedicated to GMP development, groundwater model development, and a page that provides notices, newsletters, and quarterly reports.

Mailing/Contact List - A list of the names and addresses of participants and interested parties will be created by BC and used for communicating information regarding meetings and materials related to the GMP.

Newsletters - Public outreach will include three newsletters. Newsletters will consist of a double-sided full page color flyer that provides basic information about the project including the project goal, sponsoring agencies, and who to contact for more information. Each newsletter will address specific components of the project. The newsletters will be distributed at each partnership agency office and be uploaded onto the website.

Public Workshops, Public Hearings, and SWG Meetings

An important part of the public outreach will be the communications provided by the GMP team and comments provided by those participating in a particular forum. In general, the framework for the various forums conducted by Brown and Caldwell will be as described below. The timing for conducting the respective forums is shown on attached Table 1. Communications and notifications will be made in advance of each forum using the means noted.

Public Workshops – Two public workshops will be conducted. The 1st public workshop will be held to explain the process of GMP and model development to the public. This goal of this workshop is to inform the public of the purpose of the GMP and expected outcomes of GMP and model development. The second public workshop will provide an overview of GMP content and present groundwater modeling results. The goal of this workshop is to build public support of the GMP and model. Public workshops will be held using an open format, with presenters at multiple stations in different parts of the meeting room. Each presenter will be focused on a specific component of project development, and will have visual materials with them to facilitate explanation of the subject matter. Meeting participants will move from station to station according to their interests and time constraints.

Public Hearings – Two public hearings are required to adopt a GMP in compliance with the California Water Code, Article 17050. The first public hearing is conducted to adopt a resolution of intent to prepare a GMP and the second public hearing will be conducted to determine whether or not to adopt the GMP. Hearings were held by each partnership agency in April, 2011 to indicate to the public the intent of the agencies to develop a GMP.

Stakeholder Working Group Meetings – During the course of the project, meetings will be held with the partnership agencies and the SWG. All meetings will have an agenda and PowerPoint presentation with copies of pertinent information, as appropriate. Notes of the meetings will be prepared to document the salient items discussed. The anticipated content of the SWG meetings are as follows:

- The 1st SWG meeting will be held to introduce SWG members to the project and solicit their involvement. Presentation materials will include an overview of GMP content, discussion of the GMP's relationship with the groundwater model, and discussion of SWG member's local knowledge and the SWG's role during GMP development.
- The 2nd SWG meeting will present the conceptual model and physical conditions of the groundwater basin to SWG members. The physical conditions of the Martis Valley groundwater basin will be presented, including cross sections, monitoring well hydrographs, and other information as appropriate. The goal of this meeting is form consensus on what groundwater resources are present in the basin to be managed by the GMP.
- The 3rd SWG meeting will present preliminary GMP goals and management objectives for comment and suggestions to SWG members. The goal of this meeting is to build consensus about the identified goal and management objectives of the GMP.
- The 4th SWG meeting will present preliminary implementation actions and implementation schedule to the SWG for comment and suggestions. The goal of this meeting is to fully identify implementation actions for the GMP.
- The goal of the 5th SWG meeting is to discuss steps taken after adoption of the GWMP.

Summary of Opportunities for Public Participation

The partnership agencies are providing numerous opportunities for the public to participate in and to stay informed throughout the GMP planning process. A summary of the opportunities noted above with the anticipated timing of the event, as shown on the Outreach Activity Schedule, include the following:

- Partnership agency meetings and public hearings.
- Public Workshops.

In addition, a website will be available to the public to facilitate being informed of meeting dates, draft documents, notices, newsletters, and contact information.

	Outreach Activity	2011										2012													
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	Hearing to Adopt Intent to Develop GMP		□																						
2	Agency Meetings		▣				▣		▣				▣			▣		▣			▣				
3	Public Outreach pPlan			☆																					
4	Website and Monthly Updates			✪	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★
5	Stakeholder Working Group Meeting		■																						
6	Public Workshop					□																			
7	Stakeholder Working Group Meeting						■																		
8	Newsletter							📰																	
9	Stakeholder Working Group Meeting												■												
10	Stakeholder Working Group Meeting														■										
11	Newsletter															📰									
12	Newsletter																		📰						
13	Public Workshop																		□						
14	Stakeholder Working Group Meeting																			■					
15	Hearing to Adopt GMP																					□			

KEY

Client Agencies Meeting	▣
Stakeholder Group Meeting	■
Public Meeting or Hearing	□
Public Outreach Plan	☆
Website Live	✪
Website update	★
Newsletter	📰

Table 1 Outreach Schedule

Appendix D: CASGEM Monitoring Plan

Martis Valley Groundwater Monitoring Program

California Statewide Groundwater Elevation Monitoring (CASGEM)

Placer County Water Agency

Truckee Donner Public Utilities District

Northstar Community Services District

December 2011

Revised July 12, 2012

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APPENDICES

Appendix A – CASGEM Guidelines
Appendix B – CASGEM Monitoring Plan Summary

1.0 INTRODUCTION

This Martis Valley (MV) Groundwater Monitoring Program (Monitoring Program) report serves to describe the activities related to the monitoring of groundwater elevations in the MV area, as shown on **Figure 1-1**.

The elevation data gathered as part of this program will be included as part of the California Statewide Groundwater Elevation Monitoring (CASGEM) Program recently adopted by the California Department of Water Resources (DWR) as part of their mandated monitoring requirements under Senate Bill (SB) 6[1] of the State Water Code. This report strongly encourages the reader to review and understand the full text of the CASGEM Well Monitoring Guidelines, attached as **Appendix A**.

This Monitoring Program pulls together the efforts completed to date in the identification of existing and future well monitoring sites that satisfy the local and state requirements for a monitored groundwater basin. In addition, the Monitoring Program prepares the MV groundwater users to initiate a semi-annual monitoring event, which started with its first measurements in fall of 2011. Placer County Water Agency (PCWA), Truckee Donner Public Utilities District (TDPUD), and Northstar Community Services District (NCSD) are the three partners in MV area, in which their respective services areas are presented in Figure 1-1.

All field forms and measurement methods are included herein for the sole purpose of providing monitoring staff with easy access to printing and using these forms as part of their monitoring activities. The MV Monitoring Program report is a living document subject to change over time as more information is collected on the wells, and as technologies change to provide the best measurement of groundwater levels and water quality, and as more wells become available.

[1] SB 6 requires collaboration between local monitoring parties, or entities, and DWR to collect groundwater elevations statewide and that this information is made available to the public. SB 6 provides that:

- Local parties may assume responsibility for monitoring and reporting groundwater elevations.
- DWR work cooperatively with local Monitoring Entities to achieve monitoring programs that demonstrate seasonal and long-term trends in groundwater elevations.
- DWR accept and review prospective Monitoring Entity submittals, then determine the designated Monitoring Entity, notify the Monitoring Entity, and make that information available to the public.
- DWR perform groundwater elevation monitoring in basins where no local party has agreed to perform the monitoring functions.
- If local parties (for example, counties) do not volunteer to perform the groundwater monitoring functions, and DWR assumes those functions, then those parties become ineligible for water grants or loans from the State.

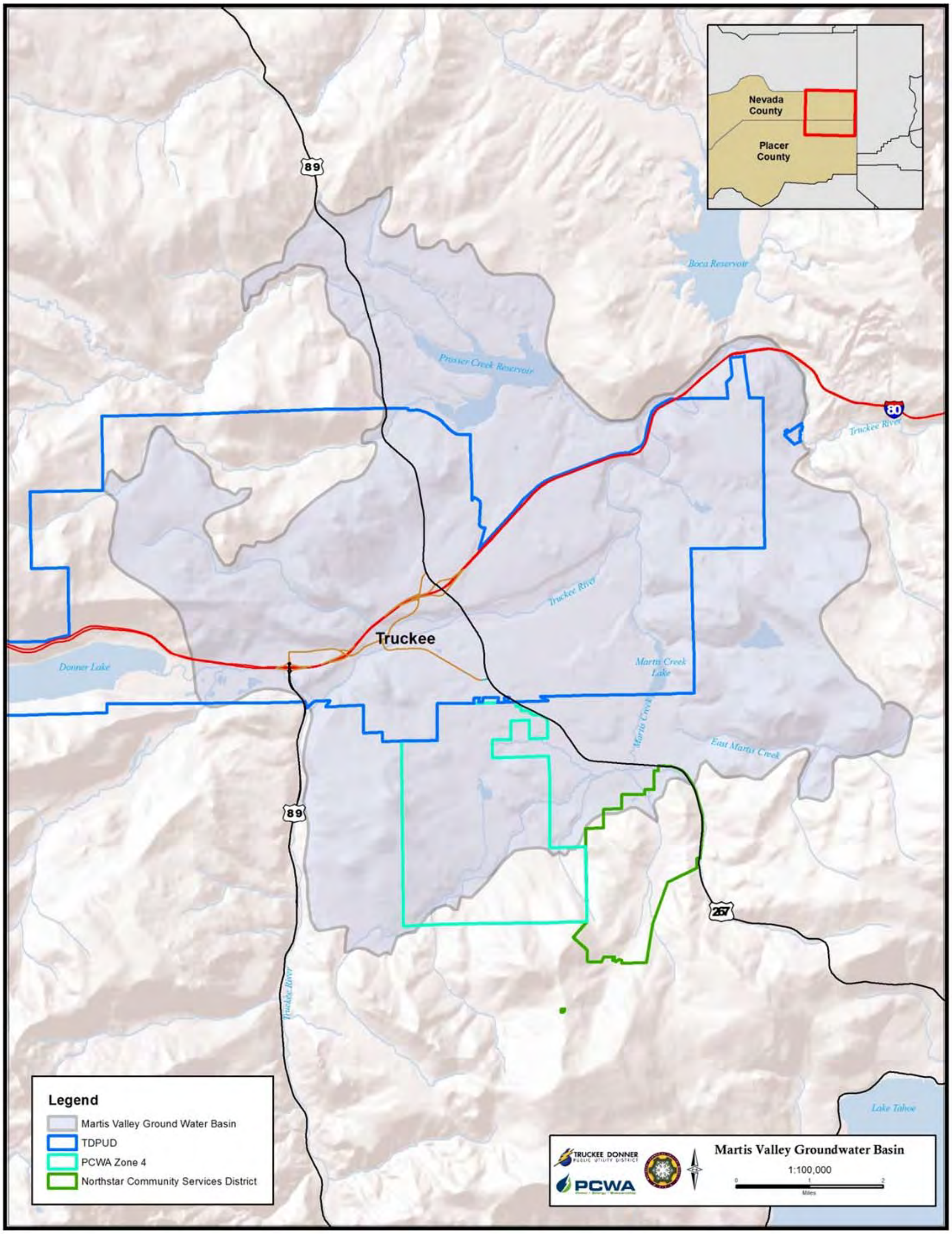

FIGURE 1-1. MAP OF GROUNDWATER BASIN TO BE MONITORED

1.1 ORGANIZATION OF REPORT

The Monitoring Program will be described in the sections summarized below:

- **Section 1. Introduction –** An initial summary of the report's contents and goals while highlighting the reasons for the Monitoring Program.
- **Section 2. Background –** A brief understanding of the groundwater aquifer is provided to ensure a minimum level of understanding by field staff of the conditions taking place below the ground.
- **Section 3. Monitoring Network –** Criteria for selection of monitoring wells is described and the current list of wells to be monitored is provided.
- **Section 4. Monitoring Equipment and Preparation –** Each monitoring event requires an inventory of the equipment that will be taken out into the field and to have staff trained to conduct the measurement and interface with the well owners.
- **Section 5. Depth-to-Groundwater Procedures and Frequency of Monitoring and Reporting –** The resolution of measurement data is described with a brief discussion of the pros and cons of high and low sampling frequency.
- **Section 6. Recording of Monitoring Data, Data Management and the CASGEM Requirements –** Once data is brought back from the field (and laboratory); all data will need to be uploaded to the State. DWR will allow batch uploading and downloading using the CASGEM database and graphical user interface.

2.0 BACKGROUND

This section briefly describes the MV groundwater basin. The MV basin is located beneath the Truckee River, near Truckee, CA, in which the Truckee River crosses the basin from south to east in a shallow, incised channel. Principal tributaries to the Truckee River are Donner Creek, Martis Creek, and Prosser Creek. Major surface water storage reservoirs include Donner Lake, Martis Creek Lake, and Prosser Creek Reservoir. State driller logs required as part of the well construction process provide the lithology (i.e., soil types and thickness) to characterize the water-bearing formations.

Figure 1 delineates the MV groundwater basin along with overlying geography and the alignment of three basin cross sections. These cross sections are presented in **Plates 1, 2, and 3**. The geological formations in the MV basin include basement rocks, sedimentary deposits, and volcanic deposits. The two types of basement rock in this region are Cretaceous-Jurassic plutonic/metamorphic rocks and Miocene volcanic units. Plutonic/metamorphic rocks appear east of the basin and Miocene volcanic units which ranges from andesite to basalt appear adjacent to the basin. These basement rocks contain a very small portion of the groundwater. Sedimentary deposits which include stream/lake deposits and alluvial material provide storage for groundwater. Volcanic deposits include basaltic andesite lava, tuff breccia and volcaniclastic deposits, and also provide storage for groundwater. Municipal and private wells in the basin primarily extract from the Prosser Creek Alluvium and Truckee Formation, with some Shallow wells also extracting from Outwash Deposits.

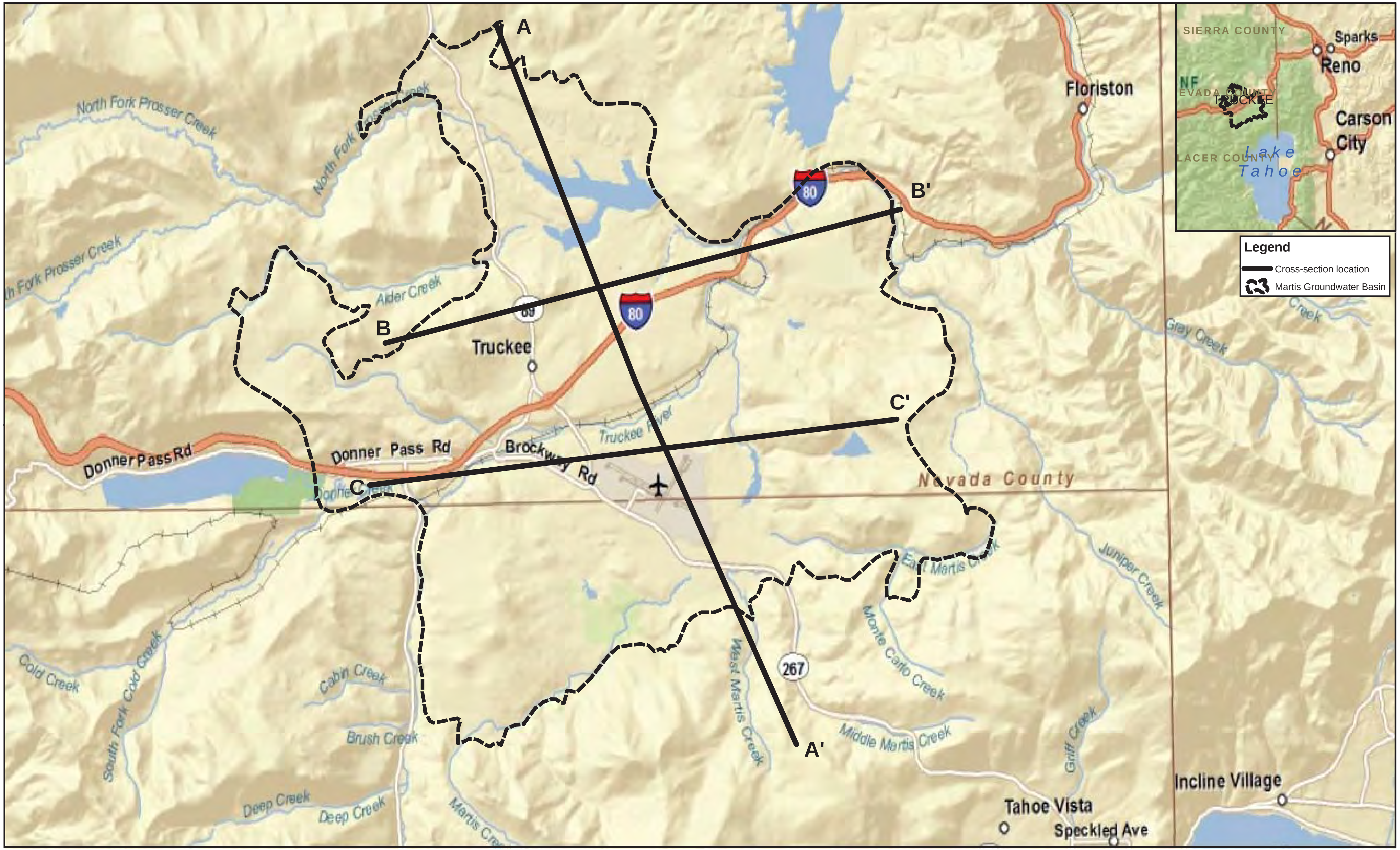

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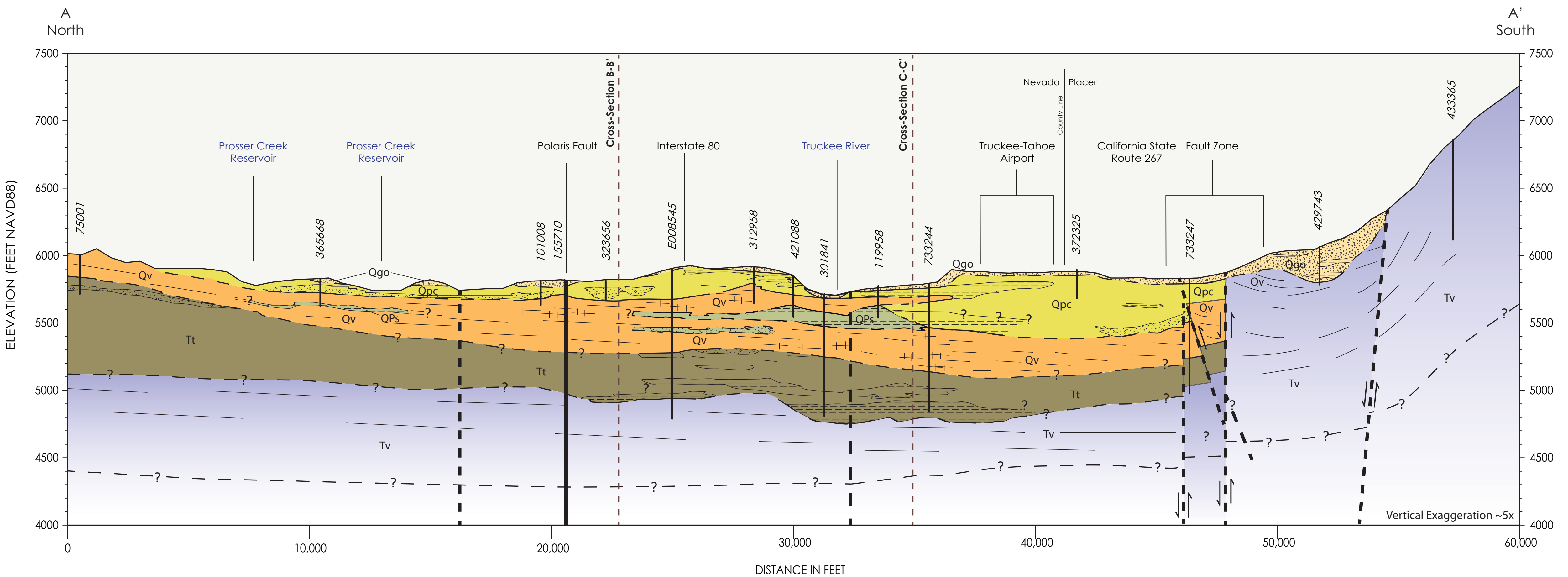
Figure 1. **Geologic cross-section locations, Martis Groundwater Management Plan, Placer and Nevada Counties, California**

210142 X-sec locations.mxd



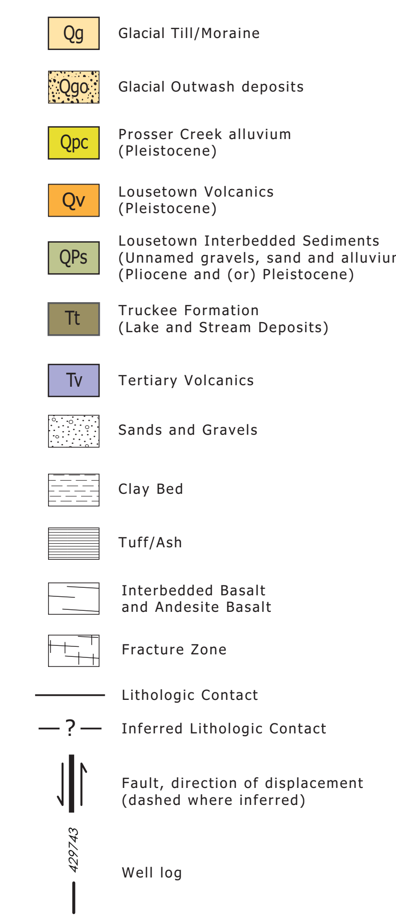


Plate 1: Cross-section A-A' Martis Groundwater Basin,

Placer and Nevada Counties, California

NOTES:

1. Approximate vertical exaggeration = 5x.
2. Elevation profile developed from 30-meter digital elevation model, downloaded from National Elevation Dataset (http://seamless.usgs.gov/index.php).
3. Well log locations are approximate within 600 feet.
4. Fault locations are approximate, based on Saucedo, "Geologic Map of Lake Tahoe Basin," 2005 and Hunter and others, 2011.
5. Surficial geology inferred from Saucedo, 2005.
6. Significant sand, gravel, and clay beds shown where noted in well logs.
7. Fracture zones shown where noted in well logs.

References:

Birkeland, P.W., 1963 Pleistocene History of the Truckee area, north of Lake Tahoe, California, Geological Society of America Bulletin, v. 64, p. 1453-1464.

Hunter, L.E., Howle, J.F., Rose, R.S., and Bawden, G.W., 2011, LiDAR – assisted identification of an active fault near Truckee, California, Bulletin of the Seismological Society of America, v. 101, n. 3, p. 1162-1181.

Latham, T.S., 1985, Stratigraphy, structure, and geochemistry of Plio-Pleistocene volcanic rocks of the western Basin and Range Province, near Truckee, California, unpublished doctoral dissertation, University of California, Davis, 341 p.

Melody, A., 2009, Active faulting and Quaternary paleohydrology of the Truckee Fault Zone north of Truckee, California, MS Thesis, Humboldt State University, Humboldt, CA 71 p.

Saucedo, G.J., 2005, Geologic Map of Lake Tahoe Basin, California and Nevada, California Geological Survey Regional Geologic Map Series, Map No. 4, 1:100,000 scale.

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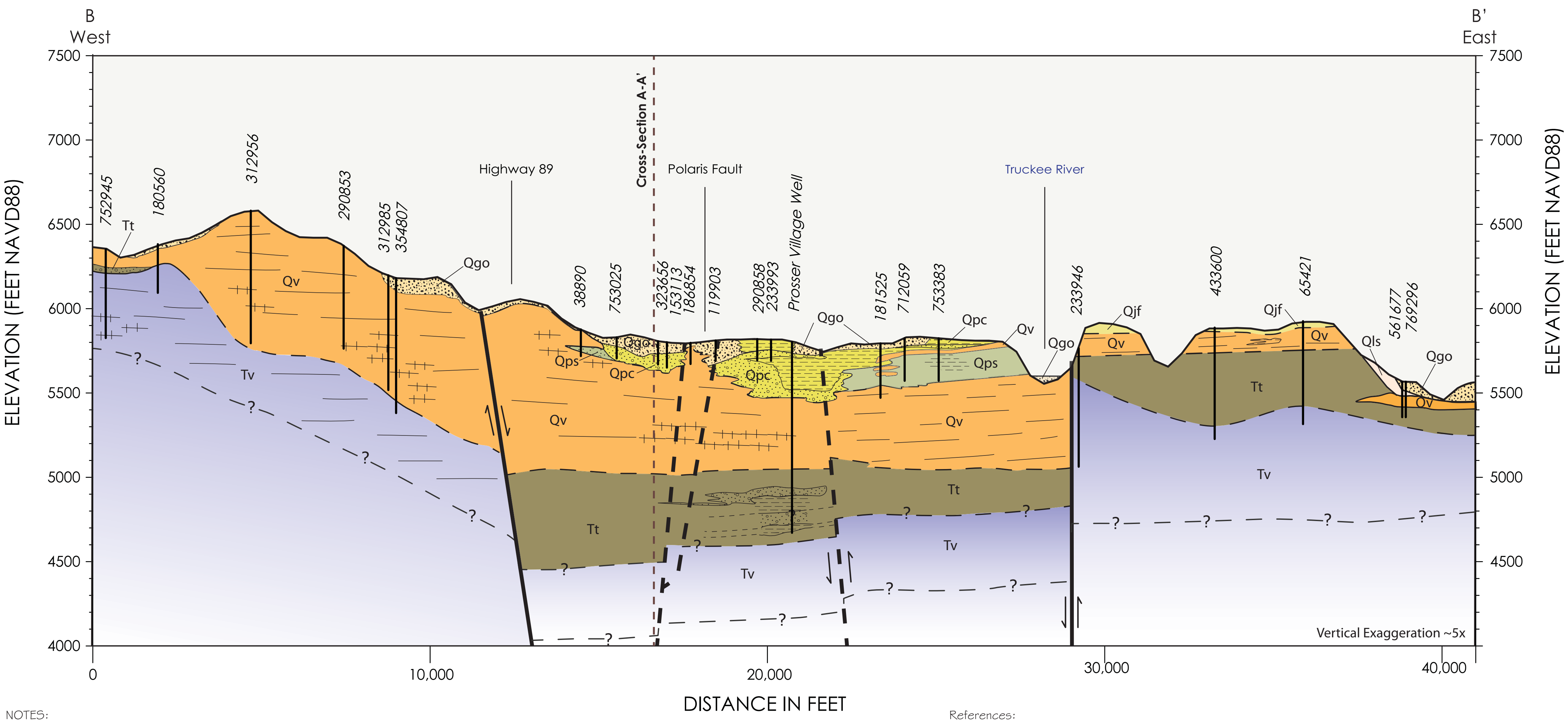
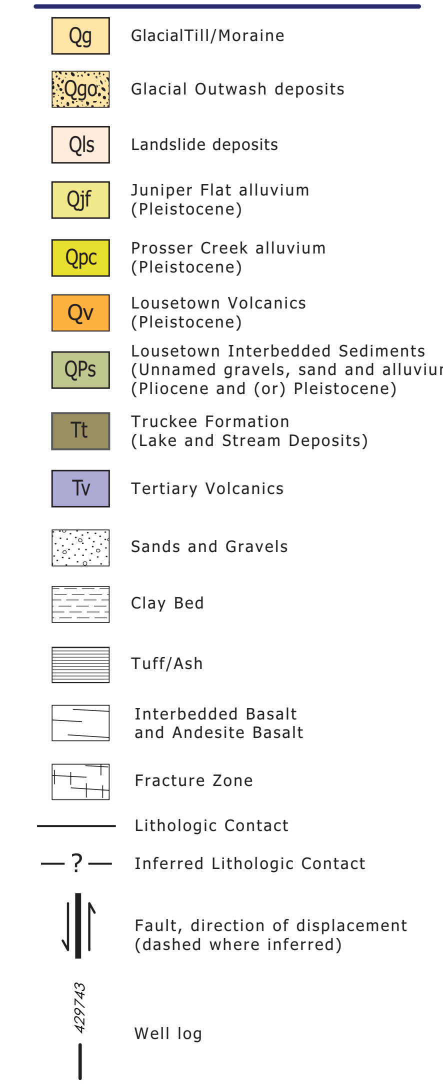
Plate 2: Cross-section B-B'
Martis Groundwater Basin,
Placer and Nevada Counties, California





NOTES:
1. Approximate vertical exaggeration = 5x.
2. Elevation profile developed from 30-meter digital elevation model, downloaded from National Elevation Dataset (http://seamless.usgs.gov/index.php).
3. Well log locations are approximate within 600 feet.
4. Fault locations are approximate, based on Saucedo, "Geologic Map of Lake Tahoe Basin," 2005 and Hunter and others, 2011.
5. Surficial geology inferred from Saucedo, 2005.
6. Significant sand, gravel, and clay beds shown where noted in well logs.
7. Fracture zones shown where noted in well logs.

References:

Birkeland, P.W., 1963 Pleistocene History of the Truckee area, north of Lake Tahoe, California, Geological Society of America Bulletin, v. 64, p. 1453-1464.

Hunter, L.E., Howle, J.F., Rose, R.S., and Bawden, G.W., 2011, LiDAR – assisted identification of an active fault near Truckee, California, Bulletin of the Seismological Society of America, v. 101, n. 3, p. 1162-1181.

Latham, T.S., 1985, Stratigraphy, structure, and geochemistry of Plio-Pleistocene volcanic rocks of the western Basin and Range Province, near Truckee, California, unpublished doctoral dissertation, University of California, Davis, 341 p.

Melody, A., 2009, Active faulting and Quaternary paleohydrology of the Truckee Fault Zone north of Truckee, California, MS Thesis, Humboldt State University, Humboldt, CA 71 p.

Saucedo, G.J., 2005, Geologic Map of Lake Tahoe Basin, California and Nevada, California Geological Survey Regional Geologic Map Series, Map No. 4, 1:100,000 scale.

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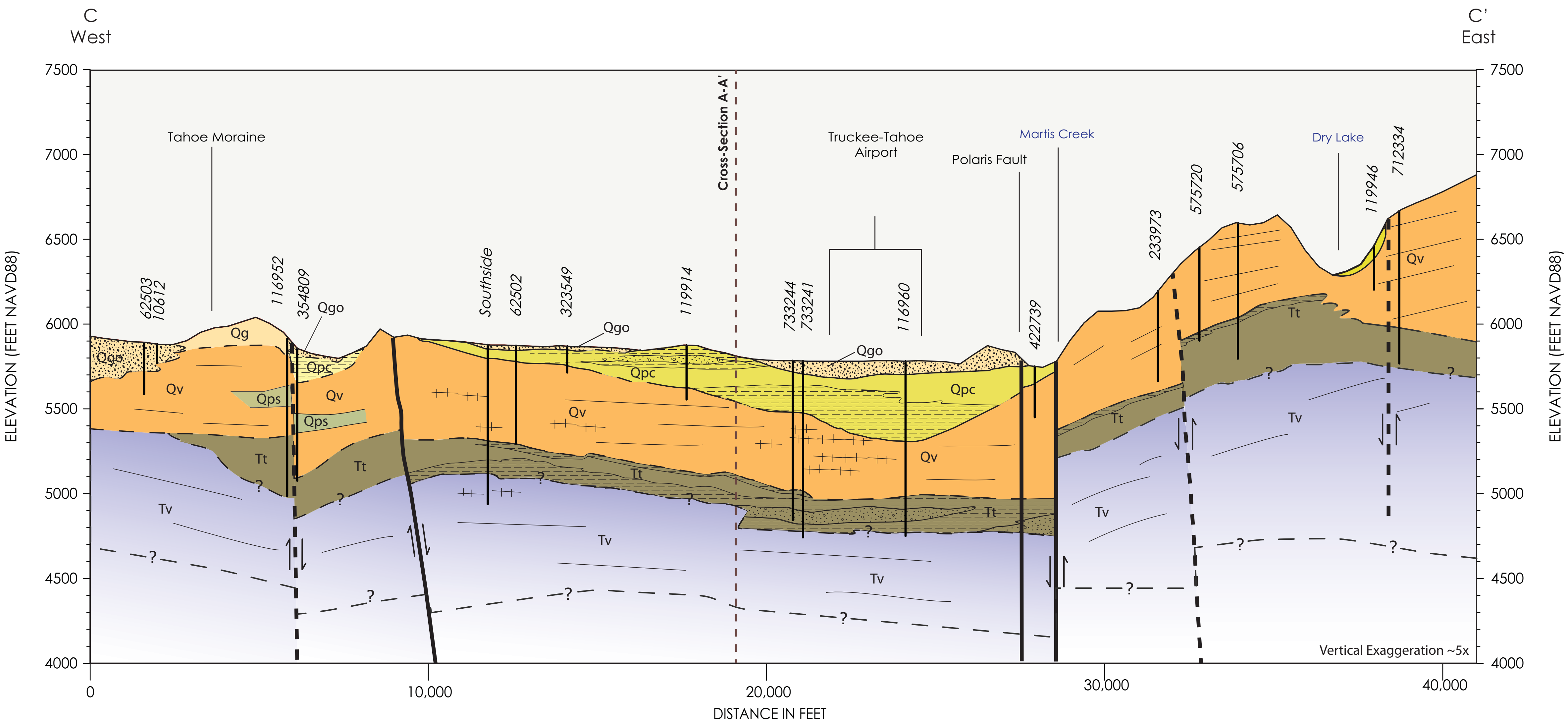
Plate 3: Cross-section C-C' Martis Groundwater Basin,

Placer and Nevada Counties, California



Qg	Glacial Till/Moraine
Qgo	Glacial Outwash deposits
Qpc	Prosser Creek alluvium (Pleistocene)
Qv	Lousetown Volcanics (Pleistocene)
QPs	Lousetown Interbedded Sediments (Unnamed gravels, sand and alluvium) (Pliocene and (or) Pleistocene)
Tt	Truckee Formation (Lake and Stream Deposits)
Tv	Tertiary Volcanics
	Sands and Gravels
	Clay Bed
	Tuff/Ash
	Interbedded Basalt and Andesite Basalt
	Fracture Zone
	Lithologic Contact
— ? —	Inferred Lithologic Contact
	Fault, direction of displacement (dashed where inferred)
429743	Well log

NOTES:
1. Approximate vertical exaggeration = 5x.
2. Elevation profile developed from 30-meter digital elevation model, downloaded from National Elevation Dataset (http://seamless.usgs.gov/index.php).
3. Well log locations are approximate within 600 feet.
4. Fault locations are approximate, based on Saucedo, "Geologic Map of Lake Tahoe Basin," 2005 and Hunter and others, 2011.
5. Surficial geology contacts inferred from Saucedo, 2005.
6. Significant sand, gravel, and clay beds shown where noted in well logs.
7. Fracture zones shown where noted in well logs.

References:
Birkeland, P.W., 1963 Pleistocene History of the Truckee area, north of Lake Tahoe, California, Geological Society of America Bulletin, v. 64, p. 1453-1464.
Hunter, L.E., Howle, J.F., Rose, R.S., and Bawden, G.W., 2011, LiDAR – assisted identification of an active fault near Truckee, California, Bulletin of the Seismological Society of America, v. 101, n. 3, p. 1162-1181.
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3.0 MONITORING NETWORK

The following sections describe the rationale for selection of monitoring wells to be included in the monitoring network. Because surface water and groundwater may interact, the monitoring network may need to be expanded at some future date to include data available from surface water monitoring of major rivers and local streams. The partners involved in this Monitoring Program are also underway in preparing an updated Groundwater Management Plan (GMP) and groundwater model. It is anticipated that knowledge gained from that effort will help inform the partners and the State on where additional monitoring points, in the ground and at the surface, should be located. If existing wells are not available at such locations, the partners will seek opportunities to construct new ones in data gap areas.

3.1 RATIONALE OF MONITORING NETWORK

In order to manage groundwater resources for long-term sustainability, key issues in the basin that need to be documented include:

- Identification of sources of recharge and the protection of recharge areas
- Changes in groundwater elevations that affect groundwater storage
- Groundwater quality and changes over time

The following sections describe the rationale for selecting the MV monitoring network well sites. MV groundwater monitoring wells will be selected to provide regional coverage that can be economically accomplished yet provide high quality, reliable data that adequately characterizes basin conditions over time. The location and spacing of the MV monitoring wells are expected to vary, dependent upon a group of selected characteristics (i.e., geographic location, accessibility, age, well construction, well log availability, etc.). The approach described herein is intended to assist in the selection of monitoring locations that are sufficiently distinct from each other and address the issues bulleted above.

3.2 GROUNDWATER WELL NETWORK DEVELOPMENT PROCESS

A database of wells in Martis Valley was developed as part of the GMP and modeling effort. The State well logs provided more than 700 wells; however, these were filtered to omit wells that had limited information available, shallow depths, and other factors that rendered them not useful for hydrogeologic evaluation. The database includes 197 wells that are presented in **Figure 3-1**, in which wells owned and operated by the three partners are distinguished from the others. These wells include municipal and private, monitoring and production, and are generally concentrated in the lowland areas of the basin surrounding the Truckee River and other surface waters. In addition to these wells, wells currently monitored by the State Department of Water Resources (DWR) are presented.

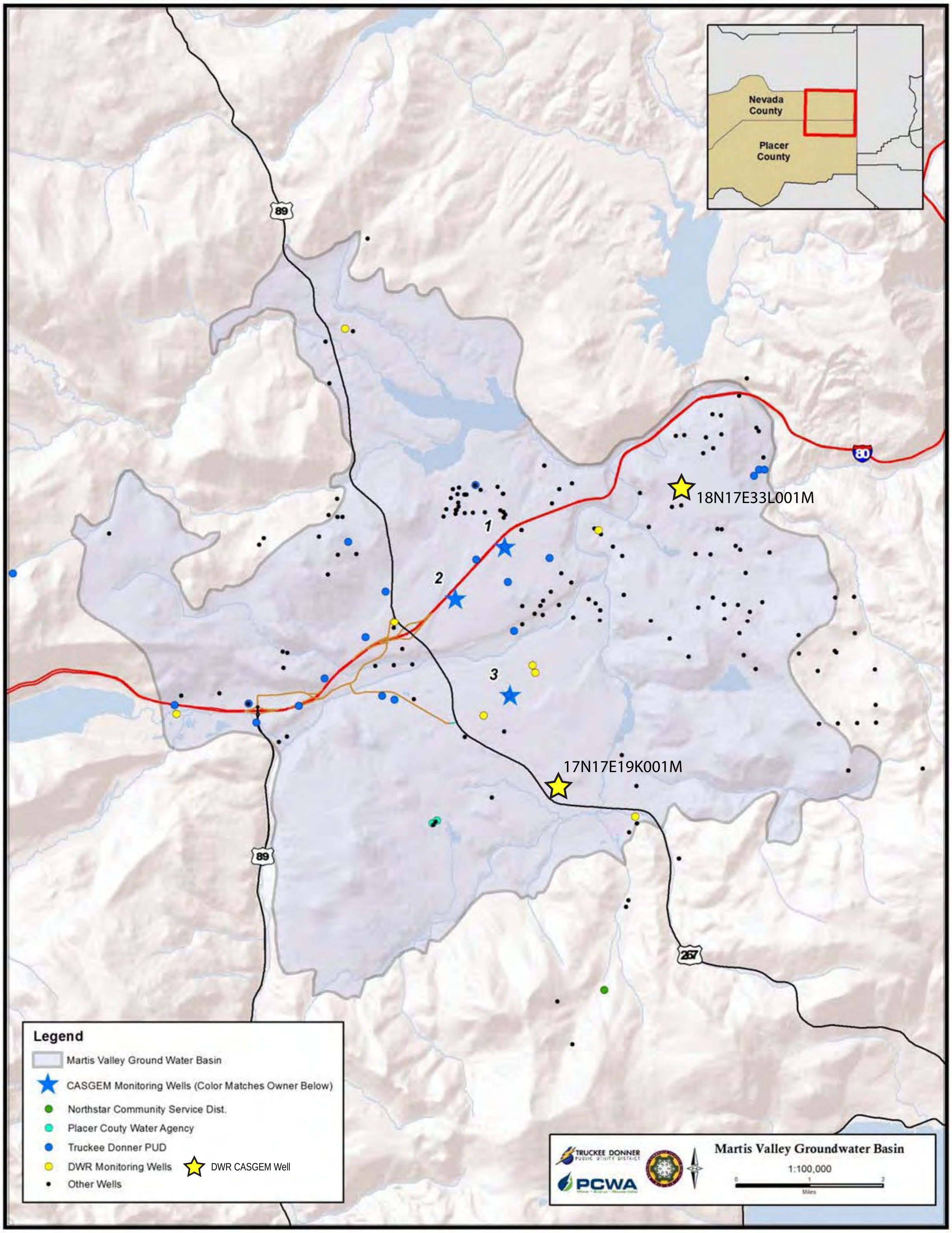

FIGURE 3-1. EXISTING WELLS IN MARTIS VALLEY

Development of a full well monitoring network will be a long-term process that is based on the scientific knowledge gained from the GMP and modeling effort that is currently underway. The network is currently limited to monitoring wells owned by TDPUD. This network includes a total of three wells that are presented in **Table 3-1** along with pertinent well information. It is expected that ideal monitoring locations as related to the issues bulleted above will be scientifically resolved in the next few years. If existing wells, such as those shown in Figure 3-1, meet the monitoring well requirements described below and can be made available, they will be used. If existing wells cannot be used, the partners will seek funding and property rights to construct designated monitoring wells in these locations. It is anticipated that desired new monitoring sites will be prioritized based on value, availability of existing wells, feasibility of installing new wells, and cost. This prioritization will ensure optimal value relative to these constraints in establishing new monitoring locations until the full network is established.

3.3 MONITORING WELL REQUIREMENTS

The following are criteria for selecting monitoring wells in the MV groundwater basin. Wells selected for monitoring should have:

- A State Well Driller Log that describes the well construction details and a description of the sediments encountered
- A detailed description of the well's location
- A brief description of the well's use (i.e. irrigation, residential)
- A relatively short screen interval in only one aquifer
- A sanitary seal to prevent surface water from entering the well
- Wells cannot be municipal (public) production wells for water supply

The most desirable wells to be included in the monitoring network are wells with short screen intervals completed within a specified aquifer. However, some wells with longer screen intervals may need to be initially included in the network when no others are available. Wells with long screen intervals may also be designated for monitoring because their long historic records provide valuable trending information. Data obtained from the longer screen wells usually represents an average of groundwater elevations across the unconfined and semi-confined aquifers.

TABLE 3-1. SELECTED INFORMATION FOR CURRENT MONITORING WELLS IN MARTIS VALLEY GROUNDWATER BASIN

Figure 3-1 Reference Index	1	2	3
State Well Number	17N16E01	17N16E01	17N16E13
Reference Point Elevation (ft - NAVD88)	5,843	5,904	5,796
Reference Point Description	Top of Casing (All Three)		
Ground Surface Elevation (ft - NAVD88)	5,839	5,900	5,792
Method of Determining Elevation	Digital Terrain Model (All Three)		
Accuracy of Elevation (ft)	+/- 3 (All Three)		
Well Use	Monitoring (All Three)		
Well Status	Active (All Three)		
Geographic Coordinates (NAD83, CA Z2)			
Latitude:	39.354541	39.344834	39.325769
Longitude:	-120.14377	-120.156033	-120.143471
Method of Determining Coordinates	GPS (All Three)		
Accuracy of Coordinates (ft)	+/- 3 (All Three)		
Well Completion Type	Single (All Three)		
Casing Diameter (in.)	8	6	8
Total Depth (ft)	1,197	1,220	1,040
Screen Intervals (2 ea.) (ft)			
First Screen:	360 to 620	120 to 160	315 to 633
Second Screen:	760 to 1,160	200 to 240	707 to 978
Well Completion Report Number	733242	E008043	733241
Year Drilled	2000	2003	2000
Common Name	Prosser Village	Fibreboard	Martis Valley
Well Location Description	12546 Fairway Drive 75 Yards Southwest of Building	12650 Caleb Circle On Path to Pond	12201 Joerger Road 50 Yards East of Building

TABLE 3-1 CONTINUED. SELECTED INFORMATION FOR DWR CASGEM MONITORING WELLS IN MARTIS VALLEY GROUNDWATER BASIN		
Figure 3-1 Reference Index	17N17E19K001M	18N17E33L001M
State Well Number	17N17E19K001M	18N17E33L001M
Reference Point Elevation (ft-NAVD88)	5862.8	5922.5
Reference Point Description	Top of PVC Casing	Top of PVC Casing
Ground Surface Elevation (ft-NAVD88)	5860	5920
Method of Determining Elevation	Surveying	
Accuracy of Elevation (ft)	Within 0.1 ft.	
Well Use	Observation	Observation
Well Status	Active	Active
Geographic Coordinates (NAD83)		
Latitude:	39.3072	39.3653
Longitude	-120.1315	-120.099
Method of Determining Elevation	Unkown	
Accuracy of Elevation (ft)	Unkown	
Well Completion Type	Single Well	Single Well
Casing Diameter (in.)	2	2
Total Depth (ft)	201	200
Screen Intervals (ft)	187-197	180-190
Well Completion Report Number	N/A	365669
Year Drilled	1990	1990
Well Location Description	50 ft. South of Martis Creek Rd. 1000 ft. east of the intersection of Martis Creek Rd. and Hwy 267.	Truckee Fire Protection District P.O. Box 686 Truckee, CA

3.4 REQUIRED STEPS IN SELECTING A NEW MV MONITORING WELL

Upon selection of any new well, that is not currently a MV monitoring well, to be potentially included in the monitoring network, a site visit will be necessary to assess the field conditions. The conditions necessary for a well to be used in the network include:

- A well owner (and tenant) who will allow access for monitoring.
- All-weather access, key to locked gates or fences, and no guard dogs.
- Ability to survey the ground elevation and reference point elevation of the well. See Page 9 of the DWR Groundwater Elevation Monitoring Guidelines for details establishing the reference point.
- A clear access point through the pump or well casing for water-level sounders. Figure 3-2 shows a typical well sounding location detail.
- An assessment to determine if lubrication oil from a turbine pump has accumulated in the well or if there are obstructions in the well that would prevent obtaining repeat and reliable measurements.
- If currently in use, to have access in shutting a well down for a minimum 2-hour period (24-hous preferred) for reaching quasi-equilibrium.
- For wells that are owned by others, private or public, the protocols discussed below shall be followed for explaining the project purpose and establishing rights for access.
- If a new monitoring well is to be installed, appropriate hydrogeologic investigation shall be made, a design that considers the specific needs of monitoring shall be prepared, and the well shall be drilled under the observation and direction of a hydrogeologist.

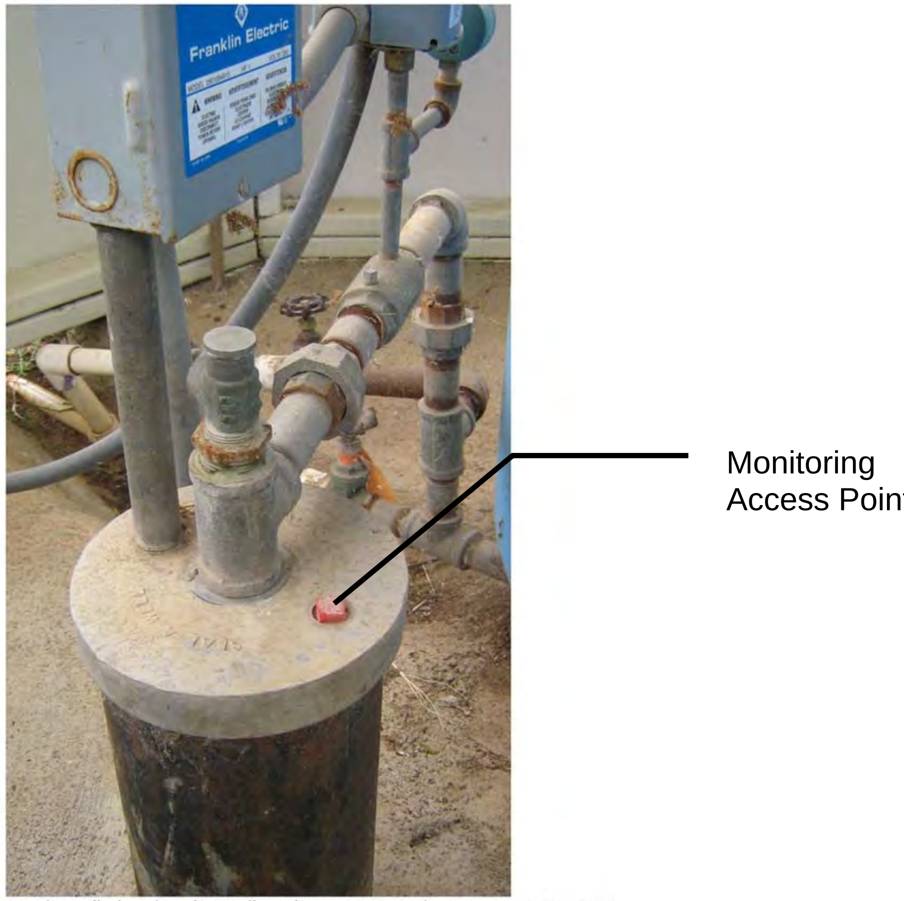

Photo: A domestic well showing the well casing, cover, and conveyance system.
The well is located inside a shed with a concrete floor.

FIGURE 3-2. ACCESS POINT ON A WELL

Before knocking on the door of potential well owners, every effort should be made to justify the need for the owner's well in the network. Staff shall coordinate with Right-of-Way personnel to arrange a field visit if the owner allows it. The reason for monitoring and the benefits to long-term sustainability shall be described. Additionally, practical details about site access and how measurements are made shall be discussed. If the owner is interested in allowing their well into the network, the well shall be inspected for adequacy based on the bulleted criteria above. If the well is adequate, formal rights of entry shall be prepared by Right-of-Way personnel before proceeding. Any special contact information to perform the monitoring should also be noted along with information related to sites where a tenant is renting from the property owner. These steps will ensure consistent monitoring even though monitoring staff, tenants and well site access may change over time.

4.0 MONITORING EQUIPMENT AND PREPARATION

This section provides the MV monitoring entities with a "how to" manual for accessing monitoring wells and, taking depth-to-groundwater measurements and water quality samples. The range of equipment and protocols covered in this section will assist monitoring staff with the challenges that exist in the field. Each time a well is accessed as part of a monitoring event, staff needs to conduct themselves in a professional manner by being prepared with the right equipment and looking prepared with the correctly labeled vehicle and clothing, and pertinent staff identification. Staff should also strive to maintain a good relationship with the well owners and demonstrate genuine courtesy.

This section also provides relevant portions of the CASGEM Groundwater Elevation Monitoring Guidelines (Guidelines) handbook attached as Appendix A. The CASGEM handbook is intended for the following purpose:

> *…Guidelines were developed to assist DWR by establishing criteria for the selection and measurement of monitoring wells in the event that DWR is required to perform the groundwater monitoring functions in lieu of a local monitoring agency pursuant to Water Code Section 10933.5(a).*

The Guidelines also imply that a local agency that wishes to take over an existing monitoring well or create a new monitoring well should follow a documented consistent approach for each well over the life of the well. Given the unique location, construction technique, and down-hole equipment installation, measurement of each well should endeavor to follow the Guidelines knowing that field conditions may require slight deviations. This endeavor leads to the need of having a specialized documented procedure for each monitoring well that ensures a consistent measurement technique over time (some wells dating back to the 1930s). Changes in the well setting, use, and equipment may change over time, requiring changes in monitoring techniques. Wells constructed for and devoted to monitoring the groundwater can also change depending on activities around the well that may artificially change the static condition of groundwater levels (e.g., construction and use of a nearby high-production municipal well) or the elevation of the well head (e.g., well is located in proposed paved area where the well head will be cut below grade with a sealed and locked access chamber flush to pavement).

4.1 PERSONNEL TRAINING

All well monitoring programs are subject to turnover in agency staff. The best and most effective way of transitioning and training new staff is to have new staff work alongside the experienced staff during a transition period. Absent this on-the-job-training, thorough record keeping, periodic updating of the monitoring plan, and review of this document will expose new staff to the wells and the protocols followed from previous measurements.

4.2 WELL MONITORING LOG BOOK (WMLB)

The WMLB is the definitive field document that contains the following:

- Well owner and contact information
- Special entrance instructions (e.g., call at gate, honk horn, or dog off leash)
- A schematic identifying the location of the well (high-resolution aerial imagery can also be used if the monitoring well can be clearly identified)
- Pictures of the well including reference point and access port (See **Figure 4-1**)
- Checklist of special instructions based on well owner requirements or special conditions (i.e. – closed gates, protected wetlands, electrical power shut off, etc.)
- Equipment needed for measurement (i.e., some wells require walking a fair distance into the field, wrench to remove access plug)
- Ground and reference point elevations and source of measurement
- List of historical measurements and codes identifying questionable measurements or field conditions making measurements impossible

Multiple wells can be in the same WMLB for convenience out in the field. This will likely be the case if multiple agencies will be making measurements within their respective jurisdiction. An example of the minimum data form and information kept for each well is taken from the CASGEM Guidelines, as shown on Figure 4-1.

4.2.1 Required Equipment

The monitoring agency will need to compile a set of tools and have them stored in a designated location at the monitoring agency's premises. The equipment should be in a locked toolbox that can easily be carried by one person, if needed. The CASGEM Guidelines include a list of field equipment needed for the initial well measurements, as shown on **Figure 4-2**. Once all wells have established reference points and measurement conditions, a shorter list of supplies can be assembled for field measurements as follows:

- Digital camera
- Crescent wrench (large and small)
- Channel lock pliers (large and small)
- Small hammer and rubber mallet

State of California | DEPARTMENT OF WATER RESOURCES | California Natural Resources Agency

WELL DATA

State No. ______

District ______

OWNER		STATE NO.	
ADDRESS		OTHER NO.	
TENANT			
ADDRESS			
TYPE OF WELL	☐ SPECIAL STUDIES	☐ MONTHLY	☐ SEMI ANNUAL ☐ WATER QUALITY
LOCATION: COUNTY	BASIN		NO.
U.S.G.S. QUAD.		QUAD NO.	
$^{1}/_{4}$	$^{1}/_{4}$ SECTION	TWP.	RGE. MD ☐ SB ☐ H ☐ BASE & MERIDIAN
COORDINATES X:	Y:	SOURCE:	
DESCRIPTION			
REFERENCE POINT DESCRIPTION			
WHICH IS FT. ABOVE ☐ BELOW ☐	LAND SURFACE.	GROUND ELEVATION	FT.
REFERENCE POINT ELEVATION FT.	DETERMINED FROM		
WELL: USE	CONDITION	DEPTH	FT.
CASING, SIZE IN.,	PERFORATIONS		
MEASUREMENTS BY: ☐ DWR ☐ USGS	☐ USBR ☐ COUNTY	☐ IRR. DIST. ☐ WATER DIST.	☐ CONS. DIST.
CHIEF AQUIFER: NAME	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.	
TYPE OF MATERIAL	PERM. RATING	THICKNESS	
GRAVEL PACKED? ☐ YES ☐ NO	DEPTH TO TOP GR.	DEPTH TO BOT GR.	
SUPP. AQUIFER	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.	
DRILLER	DATE DRILLED:	LOG NUMBER:	
EQUIPMENT: PUMP, TYPE	MAKE		
SERIAL NO.	SIZE OF DISCHARGE PIPE IN.	WATER ANALYSIS: MIN. (1)	SAN. (2) H.M. (3)
POWER, KIND	MAKE	WATER LEVELS AVAILABLE: YES (1)	NO
H.P.	MOTOR SERIAL NO	PERIOD OF RECORD: BEGIN	END
ELEC. METER NO.	TRANSFORMER NO.	COLLECTING AGENCY:	
YIELD	G.P.M. PUMPING LEVEL FT.	PROD. REC. (1)	PUMP TEST (2) YIELD (3)
SKETCH	N	REMARKS	
		RECORDED BY:	
		DATE:	

DWR 429 (Rev. 1/09)

Source: Table 3. General Well Data Form, CASGEM Guidelines, DWR, December 2010

FIGURE 4-1. GENERAL WELL DATA FORM (DWR FORM 429)

FIGURE 4-2. CASGEM FIELD EQUIPMENT LIST

Equipment and supplies needed for (a) all measurements, (b) establishing permanent RP, (c) steel tape method, (d) electric sounding tape method, (e) sonic water-level meter, and (f) automated measurements with pressure transducer.
(a) All measurements
GPS instrument, digital camera, watch, calculator, and maps
General well data form (DWR Form 429; see Table 3)
Pens, ballpoint with non-erasable blue or black ink, for writing on field forms and equipment log books
Well file with previous measurements
Measuring tape, graduated in feet, tenths, and hundredths of feet
Two wrenches with adjustable jaws and other tools for removing well cap
Key(s) for opening locks and clean rags
(b) Establishing a permanent reference point
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Paint (bright color), permanent marker, chisel, punch, and(or) casing-notching tool
(c) Steel tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Weight (stainless steel, iron, or other noncontaminating material – do not use lead)
Strong ring and wire, for attaching weight to end of tape. Wire should be strong enough to hold weight securely, but not as strong as the tape, so that if the weight becomes lodged in the well the tape can still be pulled free.
Carpenters' chalk (blue) or sidewalk chalk
Disinfectant wipes, and deionized or tap water for cleaning tape.
(d) Electric sounding tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
An electric tape, double-wired and graduated in feet, tenths, and hundredths of feet, accurate to 0.01 ft. Electric sounding tapes commonly are mounted on a hand-cranked and powered supply reel that contains space for the batteries and some device ("indicator") for signaling when the circuit is closed.
Electric-tape calibration and maintenance log book; manufacturer's instructions.
Disinfectant wipes, and deionized or tap water for cleaning tape.
Replacement batteries, charged.
(e) Sonic water-level meter method
DWR field form 1213 (see Table 5)
Temperature probe with readout and cable
Sonic water-level meter with factory cover plate
Custom sized cover plates for larger well diameters
Replacement batteries
(f) Automated measurements with pressure transducer
Transducer field form (see Figures 1 and 2 in Drost, 2005: http://pubs.usgs.gov/of/2005/1126/pdf/ofr20051126.pdf)
Transducer, data logger, cables, suspension system, and power supply.
Data readout device (i.e., laptop computer loaded with correct software) and data storage modules.
Spare desiccant, and replacement batteries.
Well cover or recorder shelter with key.
Steel tape (with blue carpenters' chalk or sidewalk chalk) or electric sounding tape, both graduated in hundredths of feet.
Tools, including high-impedance (digital) multimeter, connectors, crimping tool, and contact-burnishing tool or artist's eraser.

Source: Table 4- Equipment and Supply List, CASGEM Guidelines, DWR, December 2010

- Keys for gates and monitoring well covers
- Stop watch
- Wasp or hornet nest spray
- Twelve-foot tape measure
- Pencil and graph paper
- First aid kit

Minimum Tools needed for actual in the field depth-to-groundwater measurements include:

- 200-foot well sounding steel tape measure
- Blue chalk for metal tape
- 200-foot electronic well sounding probe (See **Figure 4-3**)
- Soap, high-purity water, and spray bottle for cleaning tape and probe
- Sterilizer solution for tape and probe to prevent introducing contaminants to a the well

FIGURE 4-3. WELL SOUNDING PROBE AND TAPE

4.3 CHALLENGES TO BE PREPARED FOR

The steps necessary to complete a measurement of depth to groundwater are different for each monitoring well. See Pages 14 through 28 of the DWR Groundwater Elevation Monitoring guidelines for details on measuring water levels. Monitoring staff will need to understand these steps before accessing the well's property location. The WMLB will include a written and graphical stepwise illustration to fully inform monitoring staff. Consideration of how diversified the steps could be are illustrated in the following real-life examples:

- **Well is located on hilly terrain with no defined access trail or markers –** This type of well benefits from training new staff for at least two monitoring events. Absent the on-the-job experience the WMLB should be detailed enough in its descriptions and images to find the well. Steeper terrain may also require several trips to the vehicle for equipment to ensure free hands are available in case of a fall.

- **Well has no access port or casing bolt –** Many of the older wells and private domestic wells were not designed for dropping a tape measure or probe into the well. In these cases, the monitoring staff should clearly identify the access point by using orange utility marking spray paint while being careful to not get paint overspray into the well itself. Absent the paint identifier, the tape chalk can be used as well, but it may disappear over time due to rain and wind. Wells with only a small slit at the base of the concrete casing interface will require a tape measurement.

- **Well can only be accessed when owner is home –** This occurs in many cases where the well owner has to unlock a gate or simply wants to be home when the monitoring event occurs. In this case, an appointment is made by phone providing owner with a 1 hour or less window when monitoring staff will show up. In cases where this is needed to open a locked gate, the owner may allow access and then request that the gate be closed and locked when finished. Review the checklist in the WMLB before leaving the monitoring well.

- **Well is running when monitoring staff arrive –** If the well is a municipal production well or large agricultural well, it is best to work with the well owner to allow a 24-hour period of off-time before taking a measurement. If the well owner is not responsive to this request, ask to turn off the well upon arrival and monitor recovery. If the well is a private domestic well, ask if the water use can be turned off (typically a hydropneumatic tank will allow small quantities of water use without the well turning on) and monitor recovery as explained in next chapter.

- **Well casing is set flush to the ground –** This occurs when a well uses a submersible pump or no pump and no onsite hydropneumatic tank– in most cases this is a private well that may be abandoned or the tank is located away from well. In addition, wells with no visible casing can become covered with vegetation or debris and be difficult to find. In both cases, monitoring staff should stake the well and paint the wood stake orange.

- **Reference point is missing or the wellhead has been replaced –** This occurs if the reference point is not a permanent mark such as a cut or welded steel marker. This will also occur when a well is deepened or redrilled and the upper casing has been replaced. Monitoring staff will need to select a permanent mark (e.g., top of casing, monitoring hole) where the depth to groundwater can be measured. Monitoring staff should also measure the distance between the new reference point and the ground elevation at the base of the well. This measurement should be noted in the logbook.[2]

[2] The elevation of the new reference point will be calculated by the assigned data entry personnel using the ground elevation from the original survey and the reference point distance measured by field staff. The data entry personnel will need to be careful if the groundwater elevation is an automated calculation (i.e., past measurements will need to keep the old reference point) in a spreadsheet or DMS.

5.0 DEPTH-TO-GROUNDWATER PROCEDURES AND FREQUENCY OF MONITORING AND REPORTING

The following section describes the frequency for monitoring and reporting and describes the depth-to-groundwater measurement during each of the designated monitoring periods. **Figure 5-1** provides a form for documenting these described field measurements. An alternate form can be used if desired as long as the salient information is included. See also Pages 5 through 7 of the DWR Groundwater Elevation Monitoring Guidelines for additional details.

5.1 SEMIANNUAL GROUNDWATER-LEVEL MONITORING

Groundwater levels from all designated monitoring wells listed in Table 3-1 will be measured in the spring and fall (semiannually). Spring is generally considered to be the first week in May. Fall is generally considered to be the first week of November. If possible, all groundwater-level measurements should be taken within a 2-week period and, if possible, coordinate groundwater-level monitoring with DWR and its semiannual measurements.

5.2 DEPTH-TO-GROUNDWATER MONITORING PROCEDURES

DWR's Groundwater Elevation Monitoring Guidelines (see Appendix A) provide a complete set of procedures for measuring the depth to groundwater. The following procedures are included to supplement the CASGEM's broader guidelines. Over time, as monitoring staff become familiar with the well sites, a customized list can be documented. Staff will find that steps and monitoring equipment identified in the Guidelines do not apply to the wells being measured in the MV region or additional steps are required. The one exception to the MV monitoring wells is those that are measured through a continuous data logger. It is expected that the agency owning these wells will be downloading data collected by these devices separately from the MV Monitoring Program. This section focuses on measuring the depth to groundwater at designated MV monitoring well sites using a sounding probe or metal tape. Water-level measurements will be collected semiannually to assess the groundwater flow direction and to detect trends that can lead to improved management of the groundwater resources.

Each well has been assigned a unique Well Log identification (ID) number. The numbers and pertinent information for each well are listed in Table 3-1. Figure 6-1 (DWR Form 429, Page 11) extracted from the DWR's CASGEM Monitoring Guideline Handbook, along with the time and date of the measurement is recorded with groundwater-level measurements during the semiannual monitoring event.

GROUNDWATER LEVEL DATA FORM
MANUAL MEASUREMENTS

WELL ID NUMBER	WELL NAME	STATE WELL NUMBER	COUNTY	B-118 BASIN OR SUBBASIN	MEASURING AGENCY	LAND SURFACE DATUM (LSD) ELEV.	RP TO LAND SURFACE DATUM (LSD), IN FT	REFERENCE POINT (RP) ELEV.

NO MEASUREMENT (NM)	QUESTIONABLE MEASUREMENT (QM)	MEASUREMENT METHOD (MM)
0. Measurement discontinued 1. Pumping 2. Pump house locked 3. Tape hung up 4. Can't get tape in casing 5. Unable to locate well 6. Well has been destroyed 7. Special 8. Casing leaky or wet 9. Temporarily inaccessible	0. Caved or deepened 1. Pumping 2. Nearby pump operating 3. Casing leaky or wet 4. Pumped recently 5. Air or pressure gauge measurement 6. Other 7. Recharge operation at or nearby well 8. Oil in casing	0. Steel tape 1. Electric sounding tape 2. Other

DATE	TIME	N M	Q M	MM	TAPE at RP	TAPE at WS	RP to WS	LSD to WS	OBS	COMMENTS

[For explanation of terms, see figure 1.]

DWR Form 1213 (modified 6/28/2010) (data for Water Data Library)

FIGURE 5-1. GROUNDWATER-LEVEL DATA FORM FOR MANUAL MEASUREMENTS

The depth-to-static-groundwater level will be obtained at each well using an electric water-level sounder with a cable graduated in increments of 0.01 foot. Before measurement, monitoring staff will need to review the WMLB for the location of the reference point and measurement access port. A crescent wrench may be needed to access the well casing for measurement. Monitoring staff will need to also review past measurements in the WMLB to allow for careful lowering of the probe or tape.[3] To obtain a depth-to-water measurement, the electric sounder cable or tape will be lowered into the well to within 20 feet short of past measurements taken in the same season of the year, spring or fall.

Monitoring staff will continue to slowly lower the probe through the access port until the sounder indicates submergence by either a beeping sound or a light, depending on the type of signal installed for that particular model. At this point, the sampling personnel will note the depth to water (to the nearest 0.01 foot) from the reference point. The depth will be confirmed by lifting the sounder above the water surface by about 2 to 3 feet and then remeasuring the depth to water. If the depth remains constant, the depth to water will be recorded on Figure 6-1 (DWR Form 1213, Page 18). If measurements are showing change with each measurement, the monitoring staff will indicate the issue on the form and, with it, attach a graphic curve of the variable nature of the measurement, and its possible cause (e.g., bouncing, recovering water level).

5.3 QUALITY CONTROL

After completing their field work, the monitoring staff will enter the data into an electronic database management system. The monitoring staff will review the groundwater-level and water quality data for accuracy within 5 days of obtaining the measurements. Should a measurement appear suspicious, a groundwater level confirmation reading will be obtained.

[3] Tape measurements will require chalking of the tape and repeated measurements as per the CASGEM Guidelines (Page 15).

6.0 RECORDING OF MONITORING DATA, DATA MANAGEMENT AND THE CASGEM REQUIREMENTS

Once data is brought back from the field it will need to be digitized and loaded onto the CASGEM website. The partners will be collecting data from their respective wells and distributing it to the plan administrator, which is currently Placer County Water Agency. The Agency will function as the clearinghouse of all data that is relevant to the MV groundwater basin. In addition, the Agency will be the primary point of contact for the CASGEM Program and will upload all relevant data in a timely manner. The steps laid out currently for CASGEM participation are described as follows (see Appendix C, On-line Submittal System Manual):

> *Phase 1 of the CASGEM System was released in December, 2010, and allows prospective Monitoring Entities to do the following:*
>
> - *Create, edit, and submit notifications to become a Monitoring Entity*
> - *Create and manage user accounts*
> - *Create and manage agency information*
> - *Submit GIS shapefiles of mapped monitoring areas*
>
> *Phase 2 of the CASGEM System, released in May, 2011, makes the following additional functions available to prospective Monitoring Entities:*
>
> - *Submittal of groundwater monitoring plans*
> - *Submittal of well construction and location information on monitoring wells proposed to be monitored*
> - *Allow corrections to initial Monitoring Entity notifications or submittal of additional information requested by DWR*
> - *Ability to view and query maps of groundwater basins, proposed monitoring areas, monitored wells, and other geographic information associated with the CASGEM Program Phase 3 of the CASGEM System, scheduled for release in late fall, 2011, will allow designated Monitoring Entities to do the following:*

- *Submit groundwater elevation measurement data*
- *View and update their CASGEM data, as needed*

With Phase 3 of the CASGEM System, public access to the Statewide CASGEM data will be available. Users will be able to download data and view spatial and temporal groundwater elevation trends in the GIS viewer application.

(URL: http://www.water.ca.gov/groundwater/casgem/submittal_system.cfm, On-line Submittal System, DWR)

The Agency has already completed Phase 1 of the CASGEM Program. The next step requires entry of data for each of the monitoring wells included as part of this Monitoring Program. **Figure 6-1** is taken from the CASGEM On-line System manual. The manual states that "Data may be entered on a well-by-well basis on a system data entry screen, or users can do a batch upload of information from multiple wells (using a spreadsheet template available for download within the system)." The latter will likely be the best method for entering the data given that most of the well information is already captured in an Excel Workbook.

Data entry for groundwater elevations is not fully described but will likely be similar to the well inventory where a spreadsheet template can be uploaded for all groundwater-elevation data. The conversion of groundwater-elevation data from a database (including GIS) platform is typically straight forward with a copy-and-paste step or a small routine that outputs the data in the desired format.

The inventory of Martis Valley well data will be based on DWR's CASGEM Monitoring Plan Summary attached as **Appendix B**. The set of data fields used for each well will require a decision on its need based on Appendix B requirements.

CASGEM
CASGEM Online Submittal System

Welcome: Jane Doe for Jane Doe Water Co as Administrator

Home | Notifications | Manage Wells | View Map | Administration | My Profile | Sign Out

Monitoring Plan: Add/Review Wells

Identification

Local Well Designation * 01N04W23G002S

Is Local Designation the same as State Well #? Yes No

State Well Number 01N04W23G002S

Master Site Code 341600N1172707W002

Data submittals for this well are under CASGEM Voluntary

Coordinates

Latitude * 34.160000 North

Longitude * 117.270700 West

see on map

Method * Surveyed

Accuracy * 1 ft.

Reference and Ground Surface

RP Elevation * 100 ft.

Description * n/a

GS Elevation * 90 ft.

Method * USGS quad

Accuracy * 0.1 ft.

Distance from RP 10

Well Construction

Completion Type * Single Well

Total Depth * Enter Total Depth ft. Unknown

Do you have well construction data? Yes No

Depth of screened interval(s)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Top										
Bottom										

Well completion report available? Yes No

Well Completion Report #

Well Usage

Well Use * Unknown

Well Status * Active

Associated Basin & County

Basin/Portion Not Associated

County * San Bernardino

Additional Information

Written description of location of well

Enter description

Any additional comments

Enter additional comments

Save | Cancel | Back To Manage Wells

FIGURE 6-1. CASGEM'S WELL INVENTORY INPUT FORM

Appendix A

CASGEM Guidelines

Department of Water Resources

Groundwater Elevation Monitoring

Guidelines

December 2010

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INTRODUCTION TO THE CASGEM PROGRAM

On November 4, 2009 the state legislature amended the Water Code with SB 6, which mandates a statewide, locally-managed groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal the amendment requires collaboration between local Monitoring Entities and the Department of Water Resources (DWR) to collect groundwater elevation data. In accordance with the amendment, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program.

If no local entities volunteer to monitor groundwater elevations in a basin or part of a basin, DWR may be required to develop a monitoring program for that part. If DWR takes over monitoring of a basin, certain entities in the basin may not be eligible for water grants or loans administered by the state.

DWR will report findings of the CASGEM program to the Governor and the Legislature by January 1, 2012 and thereafter in years ending in 5 or 0.

PURPOSE OF GUIDELINES FOR DWR MONITORING

The following Guidelines were developed to assist DWR by establishing criteria for the selection and measurement of monitoring wells in the event that DWR is required to perform the groundwater monitoring functions in lieu of a local monitoring agency pursuant to Water Code Section 10933.5(a).

The primary objective of the CASGEM monitoring program is to define the seasonal and long-term trends in groundwater elevations in California's groundwater basins. The scale for this evaluation should be the static, regional groundwater table or potentiometric surface. A secondary objective is to provide sufficient data to draw representative contour maps of the elevations. These maps could be used to estimate changes in groundwater storage and to evaluate potential areas of overdraft and subsidence.

Although it is not an objective of the CASGEM program, it would be valuable to include monitoring wells near localized features that impact more dynamic groundwater elevations. These features would include wells near aquifer storage and recovery projects, near high volume pumping wells, and near rivers.

Network Design Concepts

Selection of Monitoring Wells for Monitoring Plans

The number of groundwater wells that need to be monitored in a basin to adequately represent static water levels (and corresponding elevations) depends on several factors, some of which include: the known hydrogeology of the basin, the slope of the groundwater table or potentiometric surface, the existence of high volume production wells and the frequency of their use, and the availability of easily-accessible monitoring wells. Dedicated groundwater monitoring wells with known construction information are preferred over production wells to determine static water levels, and monitoring wells near rivers or aquifer storage and recovery projects should be avoided due to the potential for rapidly fluctuating water levels and engineered groundwater systems. The selection of wells should be aquifer-specific and wells which are screened across more than one aquifer should not be candidates for selection.

Heath (1976) suggested a density of groundwater monitoring wells ranging from 2 wells per 1,000 square miles (mi^2) for a large area in which only major features are to be mapped, to 100 wells per 1,000 mi^2 for a complex area to be mapped in considerable detail. The objective of the Heath (1976) design was to evaluate the status of groundwater storage and the areal extent of aquifers.

Sophocleous (1983) proposed a redesign of a water-level monitoring program for the state of Kansas based on efficiency, economics, statistical analysis, comparison of water-level hydrographs, and consistency across the state. The Sophocleous study recommended a "square well network" with a density of 1 observation well per 16 mi^2.

The Texas Water Development Board proposed varying well network densities for counties according to the amount of groundwater pumpage. These densities range from 0.7 wells per 100 mi^2 for counties with 1,000-2,500 acre-feet per year (AF/yr) of pumpage to 4 wells per 100 mi^2 for counties with over 100,000 AF/yr of pumpage (Hopkins, 1994). These densities were converted to pumpage per 100 mi^2 area by dividing by the size of an average county in Texas of about 1,000 mi^2 (Table 2)

Most designs of water-level monitoring programs rely on a probabilistic approach. Alley (1993) discussed four probabilistic designs: (1) simple random sampling throughout an aquifer; (2) stratified random sampling within different strata of an aquifer; (3) systematic grid sampling (e.g., at the midpoint of each section within an aquifer); and (4) random sampling within blocks (e.g., randomly selected wells within each section of an aquifer). The Sophocleous (1983) program used the third approach, systematic grid sampling. The guidelines on well density from the programs mentioned above are summarized in Table 2.

Based on the few referenced studies with specific recommendations, the consensus appears to fall between 2 and 10 groundwater monitoring wells per 100 mi^2. The exceptions to this density range include the lower end of the Heath (1976) range and the low-use counties in Texas.

There will always be a tradeoff between the improved spatial (and temporal) representation of water levels in an aquifer and the expense of monitoring. A higher-resolution contour map would be warranted in an area with a greater reliance upon groundwater in order to anticipate potential problems, such as supply and groundwater contamination concerns, while a lower-resolution contour map might be sufficient in an area with few people or a low reliance upon groundwater. Ideally, areas with relatively steep groundwater gradients or areas of high recharge or discharge would have a greater density of monitoring wells.

The illustrations in Figure 1 show a local groundwater elevation contour map developed with different numbers of wells. The examples cover the same area and use the same dataset, with wells randomly deleted by grid area from the full dataset to create a less dense network of wells. The resulting range of plotting density is 2 to 20 groundwater monitoring wells per 100 mi^2. The contours in Figure 1 show how the accuracy and resolution of the contour map increases with the density of wells used for plotting. To avoid presenting misleading contour maps, only wells with the best possible elevation accuracies should be used. These accuracies are a combination of the accuracies in the water-level measurement and the reference point (RP) measurement. Unless the RP elevation has been surveyed, it will be the limiting factor on elevation accuracy.

Program and(or) Reference	**Density of monitoring wells (wells per 100 mi^2)**
Heath (1976)	0.2 – 10
Sophocleous (1983)	6.3
Hopkins (1994) (a) Basins with >10,000 AF/yr groundwater pumping per 100 mi^2 area	4.0
(b) Basins with 1,000-10,000 AF/yr groundwater pumping per 100 mi^2 area	2.0
(c) Basins with 250-1,000 AF/yr groundwater pumping per 100 mi^2 area	1.0
(d) Basins with 100--250 AF/yr groundwater pumping per 100 mi^2 area	0.7

Table 1. Recommended density of monitoring wells for groundwater-level monitoring programs.

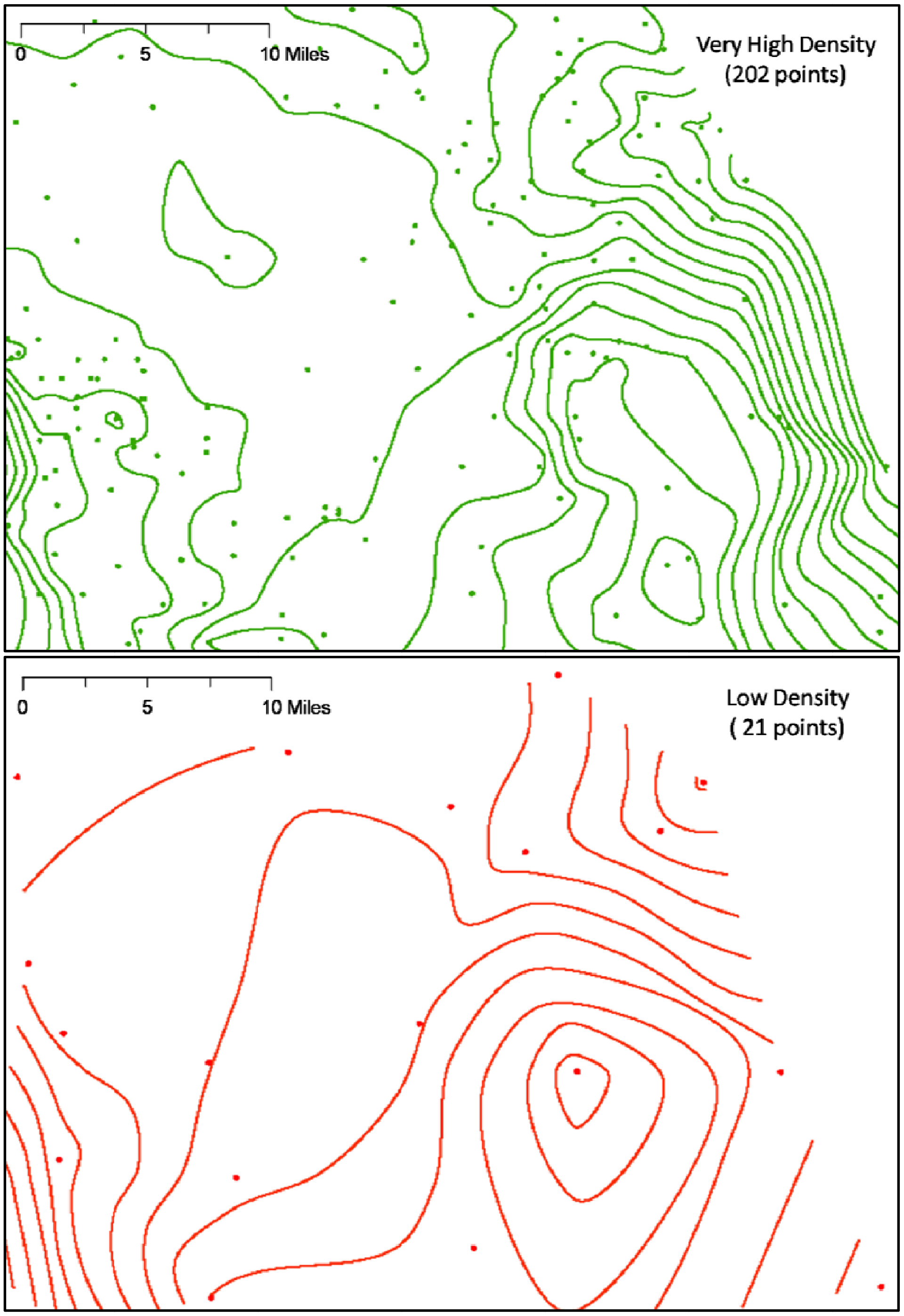

Figure 1. Contour maps – Contours of a very high-density well network (about 20 wells per 100 mi^2) compared to a low-density well network (about 2 wells per 100 mi^2).

Frequency of Water-Level Measurements

To determine and define seasonal and long-term trends in groundwater levels a consistent measurement frequency must be established. At minimum, semi-annual monitoring of the designated wells in each basin or subbasin should be conducted to coincide with the high and low water-level times of year for each basin. However, quarterly- or monthly-monitoring of wells provides a better understanding of groundwater fluctuations. The DWR office responsible for monitoring a particular basin should use independent judgment to determine when the high and low water-level times occur in a groundwater basin, and to provide a justification for measurement rationale. The semi-annual frequency is a compromise between more frequent measurements (continuous, daily, monthly, or quarterly) and less frequent measurements (annual). A good discussion of water level measurement frequency and other issues related to the design of water-level monitoring programs can be found in the USGS Circular 1217 (Taylor and Alley, 2001).

An example of the effect of different measurement frequencies on the water-level hydrographs in a Northern California well is shown in Figure 2. The data shows that higher-frequency monitoring (e.g., daily or monthly) best captures the seasonal fluctuations in the groundwater levels, quarterly monitoring identifies some of the elevation change, but semi-annual measurements often miss the true seasonal highs and lows.

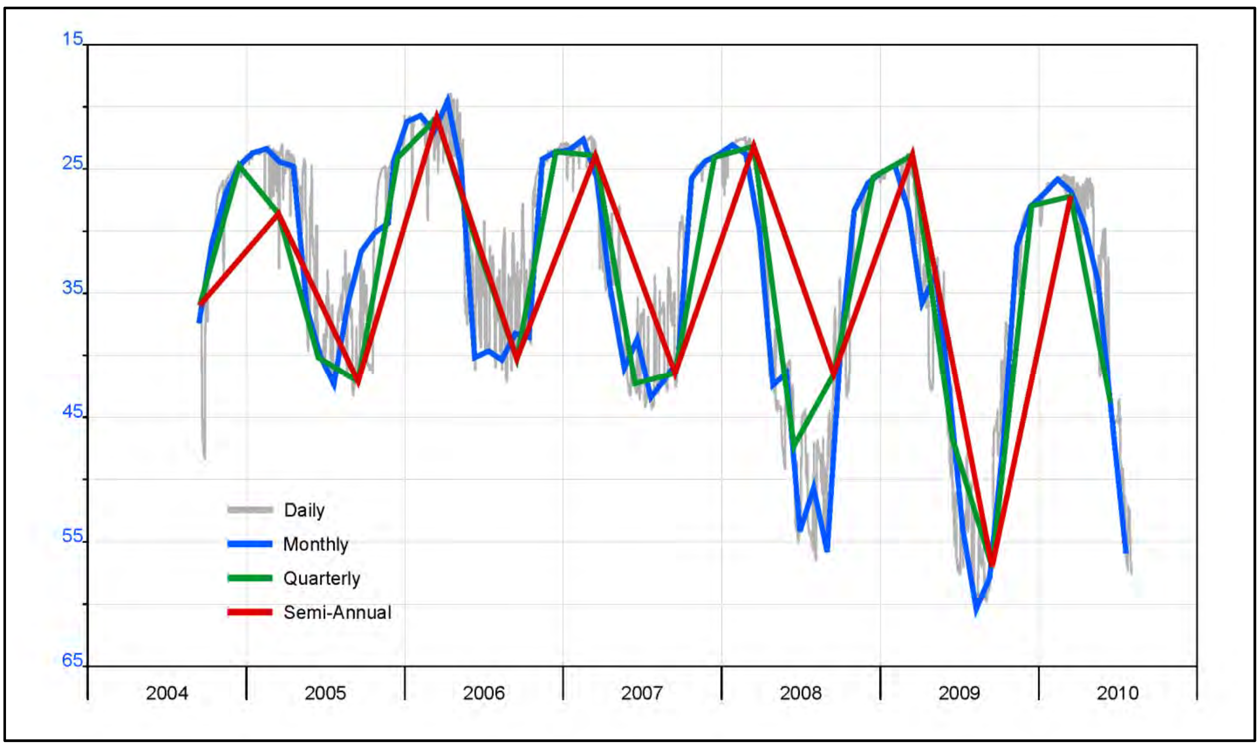

Figure 2. Groundwater Hydrographs – Groundwater elevation changes in a monitoring well over time comparing various measurement frequencies.

The Subcommittee on Ground Water of the Advisory Committee on Water Information generally recommends more frequent measurements than are being required by the CASGEM program; quarterly to annually for aquifers with very few groundwater withdrawals, monthly to quarterly for aquifers with moderate groundwater withdrawals, and daily to monthly for aquifers with many groundwater withdrawals (Table 2). The general effect of environmental factors on the recommended measurement frequency is illustrated in Figure 3.

Measurement Type	Aquifer Type	Nearby Long-Term Aquifer Withdrawals		
		Very Few Withdrawals	***Moderate Withdrawals***	***Many Withdrawals***
Baseline Measurements	**All aquifer types**	Once per month	Once per day	Once per hour
Surveillance Measurements	**All aquifer types:** "low" hydraulic conductivity (<200 ft/d), "low" recharge (<5 in/yr)	Once per year	Once per quarter	Once per month
	All aquifer types: "high" hydraulic conductivity (>200 ft/d), "high" recharge (>5 in/yr)	Once per quarter	Once per month	Once per day
Data made available to NGWMN	All aquifer types, throughout range of hydraulic conductivity	As stored in local database, but at least annually	As stored in local database, but at least annually	As stored in local database, but at least annually

Table 2. Information on recommended minimum water-level measurement frequency from the Subcommittee on Ground Water of the Advisory Committee on Water Information (2009) (abbreviations: ft/d, feet per day; in/yr, inches per year; NGWMN, National Ground Water Monitoring Network). NOTE: These are not recommendations of the CASGEM program.

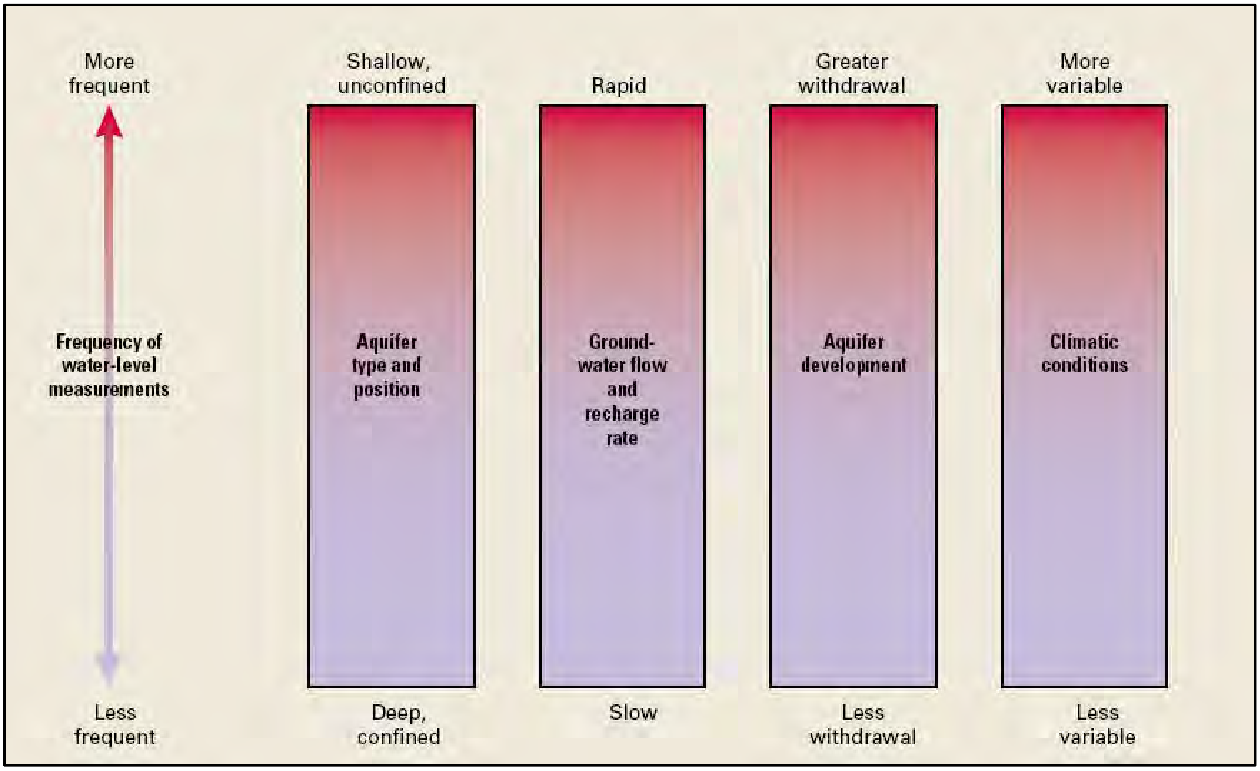

Figure 3. Common environmental factors that influence the choice of frequency of water-level measurements (from Taylor and Alley, 2001).

FIELD GUIDELINES FOR CASGEM WATER-LEVEL MEASUREMENTS

INTRODUCTION

This document presents guidelines for measuring groundwater levels in wells for the CASGEM program to ensure consistency between DWR offices. Following these guidelines will help ensure that groundwater level measurements are accurate and consistent in both unconfined and confined aquifers. Although a well network comprised entirely of dedicated monitoring wells (hereafter referred to as monitoring wells) is preferred, by necessity active production wells used for irrigation or domestic purposes and abandoned production wells that were used for domestic, irrigation, and public supply purposes will also need to be included. **The portions of these guidelines that apply to only production wells will be shown in bold throughout.** DWR does not currently plan to include public supply wells in the CASGEM well networks due to security concerns of the California Department of Public Health.

The main reference used for these guidelines is the United States Geological Survey (USGS) National Field Manual (NFM) (U.S. Geological Survey, 2006). The final report of the Subcommittee on Groundwater (SOGW) of the Advisory Committee on Water Information was also used as a main reference, although in general it relied on the USGS guidelines (Subcommittee on Ground Water of the Advisory Committee on Water Information, 2009). The water-level measurement portion of the USGS guidelines were written for monitoring wells and not for production wells (Taylor and Alley, 2001; U.S. Geological Survey, 2006). Thus, although the USGS guidelines have been adopted with only minor modifications for the monitoring well guidelines of the CASGEM program, additional modifications have been incorporated in the guidelines for production wells. **The most significant changes made to the USGS guidelines for production wells are: (1) reducing the required precision for consecutive depth to water measurements, (2) checking for obstructions in the well, and (3) not attaching weights to the steel tape so as not to hang up on obstructions.**

The guidelines presented in this document are for the use of steel tape, electric sounding tape, sonic water-level meters, or pressure transducers. Although the semi-annual measurements required by the CASGEM program can be satisfied with the use of a steel or electric sounding tape or sonic meter, a pressure transducer with a data logger provides a much better picture of what is happening with water levels over time. The use of the air-line or flowing-well methods should not be needed in most basins. However, if they are, guidelines for these methods are available in sections A4-B-4 (pages B17-B20) and A4-B-5 (pages B21-B24), respectively of the NFM (U.S. Geological Survey, 2006).

Establishing the Reference Point

Water-level measurements from a given well must be referenced to the same datum (the reference point, or RP) to ensure data comparability (see Figure 4). For monitoring wells, the RP should be marked on the top of the well casing. For production wells, the RP will most likely be the top of the access tube or hole to the well casing. The RP must be as permanent as possible and be clearly visible and easily located. It can be marked with a permanent marker, paint, imprinting a mark with a chisel or punch, or by cutting a slot in the top of the casing. In any case, the location of the RP should be clearly described on DWR Form 429 (see Table 3). A photograph of the RP, with clear labeling, should be included in the well folder. In some cases, it may be valuable to establish multiple RPs for a well, depending on the consistent accessibility of the primary RP. In this case, each RP should be clearly described on DWR Form 429 and labeled in the field. The RP should be established with the following coordinate system: horizontal location (decimal latitude and longitude referenced to the North American Datum of 1983; NAD83) and vertical elevation (referenced to the North American Vertical Datum of 1988; NAVD88, in feet).

The land-surface datum (LSD) is established by the person making the initial water-level measurement at the well. The LSD is chosen to represent the average elevation of the ground around the well. Because LSD around a well may change over time, the distance between the RP and LSD should be checked every 3 to 5 years. If appropriate, a concrete well pad or well vault may be chosen as the LSD, since they will be more permanent than the surrounding ground surface.

The elevation of the RP can be determined in several ways: (1) surveying to a benchmark, (2) using a USGS 7.5' quadrangle map, (3) using a digital elevation model (DEM), or (4) using a global positioning system (GPS). While surveying is the most accurate (± 0.1 ft), it is also the most expensive. Depending on the distance to the nearest benchmark, the cost can be prohibitive. The latitude and longitude of the well can be established accurately using a handheld GPS. From this information, the LSD can be located on a USGS quadrangle and the elevation estimated. However, the accuracy is only about ± one half of the contour interval. Thus, for a contour interval of 5 feet, the accuracy of the elevation estimate would be about ± 2.5 feet. The contour interval of high quality DEMs is currently about 30 feet. Therefore, the accuracy of using

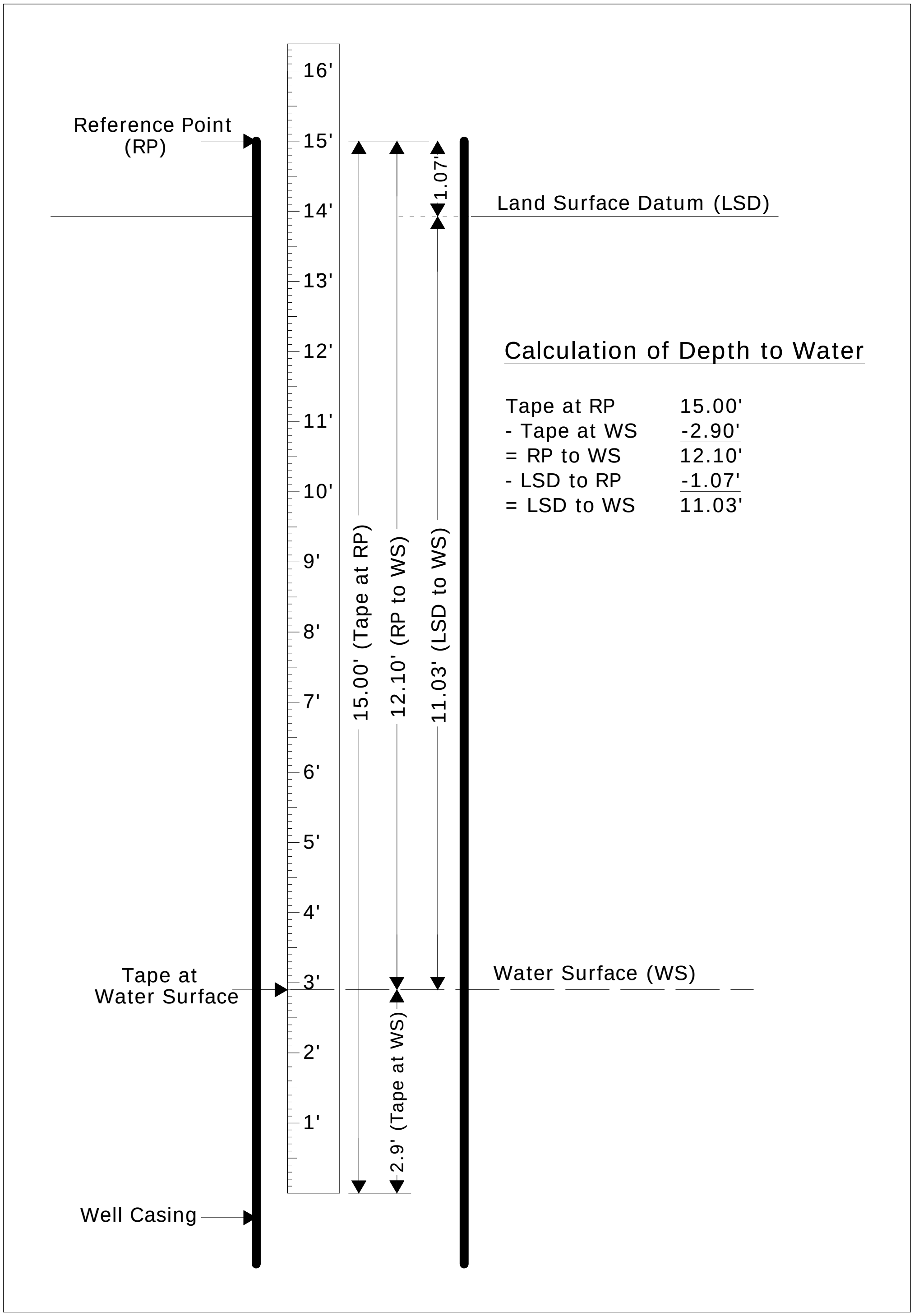

Figure 4. Groundwater-level measurements using a graduated steel tape (modified from U.S. Geological Survey, 2006).

State of California | DEPARTMENT OF WATER RESOURCES | California Natural Resources Agency

WELL DATA

State No. ____________________

District ____________________

OWNER	STATE NO.
ADDRESS	OTHER NO.
TENANT	
ADDRESS	

TYPE OF WELL	☐ SPECIAL STUDIES	☐ MONTHLY	☐ SEMI ANNUAL	☐ WATER QUALITY
LOCATION: COUNTY	BASIN		NO.	
U.S.G.S. QUAD.			QUAD NO.	
1/4	1/4 SECTION	TWP.	RGE.	MD ☐ SB BASE & MERIDIAN H ☐
COORDINATES X:	Y:		SOURCE:	

DESCRIPTION

REFERENCE POINT DESCRIPTION

WHICH IS	FT.	ABOVE ☐ BELOW ☐ LAND SURFACE.	GROUND ELEVATION	FT.
REFERENCE POINT ELEVATION	FT.	DETERMINED FROM		
WELL: USE	CONDITION		DEPTH	FT.
CASING, SIZE	IN.,	PERFORATIONS		

MEASUREMENTS BY: ☐ DWR ☐ USGS ☐ USBR ☐ COUNTY ☐ IRR. DIST. ☐ WATER DIST. ☐ CONS. DIST.

CHIEF AQUIFER: NAME	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.
TYPE OF MATERIAL	PERM. RATING	THICKNESS
GRAVEL PACKED? ☐ YES ☐ NO	DEPTH TO TOP GR.	DEPTH TO BOT GR.
SUPP. AQUIFER	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.
DRILLER	DATE DRILLED:	LOG NUMBER:

EQUIPMENT: PUMP, TYPE		MAKE		
SERIAL NO.	SIZE OF DISCHARGE PIPE IN.	WATER ANALYSIS: MIN. (1)	SAN. (2)	H.M. (3)
POWER, KIND	MAKE	WATER LEVELS AVAILABLE: YES (1)	NO	
H.P.	MOTOR SERIAL NO	PERIOD OF RECORD: BEGIN	END	
ELEC. METER NO.	TRANSFORMER NO.	COLLECTING AGENCY:		
YIELD	G.P.M. PUMPING LEVEL FT.	PROD. REC. (1)	PUMP TEST (2)	YIELD (3)

SKETCH	REMARKS
N	
	RECORDED BY:
	DATE:

DWR 429 (Rev. 1/09)

Table 3. General well data form (DWR Form 429).

DEMs to determine the elevation of the LSD is about ± 15 feet. While a handheld GPS unit is not very accurate for determining elevation, more expensive units with the Wide Area Augmentation System can be more accurate. However, GPS readings are subject to environmental conditions, such as weather conditions, overhead vegetative cover, topography, interfering structures, and location. Thus, the most common method of determining the elevation will probably be the use of USGS quadrangles. The method used needs to be identified on DWR Form 429 (Table 3). The important matter is that all measurements at a well use the same RP, as the elevation of that point can be more accurately established at a later date. The equipment and supplies needed for establishing the RP are shown in Table 4.

If possible, establish a clearly displayed reference mark (RM) in a location near the well; for example, a lag bolt set into a nearby telephone pole or set in concrete in the ground. The RM is an arbitrary datum established by permanent marks and is used to check the RP or to re-establish an RP should the original RP be destroyed or need to be changed. Clearly locate the RP and RM on a site sketch that goes into the well folder (see Table 3). Include the distance and bearing between the RP and the RM and the height of the lag bolt above the ground surface. Photograph the site, including the RP and RM locations; draw an arrow to the RP and RM on the photograph(s) using an indelible marker, and place the photos in the well file.

Table 4. Equipment and Supply List

Equipment and supplies needed for (a) all measurements, (b) establishing permanent RP, (c) steel tape method, (d) electric sounding tape method, (e) sonic water-level meter, and (f) automated measurements with pressure transducer.
(a) All measurements
GPS instrument, digital camera, watch, calculator, and maps
General well data form (DWR Form 429; see Table 3)
Pens, ballpoint with non-erasable blue or black ink, for writing on field forms and equipment log books
Well file with previous measurements
Measuring tape, graduated in feet, tenths, and hundredths of feet
Two wrenches with adjustable jaws and other tools for removing well cap
Key(s) for opening locks and clean rags
(b) Establishing a permanent reference point
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Paint (bright color), permanent marker, chisel, punch, and(or) casing-notching tool

Table 4. Equipment and Supply List (continued)

(c) Steel tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Weight (stainless steel, iron, or other noncontaminating material – do not use lead)
Strong ring and wire, for attaching weight to end of tape. Wire should be strong enough to hold weight securely, but not as strong as the tape, so that if the weight becomes lodged in the well the tape can still be pulled free.
Carpenters' chalk (blue) or sidewalk chalk
Disinfectant wipes, and deionized or tap water for cleaning tape.
(d) Electric sounding tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
An electric tape, double-wired and graduated in feet, tenths, and hundredths of feet, accurate to 0.01 ft. Electric sounding tapes commonly are mounted on a hand-cranked and powered supply reel that contains space for the batteries and some device ("indicator") for signaling when the circuit is closed.
Electric-tape calibration and maintenance log book; manufacturer's instructions.
Disinfectant wipes, and deionized or tap water for cleaning tape.
Replacement batteries, charged.
(e) Sonic water-level meter method
DWR field form 1213 (see Table 5)
Temperature probe with readout and cable
Sonic water-level meter with factory cover plate
Custom sized cover plates for larger well diameters
Replacement batteries
(f) Automated measurements with pressure transducer
Transducer field form (see Figures 1 and 2 in Drost, 2005: http://pubs.usgs.gov/of/2005/1126/pdf/ofr20051126.pdf)
Transducer, data logger, cables, suspension system, and power supply.
Data readout device (i.e., laptop computer loaded with correct software) and data storage modules.
Spare desiccant, and replacement batteries.
Well cover or recorder shelter with key.
Steel tape (with blue carpenters' chalk or sidewalk chalk) or electric sounding tape, both graduated in hundredths of feet.
Tools, including high-impedance (digital) multimeter, connectors, crimping tool, and contact-burnishing tool or artist's eraser.

Guidelines for Measuring Water Levels

Monitoring wells typically have a cap on the wellhead. After the cap is removed, the open top of the well is easily accessible for sampling water levels and water quality. If the well is to be sampled for water quality in addition to water level, the water-level measurement should be made before the well is purged. Before discussing the detailed measurement steps for different methods, some guidance is provided on the common issues of well caps, recovery time after pumping, and cascading water in a well.

Well caps are commonly used in monitoring wells to prevent the introduction of foreign materials to the well casing. There are two general types of well caps, vented and unvented. Vented well caps allow air movement between the atmosphere and the well casing. Unvented well caps provide an airtight seal between the atmosphere and the well casing.

In most cases it is preferred to use vented well caps because the movement of air between the atmosphere and the well casing is necessary for normal water level fluctuation in the well. If the cap is not vented the fluctuation of groundwater levels in the well will cause increased or decreased air pressure in the column of air trapped above the water in the casing. The trapped air can prevent free movement of the water in the casing and potentially impact the water level that is measured. Vented caps will allow both air and liquids into the casing so they should not be used for wells where flooding with surface water is anticipated or contamination is likely from surface sources near the well.

Unvented well caps seal the top of the well casing and prevent both air and liquid from getting into the well. They are necessary in areas where it is anticipated that the well will be flooded from surface water sources or where contamination is likely if the casing is not sealed. Because the air above the water in the casing is trapped in the casing and cannot equalize with the atmospheric pressure, normal water level fluctuation may be impeded. When measuring a well with an unvented cap it is necessary to remove the cap and wait for the water level to stabilize. The wait time will vary with many different factors, but if several sequential water-level measurements yield the same value it can be assumed the water level has stabilized.

Unlike monitoring wells, production wells have obstructions in the well unless it is an abandoned production well and the pump has been removed. In addition, the wellhead is not always easily accessible for monitoring water levels. Since pumping from the production wells will create a non-static water level, the water-level measurement should ideally not be made until the water level has returned to static level. However, this recovery time will vary from site to site. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Thus, as a general recommendation, measurements should not be collected until 24 hours after pumping has ceased, however, site specific

conditions may require deviating from this. The time since pumping should be noted on the field form.

Water may enter a well above the water level, drip or cascade down the inside of the well, and lead to false water level measurements. Sometimes cascading water can be heard dripping or flowing down the well and other times it is discovered when water levels are abnormally shallow and/or difficult to determine. Both steel tapes and electric sounding tapes can give false readings. A steel tape may be wet from the point where water is entering the well making it hard to see the water mark where the tape intersects the water level in the well. An electric sounding tape signal may start and then stop as it is lowered down the well. If this happens, you can lightly shake the tape. The signal often becomes intermittent when water is running down the tape, but remains constant in standing water. On most electric sounding tapes, the sensitivity can be turned down to minimize false readings. It should be noted when a water level measurement is taken from a well with cascading water.

(1) Steel Tape Method

The graduated steel-tape (wetted-tape) procedure is considered to be the most accurate method for measuring water levels in nonflowing wells. A graduated steel tape is commonly marked to 0.01 foot. When measuring deep water levels (>500 ft), thermal expansion and stretch of the steel tape starts to become significant (Garber and Koopman, 1968). The method is most accurate for water levels less than 200 feet below land surface. The equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- It may be difficult or impossible to get reliable results if water is dripping into the well or condensing on the well casing.
- If the well casing is angled, instead of vertical, the depth to water should be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the tape is not hung up on obstructions.**

Before making a measurement:

1. Maintain the tape in good working condition by periodically checking the tape for rust, breaks, kinks, and possible stretch. Record all calibration and maintenance data associated with the steel tape in a calibration and maintenance log book.

2. If the steel tape is new, be sure that the black sheen on the tape has been dulled so that the tape will retain the chalk.

3. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

4. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. In the field, wipe off the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape.

6. If possible, attach a weight to the tape that is constructed of stainless steel or other noncontaminating material to protect groundwater quality in the event that the weight is lost in the well. **Do not attach a weight for production wells.**

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Chalk the lower few feet of the tape by pulling the tape across a piece of blue carpenter's chalk or sidewalk chalk (the wetted chalk mark identifies that part of the tape that was submerged).

3. Slowly lower the weight (for monitoring wells only) and tape into the well to avoid splashing when the bottom end of the tape reaches the water. Develop a feel for the weight of the tape as it is being lowered into the well. A change in this weight will indicate that either the tape is sticking to the side of the casing or has reached the water surface. Continue to lower the end of the tape into the well until the next graduation (a whole foot mark) is at the RP and record this number on DWR Form 1213 (Table 5) next to "Tape at RP" as illustrated on Figure 4.

4. Rapidly bring the tape to the surface before the wetted chalk mark dries and becomes difficult to read. Record the number to the nearest 0.01 foot in the column labeled as "Tape at WS."

5. If an oil layer is present, read the tape at the top of the oil mark to the nearest 0.01 foot and use this value for the "Tape at WS" instead of the wetted chalk mark. Mark an "8" in the QM column of DWR Form 1213 (see Table 5) to indicate a questionable measurement due to oil in the well casing. There are methods to correct for oil, such as the use of a relatively inexpensive water-finding paste. The paste is applied to the lower end of the steel tape and the top of the oil shows as a wet line and the top of the water shows as a distinct color change. Since oil density is about three-quarters that of water, the water level can be estimated by adding three-quarters of the thickness of the oil layer to the oil-water interface elevation (U.S. Geological Survey, 2006).

6. Subtract the “Tape at WS” number from the “Tape at RP” number and record the difference (to the nearest 0.01 ft) as “RP to WS”. This reading is the depth to water below the RP.

7. Wipe and dry off the tape and re-chalk based on the first measurement.

8. Make a second measurement by repeating steps 3 through 5, recording the time of the second measurement on the line below the first measurement (Table 5). The second measurement should be made using a different “Tape at RP” than that used for the first measurement. If the second measurement does not agree with the original within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement, recording this measurement and time on the row below the second measurement with a new time. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Clean the exposed portion of the tape using a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape. Do not store a steel tape while dirty or wet.

GROUNDWATER LEVEL DATA FORM
MANUAL MEASUREMENTS

WELL ID NUMBER	WELL NAME	STATE WELL NUMBER	COUNTY	B-118 BASIN OR SUBBASIN	MEASURING AGENCY	LAND SURFACE DATUM (LSD) ELEV.	RP TO LAND SURFACE DATUM (LSD), IN FT	REFERENCE POINT (RP) ELEV.

NO MEASUREMENT (NM)
0. Measurement discontinued
1. Pumping
2. Pump house locked
3. Tape hung up
4. Can't get tape in casing
5. Unable to locate well
6. Well has been destroyed
7. Special
8. Casing leaky or wet
9. Temporarily inaccessible

QUESTIONABLE MEASUREMENT (QM)
0. Caved or deepened
1. Pumping
2. Nearby pump operating
3. Casing leaky or wet
4. Pumped recently
5. Air or pressure gauge measurement
6. Other
7. Recharge operation at or nearby well
8. Oil in casing

MEASUREMENT METHOD (MM)
0. Steel tape
1. Electric sounding tape
2. Other

DATE	TIME	N M	Q M	MM	TAPE at RP	TAPE at WS	RP to WS	LSD to WS	OBS	COMMENTS

[For explanation of terms, see figure 1.]

DWR Form 1213 (modified 6/28/2010) (data for Water Data Library)

Table 5. Groundwater level data form for manual measurements (DWR Form 1213).

(2) Electric Sounding Tape Method

The electric sounding tape procedure for measuring depth to the water surface is especially useful in wells with dripping water or condensation, although there are still precautions needed as noted in the beginning of this section. Other benefits of this method include:

- Easier and quicker than steel tapes, especially with consecutive measurements in deeper wells.
- Better than steel tapes for making measurements in the rain.
- Less chance for cross-contamination of well water than with steel tapes, as there is less tape submerged.

The accuracy of electric sounding tape measurements depends on the type of tape used and whether or not the tape has been stretched out of calibration after use. Tapes that are marked the entire length with feet, tenths, and hundredths of a foot should be read to 0.01 ft. Electric sounding tapes are harder to keep calibrated than are steel tapes. As with steel tapes, electric sounding tapes are most accurate for water levels less than 200 ft below land surface, and thermal expansion and stretch start to become significant factors when measuring deep water levels (>500 ft) (see Garber and Koopman, 1968). Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- If the well casing is angled, instead of vertical, the depth to water will have to be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the electric sounding tape is not hung up on an obstruction in the well.**
- The electric sounding tape should be calibrated annually against a steel tape in the field (using monitoring wells only) as follows: Compare water-level measurements made with the electric sounding tape to those made with a steel tape in several wells that span the range of depths to water encountered in the field. The measurements should agree to within ± 0.02 ft. If this accuracy is not met, a correction factor should be applied. All calibration and maintenance data should be recorded in a calibration and maintenance log book for the electric sounding tape.
- **Oil on the surface of the water may interfere with obtaining consistent readings and could damage the electrode probe. If oil is present, switch to a steel tape for the water-level measurement.**
- If using a repaired/spliced tape: see section A4-B-3(b) (page B16) of the NFM (U.S. Geological Survey, 2006).

Before making a measurement:

1. Inspect the electric sounding tape and electrode probe before using it in the field. Check the tape for wear, kinks, frayed electrical connections and possible stretch; the

cable jacket tends to be subject to wear and tear. Test that the battery and replacement batteries are fully charged.

2. Check the distance from the electrode probe's sensor to the nearest foot marker on the tape, to ensure that this distance puts the sensor at the zero foot point for the tape. If it does not, a correction must be applied to all depth-to-water measurements. Record this in an equipment log book and on the field form.

3. Prepare the field forms (DWR Form 1213; see Table 5) and place any previous measured water-level data for the well into the field folder.

4. After reaching the field site, check that the RP is clearly marked on the well and is accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. Check the circuitry of the electric sounding tape before lowering the electrode probe into the well. To determine proper functioning of the tape mechanism, dip the electrode probe into tap water and observe whether the indicator needle, light, and/or beeper (collectively termed the "indicator" in this document) indicate a closed circuit. For an electric sounding tape with multiple indicators (sound and light, for instance), confirm that the indicators operate simultaneously. If they do not operate simultaneously, determine which is the most accurate and use that one.

6. Wipe off the electrode probe and the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry.

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made. Avoid letting the tape rub across the top of the well casing. Place the tip or nail of the index finger on the insulated wire at the RP and read the depth to water to the nearest 0.01 foot. Record this value in the column labeled "Tape at RP", with the appropriate measurement method code and the date and time of the measurement (see Table 5).

3. Lift the electrode probe slowly up a few feet and make a second measurement by repeating step 2 and record the second measurement with the time in the row below the first measurement in Table 5. Make all readings using the same deflection point on the indicator scale, light intensity, or sound so that water levels will be consistent between measurements. If the second measurement does not agree with the first measurement within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement,

recording this measurement with the time in the row below the second measurement. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Wipe down the electrode probe and the section of the tape that was submerged in the well water, using a disinfectant wipe and rinse thoroughly with de-ionized or tap water. Dry the tape and probe and rewind the tape onto the tape reel. Do not rewind or otherwise store a dirty or wet tape.

(3) Sonic Water-Level Meter Method

This meter uses sound waves to measure water levels. It requires an access port that is 5/8 – inch or greater in diameter and measurement of the average air temperature in the well casing. The meter can be used to quickly measure water levels in both monitoring wells and production wells. Also, since this method does not involve contact of a probe with the water, there is no concern over cross contamination between wells. However, the method is not as accurate as the other methods, with a typical accuracy of 0.2 ft for water levels less than 100 ft or 0.2% for water levels greater than 100 ft. Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- The accuracy of the meter decreases with well diameter and should not be used with well diameters greater than 10 inches.
- An accurate air temperature inside the well casing is necessary so that the variation of sound velocity with air temperature can be accounted for.
- **Obstructions in the well casing can cause erroneous readings, especially if the obstruction is close to half the well diameter or more.**

Before making a measurement:

1. Check the condition of the meter, especially the batteries. Take extra batteries to the field.

2. Take a temperature probe with a readout and 50-ft cable.

3. If open wellheads with diameter greater than the factory cover plate and less than 10 inches will be monitored, fabricate appropriately-sized cover plates using plastic or sheet metal.

4. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

5. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

Making a measurement:

1. If the water level was measured previously at the well, lower the temperature probe to about half that distance in the well casing. Preferably, use measurements that were obtained during the same season of the year.

2. Record this temperature in the comments column of DWR form 1213 (see Table 5). Use this temperature reading to adjust the temperature toggle switch on the sonic meter.

3. Select the appropriate depth range on the sonic meter.

4. For a covered wellhead, insert the meter duct into the access port and push the power-on switch. Record the depth from the readout.

5. For an open wellhead, slip the provided cover plate onto the wellhead to provide a seal. If the cover plate is not large enough, use a fabricated cover plate for diameters up to 10 inches. Record the depth from the readout.

After making a measurement:

1. Make sure the temperature probe and the sonic meter are turned off and put away in their cases.

(4) Pressure Transducer Method

Automated water-level measurements can be made with a pressure transducer attached to a data logger. Care should be taken to choose a pressure transducer that accurately measures the expected range of groundwater levels in a well. Pressure-transducer accuracy decreases linearly with increases in the depth range (also known as pressure rating). A pressure transducer with a depth range of 0 to 10 ft (0 to 4.3 psi) has an accuracy of 0.01 ft while a pressure transducer with a depth range of 0 to 100 ft (0 to 43 psi) has an accuracy of 0.1 ft. But if the measurement range exceeds the depth range of a pressure transducer, it can be damaged. So it is important to have a good idea of the expected range of groundwater levels in a well, and then refer to the manufacturer's specification when selecting a pressure transducer for that well.

Some of the advantages of automated monitoring include:

- No correction is required for angled wells, as pressure transducers only measure vertical water levels.
- A data logger can be left unattended for prolonged periods until data can be downloaded in the field.
- Downloaded data can be imported directly into a spreadsheet or database.

Some of the disadvantages of automated monitoring include:

- It may be necessary to correct the data for instrument drift, hysteresis, temperature effects, and offsets. Most pressure transducers have temperature compensation built-in.
- Pressure transducers operate only in a limited depth range. The unit must be installed in a well in which the water level will not fluctuate outside the operable depth range for the specific pressure transducer selected. Wells with widely fluctuating water levels may be monitored with reduced resolution or may require frequent resetting of the depth of the pressure transducer.
- With some data loggers, previous water-level measurements may be lost if the power fails.

There are two types of pressure transducers available for measuring groundwater levels; non-vented (absolute) and vented (gauged). A non-vented pressure transducer measures absolute pressure, is relative to zero pressure, and responds to atmospheric pressure plus pressure head in a well (see Figure 5). A vented pressure transducer measures gauge pressure, is relative to atmospheric pressure, and only responds to pressure head in a well.

Non-vented pressure transducer data require post processing. Barometric pressure data must be collected at the same time as the absolute pressure data at the well, and subtracted from each absolute pressure data record before the data can be used to calculate groundwater levels. Thus, if a non-vented pressure transducer is used, a barometric pressure transducer will also be needed near the well. This subject is usually covered in more detail by the manufacturer of the pressure transducer. In an area with little topographic relief, a barometer at one site should be sufficient for use by other sites within a certain radius (9 miles reported by Schlumberger http://www.swstechnology.com/ groundwater-monitoring/groundwater-dataloggers/baro-diver and 100 miles reported by Global Water http://www.globalw.com/support/barocomp.html). In an area of significant topographic relief, it would be advisable to have a barometer at each site.

Vented pressure transducers can be programmed so no post processing of the data is necessary. The vent is usually a small tube in the communication cable that runs from the back of the pressure transducer to the top of the well. This vent enables the pressure transducer to cancel the effect of atmospheric pressure and record groundwater level as the distance from the RP to the WS (see Figure 5). However, if the vent is exposed to excessive moisture or submerged in water it can cause failure and damage to the pressure transducer.

The existing well conditions should be considered when deciding which type of pressure transducer to use. Non-vented pressure transducers should be used when the top of a well or its enclosure may at any time be submerged in water. This can happen when artesian conditions have been observed or are likely, the well is completed at or below the LSD, or the well or its enclosure are susceptible to periods of high water. Otherwise, it is advisable to use a vented pressure transducer.

The following guidelines are USGS guidelines from Drost (2005) and Freeman and others (2004) for the use of pressure transducers. These USGS guidelines have not been incorporated as yet in the NFM. The equipment and supplies needed for automated measurements of water level using a pressure transducer are shown in Table 4.

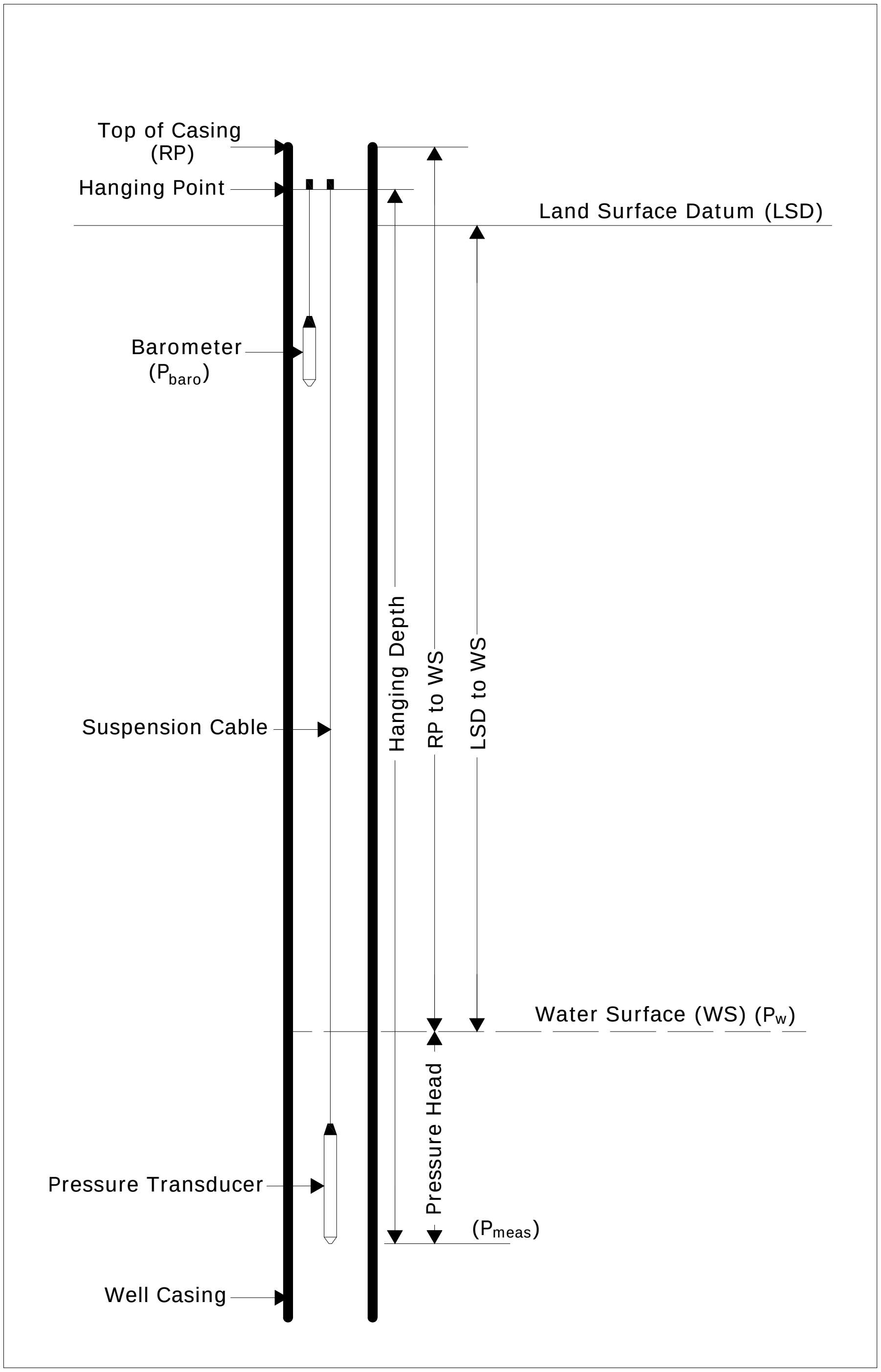

Figure 5. Groundwater-level measurements using a pressure transducer (vented or non-vented) (modified from Drost, 2005).

Before making a measurement:

1. Keep the pressure transducer packaged in its original shipping container until it is installed.

2. Fill out the DWR field form (Table 6), including the type, serial number, and range of measurement device; and what units are being measured (ft, psi).

3. Take a reading from the pressure transducer before placing into the well. For a vented pressure transducer the reading should be zero. For a non-vented pressure transducer the reading should be a positive number equivalent to atmospheric pressure. Configure the units (ft, psi) on a barometric pressure transducer the same as the non-vented pressure transducer. A reading from the barometric pressure transducer should be the same as the non-vented pressure transducer reading.

4. Lower the pressure transducer into the well slowly. Conduct a field calibration of the pressure transducer by raising and lowering it over the anticipated range of water-level fluctuations. Take two readings at each of five intervals, once during the raising and once during the lowering of the pressure transducer. Record the data on the DWR field form (see Table 6). If using a non-vented pressure transducer, take a reading from the barometric pressure transducer at the same time as the other readings.

5. Lower the pressure transducer to the desired depth below the water level (caution: do not exceed the depth range of the pressure transducer).

6. Fasten the cable or suspension system to the well head using tie wraps or a weatherproof strain-relief system. If the vent tube is incorporated in the cable, make sure not to pinch the cable too tightly or the vent tube may be obstructed.

7. Make a permanent mark on the cable at the hanging point, so future slippage, if any, can be determined.

8. Measure the static water level in the well with a steel tape or electric sounding tape. Repeat if measurements are not consistent within 0.02 ft **(0.2 ft for production wells)**.

9. Record the well and RP configuration, with a sketch. Include the RP height above the LSD, the hanging point, and the hanging depth (see Figure 5).

GROUNDWATER LEVEL DATA FORM
VENTED OR NON-VENTED PRESSURE TRANSDUCER WITH DATALOGGER

Station Information						Transducer Information						
Well ID Number	Well Name	State Well Number	County	Bulletin 118 GW Basin or Subbasin	Measuring Agency	Type of Pressure Transducer -- (A) Gauged (vented) or (B) Absolute (non-vented)?	Manufac-turer	Model	Serial Number	PSI Rating	Cable Length	Barometer Serial Number

Datum Measurements (in feet) [Date of Measurements:]

Reference Point (RP) Elevation (MSL) [from DWR Form 429]	RP to Land Surface Datum (LSD)	(1) RP to Hanging Point	(2) Hanging Depth	(3) RP to Pressure Transducer

Manual Readings									Datalogger Readings						Datalogger Servicing		
Date	Time	Obser-ver	NM	QM	MM	(4) Tape at RP	(5) Tape at WS	(6) RP to WS	(7) Transducer pressure (psi)	(8) Barometric pressure (psi)	(9) WS pressure (psi)	(10) WS above transducer (ft)	(11) RP to WS (ft)	Test Name	Download-ed data? (Y/N)	Batt. life left / new batteries? (%; Y/N)	Comments

These cells only need to be filled out for non-vented transducers (which will have a barometer at the well in addition to the transducer)

Notes about calculated entries in form (referenced by number in cell): (3) = (1) + (2); (6) = (4) - (5) for steel tape; (6) = (4) for electric sounding tape; (9) = (7) - (8) for non-vented transducer; (9) = (7) for vented transducer; (10) = 2.3067 * (9); (11) = (3) - (10) [for explanation of terms, see figure 2]

NM (No Measurement) Codes: 0--Measurement discontinued 1--Pumping 2--Pump house locked 3--Tape hung up 4--Can't get tape in casing 5--Unable to locate well 6--Well has been destroyed 7--Special 8--Casing leaky or wet 9--Temporarily inaccessible

QM (Questionable Measurement) Codes: 0--Caved or deepened 1--Pumping 2--Nearby pump operating 3--Casing leaky or wet 4--Pumped recently 5--Air or pressure gauge measurement 6--Other 7--Recharge operation at or nearby well 8--Oil in casing

MM (Measurement Method) Codes: 0--Steel tape 1--Electric sounding tape 2--Other

DWR Form xxxx (data for Hydstra)

Table 6. Groundwater level data form for vented or non-vented pressure transducer with data logger.

10. Connect the data logger, power supply, and ancillary equipment. Configure the data logger to ensure the channel, scan intervals, units, etc., selected are correct. Activate the data logger. Most data loggers will require a negative slope in order to invert water levels for ground-water applications (i.e., distance from the RP to the WS). If using a non-vented pressure transducer the data logger will not require a negative slope, but atmospheric pressure data will need to be collected by a barometric pressure transducer.

Making a measurement:

1. Retrieve water-level data (to 0.01 ft) using instrument or data logger software. If using a non-vented pressure transducer, retrieve barometric pressure data.

2. Measure the water level with a steel tape or electric sounding tape (to 0.01 ft) and compare the reading with the value recorded by the pressure transducer and data logger. Record the reading and time in the file folder. If using a non-vented pressure transducer, subtract the barometric pressure value from the transducer pressure value to obtain the water level pressure value. The water level pressure can then be multiplied by 2.3067 to convert from psi of pressure to feet of water (Freeman and others, 2004). Report the calculated water level to the nearest 0.01 ft.

3. If the tape and pressure transducer readings differ by more than **(the greater of 0.2 ft or)** two times the accuracy of the specific pressure transducer, raise the pressure transducer out of the water and take a reading to determine if the cable has slipped, or whether the difference is due to drift. The accuracy of a pressure transducer is typically defined as 0.001 times the full scale of the pressure transducer (e.g., a 0 to 100 ft pressure transducer has a full scale of 100 ft). The accuracy of a specific pressure transducer should be specified by the manufacturer’s specifications.

4. If drift is significant, recalibrate the pressure transducer as described using a steel tape. If using a non-vented pressure transducer, keep the pressure transducer out of the water and calibrate to the barometric pressure transducer value. If field calibration is not successful, retrieve the transducer and send back to the manufacturer for re-calibration.

5. Use the multimeter (see Table 4) to check the charge on the battery, and the charging current supply to the battery. Check connections to the data logger, and tighten as necessary. Burnish contacts if corrosion is occurring.

6. Replace the desiccant, battery (if necessary), and data module. Verify the data logger channel and scan intervals, document any changes to the data logger program and activate the data logger.

7. If possible, wait until data logger has logged a value, and then check for reasonableness of data.

GLOSSARY OF TERMS

The following terms are used in this document. Although many are commonly used in the groundwater- and data-management fields, they are defined here to avoid confusion.

Aquifer – A geologic formation from which useable quantities of groundwater can be extracted. A confined aquifer is bounded above and below by a confining bed of distinctly less permeable material. The water level in a well installed in a confined aquifer stands above the top of the confined aquifer and can be higher or lower than the water table that may be present in the material above it. In some cases, the water level can rise above the ground surface, yielding a flowing well. An unconfined aquifer is one with no confining beds between the saturated zone and the ground surface. The water level in a well installed in an unconfined aquifer stands at the same level as the groundwater outside of the well and represents the water table. An alternative and equivalent definition for an unconfined aquifer is an aquifer in which the groundwater surface is at atmospheric pressure.

Atmospheric or barometric pressure – The force per unit area exerted against a surface by the weight of the air above that surface at any given point in the Earth's atmosphere. At sea level, the atmospheric pressure is 14.7 psi. As elevation increases, atmospheric pressure decreases as there are fewer air molecules above the ground surface. The atmospheric pressure is measured by a barometer. This pressure reading is called the barometric pressure. Weather conditions can increase or decrease barometric pressure.

Blue carpenter's chalk – A primarily calcium carbonate chalk with some silica. It is primarily used to make chalk-lines for long lasting bright marks. Some other formulations of chalk (e.g., sidewalk chalk) substitute different ingredients such as rice starch for silica.

Data logger – A microprocessor-based data acquisition system designed specifically to acquire, process, and store data. Data usually are downloaded from onsite data loggers for entry into office data systems. The storage device within a data logger is called the data module. A desiccant, such as, silica gel, calcium sulfate, or calcium chloride, is used to absorb and keep moisture away from the data module.

Dedicated monitoring well – A well designed for the sole purpose of long-term monitoring.

Domestic well – A water well used to supply water for the domestic needs of an individual residence or systems of four or fewer service connections.

DWR Bulletin 118 – DWR publication on the status of California's groundwater. Prior to this 2003 update, the latest Bulletin 118 was published in 1980. This publication defines the 515 basins to be monitored in the SB 6 monitoring program. The report reference is: California Department of Water Resources, 2003, California's groundwater: Bulletin 118, 246 p., available online at: http://www.water.ca.gov/pubs/groundwater/bulletin_118/california's_groundwater__bulletin_118_-_update_2003_/bulletin118_entire.pdf

Electric sounding tape – This term is used in this document to mean both the electric tape and the electrode probe attached to the end of the tape. This water-level measuring device is also known by many other names, including a sounder, an electric tape, an E tape, an electric sounder, an electric well sounder, a depth sounder, etc.

Electrode probe – This is the electronic sensor in the electronic sounder attached to the end of the electric tape. It senses water based on the electrical conductivity and triggers an alert.

GPS – This stands for global positioning system. These devices come in many sizes and costs. The handheld devices are capable of very accurate locations in the xy plane (latitude longitude). However, only very expensive and large GPS units are currently capable of accurate readings for the altitude (z direction).

Groundwater – Water occurring beneath the ground surface in the zone of saturation.

Groundwater basin – An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom.

Groundwater elevation – The elevation (generally referenced to mean sea level as the datum) to which water in a tightly cased well screened at a given location will rise. Other terms that may be used include groundwater level, hydraulic head, piezometric head, and potentiometric head.

Groundwater surface – The highest elevation at which groundwater physically occurs in a given location in an aquifer (i.e., top of aquifer formation in a confined aquifer and the groundwater level or water table in an unconfined aquifer). Also referred to as a water surface in this document.

Groundwater subbasin – A subdivision of a groundwater basin created by dividing the basin using geologic and hydrologic conditions or institutional boundaries.

Hysteresis – The maximum difference in output, at any measured value within the specified range, when the value is approached first with an increasing and then a decreasing measured property. Hysteresis is expressed in percent of the full-scale output.

Instrument Drift – A change in instrument output over a period of time that is not a function of the measured property. Drift is normally specified as a change in zero (zero drift) over time and a change in sensitivity (sensitivity drift) over time.

Irrigation well – A well used to irrigate farmland. The water from the well is not intended for domestic purposes.

Metadata – "data about data"; it is the data describing context, content and structure of records and their management through time.

NFM – This stands for National Field Manual. This is a living, online, document of the USGS. It is the protocol document for USGS methods of surface water, groundwater, and water quality field activities. The portion of the NFM that related to the field methods of collecting groundwater levels is in the following reference: U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September, accessed 12/30/09 at: http://pubs.water.usgs.gov/twri9A4/

Nonflowing well – A well in which the water level is below the land surface.

Pressure head – The height of a column of groundwater above a point that is supported by pressure at that point.

Pressure transducer – A type of measurement device that converts pressure-induced mechanical changes into an electrical signal.

Production well – A well with a pump installed that is used to bring groundwater to the land surface. This is a general term that can be applied to a domestic well, irrigation well, or public-supply well.

Public-supply well – A well that pumps groundwater from a relatively extensive saturated area and is used as part of a public water system, supplying water for human consumption to at least 3,300 people.

SOGW – This stands for Subcommittee on Groundwater. This is a subcommittee of the Advisory Committee on Water Information, which is developing a national framework for groundwater in the United States. The reference for the SOGW work is: Subcommittee on Ground Water of the Advisory Committee on Water Information, 2009, A national framework for ground-water monitoring in the United States: final version approved by the Advisory Committee on Water Information, June 2009, 78 p., accessed 1/11/10 at: http://acwi.gov/sogw/pubs/tr/index.html

Static water level – Groundwater level in a well during non-pumping conditions.

Vent tube – A tube in the cable which connects to the pressure transducer, allowing atmospheric pressure to be in contact with one side of the strain gauge in the pressure sensor. It cancels out the barometric effects in the readings.

Well casing – The metal or plastic pipe separating the well from the surrounding geologic material.

Wellhead – The top of the well containing the casing hanger and the point at which the motor is attached for a vertical line shaft turbine pump or where the seal is secured for a submersible pump.

Well purging – Pumping out standing groundwater from a monitoring well. This is done prior to water quality sampling of wells, but **not** before taking a water-level measurement.

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Appendix B

CASGEM Monitoring Plan Summary

CASGEM Monitoring Plan Summary

The goal of the CASGEM program is to regularly and systematically monitor groundwater elevations that demonstrate seasonal and long-term trends in California's groundwater basins and to make this information readily and widely available to the public. The CASGEM program will rely and build on the many, established local long-term groundwater monitoring and management programs.

In determining what information should be reported to DWR, the department will defer to existing monitoring programs if those programs result in information that demonstrates seasonal and long-term trends in groundwater elevations. Monitoring Entities may submit an existing groundwater monitoring plan that is part of a groundwater adjudication program, an AB3030 program, an IRWM program, or any other groundwater management program that satisfies the goals of CASGEM. If there are future changes in a monitoring plan that is already established with CASGEM, the Monitoring Entity should provide an update to DWR at that time.

Monitoring Plan Overview

Phase 2 of the CASGEM Online Submittal System will be available on May 18, 2011 for prospective Monitoring Entities to submit their groundwater elevation monitoring plans and detailed well information. Each CASGEM monitoring plan should describe the monitoring network and the monitoring plan rationale. The description of the well network should allow users of the CASGEM database to understand well coverage within the basin or subbasin. The monitoring plan rationale explains how the proposed monitoring is designed to capture the seasonal highs and lows and long-term groundwater elevation trends.

The basic components of a CASGEM monitoring plan include the following:

- discussion of the well network,
- map(s) of the well network,
- monitoring schedule,
- description of field methods,
- discussion of the role of cooperating agencies, if applicable, and
- description of the monitoring plan rationale.

The monitoring rationale, which explains how the plan will result in groundwater elevation data that demonstrates seasonal and long-term trends, may discuss any or all of the following information:

- history of groundwater monitoring in the basin,
- principal aquifer features of the basin (for example, multiple aquifers),

- groundwater conditions in the basin (for example, types, locations and timing of recharge and discharge),
- selection of wells for the CASGEM monitoring program (number, depths and distribution of the wells), and
- selection of the monitoring schedule.

If the well network contains any data gaps, the monitoring plan should also discuss the following:

- location and reason for gaps in the well monitoring network,
- local issues and circumstances that limit or prevent groundwater monitoring, and
- recommendations for future well locations (assuming funding for new wells or permission for access to existing wells becomes available).

Maps

The monitoring plan can include maps that show well locations, the boundaries of the area to be monitored and, ideally, the Monitoring Entity's jurisdictional boundary. The optimal density of monitoring locations will depend on the complexity of the basin. If multiple aquifers are present in a basin, maps depicting how each of the aquifers is monitored are useful. The location of gaps in the monitoring network and the location of potential future monitoring wells can also be identified on each map. A table that provides a list of wells could also be used to identify the wells in the network.

Schedule

The monitoring schedule should provide a clear description of the frequency and timing of monitoring. To demonstrate seasonal and long-term trends in groundwater elevations, basin-wide monitoring should be conducted at least twice a year to measure the seasonal high and seasonal low groundwater elevations for the basin. The seasonal high and low groundwater elevations typically occur in early spring and in summer or fall, respectively, but may vary from basin to basin. Monitoring data collected in more frequent intervals can also be submitted to CASGEM. The online system will be designed to accept a maximum frequency of daily measurements for each well. To ensure that each round of monitoring represents a snapshot in time for conditions in the basin or subbasin, it will be important to schedule each round of measurements for all the wells in the network within the narrowest possible window of time. To provide the details of the monitoring schedule, the plan should contain a table detailing the time and frequency of monitoring for each of the wells in the monitoring network.

Field Methods

Field methods are the standard procedures for the collection and documentation of groundwater elevation data. A description of field methods provides an indicator of the quality, consistency and reliability of monitoring data to the users of the CASGEM database. Many Monitoring Entities already have established field methods for their groundwater monitoring programs that meet the following basic requirements:

- step-by-step instructions to establish the Reference Point,
- methods for recording measurements,
- methods to ensure the measurement of static (non-pumping) groundwater conditions,
- step-by-step instructions to measure depth to water, and
- forms for recording measurements.

Each Monitoring Entity will develop and implement monitoring protocols appropriate for the local groundwater basin conditions. Monitoring Entities who do not have established monitoring protocols can request assistance from DWR Region Offices to help develop appropriate protocols.

Well Information

In addition to the monitoring plan, each Monitoring Entity will also input the following detailed well information into the CASGEM Online Submittal System:

- Local well ID and/or State Well Number
- Reference Point Elevation (feet, NAVD88)
- Reference Point description
- Ground Surface Elevation (feet NAVD88)
- Method of determining elevation
- Accuracy of elevation method
- Well Use
- Well Status (active or inactive)
- Well coordinates (decimal lat/long, NAD83)
- Method of determining coordinates
- Accuracy of coordinate method
- Well Completion type (single or multi-completion)
- Total depth (feet)
- Top and bottom of screened intervals (up to 10 intervals)
- Well Completion Report number
- Groundwater basin of well (or subbasin or portion)
- Written description of well location
- Any additional comments

Groundwater Elevation Information (to be developed under Phase 3)

Phase 3 development of the CASGEM Online Submittal System will be available in late fall 2011. Phase 3 will enable Monitoring Entities to submit their groundwater elevation data and will provide public access to view the CASGEM database.

Monitoring Entities will submit the following groundwater elevation information for each well during each round of monitoring:

- Well identification number
- Measurement date
- Reference point elevation of the well (feet) using NAVD88 vertical datum
- Elevation of land surface datum at the well (feet) using NAVD88 vertical datum
- Depth to water below reference point (feet) (unless no measurement was taken)
- Method of measuring water depth
- Measurement Quality Codes
    - If no measurement is taken, a specified "no measurement" code, must be recorded. Standard codes will be provided by the online system. If a measurement is taken, a "no measurement" code is not recorded.)
    - If the quality of a measurement is uncertain, a "questionable measurement" code can be recorded. Standard codes will be provided by the online system. If no measurement is taken, a "questionable measurement" code is not recorded.)
- Measuring agency identification
- Measurement time (PST/PDT with military time/24 hour format)
- Comments about measurement, if applicable

Appendix E: Groundwater Quality Reports

PCWA UPDATE
water • energy • stewardship

PLACER COUNTY WATER AGENCY

VOL 26 NO 2 APRIL-MAY 2012

IN THIS ISSUE: ***WATER QUALITY REPORT***

MARTIS VALLEY WATER SYSTEM for 2011 (Reported in 2012)

PCWA Water is Safe and Healthy

Placer County Water Agency is proud to supply safe and healthy water. We are pleased to report that the drinking water supplied to you meets or exceeds state and federal public health standards for drinking water quality and safety.

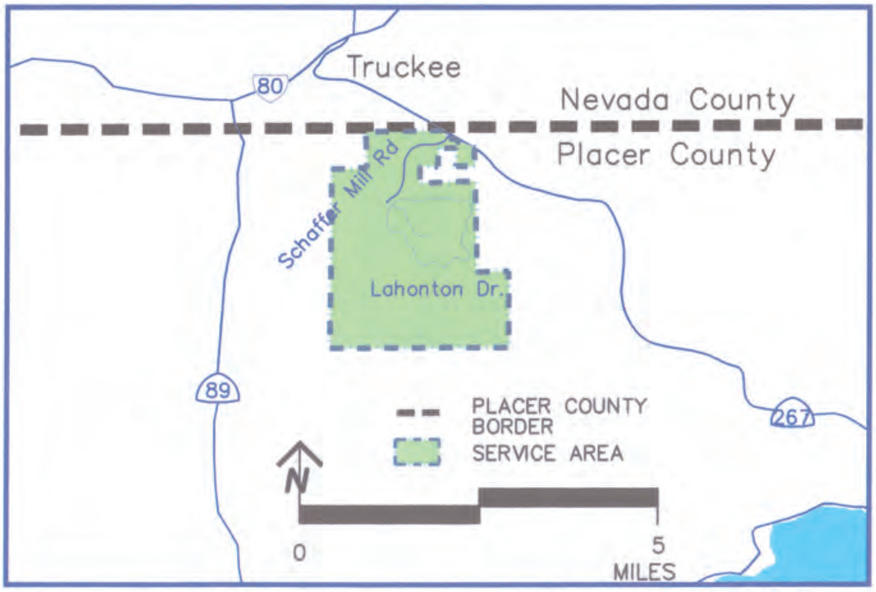
California water retailers, including PCWA, are required by law to inform customers about the quality of their drinking water. The results of PCWA's testing and monitoring programs of 2011 are reported in this newsletter.

If you have any questions about this report, please contact the PCWA Customer Services Center at (530) 823-4850 or (800) 464-0030.

About Your Drinking Water

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the U.S. Environmental Protection Agency's **Safe Drinking Water Hotline:**

1-800-426-4791



Martis Valley Service Area

Groundwater Supply

The Source of Your Water Supply

Water for the PCWA Martis Valley service area in eastern Placer County is pumped from the Martis Valley aquifer. Groundwater is drawn from two wells, approximately 900 feet in depth, located adjacent to Lahontan Drive and Schaffer Mill Road. Water is distributed to customers via pipeline.

Ensuring The Safety of Your Drinking Water Supply

In order to ensure that tap water is safe to drink, the U.S. Environmental Protection Agency (USEPA) and the state Department of Public Health prescribe regulations which limit the amount of certain contaminants in water provided by public water systems. State regulations also establish limits for contaminants in bottled water that must provide the same protection for public health.

Placer County Water Agency

Consumer Confidence Report for 2011 (Reported in 2012)

MARTIS VALLEY Water System

Primary Drinking Water Standards

Constituent	No. of Samples Collected	90th Percentile Level Detected	No. of Sites exceeding AL	AL	PHG	Typical Source of Contaminant
Copper (mg/L)	5	0.14	0	1.3	0.3	Internal corrosion of household water plumbing systems; erosion of natural deposits; leaching from wood preservatives

Constituent	Units	State MCL or {MRDL}	PHG (MCLG) or {MRDLG}	Range and Average or (HRAA)	Typical Source of Contaminant
Chlorine	mg/L	{4}	{4}	0.4-1.17 (0.89)	Drinking water disinfectant added for treatment
Arsenic	ug/L	10	0.004	0-2 1	Erosion of natural deposits; runoff from orchards, glass and electronics production wastes

Secondary Drinking Water Standards

Total Dissolved Solids	mg/L	1000	None	120-130 125	Runoff, leaching from natural deposits
Specific Conductance	uS/cm	1600	None	180-190 185	Substances that form Ions when in water
Chloride	mg/L	500	None	1.3-1.8 1.55	Runoff, leaching from natural deposits
Sulfate	mg/L	500	None	0.93-1.3 1.12	Runoff, leaching from natural deposits

STATEMENT ON LEAD *(None found in this system),* If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. PCWA is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at *http://www.epa.gov/safewater/lead.*

DEFINITIONS: Understanding Your Water Quality Report

MCL: Maximum Contaminant Level. The highest level of a contaminant that is allowed in drinking water. Primary MCL's are set as close to the PHG's (or MCLG's) as is economically and technologically feasible. Secondary MCL's are set to protect the odor, taste and appearance of drinking water.
MCLG: Maximum Contaminant Level Goal. The level of a contaminant in drinking water below which there is no known or expected risk to health. Set by the U.S. Environmental Protection Agency.
MRDL: Maximum Residual Disinfectant Level. The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
MRDLG: Maximum Residual Disinfectant Level Goal. The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLG's do not reflect the benefits of the use of disinfectants to control microbial contaminants.
Primary Drinking Water Standard. MCL's and MRDL's for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.
PHG: Public Health Goal. The level of a contaminant in drinking water below which there is no known or expected risk to health. PHG's are set by the California Environmental Protection Agency.
AL: Action Level. The concentration of a contaminant, which if exceeded, triggers treatment or other requirements which a water system must follow.
NTU: Nephelometric Turbidity Units. A measure of the clarity of water. Turbidity is monitored because it is a good indicator of water quality. High turbidity can hinder the effectiveness of disinfectants.
TT: Treatment Technique. A required process intended to reduce the level of a contaminant in drinking water.
pCi/L: picocuries per liter. A measure of radiation.
mg/L: milligrams per liter or parts per million (ppm)
ug/L: micrograms per liter or parts per billion (ppb)
uS/cm: MicroSiemens per centimeter.
HRAA: Highest Running Annual Average
<: Less Than
ND: ND or Non-Detected: An analysis result below detectable levels.
NA: Non-Applicable

Monitoring of Unregulated Substances

Constituent	Units	State MCL (or MRDL)	PHG (MCLG) (or MRDLG)	Range (Average)	Typical Source of Contaminant
Sodium	mg/L	None	None	7.9-8.7 (8.3)	Runoff, leaching from natural deposits
Hardness	mg/L	None	None	75-80 (77.5)	Runoff, leaching from natural deposits
Radon 222	pCi/L	None	None	930-1600 (1198)	Erosion of natural deposits

Radon samples were last collected in 2001. There is no current requirement to monitor for Radon in drinking water. See below.

FOR INFORMATION on water quality or questions about this report, customers are invited to contact the Placer County Water Agency Customer Services Center at (530) 823-4850 or (800) 464-0030.

Environmental Influences on Drinking Water

The sources of drinking water (both tap and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants that may be present in source water include:

- Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.
- Inorganic contaminants, such as salt and metals, which can be naturally-occurring or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining or farming.
- Pesticides and herbicides, that may come from a variety of sources such as agriculture, urban storm water runoff and residential uses.
- Organic chemical contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm water runoff, agricultural application and septic systems.
- Radioactive contaminants, that can be naturally-occurring or be the result of oil and gas production and mining activities.

Note to At-Risk Water Users

Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. USEPA/Centers for Disease Control (CDC) guidelines on appropriate means to lessen the risk of infection by Cryptosporidium and other microbial contaminants are available from the Safe Drinking Water Hotline at (800) 426-4791.

2011 Testing Results

Measurements reported here were collected in 2011 (unless otherwise noted). In accordance with federal regulations, data is from the most recent tests. We are allowed to monitor for some contaminants less than once per year because concentrations of these contaminants do not change frequently.

Este informe contiene información muy importante sobre su agua potable. Tradúzcalo o hable con alguien que lo entienda bien.

Martis Valley System

About Your Water Supply

Note on Radon

Radon is a radioactive gas that you can't see, smell, or taste. It is found throughout the U.S. Radon can move up through the ground and into a home through cracks and holes in the foundation. Radon can build up to high levels in all types of homes. Radon can also get into indoor air when released from tap water from showering, washing dishes, and other household activites. Compared to radon entering a home through soil, radon entering through tap water will in most cases be a small source of radon in indoor air. Radon is a known human carcinogen. Breathing air containing radon can lead to lung cancer. Drinking water containing radon may also cause increased risk of stomach cancer. If you are concerned about radon in your home, test the air. Testing is inexpensive and easy. Fix your home if the level of radon is 4 pCi/L or higher. There are simple ways to fix a radon problem that aren't too costly.

For additional information, call your State radon program (800-745-7236), the EPA Safe Drinking Water Act Hotline (800-426-4791) or the National Safe Council Radon Hotline (1-800-SOS-RADON).

PLACER COUNTY WATER AGENCY
144 Ferguson Road (P.O. Box 6570)
Auburn, California 95604

Annual Water Quality Report to PCWA Customers *(For 2011)*

Martis Valley Treated Water System

Public Meetings

The Placer County Water Agency Board of Directors meets regularly the first and third Thursdays of each month at 2 p.m. at the Placer County Water Agency Business Center, 144 Ferguson Road, in Auburn.
The public is welcome.

Contacting Your Elected Directors

DISTRICT 1: Gray Allen
DISTRICT 2: Alex Ferreira
DISTRICT 3: Lowell Jarvis
DISTRICT 4 & 2012 Board Chair: Mike Lee
DISTRICT 5 & 2012 Vice Chair: Ben Mavy

If you would like to contact a member of the board, please call the PCWA Customer Service Center at (530) 823-4850 or (800) 464-0030. We will be pleased to put you in touch with the elected representative from your area.

This newsletter is published as a public service of the

PLACER COUNTY WATER AGENCY
144 Ferguson Road (P.O. Box 6570)
Auburn, California 95604

(530) 823-4850 • (800) 464-0030

General Manager: David A. Breninger
Newsletter Editor: Dave Carter

www.pcwa.net

Primary Business Address
Your Address Line 2
Your Address Line 3
Your Address Line 4

Truckee Donner Public Utility District
11570 Donner Pass Road
Truckee, CA 96161

TRUCKEE DONNER Public Utility District

Truckee Donner Public Utility District

2011 Water Quality Report
Truckee Main Water System #2910003

Truckee Donner Public Utility District (TDPUD) vigilantly safeguards its mountain groundwater supplies

Last year, your tap water met all EPA and State drinking water health standards. This brochure is a snapshot of the quality of water provided to customers for the 2011 calendar year. Included in this pamphlet are details about where your water comes from, what it contains, and how it compares to State and USEPA Standards.

TDPUD is committed to providing you with the information about your water supply because customers who are well informed are the District's best allies in supporting improvements that are necessary to maintain the highest drinking water standards.

For More Information

- About this report or the water treatment process, contact Truckee Donner Public Utility District's Senior Water Quality Tech, Paul Rose at (530) 582-3926.
- About a group or class presentation, contact the Truckee Donner Public Utility District at (530) 587-3896.
- About water conservation and efficiency, the TDPUD has new water conservation programs that will help customers save water and save money. Information can be found on the TDPUD's website at www.tdpud.org or by calling (530) 582-3931.

Customer Views Are Welcome

If you are interested in participating in the decision-making process of the Truckee Donner Public Utility District, you are welcome to attend Board meetings. The Board of Directors meet at 6:00 PM on the first and third Wednesday of each month in the TDPUD Board room located at 11570 Donner Pass Road, Truckee, California. Agendas for upcoming meetings may be obtained on our website at www.tdpud.org or from the Deputy District Clerk's office, (530) 582-3909.

Este informe contiene información muy importante sobre su agua potable. Tradúzcalo ó hable con alguien que lo entienda bien.

Where Does Our Water Come From?

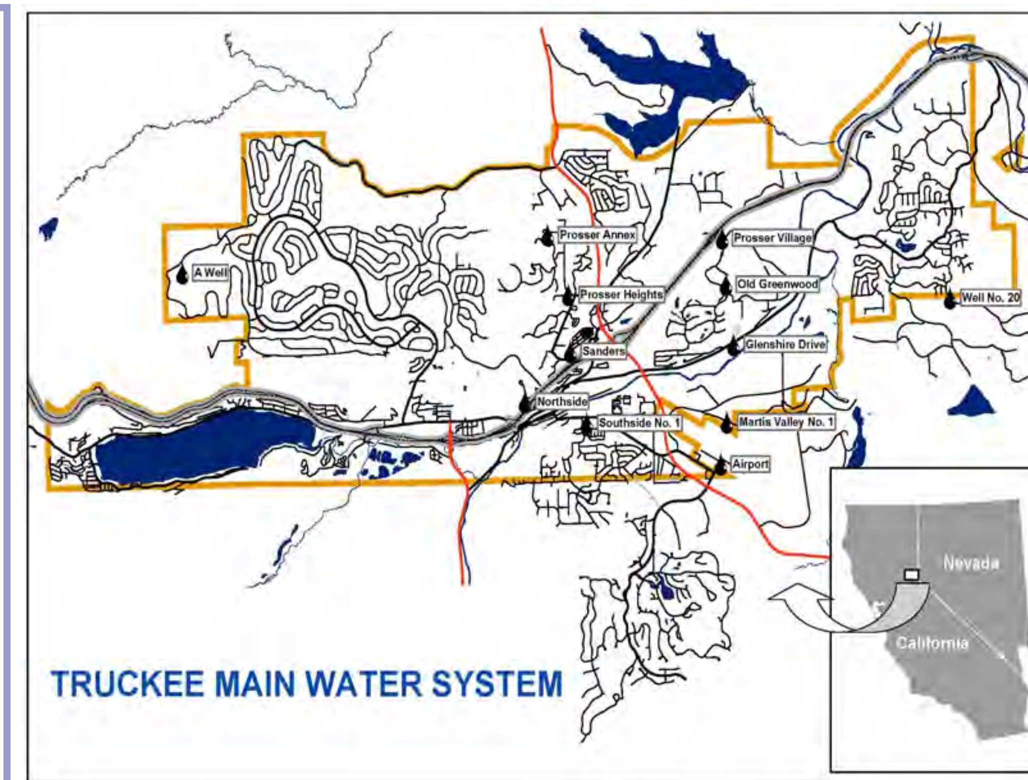
The drinking water served to Truckee Donner Public Utility District customers in the Truckee system is groundwater coming from 12 deep wells.

Each week the system is sampled for microbial quality. Because of natural filtration, the groundwater aquifer is protected from surface contamination. This gives us high quality water.

Source Water Assessment

A source water assessment was prepared in 2002 for the wells serving the Truckee area. The wells are considered most vulnerable to the following activities not associated with any detected contaminants: sewer collection systems, utility stations, railroads, and herbicide use. A copy of the complete assessment may be viewed at the Truckee Donner Public Utility District office located at 11570 Donner Pass Road, Truckee, CA or by calling Mark Thomas at (530) 582-3957.

Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, people who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. USEPA/Centers for Disease Control (CDC) guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline at 1-800-426-4791.



Radon

Radon is a radioactive gas that you cannot see, taste, or smell. It is found throughout the U.S. Radon can move up through the ground and into a home through cracks and holes in the foundation. Radon can build up to high levels in all types of homes. Radon can also get into indoor air when released from tap water from showering, washing dishes, and other household activities. Compared to radon entering the home through soil, radon entering the home through tap water will in most cases be a small source of radon in indoor air. Radon is a known human carcinogen. Breathing air containing radon can lead to lung cancer. Drinking water containing radon may also cause increased risk of stomach cancer. If you are concerned about radon in your home, test the air in your home. Testing is inexpensive and easy. You should pursue radon removal for your home if the level of radon in your air is 4 picocuries per liter of air (pCi/L) or higher. There are simple ways to fix a radon problem that are not too costly. For additional information, call your State radon program (1-800-745-7236), the EPA Safe Drinking Water Hotline (1-800-426-4791), or the National Safety Council Radon Hotline (1-800-SOS-RADON).

Lead

If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. Truckee Donner Public Utility District is responsible for providing high quality water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at http://www.epa.gov/safewater/lead.

No Cryptosporidium or Giardia in District Water

You may have seen or heard news reports about Cryptosporidium and Giardia, microscopic organisms that can enter surface waters from run-off containing animal wastes. If ingested, Cryptospridium and Giardia can cause diarrhea, fever and other gastro-intestinal symptoms. Because the Truckee Donner Public Utility District's water comes from deep wells rather than surface water, it is almost impossible to have these contaminants in the District's water supply.

DETECTED COMPOUNDS

The data presented in this table is from the most recent monitoring done in compliance with regulations. Some data is more than a year old.

Primary Contaminants (PDWS)	MCL	PHG (MCLG)	Airport Well	Northside Well	Martis Valley Well	Southside Well # 2	"A" Well	Glenshire Dr Well	Sanders Well	Prosser Annex Well	Prosser Heights Well	Well 20	Prosser Village Well	Old Greenwood Well	Violation	Major Origins in Drinking Water
Arsenic (ppb)	10	0.004	9.8	N/D	8	N/D	N/D	9.4	8.9	N/D	N/D	N/D	N/D	2.4	NO	Erosion of natural deposits
Fluoride (ppm)	2	1	N/D	0.011	N/D	N/D	N/D	N/D	N/D	0.05	N/D	N/D	0.11	N/D	NO	
Nitrate (asNO_3) (ppm)	45	45	2.9	N/D	1.9	3.7	N/D	2	N/D	N/D	N/D	1.2	2.1	N/D	NO	Leaching of natural deposits, sewage, runoff from fertilizer use.
Nitrite (ppm)	1	1	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.79	NO	
Radionuclides																
Radon (pCi/L)	N/A	N/A	1600	990	N/T	885	540	765	1050	740	N/D	293	560	530	N/A	Erosion of natural deposits
Regulated Contaminants with Secondary MCLs (a) (SDWS)																
Color (ACU)	15	15	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	3	N/D	5	N/D	NO	Natural-occurring organic materials
Odor	3	3	2	1	N/D	1	1	N/D	1	1	1	1	N/D	1	NO	
Iron (ppb)	300	300	N/D	N/D	6	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	NO	Leaching from natural deposits
Chloride (ppm)	500	500	5.5	17	7.1	5.7	N/D	12	53	N/D	N/D	N/D	6.4	2.2	NO	
Copper (ppm)	1	1	N/D	N/D	87	0.04	N/D	N/D	0.28	0.02	N/D	N/D	N/D	N/D	NO	
Manganese (ppb)	50	50	N/D	N/D	6.4	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	26	NO	
Total Dissolved Solids (ppm)	1000	1000	126	170	120	112	68	140	230	112	110	110	108	110	NO	
Sulfate (ppm)	500	500	4.1	8.9	3.5	1.3	N/D	6.7	16	N/D	N/D	N/D	1.4	1.1	NO	
Specific Conductance (µS/cm)	1600	1600	187	241	160	160	107	200	360	166	166	166	180	160	NO	Substances that form ions when in water
pH	N/A	N/A	8.1	8.3	8.1	7.1	7.4	8.3	8	8.1	8.3	8.1	8.2	8	N/A	Leaching of natural deposits
Unregulated General Minerals																
Hardness (ppm)	N/A	N/A	67	77	57	92	44	72	97	41	72	56	55	62	N/A	Leaching of natural deposits
Sodium (ppm)	N/A	N/A	10	32	9.3	4.9	3.5	12	29	15	6.4	12	16	8.5	N/A	

Microbial Contaminants	MCL	TDPUD System Highest Month		
Total Coliform Bacteria	> Than 2 positive samples or more than 5% positive samples per month	0.0 %	NO	Naturally present in the environment

Copper/Lead	AL	MCLG	TDPUD Water System 90th Percentile Value	# of Sites Sampled	# of Sites that Exceeded Action Level		
Copper (ppm)	1.3	0.3	0.074	30	0	NO	Corrosion of household plumbing systems. Flushing prior to use recommended
Lead (ppb)	15	2	2	30	0	NO	

Disinfection Residual	MRDL	MRDLG	Average	Range for TDPUD Water System		
Chlorine (ppm)	4	4	0.35	0.32 - 0.47	NO	Drinking Water Disinfectant added for treatment

Disinfection Byproducts	MCL	PHG (MCLG)	Average	Range for TDPUD Water System	Sample Date		
Total Trihalomethanes (ppb)	80	N/A	3.8	N/D - 6.2	08/04/2011	NO	By-product of drinking water disinfection

Arsenic above 5 ppb up to 10 ppb: While your drinking water meets the current Federal and State standards for arsenic, it does contain low levels of arsenic. The standard balances the current understanding of arsenic's possible health effects against the costs of removing arsenic from drinking water. The USEPA continues to research the health effects of low levels of arsenic, which is a mineral known to cause cancer in humans at high concentrations and is linked to other health effects such as skin damage and circulatory problems.

GENERAL INFORMATION

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants that may be present in source water include:

- ***Microbial contaminants***, such as viruses and bacteria, that may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife.
- ***Inorganic contaminants***, such as salts and metals, that can be naturally-occurring or result from urban storm-water runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming.
- ***Pesticides and herbicides***, that may come from a variety of sources such as agricultural, urban storm-water runoff and residential uses.
- ***Organic chemical contaminants***, including synthetic and volatile organic chemicals, that are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm-water runoff, agricultural application, and septic systems.
- ***Radioactive contaminants***, that can be naturally-occurring or be the result of oil and gas production and mining activities.

In order to ensure that tap water is safe to drink, the U.S. Environmental Protection Agency (USEPA) and the State Department of Public Health (Department) prescribe regulations that limit the amount of certain contaminants in water provided by public water systems. Department regulations also establish limits for contaminants in bottled water that must provide the same protection for public health.

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the USEPA's Safe Drinking Water Hotline at 1-800-426-4791 or at http://water.epa.gov/drink/index.cfm.

TERMS USED IN THIS REPORT

Detected Compounds: The State allows us to monitor for some contaminants less than once per year because the concentrations of these contaminants do not change frequently. Some of our data, though representative, are more than one year old. Not listed are the hundreds of other compounds for which we tested that were not detected.
Regulated Contaminants with Secondary MCLs (a): There are no PHGs, MCLGs, or mandatory standard health effects language for these constituents because secondary MCLs are set on the basis of aesthetics.
Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the PHGs (or MCLGs) as is economically and technologically feasible. Secondary MCLs are set to protect the odor, taste and appearance of drinking water.
Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. Environmental Protection Agency.
Public Health Goal (PHG): The level of a contaminate in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency.
Primary Drinking Water Standards (PDWS): MCLs and MRDLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.
Maximum Residual Disinfectant Level (MRDL): The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
Maximum Residual Disinfectant Level Goal (MRDLG): The level of a drinking water disinfectant below which there is no known or expected risk of health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
Secondary Drinking Water Standards (SDWS): MCLs for contaminants that affect taste, odor, or appearance of the drinking water. Contaminants with SDWSs do not affect the health a the MCL levels.
Regulatory Action Level (AL) : The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.
Radiochemical Parameters—Compounds found in drinking water which emit radiation.
Microbial Parameters—Disease-causing organisms that, at certain levels, may be harmful. Additional information about Cryptosporidium and Giardia is supplied in this report.
Unregulated Compounds Analyzed—Unregulated Compounds Analyzed— Unregulated compounds that the Truckee Donner Public Utility District has tested for. These compounds are not known to be associated with adverse health effects.

N/D– not detectable at testing limit	**pCi/L** (Picocuries per Liter) - A measure of radioactivity.
ppm—Parts per million, or milligrams per liter (mg/L)	**N/T**– not tested
ppb—Parts per billion, or micrograms per liter (ug/L)	**N/A**—Not Applicable
µS/cm—Micro Siemens per centimeter	**ACU** (Apparent Color Unit) - A measure of color in drinking water.
> - Greater than	

TABLE 8 - SAMPLING RESULTS SHOWING TREATMENT OF SURFACE WATER SOURCES	
Treatment Technique [(a)] (Type of approved filtration technology used)	Pall membrane microfiltration with chlorination.
Turbidity Performance Standards [(b)] (that must be met through the water treatment process)	Turbidity of the filtered water must: 1 – Be less than or equal to 0.1 NTU in 95% of measurements in a month. 2 – Not exceed 1.0 NTU for more than eight consecutive hours. 3 – Not exceed 1 NTU at any time.
Lowest monthly percentage of samples that met Turbidity Performance Standard No. 1.	100%
Highest single turbidity measurement during the year	0.018
Number of violations of any surface water treatment requirements	0

(a) A required process intended to reduce the level of a contaminant in drinking water.
(b) Turbidity (measured in NTU) is a measurement of the cloudiness of water and is a good indicator of water quality and filtration performance. Turbidity results which meet performance standards are considered to be in compliance with filtration requirements.

* *Any violation of a TT is marked with an asterisk. Additional information regarding the violation is provided earlier in this report.*

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that the water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the USEPA's Safe Drinking Water Hotline (1-800-426-4791).

Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. USEPA/Centers for Disease Control (CDC) guidelines on appropriate means to lessen the risk of infection by Cryptosporidium and other microbial contaminants are available from the Safe Drinking Water Hotline (1-800-426-4791).

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In 2003, the NCSD conducted a source water assessment on the Big Springs source. The source is considered most vulnerable to the following activities: recreational areas, sewer collection systems, automobile repair shops, chemical/petroleum pipelines, and machine shops. These activities are not associated with any detected contaminants.

In order to ensure that tap water is safe to drink, the USEPA and the State Department of Public Health (Department) prescribe regulations that limit the amount of certain contaminants in water provided by public water systems. Department regulations also establish limits for contaminants in bottled water that provide the same protection for public health.

Contaminants that may be present in source water include:

- *Microbial contaminants,* such as viruses and bacteria, that may come from sewage treatment plants, septic systems, agricultural livestock operations, pets and wildlife.
- *Inorganic contaminants*, such as salts and metals that can be naturally-occurring or result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming.
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If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. The NCSD is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at http://www.epa.gov/safewater/lead.

Northstar Community Services District
908 Northstar Drive
Northstar, Calif. 96161

OUR MISSION STATEMENT: TO PROVIDE OUR SERVICES TO THE NORTHSTAR COMMUNITY IN A HIGH QUALITY, SAFE, EFFICIENT, PROFESSIONAL, AND COURTEOUS MANNER

Northstar Community Services District Annual Water Quality Report

2011

This state-mandated annual report contains important information about the quality of your drinking water.

Dear Customer:

The Northstar Community Services District (NCSD) is proud to provide some of the nation's cleanest drinking water. In 2011, as in years past, our water met or exceeded federal and state standards for drinking water. The State of California mandates that we send this Annual Water Quality Report to you, which includes important information about your drinking water.

The NCSD draws its source water from two locations. The first source is a natural mountain spring located in the mid-mountain region of the Northstar-at-Tahoe Resort. The water is collected in the Big Springs collection system and then treated at the District's state-of-the-art Water Treatment Facility prior to being delivered to the customers' tap. The second source is a well (TH-2) located in the Martis Valley that was developed in 2007 to help meet future water demands as the community continues to expand.

We are committed to delivering the highest quality drinking water, ensuring that our customers receive clean, safe water from their taps.

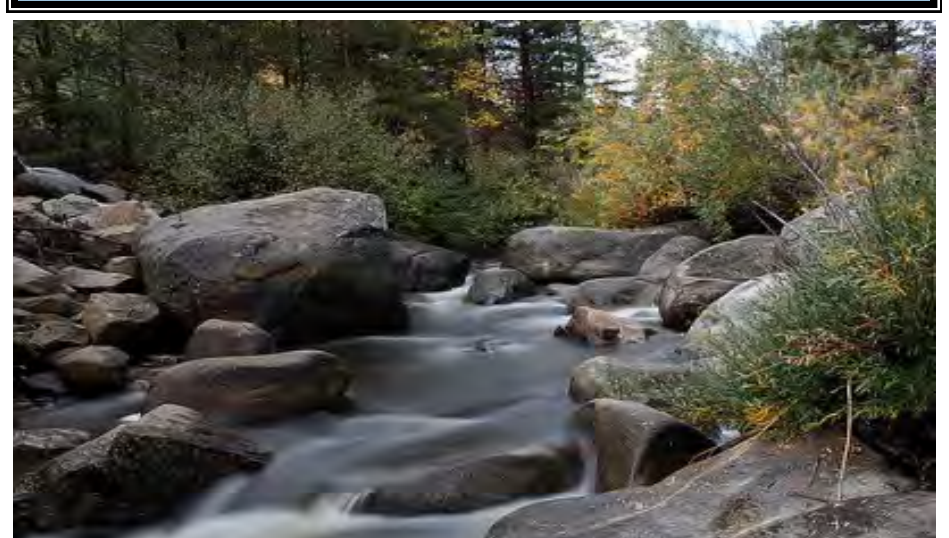
In 2011 the District delivered over 182 million gallons of drinking water through 30 miles of pipeline to over 1,800 residential and commercial services throughout the Northstar community.

Should you have any questions or would like to obtain additional information, please contact the Northstar Community Services District:

Phone: (530) 562-0747
Fax: (530) 562-1505
www.northstarcsd.com

In case of a water or sewer emergency, please call

530-562-0747



KEY WATER QUALITY TERMS

AL—Regulatory Action Level: The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.

MCL—Maximum Contaminant Level: The highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the MCLGs as is economically and technologically feasible. Secondary MCLs are set to protect the odor, taste, and appearance of drinking water.

MCLG—Maximum Contaminant Level Goal: The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. Environmental Protection Agency (USEPA).

MRDL—Maximum Residual Disinfectant Level: The level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap.

ND: Not Detectable at testing limit.

PHG—Public Health Goal: The level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency.

ppm: parts per million or milligrams per liter (mg/L)

ppb: parts per billion or micrograms per liter (µg/L)

TT—Treatment Technique: A required process intended to reduce the level of a contaminant in drinking water.

Want More Information? The NCSD Board of Directors meets regularly each month. Please feel free to participate in these meetings. For meeting dates, times and locations please contact our main office at (530) 562-0747. You may also find more information by visiting our website: www.northstarcsd.org.

Este informe contiene información muy importante sobre su agua potable. Tradúzcalo ó hablcon alguien que lo entienda bien.

NSCD WATER QUALITY TEST RESULTS THROUGH DECEMBER 31, 2011

TABLE 1 - SAMPLING RESULTS FOR COLIFORM BACTERIA

Microbiological Contaminant	Highest No. of detections	No. of months in violation	MCL	MCLG	Typical Source of Bacteria
Total Coliform Bacteria	(In a mo.) 0	0	More than 1 sample in a month with a detection	0	Naturally present in the environment
Fecal Coliform or *E. coli*	(In the year) 0	0	A routine sample and a repeat sample detect total coliform and either sample also detects fecal coliform or *E. coli*	0	Human and animal fecal waste

TABLE 2 - SAMPLING RESULTS FOR LEAD AND COPPER

Lead & Copper (units) Sample Dates	No. of samples collected	90th %tile level detected	No. sites exceeding AL	AL	PHG	Typical Source of Contaminant
Lead (ppb) 2009	20	4.0	0	15	2	Erosion of natural deposits; internal corrosion of household water plumbing; discharges from industrial manufacturers
Copper (ppb) 2009	20	202	0	1300	170	Erosion of natural deposits; internal corrosion of household plumbing; leaching from wood preservatives

TABLE 3 - SAMPLE RESULTS FOR SODIUM AND HARDNESS

Chemical or Constituent (units)	Source	Sample Date	Level Detected	MCL	PHG (MCLG)	Typical Source of Contaminant
Sodium (ppm)	Big Springs Well TH2	2005 2007	5.2 25.3	none	none	Generally found in ground & surface water
Hardness (ppm)	Big Springs Well TH2	2005 2007	51 90	none	none	Generally found in ground & surface water

TABLE 4 - DETECTION OF CONTAMINANTS WITH A PRIMARY DRINKING WATER STANDARD

Chemical or Constituent (units)	Source	Sample Date	Level Detected	MCL	PHG (MCLG)	Typical Source of Contaminant
Nickel (ppb)	Big Springs Well TH2	2005 2007	11 ND	100	12	Erosion of natural deposits; discharge from metal factories

TABLE 5 - DETECTION OF CONTAMINANTS WITH A SECONDARY DRINKING WATER STANDARD

Chemical or Constituent (units)	Source	Sample Date	Level Detected	MCL	PHG (MCLG)	Typical Source of Contaminant
Chloride (ppm)	Big Springs Well TH2	2005 2007	0.3 4.5	500	none	Substances that form ions when in water; seawater influence
Specific Conductance (µS/cm)	Big Springs Well TH2	2005 2007	130 262	1600	none	Substances that form ions when in water; seawater influence
Sulfate (ppm)	Big Springs Well TH2	2005 2007	ND 12.9	50	none	Runoff/leaching from natural deposits; industrial wastes
Total Dissolved Solids (ppm)	Big Springs Well TH2	2005 2007	101 192	1000	none	Runoff/leaching from natural deposits

TABLE 6 - DETECTION OF UNREGULATED CONTAMINANTS

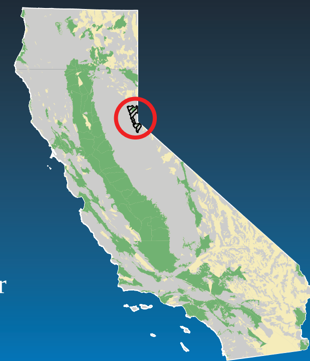
Chemical or Constituent (units)	Source	Sample Date	Level Detected	Notification Level	Typical Source of Contaminant
Vanadium (ppb)	Well TH2	2007	8.0	50	Runoff/leaching from natural deposits

TABLE 7 - DISINFECTANTS & DISINFECTION BYPRODUCTS IN THE DISTRIBUTION SYSTEM

Chemical or Constituent (units)	Sample Date	Level Detected	MCL	MRDL	Typical Source of Contaminant
Chlorine Residual (ppm)	2011	0.81	4.0	4	Water additive used to control microbes
Total Trihalomethanes (ppb)	2011	1.2	80	N/A	By-product of drinking water chlorination
Halocetic Acids (ppb)	2011	ND	60	N/A	By-product of drinking water chlorination

Tables 1, 2, 3, 4, and 5 list all of the drinking water contaminants that were detected during the most recent sampling for the constituent. The presence of these contaminants in the water does not necessarily indicate that the water poses a health risk. The Department allows us to monitor for certain contaminants less than once per year because the concentrations of these contaminants do not change frequently. Some of the data, though representative of the water quality, are more than one year old.

U.S. Geological Survey and the California State Water Resources Control Board



Groundwater Quality in the Tahoe and Martis Basins, California

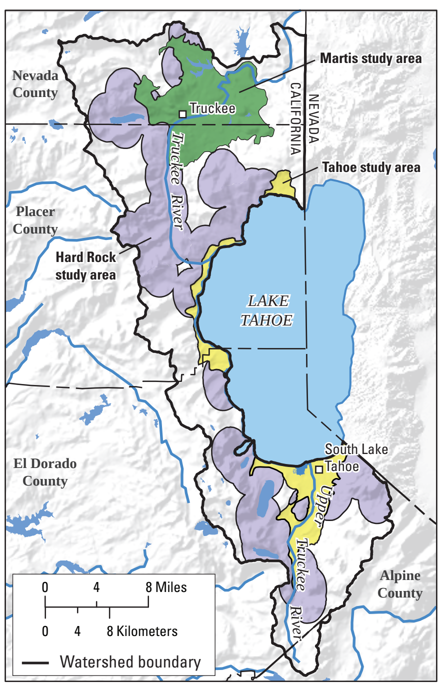
Groundwater provides more than 40 percent of California's drinking water. To protect this vital resource, the State of California created the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The Priority Basin Project of the GAMA Program provides a comprehensive assessment of the State's groundwater quality and increases public access to groundwater-quality information. The Tahoe and Martis Basins and surrounding watersheds constitute one of the study units being evaluated.

The Tahoe-Martis Study Unit

The Tahoe-Martis study unit is approximately 460 square miles and includes the groundwater basins on the south, north, and west shores of Lake Tahoe, and the Martis Valley groundwater basin (California Department of Water Resources, 2003). The study unit was divided into three study areas based primarily on geography: the Tahoe study area composed of the three Tahoe Valley basins, the Martis study area, and the Hard Rock study area composed of the parts of the watersheds surrounding the basins (Fram and others, 2009).

The primary aquifers in the Tahoe study area consist of glacial outwash sediments (mixtures of sand, silt, clay, gravel, cobbles, and boulders), interbedded with lake sediments. The primary aquifers in the Martis study area are interbedded volcanic lavas, volcanic sediments, and glacial outwash sediments. In the Hard Rock study area, groundwater is present in fractured granitic rocks in the south and fractured volcanic rocks in the north. Aquifers composed of different materials commonly contain groundwater with different chemical compositions.

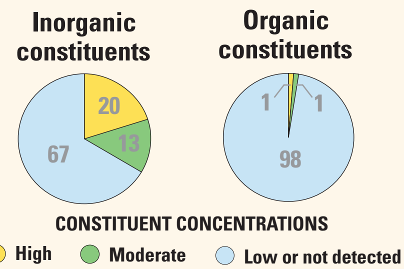
The primary aquifers in the study unit are defined as those parts of the aquifers corresponding to the screened or open intervals of wells listed in the California Department of Public Health database. In the Tahoe study area, these wells typically are drilled to depths between 175 and 375 feet, consist of solid casing from land surface to a depth of about 75 to 125 feet, and are screened or open below the solid casing. In the Martis study area, these wells typically are 200 to 900 feet deep, and are screened or open below 75 to 300 feet. Water quality in the shallower and deeper parts of the aquifer system may differ from that in the primary aquifers.The Hard Rock study area includes wells and developed springs.



The Tahoe-Martis study unit has warm, dry summers and cold, wet winters. Average annual precipitation ranges from 30 inches at Lake Tahoe to 80 inches in the surrounding mountains, and the majority of precipitation falls as snow. Land use in the study unit is approximately 88 percent (%) undeveloped (forests, grasslands, and bare rock), and 12% urban. The undeveloped lands are used mostly for recreation. The largest urban areas are the cities of South Lake Tahoe and Truckee.

Municipal and community water supply accounts for nearly all of the total water use in the study unit, with most of the remainder used for recreation, including landscape irrigation and snow-making. Groundwater provides nearly all of the water supply in the study unit, with limited use of surface water in some areas. Recharge to the groundwater flow system is mainly from mountain-front recharge at the margins of the basins, stream-channel infiltration, and direct infiltration of precipitation. Groundwater leaves the aquifer system when it is pumped for water supply or flows into streams and lakes.

Overview of Water Quality



Values are a percentage of the area of the primary aquifers with concentrations in the three specified categories. Values on pie chart may not equal 100 due to rounding of percentages.

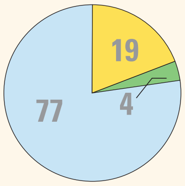
GAMA's Priority Basin Project evaluates the quality of untreated groundwater. However, for context, benchmarks established for drinking-water quality are used for comparison. Benchmarks and definitions of *high*, *moderate*, and *low* concentrations are discussed in the inset box on page 3.

Many inorganic constituents occur naturally in groundwater. The concentrations of the inorganic constituents can be affected by natural processes as well as by human activities. In the Tahoe-Martis study unit, one or more inorganic constituents were present at high concentrations in about 20% of the primary aquifers and at moderate concentrations in 13%.

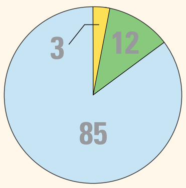
Human-made organic constituents are found in products used in the home, business, industry, and agriculture. Organic constituents can enter the environment through normal usage, spills, or improper disposal. In this study unit, one or more organic constituents were present at high concentrations in about 1% of the primary aquifers and at moderate concentrations in about 1%.

RESULTS: Groundwater Quality in the Tahoe-Martis Study Unit

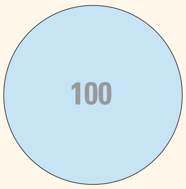
INORGANIC CONSTITUENTS



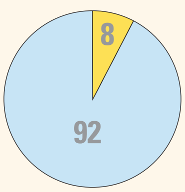
Trace elements



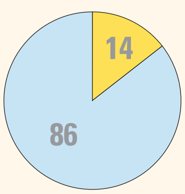
Radioactive constituents



Nutrients

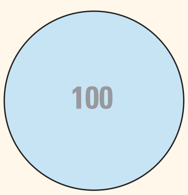


Total dissolved solids



Manganese

SPECIAL-INTEREST CONSTITUENTS



Perchlorate

Inorganic Constituents with Human-Health Benchmarks

Trace and minor elements are naturally present in the minerals in rocks and soils, and in the water that comes into contact with those materials. In the Tahoe-Martis study unit, trace elements were present at high concentrations in about 19% of the primary aquifers, and in moderate concentrations in about 4%. Arsenic was the trace element that most frequently occurred at high and moderate concentrations. Three trace elements with non-regulatory health-based benchmarks, boron, molybdenum, and strontium, also were detected at high concentrations.

Radioactivity is the emission of energy or particles during spontaneous decay of unstable atoms. Humans are exposed to small amounts of natural radioactivity every day. Most of the radioactivity in groundwater comes from decay of naturally occurring uranium and thorium in minerals in the rocks or sediments of the aquifers. Radioactive constituents occurred at high levels in about 3% of the primary aquifers, and at moderate levels in about 12%. Gross alpha particle and radon-222 activities were the radioactive constituents that most frequently occurred at high and moderate levels.

Nutrients, such as nitrogen, are naturally present at low concentrations in groundwater. High and moderate concentrations generally occur as a result of human activities. Common sources of nutrients include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. In the Tahoe-Martis study unit, nutrients were not detected at high or moderate concentrations in the primary aquifers.

Inorganic Constituents with Non-Health Benchmarks

(Not included in water-quality overview charts shown on the front page)

Some constituents affect the aesthetic properties of water, such as taste, color, and odor, or may create nuisance problems, such as staining and scaling. The State of California has a recommended and an upper limit for total dissolved solids (TDS). All water naturally contains TDS as a result of the weathering and dissolution of minerals in soils and rocks. Iron and manganese are naturally occurring constituents that commonly occur together in groundwater. Anoxic conditions in groundwater (low amounts of dissolved oxygen) may result in release of manganese and iron from minerals into groundwater.

In the Tahoe-Martis study unit, TDS was present at high concentrations (greater than the upper limit) in about 8% of the primary aquifers, and at low concentrations (less than the recommended limit) in about 92% of the primary aquifers. Manganese, with or without iron, was present at high concentrations in about 14% of the primary aquifers.

Perchlorate

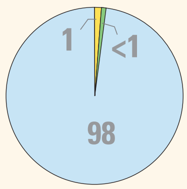
(Not included in water-quality overview charts shown on the front page)

Perchlorate is an inorganic constituent that has been regulated in California drinking water since 2007. It is an ingredient in rocket fuel, fireworks, safety flares, and other products, may be present in some fertilizers, and occurs naturally at low concentrations in groundwater. Perchlorate was not detected in the primary aquifers.

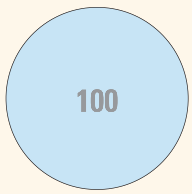
RESULTS: Groundwater Quality in the Tahoe-Martis Study Unit

ORGANIC CONSTITUENTS

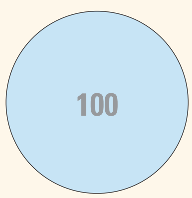
Solvents



Other volatile organic compounds



Pesticides



Organic Constituents

The Priority Basin Project uses laboratory methods that can detect the presence of low concentrations of volatile organic compounds (VOCs) and pesticides, far below human-health benchmarks. VOCs and pesticides detected at these low concentrations can be used to help trace water from the landscape into the aquifer system.

Volatile Organic Compounds with Human-Health Benchmarks

VOCs are in many household, commercial, industrial, and agricultural products, and are characterized by their tendency to volatilize (evaporate) into the air.

Solvents are used for a number of purposes, including manufacturing and cleaning. In the Tahoe-Martis study unit, solvents were present at high concentrations in about 1% of the primary aquifers. The solvent detected at high concentrations was tetrachloroethylene (PCE), which mainly was used in dry-cleaning businesses. Solvents were present at moderate concentrations in about 1% of the primary aquifers, and at low concentrations (or not detected) in about 98%.

Other VOCs include trihalomethanes, gasoline additives and oxygenates, refrigerants, and organic synthesis reagents. Trihalomethanes form during disinfection of water supplies, and may enter groundwater by the infiltration of landscape irrigation water, or leakage from distribution lines. Gasoline additives and oxygenates increase the efficiency of fuel combustion. Other VOCs were not detected at high or moderate concentrations in the primary aquifers. Trihalomethanes and gasoline oxygenates were detected at low concentrations in the primary aquifers.

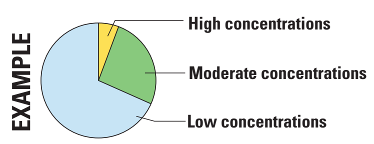
Pesticides with Human-Health Benchmarks

Pesticides, including herbicides, insecticides, fungicides, and fumigants, are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation (weeds), insects, fungi, and other pests. In the Tahoe-Martis study unit, pesticides were not detected at high or moderate concentrations in the primary aquifers. Herbicides were occasionally detected at low concentrations.

BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

GAMA's Priority Basin Project uses benchmarks established for drinking water to provide context for evaluating the quality of untreated groundwater. After withdrawal, groundwater may be disinfected, filtered, mixed, and exposed to the atmosphere before being delivered to consumers. Federal and California regulatory benchmarks for protecting human health (Maximum Contaminant Level, MCL) were used when available. Nonregulatory benchmarks for protecting aesthetic properties, such as taste and odor (Secondary Maximum Contaminant Level, SMCL), and nonregulatory benchmarks for protecting human health (Notification Level, NL, and Lifetime Health Advisory, HAL) were used when Federal or California regulatory benchmarks were not available.

CONSTITUENT CONCENTRATIONS



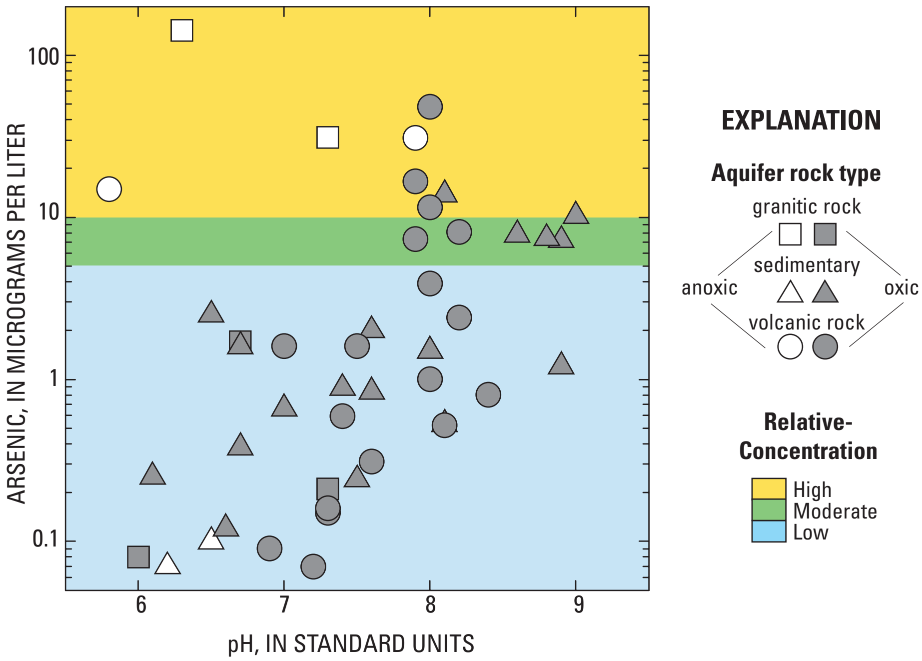
Values are a percentage of the area of the primary aquifers with concentrations in the three specified categories. Values on pie chart may not equal 100 due to rounding of percentages.

High, moderate, and low concentrations are defined relative to benchmarks

Concentrations are considered *high* if they are greater than a benchmark. For inorganic constituents, concentrations are *moderate* if they are greater than one-half of a benchmark. For organic constituents and perchlorate, concentrations are *moderate* if they are greater than one-tenth of a benchmark; this lower threshold was used because organic constituents are generally less prevalent and have smaller concentrations relative to benchmarks than inorganic constituents. *Low* values include nondetections and values less than moderate concentrations. Methods for evaluating water quality are discussed in Fram and Belitz (2012).

Factors that Affect Groundwater Quality

In the Tahoe-Martis study unit, arsenic was the constituent that most frequently occurred at high concentrations. About 18% of the primary aquifers had arsenic concentrations greater than the human-health regulatory benchmark Federal MCL) of 10 μg/L (micrograms per liter). Natural sources of arsenic to groundwater include dissolution of arsenic-bearing sulfide minerals, desorption of arsenic from the surfaces of manganese- or iron-oxide minerals (or dissolution of those oxide minerals), and mixing with geothermal waters (Welch and others, 2000).



In the Tahoe-Martis study unit, elevated arsenic concentrations likely are caused by two different processes (Fram and Belitz, 2012). In aquifers composed of sediments or volcanic rocks, high and moderate arsenic concentrations were found in groundwater that was oxic (high dissolved oxygen concentration) and alkaline (pH values greater than about 8). The elevated arsenic concentration in oxic, alkaline groundwater likely is due to desorption of arsenic from the surfaces of manganese- and iron-oxide minerals (Smedley and Kinniburgh, 2002). Oxic, alkaline conditions increase arsenic solubility in groundwater by inhibiting arsenic from adhering to mineral surfaces (sorption). In aquifers composed of granitic and volcanic rocks, high arsenic concentrations also were found in anoxic (low dissolved oxygen concentration) groundwater with low pH values. Dissolution of manganese- and iron-oxide minerals under anoxic conditions likely results in release of arsenic associated with these minerals.

By Miranda S. Fram and Kenneth Belitz

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Fram, M.S., Munday, Cathy, and Belitz, Kenneth, 2009, Groundwater quality data for the Tahoe-Martis study unit, 2007—Results from the California GAMA Program: U.S. Geological Survey Data Series 432, 87 p. (Also available at http://pubs.usgs.gov/ds/432/.)

Fram, M.S., and Belitz, Kenneth, 2012, Status and understanding of groundwater quality in the Tahoe-Martis, Central Sierra, and Southern Sierra study units,2006–2007—California GAMA Program Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2011-5216, 222 p. (Also available at http://pubs.usgs.gov/sir/2011/5216.)

Smedley, P.L., and Kinniburgh, D.G., 2002, A review of the source, behavior, and distribution of arsenic in natural waters: Applied Geochemistry, v. 17, p. 517–568.

Welch, A.H., Westjohn, D.B., Helsel, D.R., and Wanty, R.B., 2000, Arsenic in ground water of the United States—occurrence and geochemistry: Ground Water, v. 38, no. 4, p. 589–604.

Priority Basin Assessments

GAMA's Priority Basin Project (PBP) assesses water quality in that part of the aquifer system used for drinking water, primarily public supply. Water quality in the primary aquifers, assessed by the PBP, may differ from that in the deeper parts of the aquifer, or from the shallower parts, which are being assessed by GAMA's Domestic Well Project. Ongoing assessments are being conducted in more than 120 basins throughout California.

The PBP assessments are based on a comparison of constituent concentrations in untreated groundwater with benchmarks established for protection of human health and for aesthetic concerns. The PBP does not evaluate the quality of drinking water delivered to consumers.

The PBP uses two scientific approaches for assessing groundwater quality. The first approach uses a network of wells to statistically assess the status of groundwater quality. The second approach combines water-quality, hydrologic, geographic, and other data to help assess the factors that affect water quality. In the Tahoe-Martis study unit, data were collected by the PBP in 2007, and from the CDPH database for 2004–2007. The PBP includes chemical analyses generally not available as part of regulatory compliance monitoring, including measurements at concentrations much lower than human-health benchmarks, and measurement of constituents that can be used to trace the sources and movement of groundwater.

For more information

Technical reports and hydrologic data collected for the GAMA PBP Program may be obtained from:

GAMA Project Chief
U.S. Geological Survey
California Water Science Center
4165 Spruance Road, Suite 200
San Diego, CA 92101
Telephone number: (619) 225-6100
WEB: http://ca.water.usgs.gov/gama

GAMA Program Unit
State Water Resources Control Board
Division of Water Quality
PO Box 2231, Sacramento, CA 95812
Telephone number: (916) 341-5779
WEB: http://www.waterboards.ca.gov/gama

Appendix F: DRI Technical Note

Technical Note

To: Tony Firenzi, Placer County Water Agency; Tina Bauer, Brown and Caldwell

From: Seshadri Rajagopal, Donald M. Reeves, Justin Huntington, Greg Pohll (Desert Research Institute)

Date: September 10, 2012

Re: Estimates of Ground Water Recharge in the Martis Valley Ground Water Basin

Purpose and Scope

This technical note provides spatially-distributed estimates of annual ground water recharge in the Martis Valley Ground Water Basin using a physically-based hydrologic model: Precipitation Runoff Modeling System (PRMS). PRMS simulates land surface hydrologic processes of evapotranspiration, runoff, infiltration, and interflow by balancing energy and mass budgets of the plant canopy, snowpack, and soil zone on the basis of distributed climate information (Leavesley et al., 1983), and has been used in several other basins to estimate ground water recharge (e.g., Lichty and McKinley, 1995; Vaccaro and Olsen, 2007; Cherkauer and Ansari, 2005; Cherkauer, 2004). Recharge in the current study is defined as the infiltration of water to the subsurface beyond the root zone (where present) or the soil zone, in case of bare soil absent of vegetation (Figure 1). Thus, the recharge estimates contained within this report represent total annual recharge within the delineated Martis Valley Ground Water Basin. The Martis Valley Ground Water Basin was first delineated by Hydro-Search, Inc. and was later adopted by the California DWR as the official ground water basin. In this report we refer to this region as the HSI ground water basin or Martis Valley Ground Water Basin (Figure 2). Total recharge consists of both recharge to the deep ground water system and shallow recharge that ultimately discharges into streams. The technical note describes the use of climate data in PRMS, the PRMS method used to compute recharge, and recharge estimates. Recharge estimates from previous studies and an additional method are provided to place the PRMS computed results in the context of other estimates.

Previous Estimates of Recharge for Martis Valley

Past studies primarily relied on empirical and water balance methods to estimate recharge within the Martis Valley Ground Water Basin (Figure 2). One of the earliest recharge studies was conducted by Hydro-Search, Inc. (1974) which was subsequently updated in 1980 and 1995. Hydro-Search Inc. (HSI) utilized a water balance method to estimate ground water recharge to the Martis Valley Ground Water Basin of approximately 18,000 ac-ft/yr. In 2001 Nimbus Engineers used a water balance approach to compute a recharge value of 24,700 ac-ft/yr to the ground water basin. Kennedy/Jenks Consultants in 2001 published a report titled “Independent Appraisal of Martis Valley Ground Water Availability, Nevada and Placer Counties, California” where they concluded that the earlier studies by Hydro-Search, Inc (1974 and updates) and Nimbus Engineers (2001) were conservative, as the total amount of ground water discharge to streams was considered under predicted; however, updated recharge estimates were not provided in this report. Interflow Hydrology, Inc. and Cordilleran Hydrology, Inc. prepared a 2003 report indicating that ground water discharge to tributary Truckee River streams in the Martis Valley Ground Water Basin is 34,560 ac-ft/yr, of which approximately 24,240 ac-ft/yr is contributed by high altitude areas of the basin (e.g., in the vicinity of Northstar) and the remaining 10,320 ac-ft/yr occurs in lower elevation areas. In summary, previous recharge estimates based on water balance approaches range from 18,000 to 34,560 ac-ft/yr.

Description of PRMS Recharge Method

The PRMS model (Leavesley et al., 1983) is driven by daily values of precipitation and maximum and minimum air temperature, and simulates snow accumulation, ablation, canopy interception, evapotranspiration, surface runoff, infiltration, water storage in the soil zone and deep percolation through the bottom of the root or soil zone – PRMS recharge is defined as the model computed excess water leaving the root or soil zone after abstractions for surface runoff and evapotranspiration are accounted for (Figure 1). The system is modeled in its natural transient state from 1981 to 2011. Reservoir operations, irrigation within the basin, septic drainfields, and diversion of effluent to the Truckee Tahoe Sanitation Agency and subsequent release of treated effluent to the Truckee River are not explicitly simulated in the model. However, the Martis Valley PRMS model utilizes naturalized flows that remove the effects of reservoir operations during model calibration.

The current PRMS model developed for Martis Valley encompasses the entire Martis Valley hydrologic basin (Figure 2), and is subdivided into 14 watersheds for model calibration to internal stream gauges. Computation of recharge for the Martis Valley Ground Water Basin requires aggregation of the PRMS results for all cells within the delineated ground water basin (Figure 3). The model domain was discretized into square grid cells of 300 m resolution; each of these cells represents a hydrologic response unit (HRU). The model is parameterized from the National Elevation Dataset (NED), STATSGO soils database, and USGS land use land cover (LULC) dataset. The depth of the root or soil zone is determined by the LULC of the HRU. Five categories of LULC are used to assign these depths viz. bare soils, grasses, shrubs, trees, and water. For the category water, recharge is assumed zero.

Daily weather data from the Truckee #2 SNOTEL site is used to drive the PRMS model. This station is used to develop monthly ratios based on PRISM maps to distribute precipitation over the entire basin. To account for days when temperature inversions within the valley occur, an additional weather station, Mt. Rose SNOTEL, is implemented.

PRMS Recharge Estimates

The estimated mean annual ground water recharge for the Martis Valley Ground Water Basin computed from PRMS is presented in Figure 4. PRMS simulated recharge varies from year to year based on annual cycles of precipitation (Figure 5). The annual average recharge estimate from the PRMS model is 32,745 ac-ft, which is slightly lower than the Interflow Hydrology 2003 estimate of 34,560 ac-ft.

We also applied a modified Maxey-Eakin (1949) method to estimate recharge which relates mean annual precipitation to recharge using recharge coefficients applied to precipitation amounts (Figure 3) (Epstein et al., 2010). Epstein et al., 2010 computed revised Maxey-Eakin coefficients that are based on the PRISM precipitation distribution (Daly et al., 1994), which was used in this study. As shown in Figure 3, the modified Maxey-Eakin estimate of 35,168 ac-ft/yr is very close to the Interflow Hydrology estimate. Figure 6 shows the ratio of recharge computed by the PRMS model to annual precipitation. This ratio, which we term as 'recharge efficiency', can be used to describe the fraction (or percentage) of precipitation that is converted to recharge. Computed recharge efficiencies for the Martis Valley ground water basin varies annually within a range of 18-26%.

Discussion of Recharge Estimates

PRMS computed recharge presented in Figures 4, 6 and 8 show that recharge to the Martis Valley Ground Water Basin varies both spatially and temporally. The spatial variability in recharge is primarily driven by precipitation trends (Figures 7 and 8). This is clearly observed in Figure 7 where the higher elevation areas, in general, receive greater amounts of precipitation than the rest of the basin. Note that the PRMS recharge shown in Figure 8 represents infiltrated water given the processes presented in Figure 1. The PRMS model neglects the influence of low permeable bedrock areas on the potential reduced rate of infiltration of precipitation. For example, the highest infiltration rates correspond to areas with the most precipitation. In reality, the highest elevation areas within the basin that receive the greatest amount of precipitation are located in the low-permeability mountain block. The low-permeability of the mountain block restricts the amount of infiltrating water, and forces water to redistribute as run-off and infiltrate downslope near the 'bench' areas of the slope with deposits of higher permeability alluvium. This redistribution has been simulated in integrated models (e.g., Huntington et al. 2012, in press) and inferred from ground water isotopes (Singleton et al., 2010). Thus, the spatial distribution of recharge, as shown in Figure 8, will change once the PRMS modeled recharge is combined with MODFLOW. This spatial redistribution will primarily change the pattern of recharge in the mountain block watersheds with only minimal changes to the lower elevation areas, and minimal changes in the total volume of recharge.

Previous recharge estimates by Interflow Hydrology (34,560 ac-ft/yr), the Maxey-Eakin method (35,168 ac-ft/yr), and mean annual PRMS (32,745 ac-ft/yr) estimates are very similar and in agreement. Only the PRMS estimates provide insight as to annual variability in recharge with a range between 12,143 and 56,792 ac-ft/yr (Figure 4). These fluctuations in annual ground water recharge estimates are natural and primarily based on fluctuations in annual precipitation (Figure 5). Perhaps most importantly are the water years when the amount of recharge is lower than the mean (~33,000 ac-ft). As shown in Figure 4, this variability can be significant with 'wet' and 'dry' year-end members. Pumpage during dry years may deplete the ground water basin as water is extracted from storage, whereas wet years increase the storage of water in the basin. If the number of wet and dry years and the amount of recharge oscillates evenly, then the mean recharge estimates from Interflow, modified Maxey-Eakin and PRMS methods are suitable for mean annual water budget analysis. However, future changes in temperature and/or precipitation (both timing and annual quantity) can disrupt the balance between pumping and basin storage.

The PRMS computed recharge consists of the sum of shallow infiltrated water that discharges into the Truckee River and its tributaries as well as deep percolation of ground water to deeper aquifers with water supply wells. Perennial basin yield, defined by the State of Nevada as the maximum amount of groundwater that can be salvaged each year over the long term without depleting the ground water reservoir, is not an appropriate metric to determine sustainable basin pumpage as values of perennial yield for a basin are usually limited to the maximum amount of natural discharge. Natural discharge from Martis Valley Basin consists of groundwater evapotranspiration, groundwater discharge to the Truckee River, along with a small quantity of groundwater outflow. As an alternative, we suggest that an analysis that utilizes the Martis Valley ground water model to define the 'capturable' amount of streamflow by pumping within the basin (e.g., Leake and Haney, 2010) would better quantify the relationship between sustainable pumpage and natural discharge.

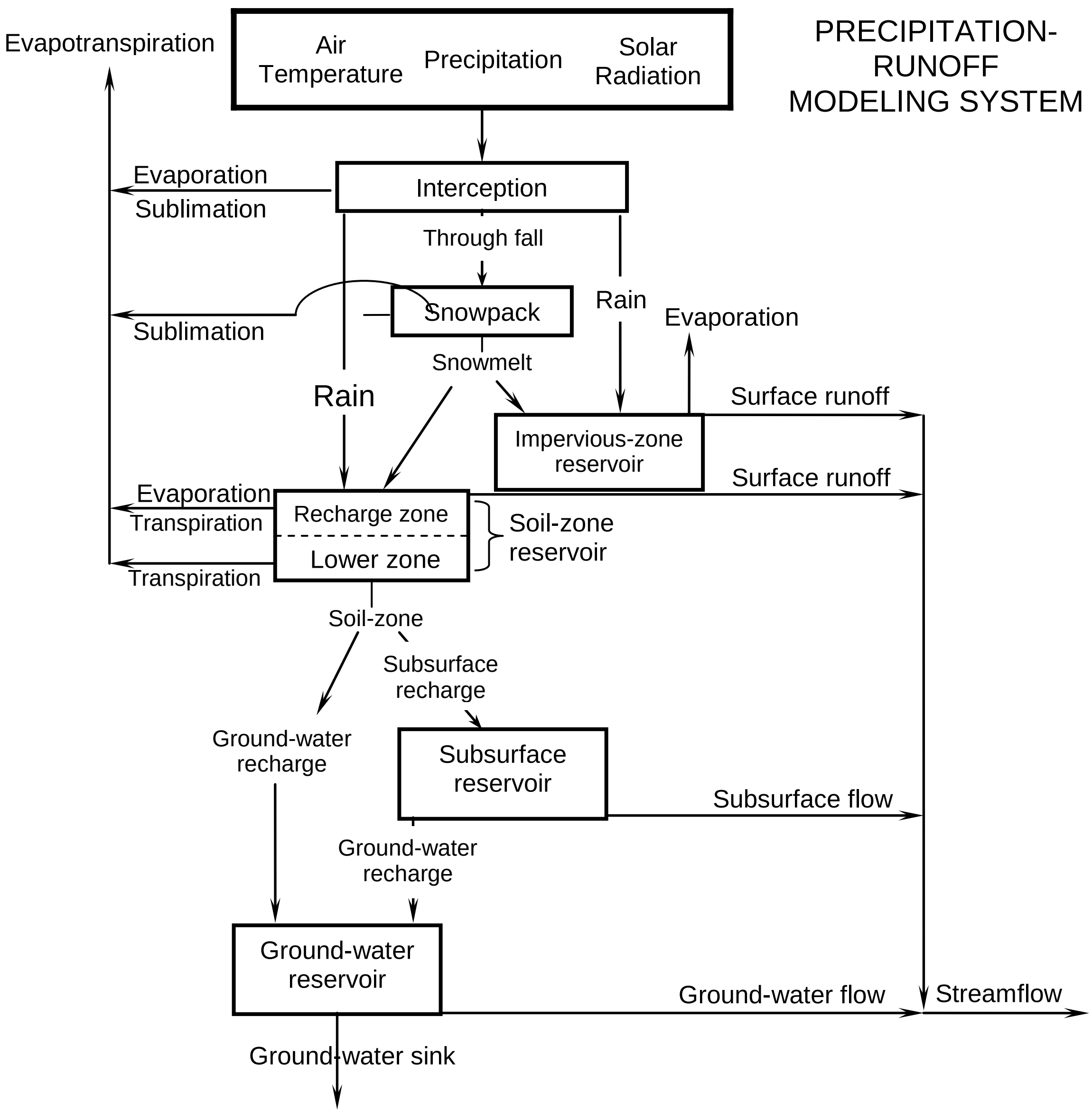

Figure 1. PRMS conceptual model schematic highlighting all simulated hydrologic processes and how ground water recharge is computed in the model (based on Leavesley et al., 1983).

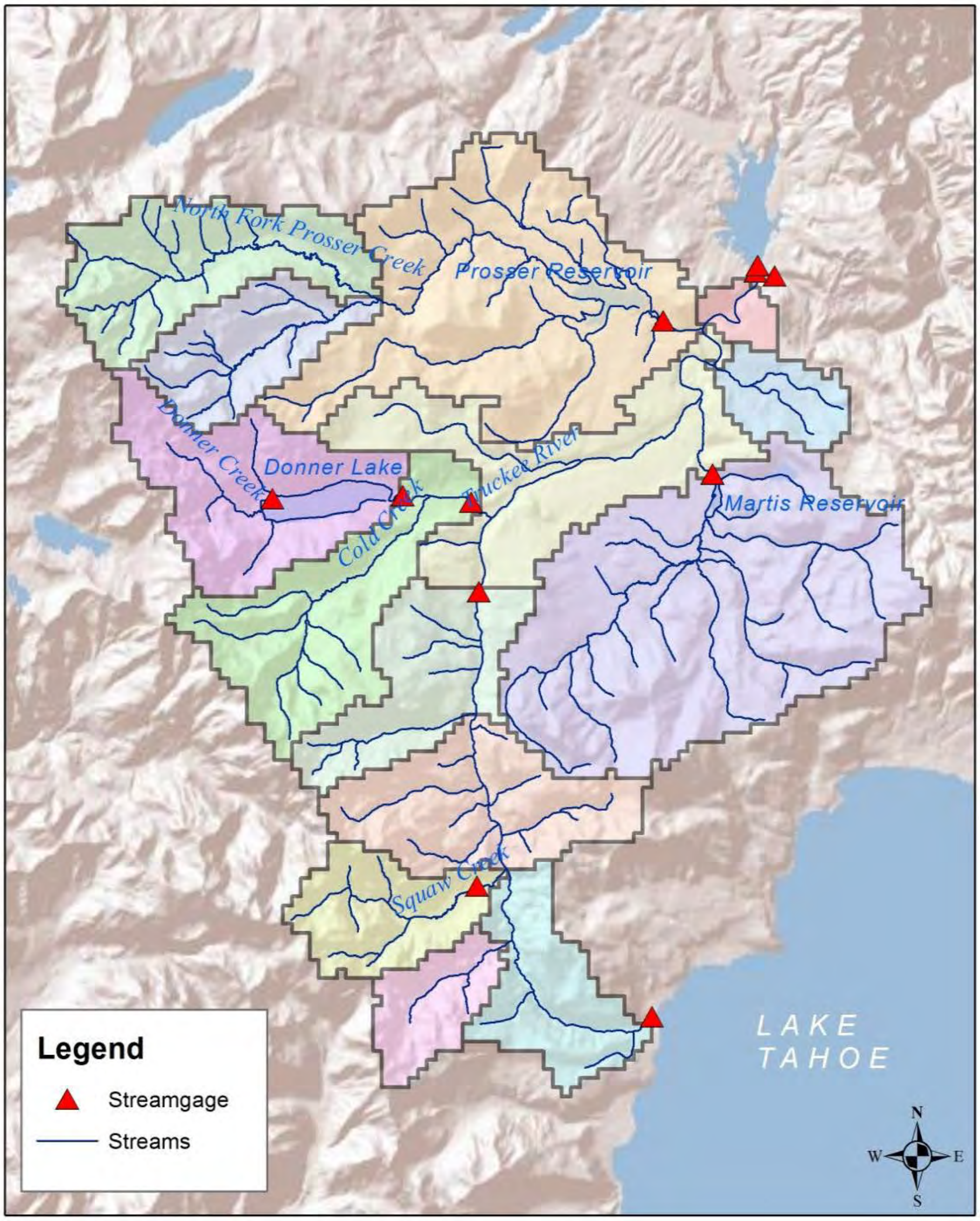

Figure 2. PRMS model domain with 14 sub-watersheds denoted by color. Stream gauges used in the PRMS calibration are denoted by triangles.

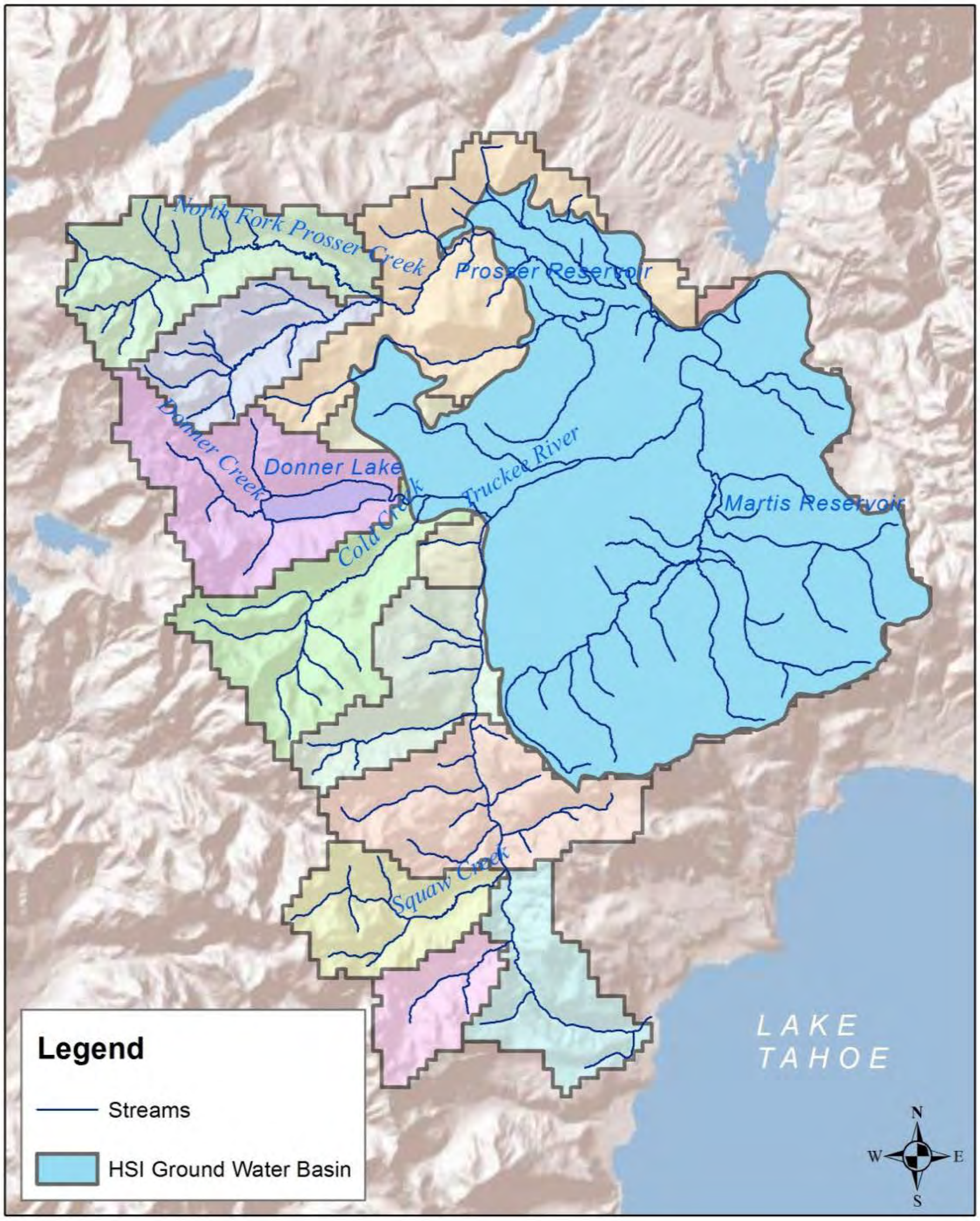

Figure 3. PRMS model domain with a portion of the sub-watersheds combined to adhere to the delineated Martis Valley Ground Water Basin inset (blue). All recharge estimates in this study are computed over the blue area. The Martis Valley Ground Water Basin area was delineated by Hydro Search Inc. (HSI).

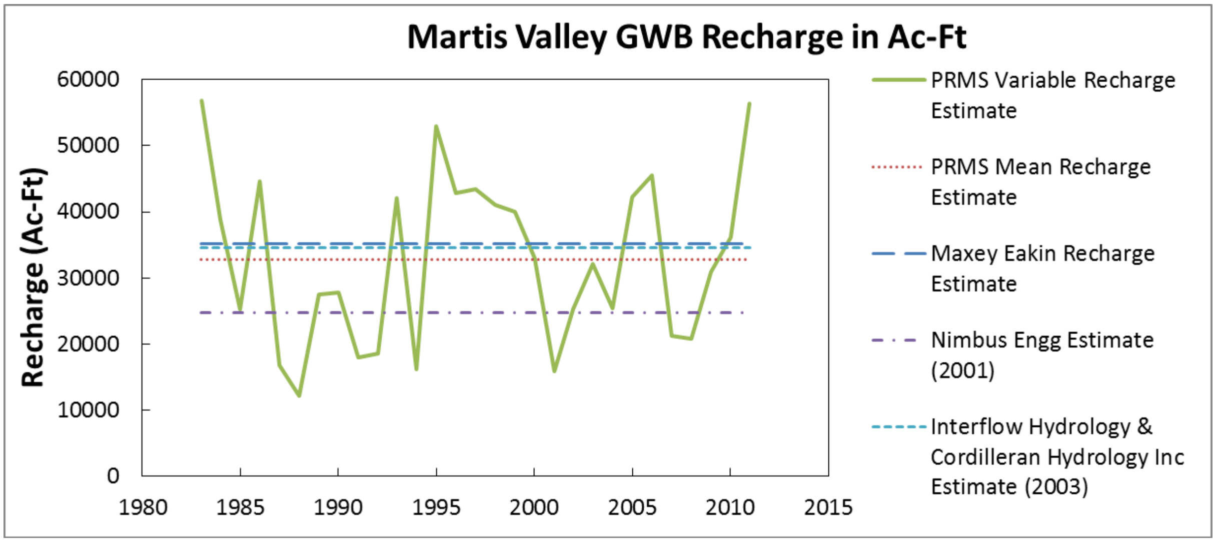

Figure 4. Annual recharge volumes computed by PRMS with comparison to recharge estimates from other methods and past studies.

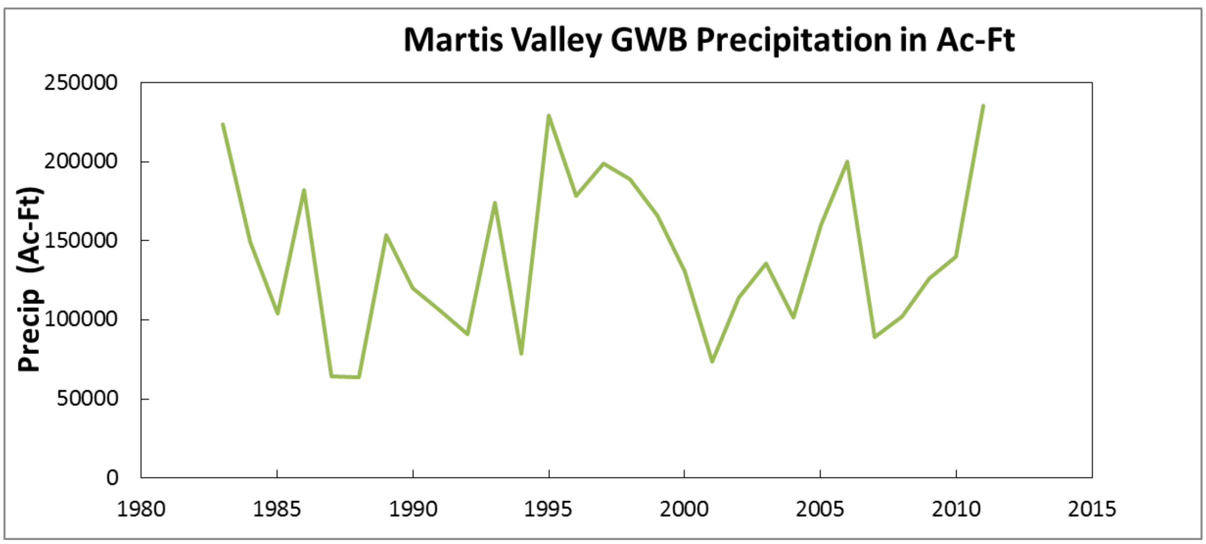

Figure 5. Annual precipitation volume over the Martis Valley Ground Water Basin

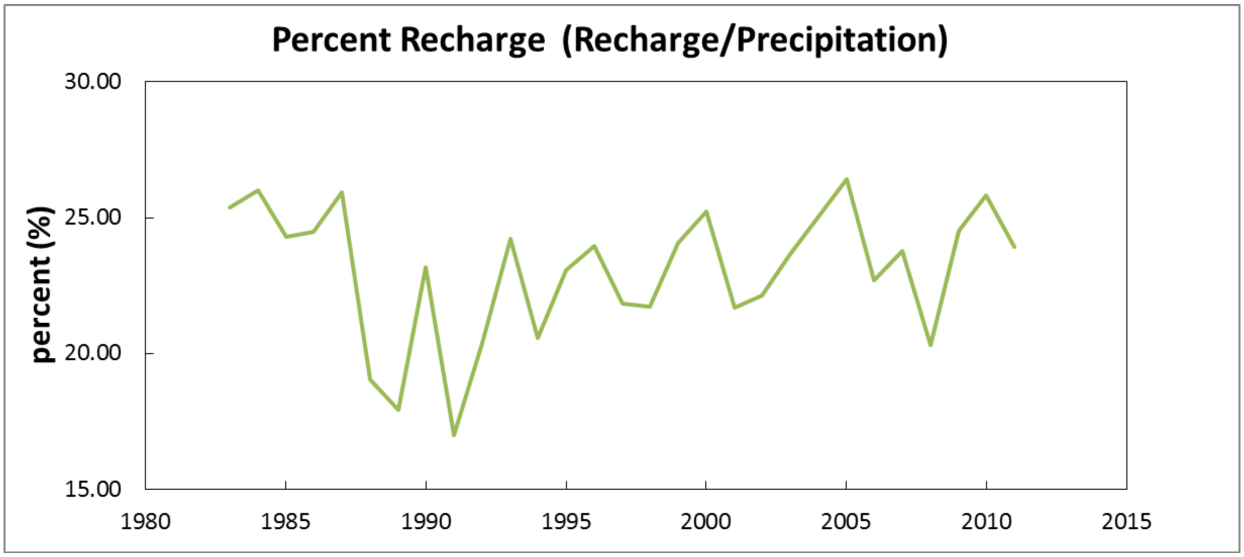

Figure 6. Value of recharge efficiency computed as the ratio of annual recharge to annual precipitation. The mean recharge efficiency value is 23%.

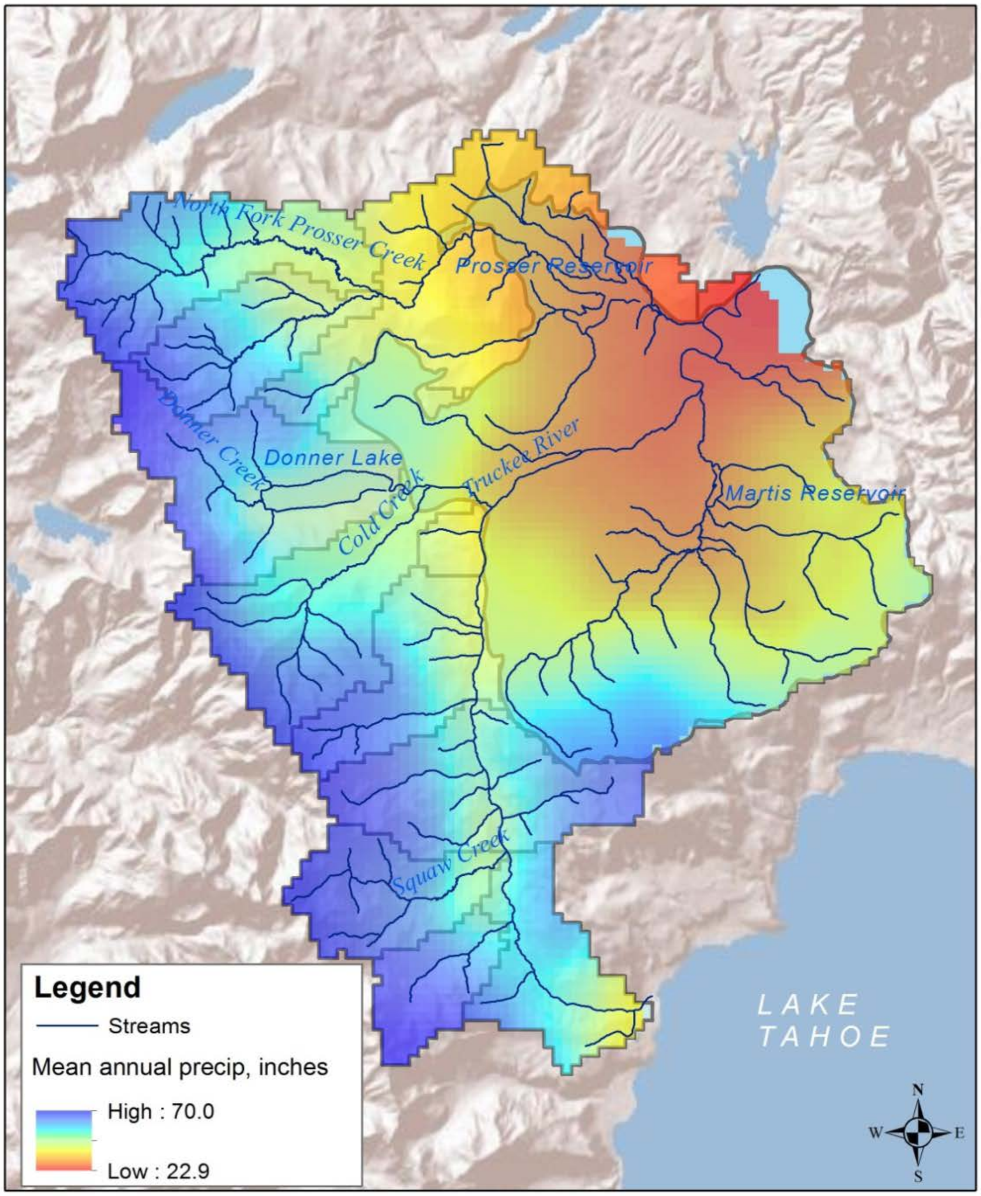

Figure 7. Mean annual precipitation (inches) in the Martis Valley PRMS model domain from PRISM (Daly et al., 1994).

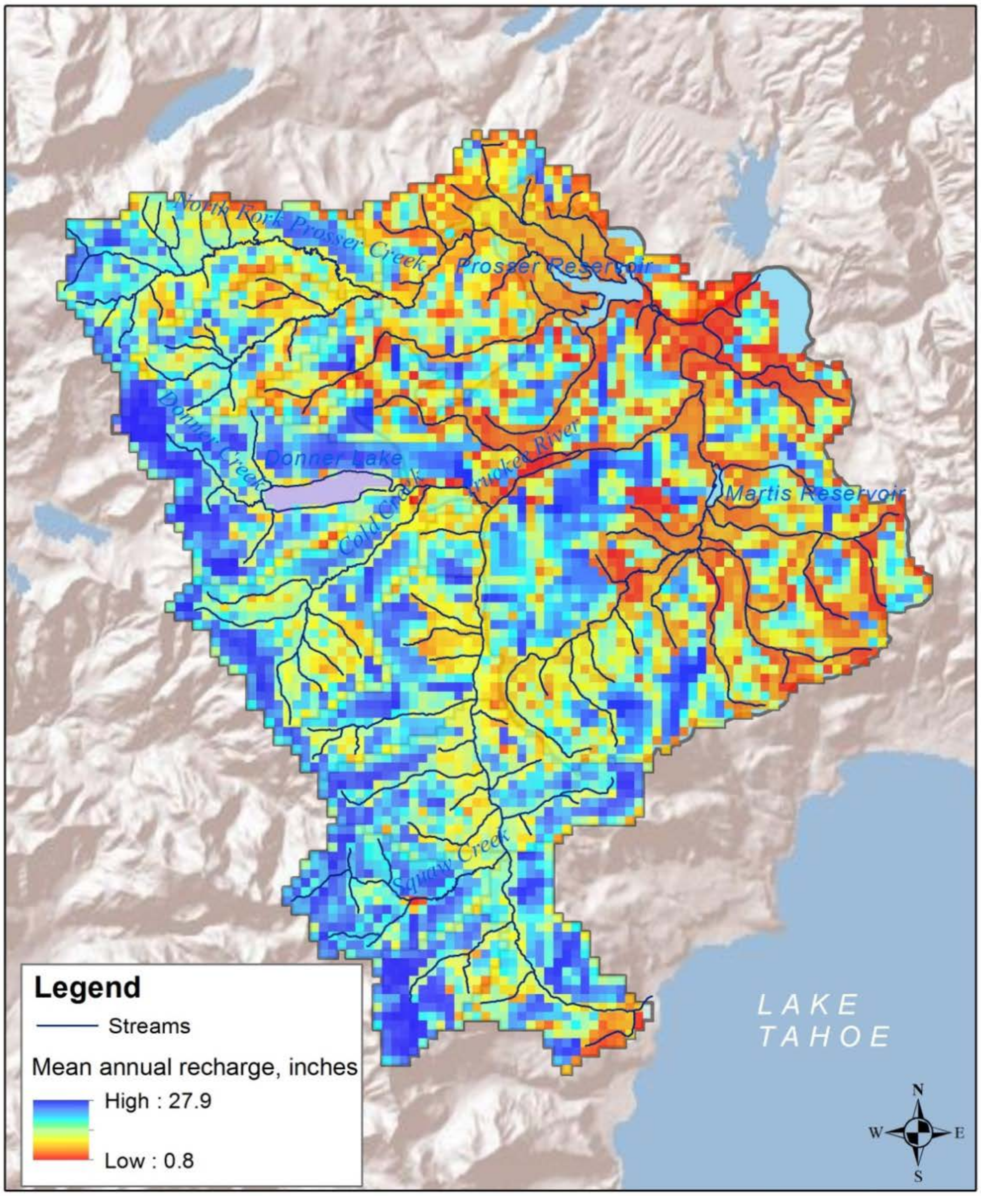

Figure 8. Mean annual recharge (inches) in the Martis Valley PRMS model domain. Note that the greatest quantities of recharge occurs in the high elevation areas which receive more precipitation (Figure 7).

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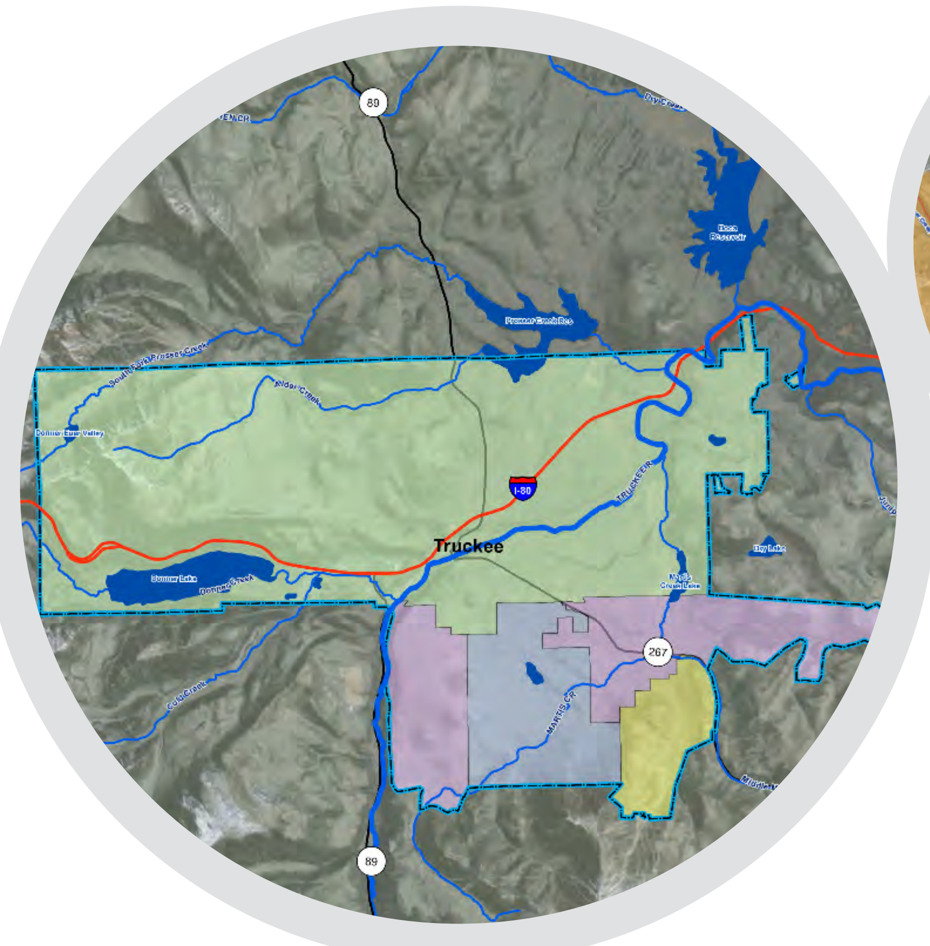

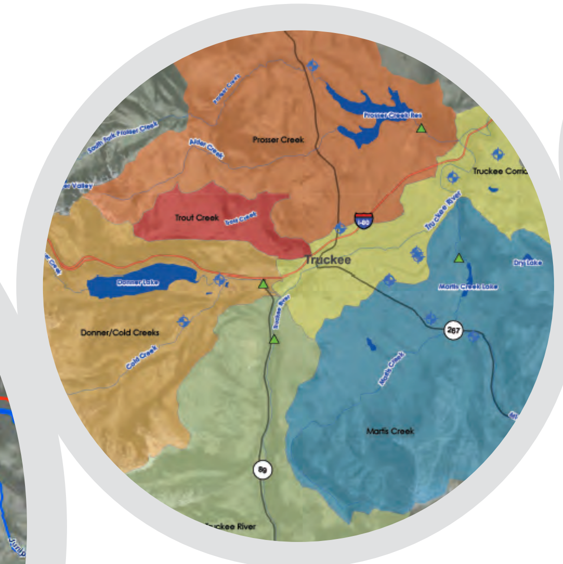

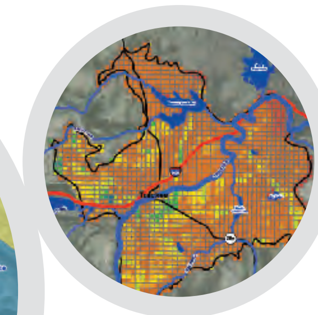

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APPENDIX B

Integrated Surface and Groundwater Modeling of Martis Valley, California, for Assessment of Potential Climate Change Impacts on Basin-Scale Water Resources

Integrated Surface and Groundwater Modeling of Martis Valley, California, for Assessment of Potential Climate Change Impacts on Basin-Scale Water Resources

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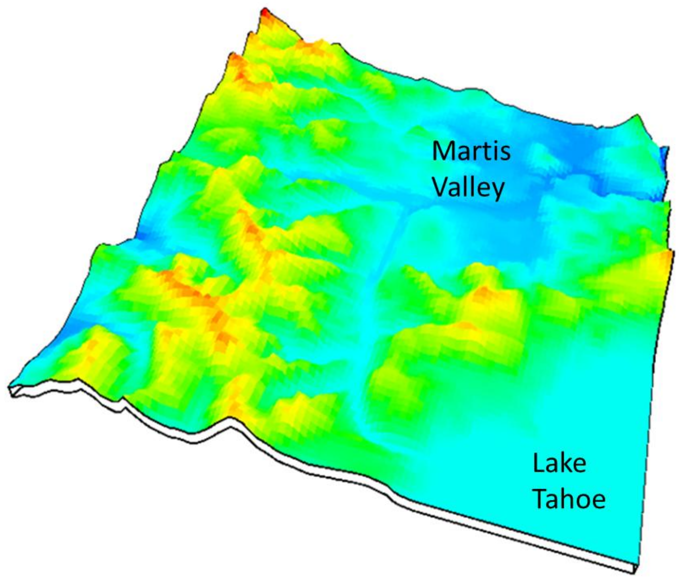

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ABSTRACT

This study develops a modeling framework to better understand surface and groundwater interactions in the Martis Valley Basin. Prior to the current study there were no physical or statistical models of the Martis Valley Basin that could be used for long term water resource planning in the Basin. Currently, groundwater is the primary source for municipal and industrial water supply in Martis Valley, and surface water from the surrounding watersheds are partly stored in Donner, Prosser reservoirs and allowed to runoff into the Truckee River. This study presents the development, calibration, and verification of the physically based surface and groundwater GSFLOW model for Martis Valley. The model was calibrated for the historical 1981-2011 observed period. Various observations were used to calibrate the model during different periods, which helped verify the model's ability to capture the dynamics of the hydrologic system. The model was calibrated to multiple fluxes and states in the hydrological system including streamflow, snow water equivalent, groundwater heads, and wetland and spring locations. In addition to comparing fluxes to multiple observations, consistency at internal gauges was also verified apart from simulating fluxes at the outlet. For future projections of hydrology, the GSFLOW model was forced with five future climate scenarios provided by CH2M HILL. Future simulations of snow water equivalent indicate reductions for all scenarios due to increasing temperatures. Groundwater recharge and its contribution to streamflow also decrease in the future for the warmer drier and hotter drier scenarios. The reduction in snowpack and earlier melt complicates the seasonally dependent nature of water resources and when combined, these results will likely add further stress to long term water availability in the Martis Valley Basin and the downstream consumers of the waters generated in the Basin.

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LIST OF ACRONYMS

BCSD	bias-corrected and statistically downscaled
CDF	cumulative distribution function
CMIP3	Coupled Model Intercomparison Project Phase 3
DOI	U.S. Department of Interior
DREAM	Differential Evolution Adaptive Metropolis
DTW	depth to water
EI	Ensemble Informed
EI	Ensemble Informed Climate Scenarios
ET	evapotranspiration
HFM	Hydrogeologic Framework Model
GDE	groundwater dependent ecosystem
GSFLOW	groundwater model
LAK7	Lake
MVGB	Martis Valley Groundwater Basin
MODFLOW	Modular Groundwater Flow model
NHD	National Hydrography Dataset
NSE	Nash Sutcliffe Efficiency
PDF	Probability Density Function
PRMS	Precipitation Runoff Modeling System
RMSE	root mean squared error
SFR2	Streamflow Routing
SCA	snow covered area
SWE	snow water equivalent
SW/GW	surface water and groundwater
TROA	Truckee River Operating Agreement
USGS	U.S. Geological Survey
UZF1	Unsaturated-Zone Flow
WCRP	World Climate Research Program

INTRODUCTION

The U.S. Department of Interior (DOI) initiated a current and future water supply and demands investigation in the Truckee River Basin as part of the WaterSMART (Sustain and Manage America's Resource for Tomorrow) program. Snowmelt runoff from the Truckee River Basin is critical to the region's economy, forest health, aquatic ecosystems, and agriculture. Martis Valley is a high elevation, snow-dominated hydrologic Basin located in Placer and Nevada Counties, California (Figure 1). The Martis Valley Basin has an area of approximately 950 km^2 and is one of three largest Basins of the upper Truckee River watershed that generates the majority of streamflow tributary to the Truckee River. Significant shifts in the timing of snowmelt and streamflow, and reductions in summer streamflow have recently been observed in the adjacent Lake Tahoe Basin and larger Sierra Nevada region (Coats, 2010; Kim and Jain, 2010). Groundwater within the Martis Valley Basin also has recently been identified as vulnerable to changing climate (Singleton et al., 2014; Singleton and Moran, 2010). The majority of water in the Martis Valley Basin emanates from high-altitude mountain catchments, thus a better understanding of how climate change affects hydrology in Martis Valley and mountain catchments in general is needed for long-term water and biological resources planning in the region.

Groundwater is currently the primary source of municipal water supply in Martis Valley. Groundwater is especially a key resource during low flow conditions, extended droughts, and is critical to maintain the health of groundwater dependent ecosystems (GDEs). Our understanding of the potential impacts of changing climate on surface water and groundwater (SW/GW) supplies is very limited. The goal of this study is to assess potential climate change impacts on watershed hydrology, SW/GW exchanges and water resources through the use of an integrated surface and groundwater model of the Martis Valley Basin.

PHYSICAL SETTING

The Lower Truckee River begins at the outlet of Lake Tahoe at Tahoe City, and flows north and east through the Martis Valley (Figure 1). The outlet of the Martis Valley Basin is upstream from the confluence of the Little Truckee River. Dominant hydrological features within the Basin include the Truckee River, numerous streams and tributaries, Donner Lake, and Martis Creek and Prosser Reservoirs. Flows of the Truckee River are regulated within the Martis Basin through a combination of operational releases from Lake Tahoe, Donner Lake, and Martis Creek and Prosser Reservoirs. Note that the Martis Valley Basin does not only refer to the groundwater Basin as shown in Figure 1 (hashed area) but also encompasses the surrounding watersheds that drain to the outlet.

The Martis Valley Basin is largely representative of typical topography, geology, climate, and hydrology of the greater Sierra Nevada region. Important characteristics that are shared among the upland watersheds of the region are the large topographic relief, high precipitation gradients, significant winter snowfall, and relatively impermeable shallow

Figure 1. Study area map and model domain. Stream gauges and climate stations used in this study are also shown as well as reservoirs.

bedrock that accentuate the dominance of shallow groundwater-flow paths in the regional system. Because the alluvial aquifers within the study area are generally thin and have limited storage, they are more responsive to climate fluctuations than larger Basin fill aquifers that are relatively thick and have high storage. Mean annual precipitation over the model domain (1,900–3,000 m above Mean Sea Level, AMSL) ranges from 530 to 1,600 mm, with 90 percent of the precipitation occurring between November and March. Monthly average extreme temperatures range from 30^{o}C in August to -10^{o}C in January. Vegetation consists of subalpine and conifer forest, with some deciduous riparian and meadows association. Mountain block geology is primarily composed of granitic and volcanic rocks, overlain with glacial moraines and stream deposits in low-elevation areas that primarily make up the alluvial aquifers, while soils are generally shallow and derived from parent rock consisting of mostly sand and silts. The mountain block includes Cretaceous-Jurassic age plutonic/metamorphic basement rocks, and in some locations, Miocene-age volcanic units. The largest alluvial aquifer is located in the center of the Basin, where groundwater discharges from numerous spring and wetland areas, to Martis Creek.

PREVIOUS WORK

Previous hydrologic investigations have primarily focused on water budget estimation and groundwater recharge using empirical approaches (Hydro-Search, Inc, 1975, 1995; Nimbus Engineers, 2001; Interflow Hydrology and Cordilleran Hydrology, 2003). These studies focus only on the Martis Valley groundwater Basin (Figure 1) and do not include any of the headwater Basins. More recently, recharge was estimated using a physically-based hydrologic model, Precipitation Runoff Modeling System (PRMS), applied over the groundwater Basin and headwaters where the majority of precipitation and runoff originates (Rajagopal *et al.*, 2012). Gardner (2014) summarized previous recharge estimates from these studies, and Table 1 highlights these estimates which are limited to the spatial extent of the Martis Valley groundwater Basin (Figure 1).

Grantz *et al.* (2007) studied the use of large scale climate information on hydrologic forecasts in the Truckee-Carson River Basin. In particular, they evaluated the forecast skill of merging 500 mb geopotential height with a decision support system to produce probabilistic

Table 1. Summary of GW Recharge Estimations in Martis Valley

Hydrosearch, Inc (1995)	18,179 ac-ft/yr
Nimbus Engineers (2001)	23,744 ac-ft/yr
Interflow Hydrology and Cordilleran Hydrology, Inc (2003)	34,560 ac-ft/yr
Epstein *et al.* Modified Maxey-Eaken (2010)	35,168 ac-ft/yr
Rajagopal *et al.* PRMS (2012)	32,745 ac-ft/yr

forecasts of streamflow. The geopotential height approximates the actual height of a pressure surface above mean sea level; in this case they were interested in the 500mb surface. Since cold air is denser than warm air, heights are lower in cold air masses and higher in warm air masses. While this study is novel, it does not use a physical hydrologic model of the system which is necessary to understand the mechanisms of streamflow generation and how climate change potentially impacts the partitioning of precipitation to streamflow. Singleton et al., (2014) used dissolved noble gas and isotopic tracers to fingerprint groundwater sources and recharge elevations in the Martis Valley groundwater Basin. Their findings indicate that deep alluvial fill groundwater is relatively young, and groundwater recharge is snowmelt and occurs primarily at lower elevations through more permeable alluvial fill material, rather than less permeable mountain block rocks at higher elevations. Given these findings, they suggest that climate change could impact groundwater recharge in lower elevation areas due to the likely shift from snow to rain, and more rapid runoff rather than diffuse snow melt infiltration.

Most climate change hydrologic modeling studies of mountain catchments have relied on simple bucket and linear reservoir representation of groundwater, while either ignoring or over simplifying the effects of the unsaturated zone. These models calculate recharge independently of dynamic groundwater levels and SW/GW interactions. Furthermore, the important interplay between snowmelt-derived streamflow and SW/GW interactions are not simulated in a coupled manner, which is essential for evaluating climate-change impacts on summertime flow (baseflow) and GDEs in snow-dominated regions (Huntington and Niswonger, 2012). Recent advancements in the development of integrated SW/GW models provide a means of simulating coupled hydrologic processes in mountain catchments. Integrated hydrologic models can provide greater insight into climate change effects on watershed hydrologic processes due to their ability to more realistically simulate feedbacks between hydrologic processes that occur above and below the land surface (Maxwell and Kollet, 2008; Ferguson and Maxwell, 2010; Sulis *et al.*, 2011; Huntington and Niswonger, 2012; Surfleet *et al.*, 2012).

OBJECTIVE

The objectives of this report are to assess potential climate change impacts to surface and groundwater resources using an integrated SW/GW model of the Martis Valley Basin, and document the construction and application of the integrated hydrologic model, GSFLOW (Markstrom *et al.*, 2008). The GSFLOW model is run using a daily timestep and forced with century-long projections of daily precipitation and temperature to evaluate how changes in climate potentially impact surface and groundwater resources, interactions, and exchanges in the Martis Valley Basin. For this report, we focus on conceptual model development and calibration of GSFLOW, and present integrated modeling results for historical and future periods.

MODELING APPROACH

GSFLOW is the integration of PRMS and the Modular Groundwater Flow model (MODFLOW). Integration of PRMS and MODFLOW was facilitated by an implicit iterative coupling approach using the Newton linearization method (Niswonger *et al.*, 2011). A complete description of GSFLOW and its theory is provided in Markstrom *et al.* (2008) and Niswonger *et al.* (2011), so only a broad description is provided here. PRMS is a modular deterministic, distributed- parameter, physical-process watershed model used to simulate precipitation, climate, and land use on watershed response (Leavesley *et al.*, 1983). Flow beneath the base of the soil zone is simulated by MODFLOW, including vertical unsaturated flow, groundwater flow, and with a wide variety of boundary conditions that represent streams, lakes, groundwater development, and many other hydrologic processes. Vertical unsaturated flow is simulated by MODFLOW using the Unsaturated-Zone Flow (UZF1) Package (Niswonger *et al.*, 2006). Stream and lake exchanges with the subsurface are simulated by MODFLOW using Streamflow Routing (SFR2) and Lake (LAK7) packages (Niswonger *et al.*, 2005; Markstrom *et al.*, 2008). The general approach for development and application of the GSFLOW model followed the methods of Huntington and Niswonger (2012) and Niswonger *et al.* (2014) where PRMS and MODFLOW models are constructed and calibrated separately, and then combined and calibrated in GSFLOW mode. The surface water model (PRMS) and the groundwater model (MODFLOW) can be setup independent of each other and hence are calibrated separately, but once combined into GSLFOW usually some additional calibration is necessary. GSFLOW is calibrated to historical observations of snow water equivalent, streamflow, reservoir and lake stage, and groundwater levels. Daily observations of precipitation and temperature are used to spatially distribute climate and force the model. Once calibrated to historical conditions, GSFLOW is forced with future climate projections of daily precipitation and temperature to evaluate potential climate change impacts on surface and groundwater fluxes. Future climate projections are bias corrected and spatially disaggregated to weather stations that are used in GSFLOW to spatially distribute climate across the model (refer to Methods section on climate distribution).

The regional scale and hydrologic complexity of mountain catchments within the Martis Valley Basin pose difficult challenges for hydrologic modeling. To overcome these challenges we implemented a novel yet simple conceptual model that reflects the availability and quality of hydrogeologic information and observations. This conceptual model, which merges data-driven hydrostratigraphic interpolation with conceptual understanding of the surface water and groundwater systems, is useful for constructing integrated models in data limited mountain block regions such as the Martis Valley Basin. Maintaining a balance between adequate horizontal and vertical grid discretization, while honoring known stream, wetland, and lake locations and elevations (i.e., heads), is particularly difficult in mountain catchments due to complex topography and geology. The geology in the Sierra Nevada is generally characterized by low-permeable mountain block overlain by thin (0-4m), high-permeable alluvium (0-210m) and glacial deposits near stream channels that gradually thicken (60-120m) in the down-valley direction. Our approach for discretizing the model based on the physical setting was to develop grid representations of the alluvium and mountain block subsurface geology using deductive reasoning and a combination of data-driven automated and manual interpolation to observed lithologies, cross sectional and surficial geologic maps, and geophysical surveys, while explicitly considering known stream and wetland locations. Key to the development of the model grid was the conditioning of the model grid-scale digital elevation model to ensure proper location of streams and wetlands, and their sub-grid scale geometries.

METHODS

Model Discretization

Discretization of the model grid was based on identifying the largest grid cell size that best preserved finer scale elevation distributions across the Basin. The objective of this approach is to represent finer scale elevation distributions while minimizing the number of grid cells to maintain computational efficiency. This was accomplished by computing the mean elevation of each model cell for varying cell sizes ranging from 100-300 m. Figure 2 illustrates the distribution of elevation for different grid cell sizes, where it is evident that a

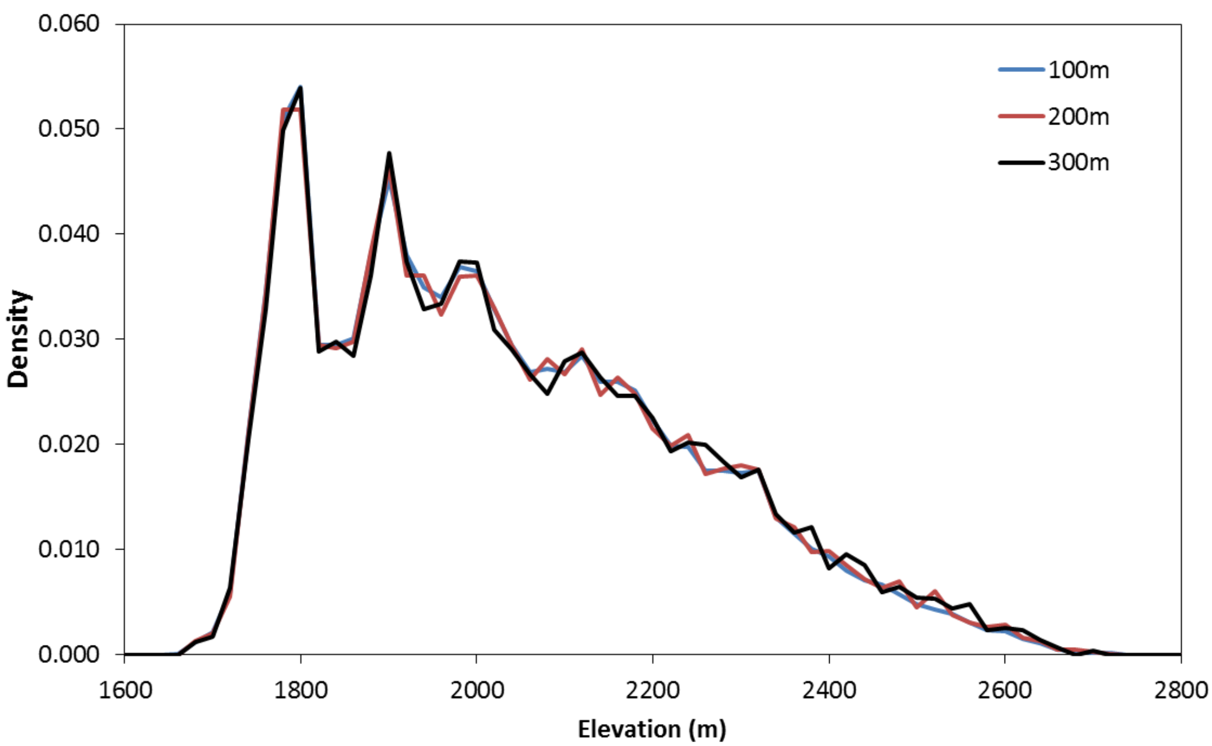

Figure 2. Probability Density Function (PDF) graph of grid elevation at various resolutions used to show that 300m resolution is sufficient for modeling the Basin.

cell size of 300 m represents the distribution of finer scale elevations fairly well. An additional benefit is that the coarser grid significantly decreases computation time without compromising elevational representation of the system. Based on this result, a discretization of 300 m for horizontal grids for PRMS and MODFLOW were chosen. Having identical grid PRMS and MODFLOW grids simplified mapping parameters and fluxes between the two models and maintained efficiency. Spatial datasets of climate, geology, vegetation, soils, and land use were mapped to the 300 m model grid for PRMS, MODFLOW, and GSFLOW parameterization (discussed below).

Climate Distribution

Precipitation is spatially distributed across the model domain using a combination of Parameter-elevation Regression on Independent Slopes Model (PRISM) monthly precipitation distributions (Daly *et al.*, 1994) and daily precipitation observations at Mt. Rose, Squaw Valley, and Truckee #2 SNOTEL stations (Figure 1, Table 2). While two of the climate stations used fall within the Basin, Mt. Rose falls outside east of the Basin. It was used to provide a climate station that is at a higher elevation which can be used to lapse temperature over the entire Basin. Figure 3 illustrates the mean annual spatial distribution of PRISM precipitation across the Basin, and highlights that the majority of the precipitation falls at high altitudes near the western edge of the watershed and decreases eastward due to precipitation-shadowing by mountains to the west, typical of the eastern Sierra. Mean monthly PRISM precipitation (400m resolution 1971-2000 normal) distributions are used in combination with mean monthly precipitation observations at each climate station to compute monthly spatial scaling factors for each model cell. The process first involves identifying collocated monthly PRISM grid cells and point station locations and subsequently computing monthly scaling factors as ratios of PRISM monthly precipitation over station monthly precipitation. The period of record used for developing mean monthly spatial scaling factors was 1981-2011. Daily precipitation was simulated at each model cell by multiplying the measured precipitation recorded at Squaw Valley, and Truckee #2 SNOTEL stations by model cell precipitation scaling factors. Daily maximum and minimum temperature were simulated at each model cell based on estimated daily temperature lapse rates between Truckee #2 and Mt. Rose SNOTEL stations and distributed based on model cell elevations.

Table 2. Climate stations used in the study

Climate Station	Description	Latitude	Longitude	Elevation
SQUAW V GC	CA SNOTEL SITE	39.189983	-120.264750	8029 ft
TRUCKEE #2	CA SNOTEL SITE	39.300867	-120.184067	6509 ft
MT ROSE SKI AREA	NV SNOTEL SITE	39.315733	-119.894733	8801 ft

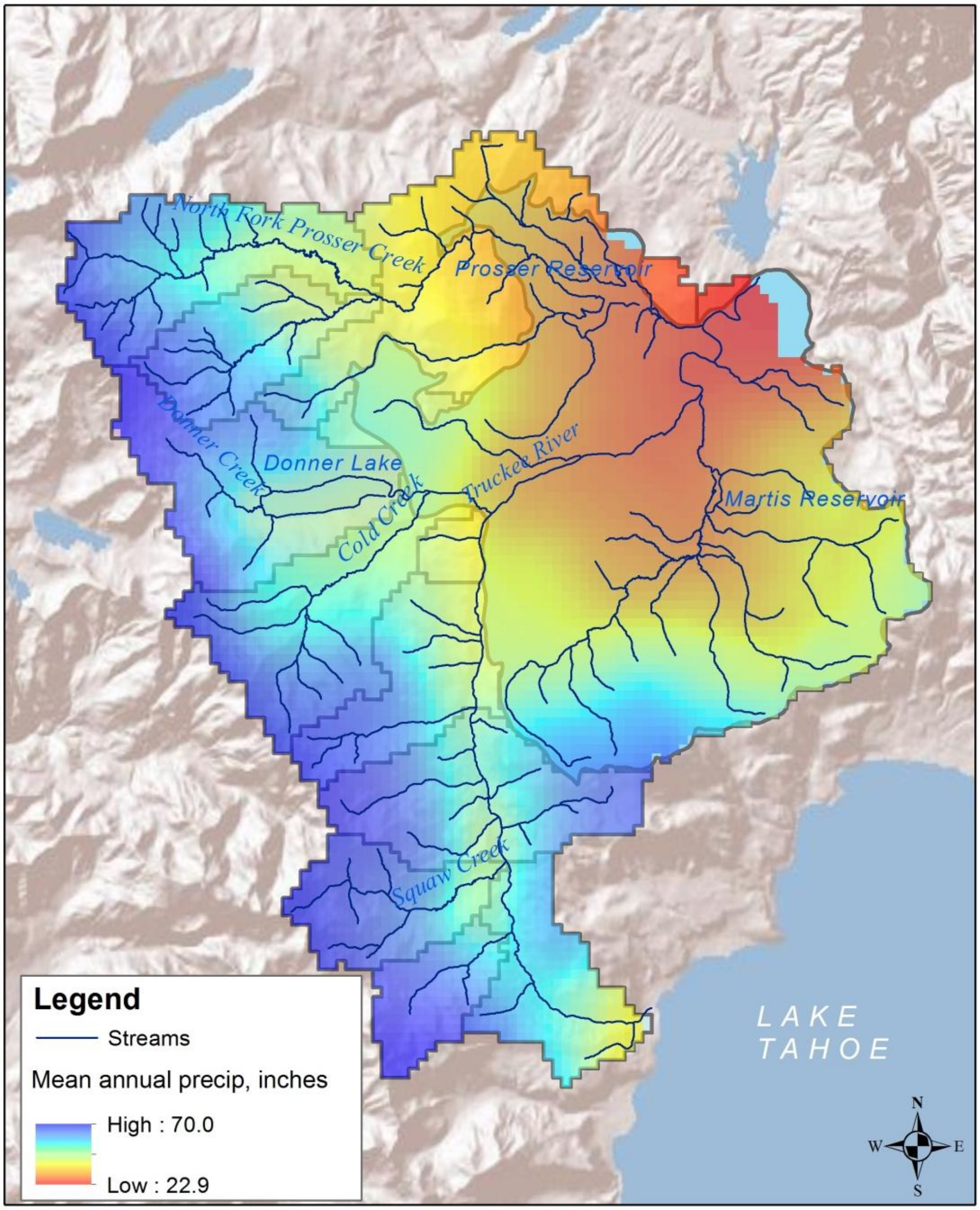

Figure 3. Spatial distribution of annual precipitation in the Martis Basin.

PRMS Setup and Calibration

PRMS employs numerous parameters to define various hydrologic processes. The parameterization of PRMS was accomplished using multiple GIS datasets including PRISM mean monthly precipitation and temperature distributions, elevation, slope, aspect, USGS National Hydrography Dataset (NHD), LANDFIRE vegetation type and density distributions (LANDFIRE, 2010)(Figure 4) , and SSURGO soils data of percent sand, silt, clay, and

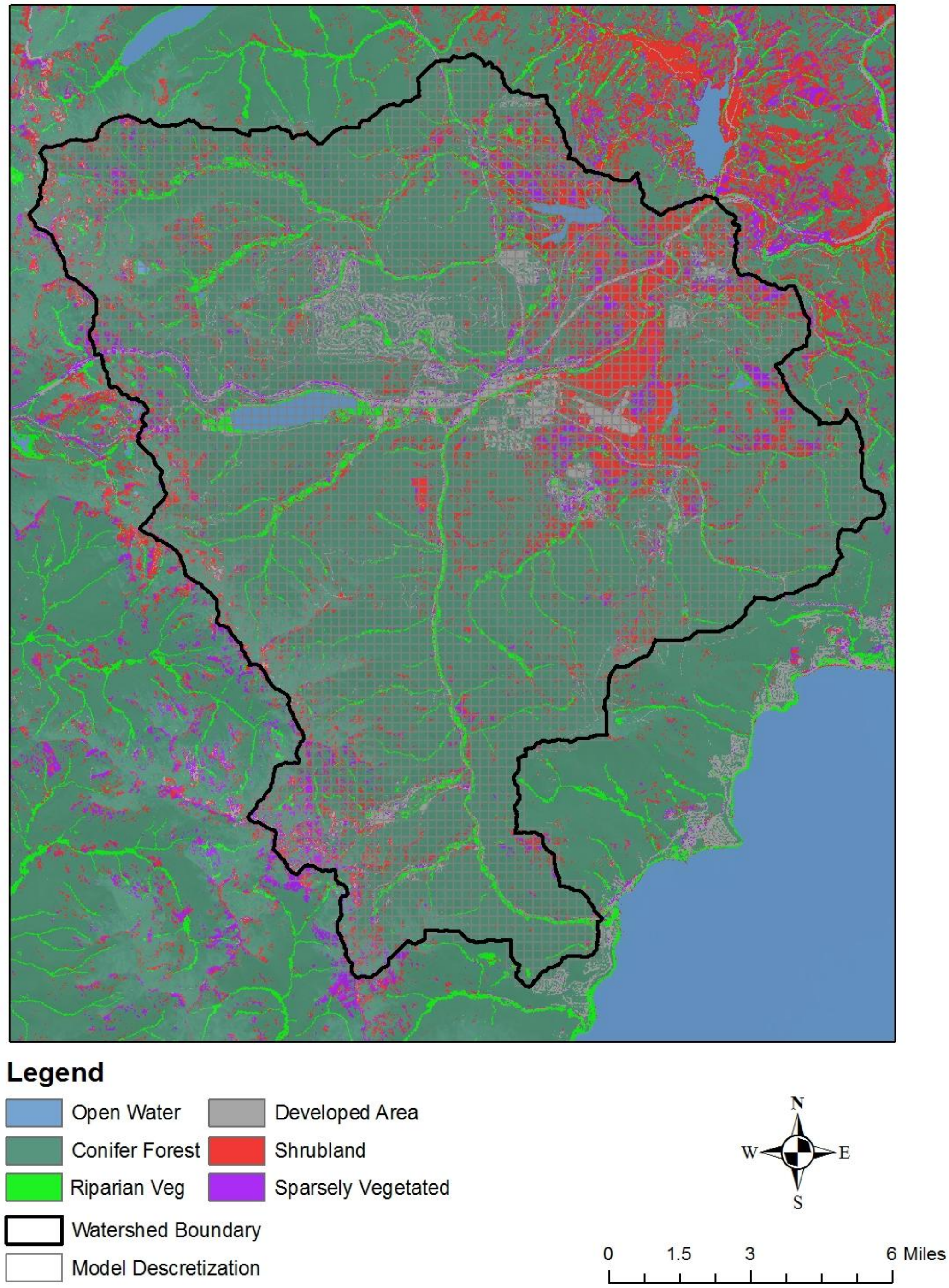

Figure 4. Landcover type in the Martis Basin

available water holding capacity (USDA, 2012). Custom scripts were developed to map GIS datasets to PRMS grid cells and compute PRMS parameters. PRMS parameters were computed following recommended equations and remap classification tables found in Viger and Leavesly (2007).

In hydrologic modeling multi-objective methods (e.g. Yapo *et al.*, 1998) have been used for model calibration along with multi-criteria methods (e.g. Livneh and Lettenmaier, 2012) that utilizes various independent data sets to calibrate models. In the current study, the multi-criteria approach was used to calibrate and evaluate the Martis Valley PRMS watershed model at annual, monthly, and daily timesteps using observed daily average streamflow, MODIS satellite snow covered area (SCA), and measured SNOTEL snow water equivalent (SWE). The PRMS solar radiation and evapotranspiration model parameters were calibrated using the Differential Evolution Adaptive Metropolis (DREAM) algorithm after Vrugt *et al.* (2008). The PRMS model was calibrated to streamflows at internal sub-watersheds and at the outlet of the watershed. PRMS simulated SCA and SWE were compared to MODIS SCA and SWE observations from SNOTEL sites. The use of PRMS gaged streamflows, SCA, and SWE to evaluate model performance against observations was possible due to the relatively fine spatial resolution of the model grid, and provided greater confidence in predications of surface and groundwater fluxes.

Measured streamflow provides integrated hydrologic information to evaluate the average water budget and simulated fluxes of precipitation, evapotranspiration (ET), and streamflow. A total of 6 gauges in the model domain were used for calibration and evaluation (Figure 1). All gauges within the Martis Valley Basin are subject to reservoir operations, therefore calibration and evaluations were made using estimated naturalized (i.e., unimpaired) streamflows in an attempt to calibrate to natural climatic and hydrologic response rather than operational response. Estimated historical naturalized flows for each gaging station were obtained from the Truckee River Operating Agreement (TROA) website www.troa.net. Table 3 lists the gage information and period of record of naturalized streamflow used to calibrate and evaluate PRMS simulations.

Table 3. Streamflow stations used in the study

Streamflow Station	Station ID	Start	End
Truckee R at Truckee, CA	**10338000**	1992-10-01	2011-09-30
Donner Creek Below Donner Lake	**10338500**	1980-10-01	2011-09-30
Prosser Creek Below Prosser Dam	**10340500**	1980-10-01	2011-09-30
Truckee River abv Boca Bridge Nr Truckee, CA	**10344505**	2002-10-01	2011-09-30
Martis Creek Reservoir	**150021**	1980-10-01	2011-09-30

MODFLOW Setup and Evaluation

MODFLOW-NWT (Niswonger *et al.*, 2011) was constructed and calibrated independent of PRMS using a steady-state stress period, including representation of stream flow (SFR2), Lakes (LAK7), and unsaturated-zone flow (UZF1). Unlike traditional groundwater models that are typically limited in extent to alluvial valley or primary aquifer areas, the model constructed in this study extends to mountain block watershed divides and simulates groundwater flow over the entire hydrographic Basin. The primary advantage to this approach is maintaining hydrologic connectivity between upland mountain block watershed and valley fill aquifers, and surface and groundwater flows. Accordingly, the conversion of precipitation to recharge and other water budget components is simulated by the model as opposed to calculating recharge external to the model and applying recharge as a boundary condition. This approach is preferred because it provides a mechanism for simulating feedbacks between climate, recharge, and groundwater storage, which is necessary, for example, to simulate the linkages between climate warming and saturation excess runoff.

The Hydrogeologic Framework Model (HFM) developed in this study formed the basis for determining total number of layers, vertical layer discretization, and assignment of hydraulic properties in the MODFLOW model. The HFM was developed using a hybrid conceptual and data driven approach. The data-driven component of the HFM consists of a lithologic database of units derived from well logs within the Basin, surficial geologic maps, and elevation distributions. An initial lithologic database was developed by Brown and Caldwell and based on approximately 200 well logs within the Martis Valley Groundwater Basin (MVGB) (Bauer *et al.*, 2013) defined by California Department of Water Resources. The MVGB is generally delineated around the extent of alluvium and Basin fill within the Martis Valley and consists of approximately 40 percent of the total Martis Valley Basin (Rajagopal *et al.*, 2012; Bauer *et al.*, 2013). The Brown and Caldwell lithologic database was modified by adding around 150 additional well logs outside the MVGB boundaries, for an approximate total of 350 well logs. The distribution of all well logs within the modified lithology database focused primarily in the valley floor area, with few wells in the mountain block (Figure 5). This database served as the basis for the data-driven approach for delineating hydrogeologic units and hydraulic properties in the alluvial fill.

The simulation of groundwater flow in mountain block areas where hydrogeological information is lacking necessitated the inclusion of a conceptual component to the HFM. This conceptual component involved integrating surficial geologic information and specifying shallow Quaternary-age alluvium areas along streams within the mountain block, and honoring observed transitions of increased alluvial thickness from the mountain block to valley floor areas (Figure 6). The combination of lithologic and conceptual information was used in combination to identify four general hydrogeologic units: shallow and deep alluvium, weathered bedrock, and unweathered bedrock (Huntington *et al.*, 2013; Gardner, 2014). Each

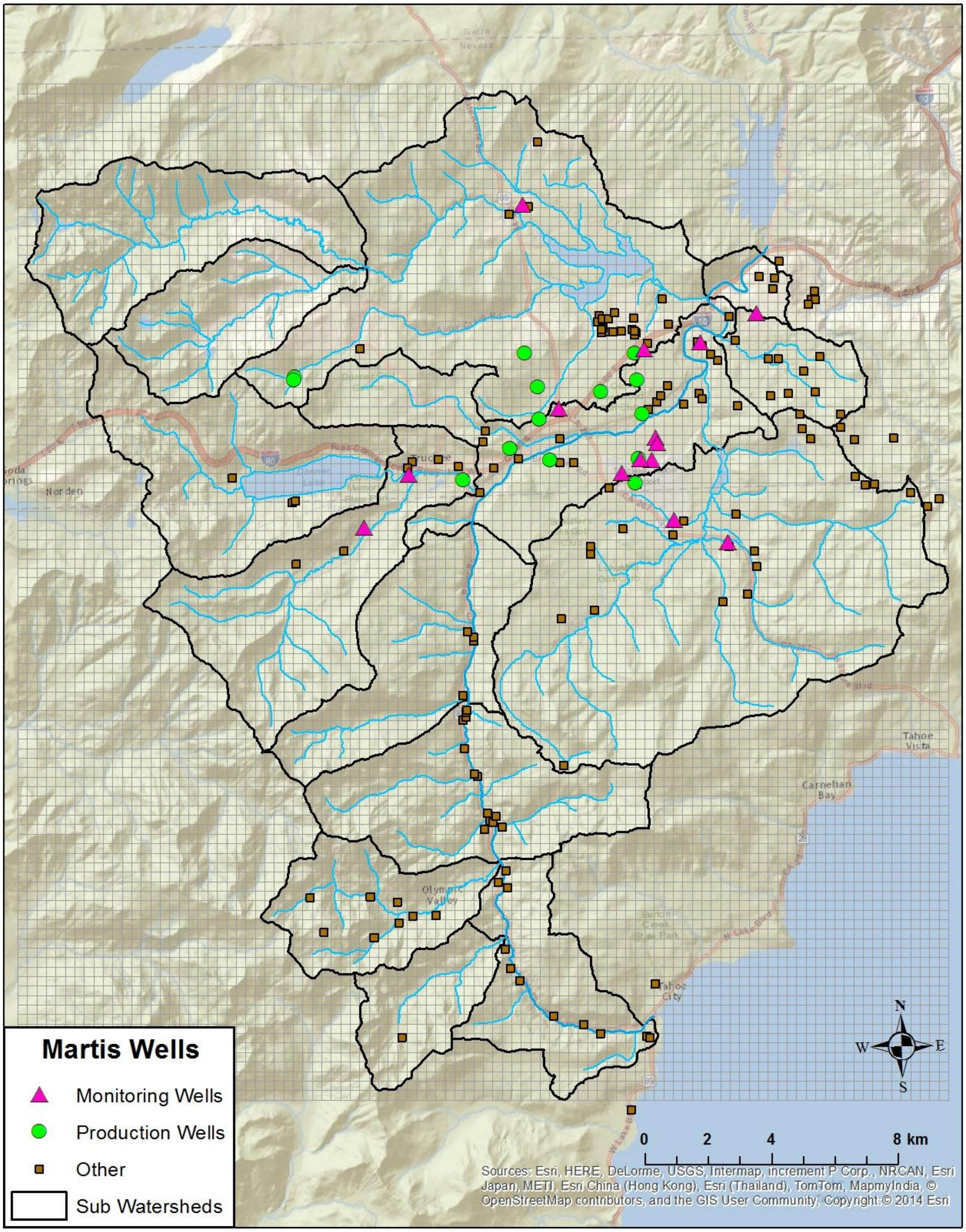

Figure 5. Well locations within Martis Valley

of these hydrogeologic units correspond to a designated MODFLOW layer, with layers 1 and 2 consisting of shallow and deep alluvium and layers 3 and 4 consisting of weathered and unweathered bedrock, respectively.

The alluvium is discontinuous over the mountain block watershed, and thus, the distribution of active cells within layers 1 and 2 of the mountain block watershed honors observed locations of streams and alluvium around streams. Total alluvial thickness begins at 5 m in the highest elevation mountain block stream areas and linearly increases towards the valley. Valley floor alluvial thicknesses honor the interpolated thickness from the lithologic database (Figure 6). Alluvial areas within the stream areas of the mountain block are assigned to layers 1 and 2 by dividing the total thickness in half. Layers 1 and 2 have zero

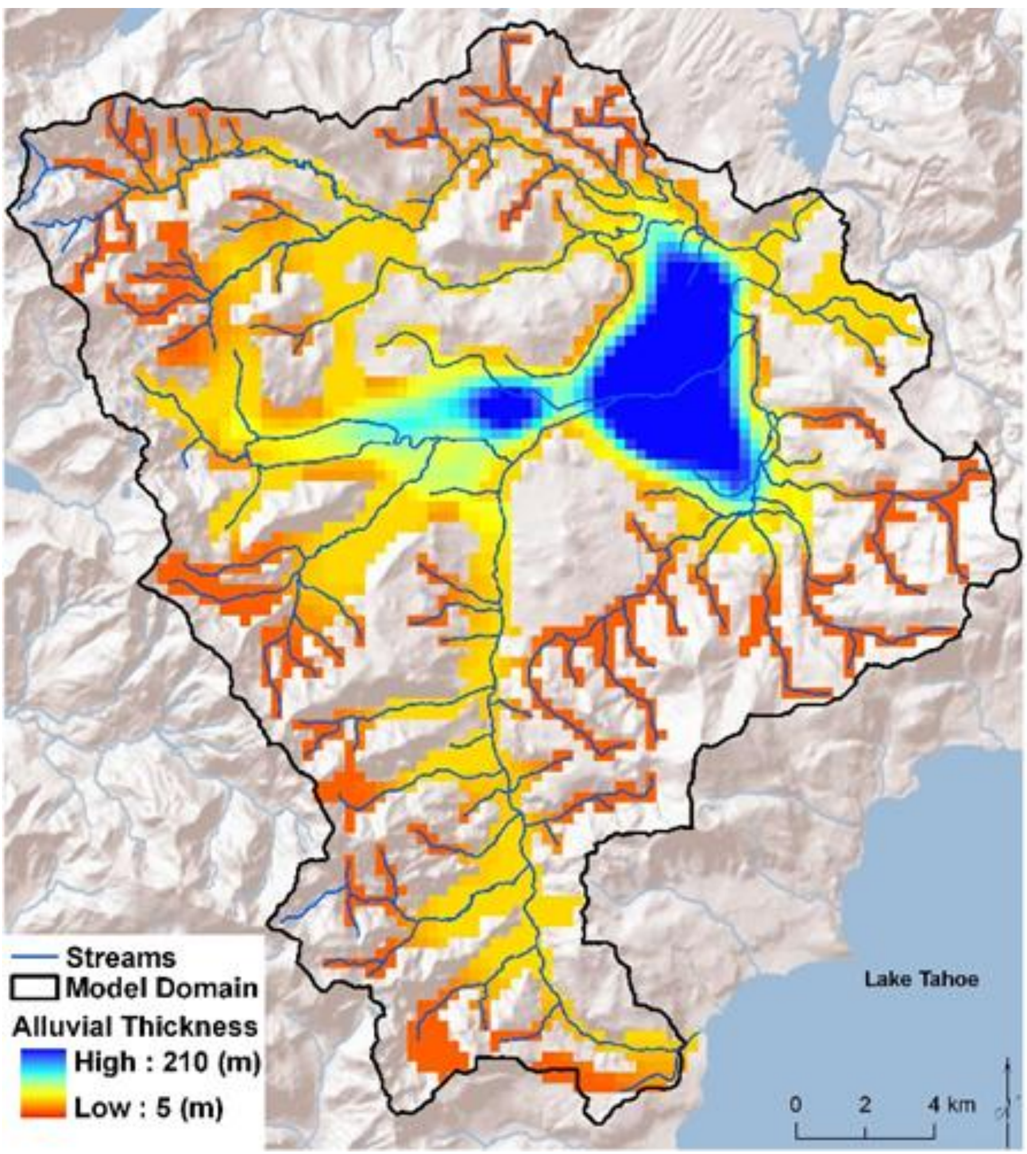

Figure 6. Total alluvial thickness in the Martis Valley HFM.

thickness outside stream alluvial areas within the mountain block. Layers 3 and 4 represent the mountain block area and are continuously active within the model domain, and represent weathered and unweathered bedrock, respectively. Based on a few well logs that were located in the mountain block, the bedrock at the surface was considered a weathered zone with enhanced permeability and assigned to be 60 m thick, and the remaining thickness was considered to represent unweathered bedrock and was assigned to have 120 m thickness.

Mean annual PRISM precipitation was scaled to represent the mean annual streamflow (i.e., sum of recharge, interflow, and overland runoff), and utilized as net infiltration for UZF1 and MODFLOW-NWT. Calibration of UZF1 and MODFLOW-NWT was performed by adjusting the precipitation scaling factor and layer specific homogeneous aquifer hydraulic conductivity values until there was a good visual correspondence between the simulated and observed steady-state flows in streams, lake and reservoir stages and outflows, groundwater heads, and the locations of major discharge and wetland areas. Wetland areas were used to calibrate the model by assuming groundwater heads were equal to land surface elevations in wetland areas and comparing surface elevations to simulated head. Steady-state lake and reservoir stages were simulated by simulating surface and groundwater inflows, while specifying mean annual outflows based on gage records.

GSFLOW Setup and Evaluation

GSFLOW set up consisted of integrating the calibrated PRMS and steady-state MODFLOW-NWT models. Several changes and additions to input files of the MODFLOW-NWT model were required for transient GSFLOW simulation, such as specifying daily stress periods, observed pumping, and observed lake and reservoir outflows from 1981 to 2011. Historical observed outflows included those from Lake Tahoe, Donner Lake and Prosser reservoirs. Martis Creek reservoir has negligible storage and operated as a flood control reservoir, therefore a constant sill elevation was used in the LAK7 package to simulate outflow from the reservoir. Other minor changes included those to the GSFLOW control file specifying model mode and output options. Once PRMS and MODFLOW-NWT were integrated using the GSFLOW mode option, the GSFLOW model required further calibration to observed streamflows, groundwater heads, and lake and reservoir stages. Transient calibration of the GSFLOW model was accomplished by adjusting PRMS, MODFLOW-NWT, and various MODFLOW package parameters to obtain satisfactory model fits to transient observations of streamflow, groundwater head elevations, and lake and reservoir stages. The GSFLOW model couples the individually calibrated PRMS and MODFLOW-NWT models and hence only a few parameters that influence flows between the two models are adjusted during the coupled model calibration. We followed the GSFLOW calibration procedures of Markstrom *et al.*, 2008 to adjust parameters related to sub surface flow, evapotranspiration in the surface water model and hydraulic conductivity in the groundwater model in a manual fashion. The criterion for a satisfactory model fit was as follows, for streamflow an annual Nash Sutcliffe Efficiency (NSE) of 0.9 or higher, for groundwater heads an RMSE of < 10m. Calibration of GSFLOW using a combination of streamflow and lake and reservoir stage observations provide valuable constraints to model calibration and thus give additional confidence in the predictive skill of surface and groundwater water fluxes. It should be noted that bathymetry information for Donner Lake does not exist, and was therefore estimated and is a likely source of simulation error. In addition, inflow measurement were also lacking for Donner or Prosser reservoirs, therefore inflows were simulated by GSFLOW.

For future climate simulations the GSFLOW control file was modified to simulate the period from 1981 to 2098. Future groundwater pumping in Martis Valley was assumed to be constant during future periods, and was specified based on 2011 monthly pumping rates. This assumption is based on a lack of knowledge of what the future municipal demand will be from groundwater. Figure 7 illustrates the historical (1981-2011) pumping rates in Martis Valley along with the annual precipitation in the Basin. It can be observed from this figure that the pumping rates in the Basin have been increasing and are not correlated to the annual precipitation change.

For future climate simulations the LAK7 package was modified by assigning constant sill elevations to Donner Lake and Prosser reservoirs. The modification (specifying the sill elevations) for the future is necessary since we do not know a priori the discharge from the lake and by specifying the sill elevation the model simulates the discharge when the lake stage is above the specified sill elevation. Lake Tahoe outflows were specified in SFR2 based on the relationship between historical annual precipitation and Lake Tahoe annual outflows.

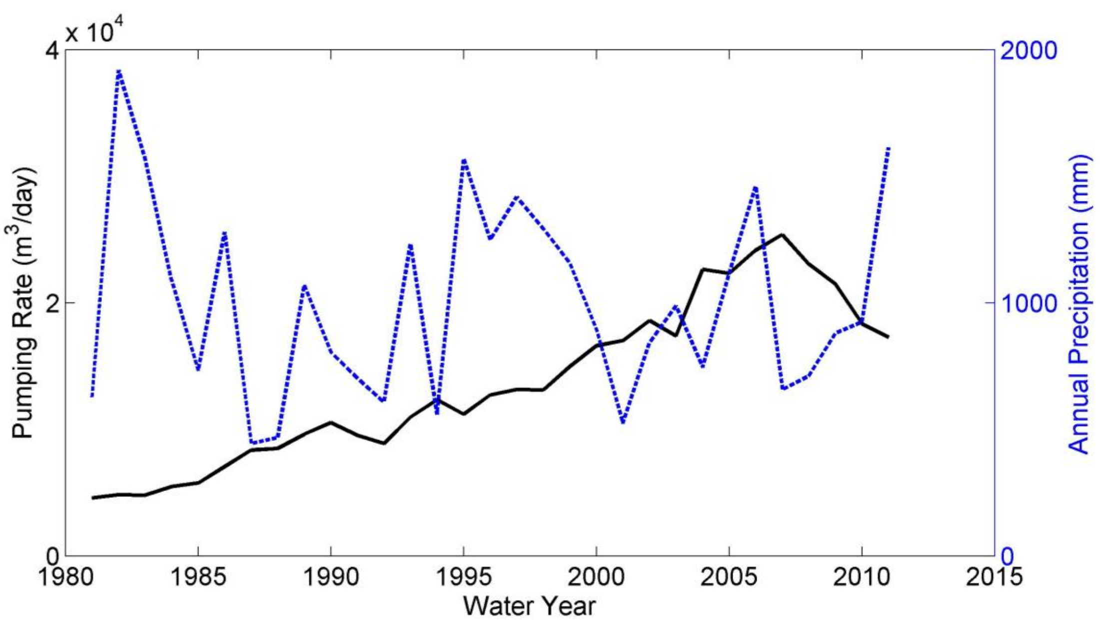

Figure 7. Pumping rates in the Martis Valley along with the annual precipitation shows an increase in pumping from the 1980’s to present.

Figure 8 shows the climate elasticity of Lake Tahoe observed historical annual outflow to respective precipitation and temperature changes recorded at Tahoe City. The technique adopted to evaluate climate elasticity of historical and future Tahoe outflow is based on Sankarasubramanian *et al.* (2001). Figure 8 illustrates that for a ten percent reduction in precipitation in and an increase in temperature of one degree Celsius in the Lake Tahoe Basin, there was no reduction in the historical amount of outflow from Tahoe. If there was a ten percent increase in precipitation and temperatures are one degree cooler, then there was about a twenty percent increase in the outflow from Tahoe. This finding is important to consider since it highlights the non-linear response of the system, which we incorporate in this study. These relationships were used along with projections of future temperature and precipitation timeseries (Q1-Q5, discussed in the next section) to simulate projections of future Lake Tahoe outflow. In addition to climate, lake operations depend on the lake level, downstream demands etc. this was not considered in this exercise. Constructed projections of

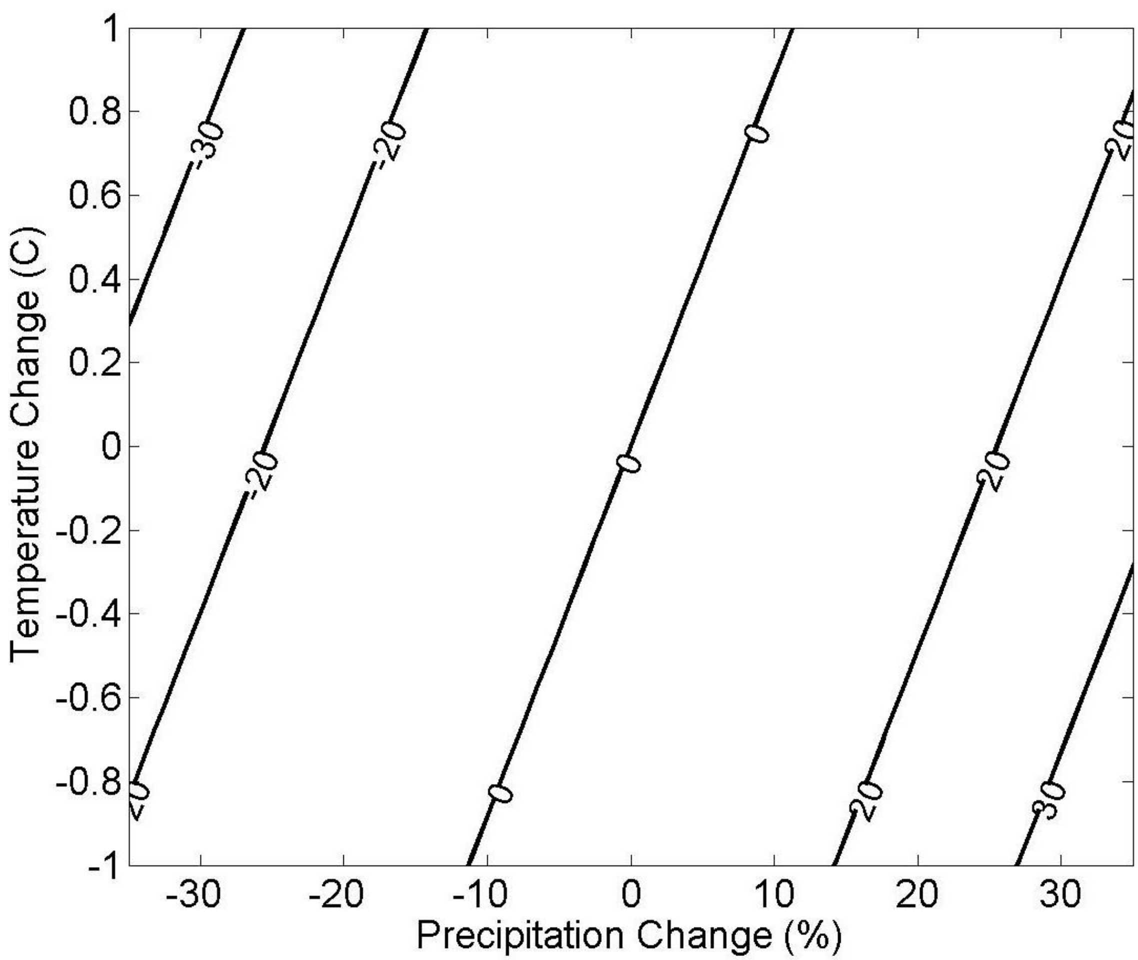

Figure 8. Elasticity of Lake Tahoe observed annual outflow to the Truckee River related to annual precipitation and temperature changes at Tahoe City.

Lake Tahoe outflow derived from historical elasticity of measured outflow, precipitation, and temperature changes were ultimately assigned as specified inflows in the SFR2 package to the respective segment representing the start of the Truckee River below the Lake Tahoe dam.

Future Climate

Climate model projections of daily precipitation and maximum and minimum daily temperatures were used to force GSFLOW and to assess relationships between projected climate and projected changes in simulated hydrology. Climate model projections cannot be directly used in such impact assessments given the coarse time and spatial resolutions of climate models. Therefore, climate model results were bias corrected to translate projections from the climate model scale (~100-250km) to the GSFLOW model scale (300mx300m grids). While precipitation and temperature are widely considered to be the primary drivers of changing hydrology, terrestrial short and longwave radiation, humidity, and windspeed projections are also important drivers of change but were not available at a usable spatial scale at the time this study was initiated.

Through collaboration with U.S. Bureau of Reclamation and MWH Global on Truckee Basin Study hydrologic modeling activities, future climate data was provided to DRI by CH2M HILL (Tapash Das, electronic communication). Figure 9 provides an illustration of the Ensemble Informed Climate Scenarios approach used to develop future climate projections in this report. A brief summary of the transient Ensemble Informed approach and development of projected climate is copied verbatim from electronic communication with CH2M Hill as: "Transient future climate scenarios were developed for selected locations over the Truckee and Carson River Basins using an Ensemble Informed Climate Scenarios (EI) method. The approach uses an ensemble of 112 climate projections used in the IPCC AR4, subsequently bias-corrected and statistically downscaled (BCSD). The downscaled climate projections were obtained from Lawrence Livermore National Laboratory under the World Climate Research Program's (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3). This archive contains climate projections generated from 16 different GCMs developed by national climate centers and for SRES emission scenarios A2, A1b, and B1. One historical and five statistically representative future temperature and precipitations projections were developed to characterize the central tendency and the range of the ensemble uncertainty including projections representing drier, less warming (Q1); drier, more warming (Q2); wetter, more warming (Q3); and wetter, less warming (Q4) conditions than the median projection (Q5). The observed natural variability in the historic climate between 1915 and 2003 was used to create the inter-annual variability in the projected climates. The EI method is described in various project reports, including Bay Delta Conservation Plan, Central Valley Project Integrated Resource Plan, and Sacramento-San Joaquin River Basins Climate Impact Study and is available online at http://www.usbr.gov/WaterSMART/wcra/docs/ssjbia/ssjbia.pdf and http://baydeltaconservationplan.com/PublicReview/PublicReviewDraftBDCP.aspx. The Ensemble Informed method results in five climate

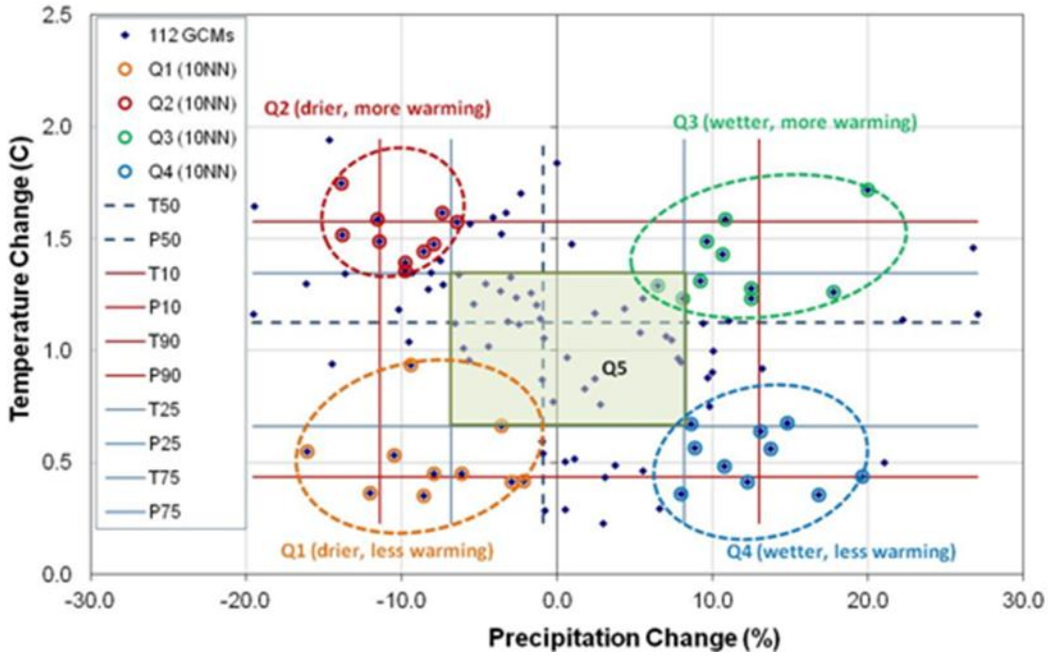

Figure 9. Illustration of the Ensemble Informed Climate Scenarios (EI) method used to derive climate projections provided by CH2M HILL.

scenarios labeled Q1 through Q5. The Q5 scenario is bounded by the 25th and 75th percentile joint temperature-precipitation change. Scenarios Q1-Q4 are selected to reflect the results of the 10 projections nearest each of 10th and 90th joint temperature-precipitation change bounds."

There are two aspects (and thus their implications) of the dataset provided to DRI by CH2M HILL that should be understood. First, the future climate data provided by CH2M HILL were 1/16th degree resolution which is approximately 6x6 Km^2 grids. Second, the future "No Climate Change" scenario is a copy of the historic climate between 1913-2003 and was based on the Livneh *et al.* (2013) dataset. The technical note provided to DRI by CH2M Hill is in Appendix-I which provides further details. Remember that the GSFLOW model uses weather station (point) data and hence to make $1/16^{th}$ degree future climate data representative of weather station locations a bias correction of the CH2M HILL data was performed. This was accomplished using a quantile-quantile cumulative distribution function (CDF) matching approach that has been commonly applied for climate impacts assessment studies (Mejia *et al.*, 2012; Wood *et al.*, 2004; Panofsky and Brier, 1968). Figure 10 illustrates results of the CDF matching approach, where cumulative distribution functions of minimum temperature for the No Climate Change scenario prior to, and after correction, for the Truckee #2 SNOTEL station data are shown. Quantile-quanitle CDF mapping was applied to all No Change and future climate projections (Q1, Q2, Q3, Q4, Q5) using respective climate station data collected at station locations listed in Table 2. The implication of the use of climate data from 1913-2003 as the future "No Climate Change" scenario is that historic droughts and wet

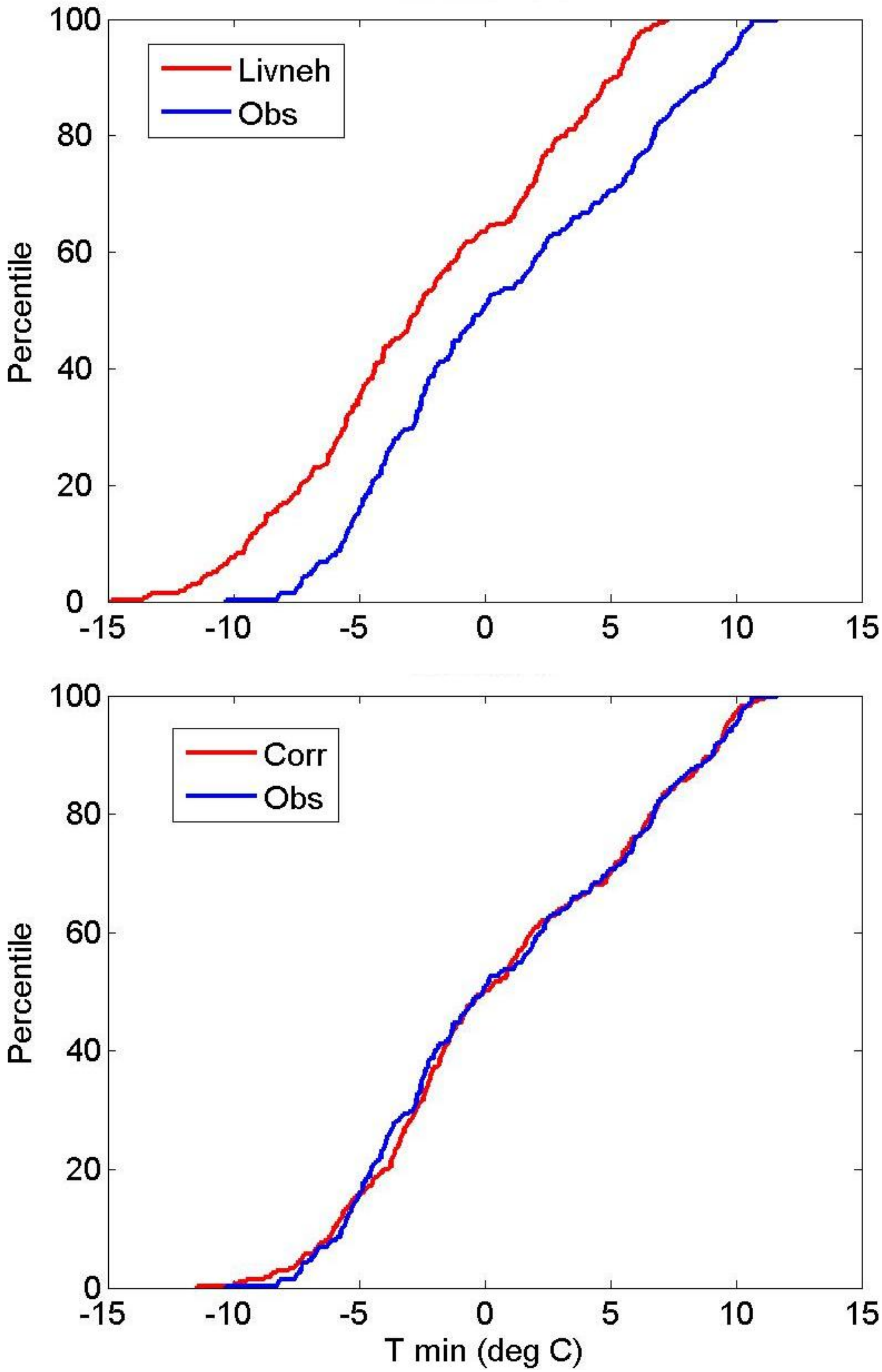

Figure 10. No Climate Change scenario minimum temperature at Truckee #2 uncorrected (top) and corrected (bottom).

periods are by experimental design repeated in the future. The future climate data for 2010-2100 (90 year) period is a repetition of the data from 1913-2003 (90 years) which means that the historic 1930's drought will be seen again in approximately 2030. It is important to recognize this as it will come up again when analyzing the future model results.

RESULTS

PRMS Calibration and Historical Simulations

Results of calibrated historical PRMS simulations of streamflow are shown at the annual and monthly timescale in Figure 11 and Figure 12, respectively. Note that the results from the first year were typically ignored to account for model spin up. The model was calibrated to naturalized streamflows at the outlet of the watershed and also at internal gauges. As a criterion for calibration, we achieved greater than 0.9 Nash Sutcliffe Efficiency (NSE based on Nash and Sutcliffe, 1970) at the annual timestep, and greater than 0.8 at the monthly timestep for most gauges as shown in Table 4. A comparison of PRMS simulated and measured daily SWE is illustrated for the Squaw Valley and Truckee # 2 SNOTEL stations in Figure 13, where it is evident that for certain years there is an under prediction,

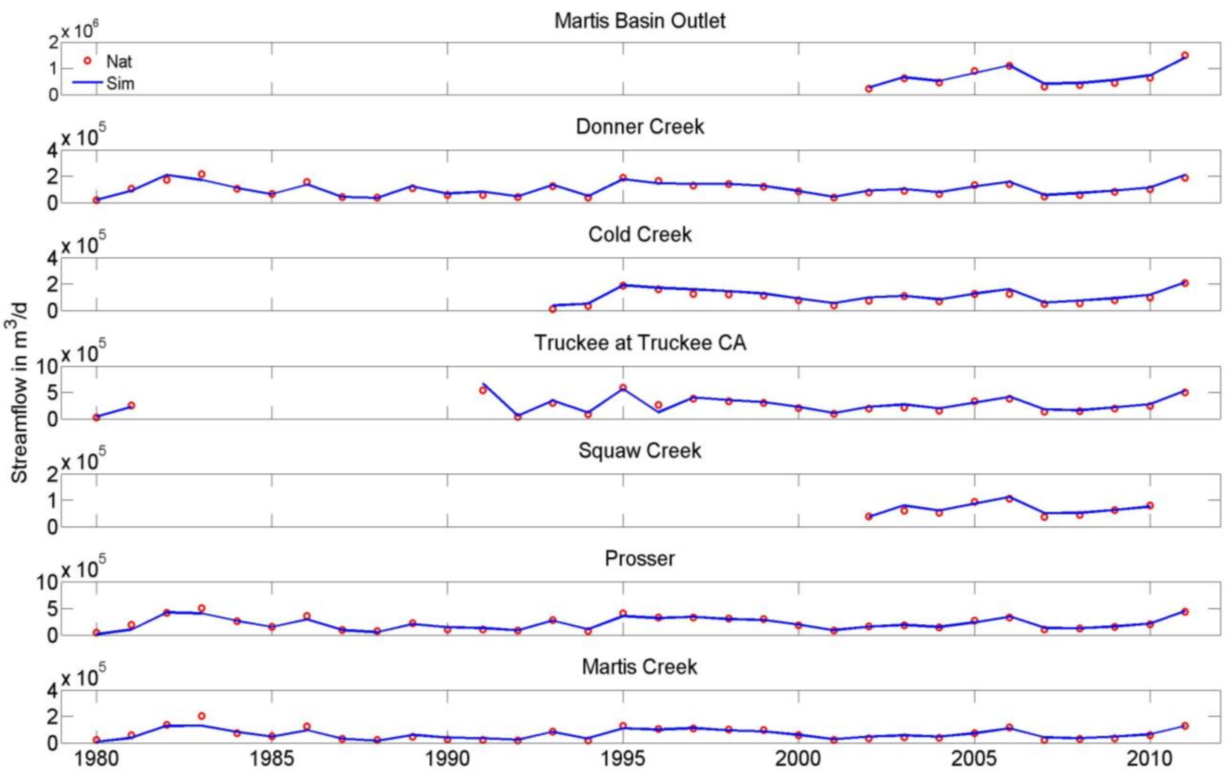

Figure 11. Simulated annual streamflow in comparison to naturalized flows at multiple locations in the Basin

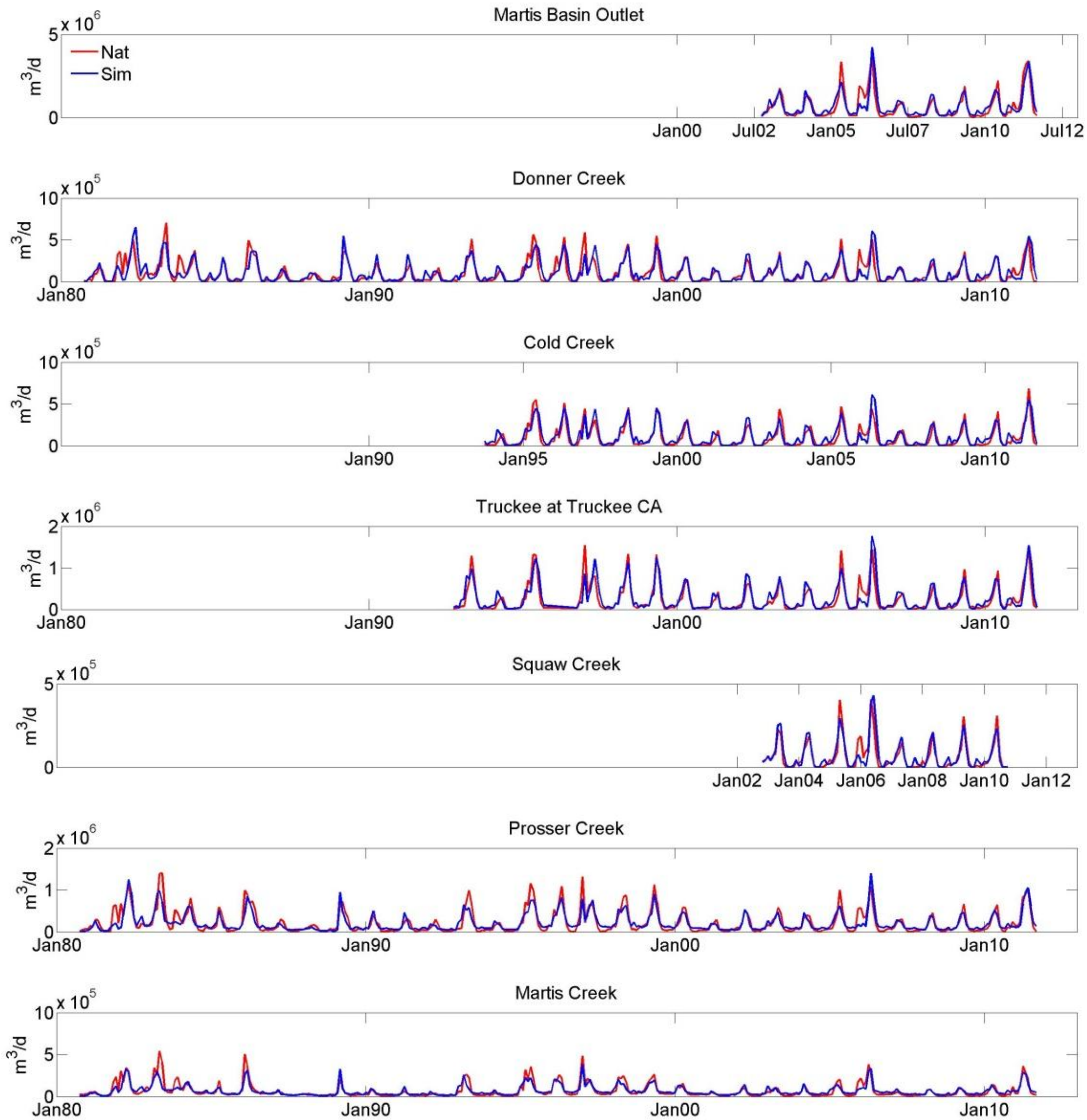

Figure 12. Simulated monthly streamflow in comparison to naturalized flows at multiple locations in the Basin

and for other years the model over predicts, but overall there is little bias in the model fit to measured streamflow. It should be noted that SNOTEL observations of SWE are point measurements, whereas PRMS simulations are 300m grid cell averages. In addition PRMS uses a temperature threshold approach to partition precipitation into rain and snow. While this approach is standard in most hydrologic modeling, it does sometimes lead to misclassification of rain and snow, especially in a complex terrain watershed such as the Martis Valley Basin.

Table 4. Evaluation criteria objective function values.

Station Name	USGS ID	Record Type	NSE		PBIAS
			Annual	Monthly	
Truckee River	10338000	N	0.91	0.71	7.1
Squaw Creek	NA	G	0.87	0.77	7.6
Donner Creek	10338500	N	0.91	0.63	5.0
Cold Creek	10338700	N	0.95	0.78	6.6
Martis Creek	NA	N	0.85	0.73	-1.5
Prosser Creek	10340500	N	0.94	0.76	-3.5
Average			**0.91**	**0.74**	**3.5**

(N=Naturalized flows; G=Gauged flows)

Another snow property comparison was made between PRMS simulated snow covered area (SCA) and MODIS Terra satellite based observed SCA for the entire model domain shown in Figure 14. It can be seen in this figure that the model reasonably simulates the timing of snow accumulation and melt over the entire Basin. The model predictions tend to allow SCA to last longer than MODIS SCA in some years, but this can be attributed to the fixed PRISM spatial scaling factors used to distribute precipitation over the Basin. While we acknowledge that getting the spatial distribution of precipitation is a challenge in this

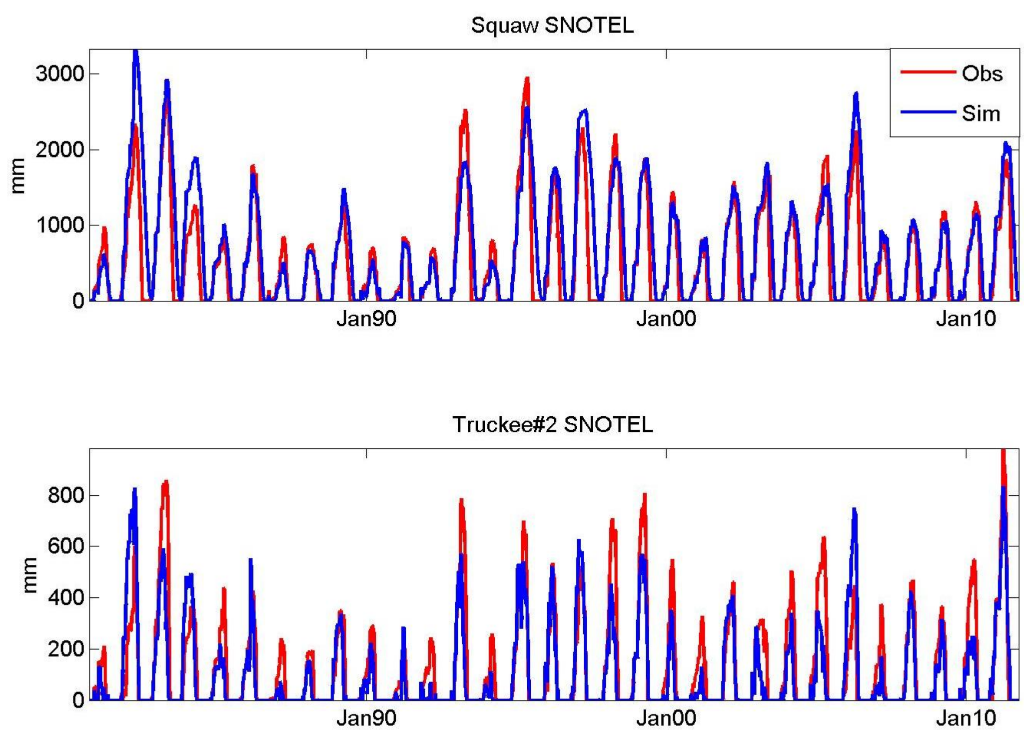

Figure 13. Simulated daily snow water equivalent (SWE) in comparison to observed daily SWE at two SNOTEL locations within the Martis Valley Basin.

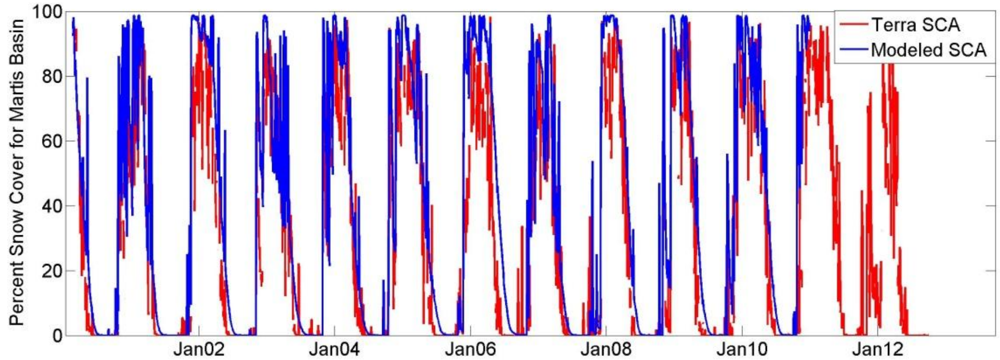

Figure 14. Simulated Basin averaged snow covered area (SCA) in comparison the MODIS Terra platform SCA.

complex terrain watershed Figure 14 shows that average the predictions are acceptable. It should be noted here that MODIS images also have caveats associated with them. MODIS images are more often than not acquired at high view angles, leading to errors in SCA estimates. High view angles combined with errors due to vegetation cover causes biases in MODIS SCA estimates, therefore only a qualitative calibration of PRMS was performed using MODIS SCA data to evaluate simulated snow accumulation and depletion.

MODFLOW Calibration and Historical Simulation

Steady-state groundwater model calibration results indicate that the groundwater model was able to simulate the limited amount of observed heads and the locations and extent of wetlands and spring areas within the Basin, without defining any structural features or heterogeneities in our hydraulic conductivity fields beyond the original HFM (i.e., additional geologic heterogeneities or faults that act as barriers or conduits for flow), indicating that nearly all springs and wetlands in these watersheds are topographically derived. Using spring and wetland locations to constrain the steady state calibration proved very useful. For example, Figure 15 shows a sensitivity analysis that demonstrates the tightly constrained aquifer hydraulic conductivity (K) values. The spatial distribution of heads within 1 m or above land surface was plotted for K distributions that were scaled by factors of 0.1 and 10 of the calibrated K values. For a factor of 0.1 (Figure 15a), it is evident that the model overpredicts heads, as it would only be expected to have heads within 1 m or above land surface around springs, wetlands, and perennial streams. For a factor of 10 (Figure 15b), it is evident that the model underpredicts heads in the upland areas and does not provide shallow groundwater levels around springs, wetlands, and perennial streams. Clearly, the calibrated K distribution provides the most accurate representation of wetland, spring, and perennial stream areas, particularly in the Martis Valley subwatershed (i.e. most south east subwatershed). Figure 16 shows steady-state simulated versus observed heads in wells, and land-surface elevations for spring and wetland areas. The 1-to-1 plot (Figure 16) shows that the model simulates the head distribution accurately over a wide range in head values, with RMSE and normalized RMSE values of 5.8 m and 2.0 percent, respectively. A small

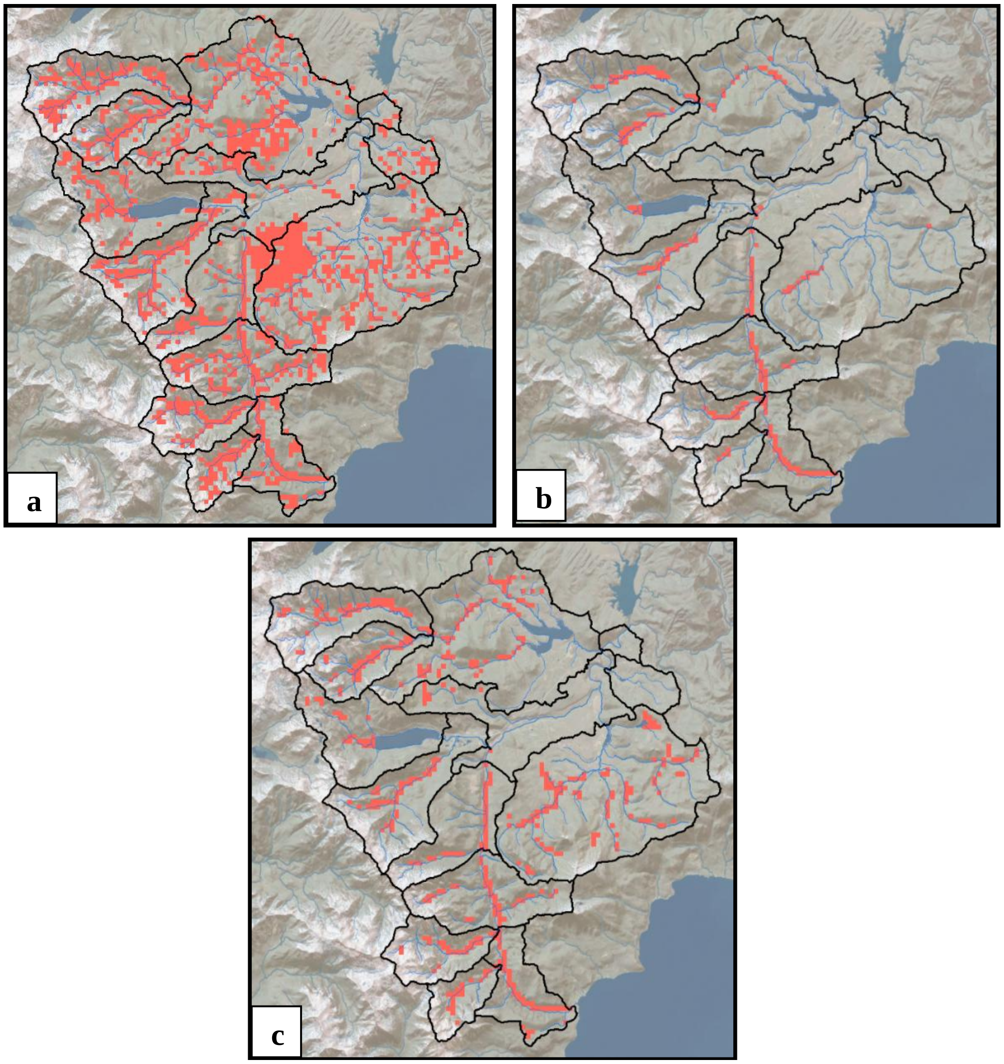

Figure 15. Spatial distribution of ground water heads within 1 meter or above land surface shown in red for (a) decrease in calibrated values by an order-of-magnitude, (b) increase in calibrated values by an order-of-magnitude and (c) optimally calibrated values. From Gardner (2014).

normalized RMSE (i.e., RMSE/total head loss of less than ~ 10%) as shown in this work indicates that model errors are only a small part of the overall model response (Anderson and Woessner, 1992).

Adding further complexity to the model to better match heads was not warranted given the model scale and uncertainty in these observation data. Most of the wells in the study are either located in steep terrain, or close to pumping wells, making direct comparisons between simulated and measured heads in these wells difficult due to the grid scale and pumping effects. Pumping was not included in the steady-state model to represent pre-development conditions in order to avoid transient conditions caused by pumping in the steady state simulation. Accordingly, it was anticipated that the model would over predict

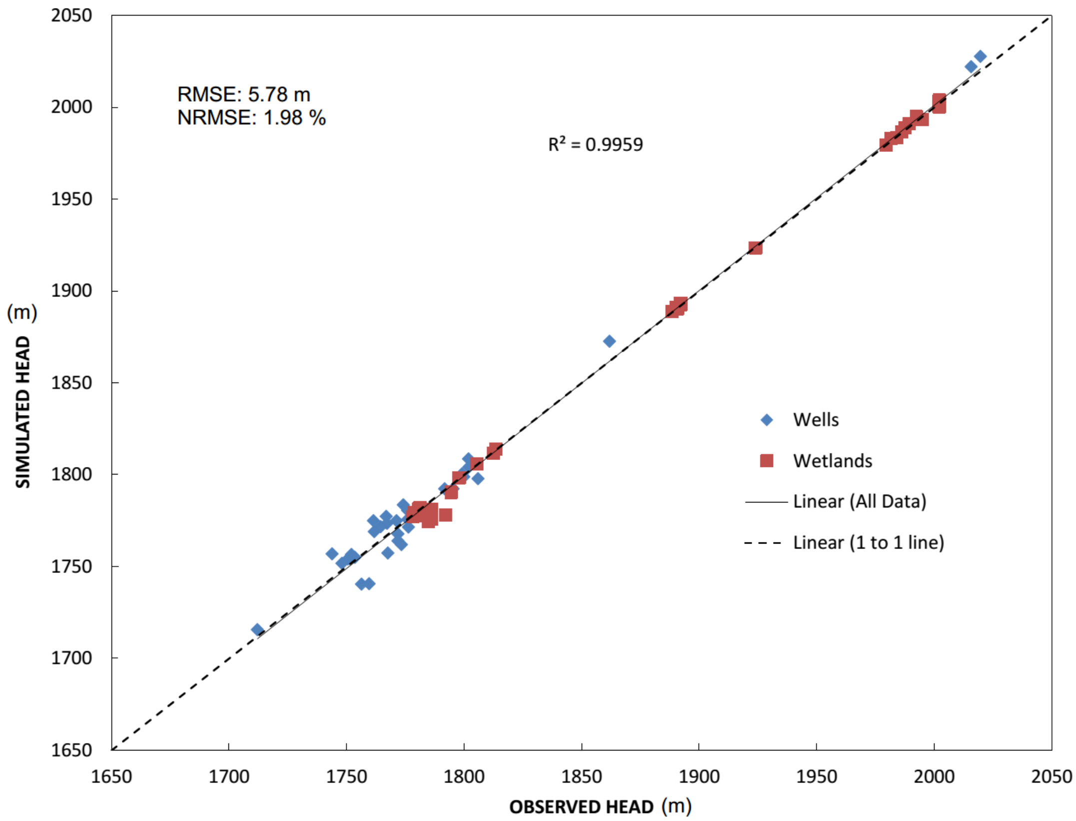

Figure 16. Steady-state calibration results to well and wetland cells.

heads at many of the wells that were pumped or in the vicinity of pumped wells (Figure 16). Despite the obvious inconsistency between the steady state simulated heads and groundwater levels affected by pumping, measured heads provide useful information to evaluate, in a broad sense, the potentiometric surface of the shallow groundwater in the Martis Valley Basin. The resulting spatial distribution of calibrated depth to water (DTW) is very intuitive, where there is shallow DTW near streams, valleys, and meadows, with DTW increasing in mountain block and high elevation areas (Figure 17). Groundwater heads are shown for layer 4 and are above land surface in some steep valley floor mountain transition zones (i.e. northwest stream zone areas), while heads in layer 2 in these areas are only slightly above land surface and discharging as groundwater ET and stream seepage. The calibrated water budget matched observations of precipitation, ET, and recharge percentages derived from past watershed modeling (Rajagopal *et al.*, 2012), water budget estimates (Hydro-Search, Inc, 1995; Nimbus Engineers, 2001; Interflow Hydrology and Cordilleran Hydrology, 2003), and chloride mass balance, and Darcian flux estimates of recharge in adjacent watersheds with similar geology, vegetation, and precipitation magnitudes (Maurer and Berger, 1997; Jeton and Maurer, 2007). In addition, the calibrated steady-state model simulates groundwater flow directions in Martis Valley that are consistent with interpretations based from geochemical and noble gas tracers collected in Martis Valley (Gardner, 2014; Segal, 2013) .

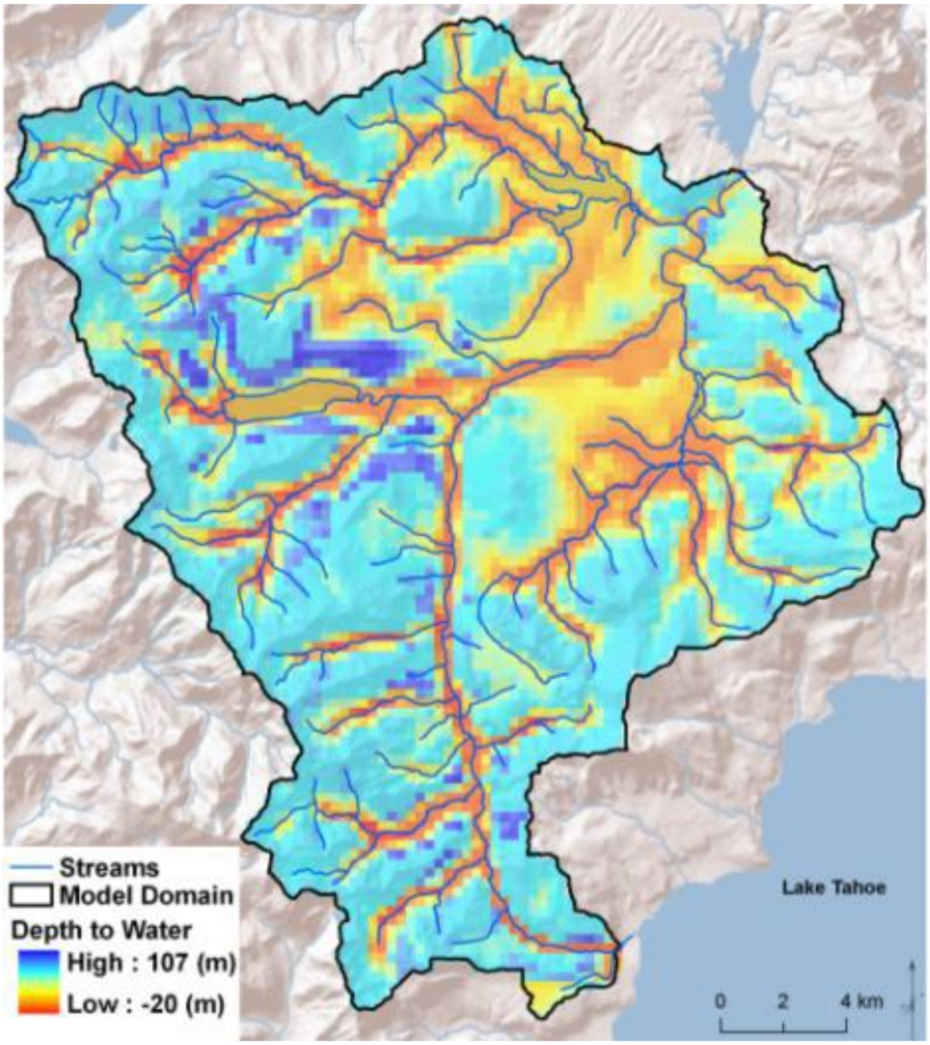

Figure 17. Steady-state simulated distribution of depth to groundwater using layer 4 (mountain block) heads.

GSFLOW Calibration and Historical Simulation

Results of calibrated GSFLOW (i.e. PRMS + MODFLOW) daily streamflow simulations at the outlet of the Martis Valley watershed, and a primary internal gage location near Truckee, CA are shown in Figure 18 for the period of gage record (2002-2011), where it is evident that simulations of streamflow compare well to observations at these locations except for the large flood event of 2006. There are some peak streamflow events (e.g., 2006) that are under simulated by the model likely due to errors in the methodology for distributing precipitation and temperature within the Basin. Warm storms that results in precipitation falling as rain instead of snow are not well represented by the limited climate stations in the watershed. In addition to verifying the model against observations of streamflow we also evaluated its simulation of lake stage in the two lakes within the model domain. Figure 19 illustrates simulated and observed lake and reservoir stage for the historical calibration

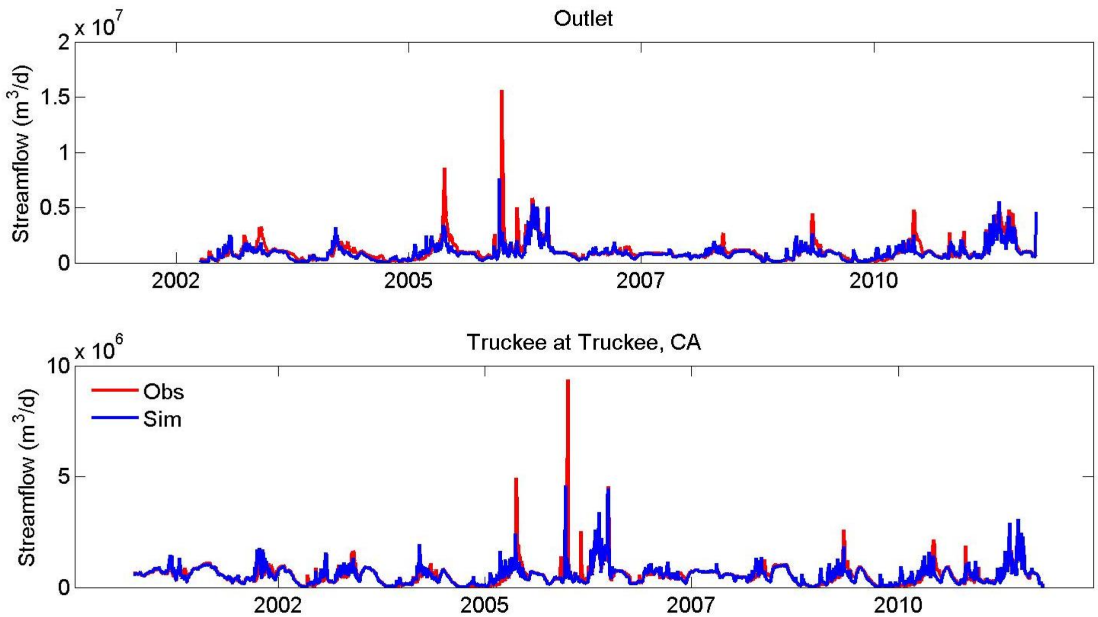

Figure 18. GSFLOW simulated daily streamflow at the outlet and at an internal gage near Truckee, CA, for the period of gage record.

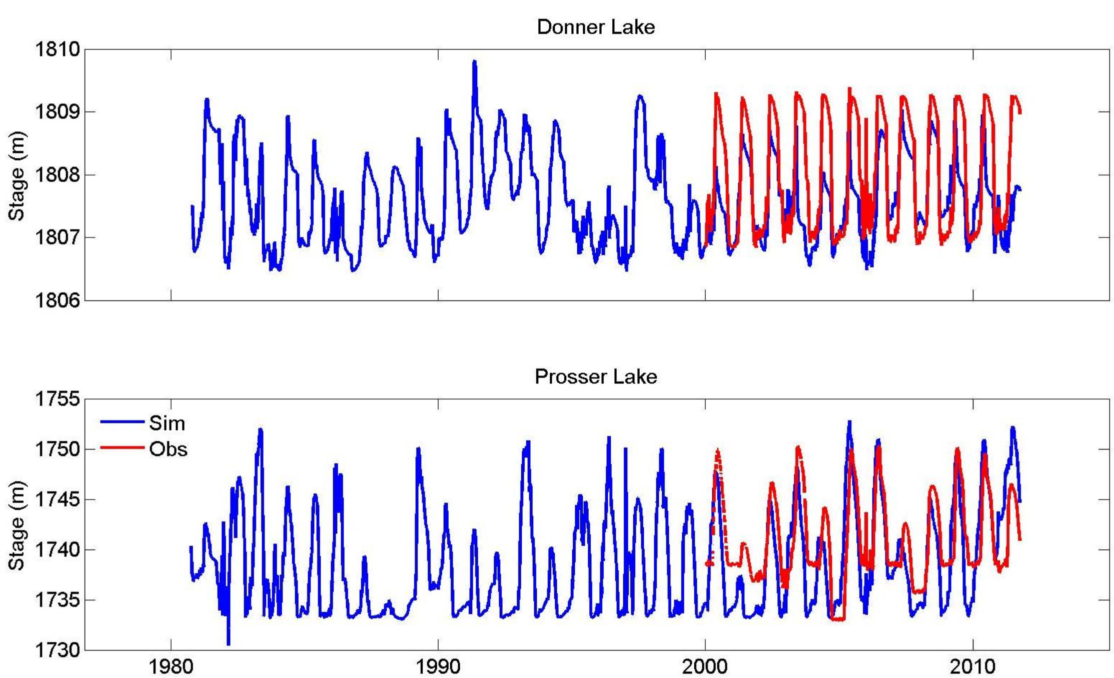

Figure 19. GSFLOW simulated daily lake stage at Donner and Prosser Lakes.

period. From this graph one may observe that the model tends to under predict stage in both lakes and especially in Donner. It should be noted that for Donner no bathymetry information was available and the estimated bathymetry could be the cause of under prediction. However, note that the outflow coming out of these two lakes were specified based on observations and hence the simulation of the lake stage by themselves do not impact the model run.

Calibration of GSFLOW to groundwater head observations consisted of using the same 48 wetland cells and 14 monitoring wells used in the steady-state analysis. Simulated heads for respective wetland and monitoring well cells were output from the model at monthly timesteps for comparison to observations. Monitoring well observations were compared at monthly time-steps for periods when transient observations were available. The 1-to-1 plot (Figure 20) shows that the model simulates the head distribution accurately over a wide range in head values. Results indicate that the root mean squared error (RMSE) between simulated and measured heads was 7.2m, and the normalized RMSE was 2.3 percent, and a bias of 2.6 percent. It should be remembered that the groundwater model covers the entire Basin and not the aquifers in Martis Valley alone. This means that groundwater heads are simulated over an elevation range of more than 1000 m's and hence we argue that the RMSE of 7.2m is acceptable. Also, errors in simulated wetland heads are acceptable given the subgrid variability in land surface elevations around wetland areas. Also, water levels in wetland areas are not always at land surface, but near land surface and within the root zone of identified wetland areas. Thus, a bias toward underpredicting the wetland heads is consistent with our conceptualization of groundwater levels in wetland areas.

Faults are commonly known to serve as conduits or barriers, or sometimes a combination of conduits and barriers to groundwater flow. Faults were not included in the HFM and thus are not represented in steady state MODFLOW or transient GSFLOW simulations of groundwater flow. Large groundwater head differences between simulated and observed heads at monitoring well locations that are close to faults may indicate the role of faults acting as flow barriers in the system (Figure 21). The locations of inferred faults in the Martis Valley Basin along with head residuals, defined as observed minus simulated head, are shown in Figure 20. Small head residuals could suggest that faults do not overtly serve as barriers to groundwater flow in Martis Valley. The second to largest head residual of -20 m (i.e. simulated head is higher than observed) is located at a monitoring well immediately adjacent to the Prosser Village pumping well with pumpage rates ranging from 1500 to 4700 m^3/day from 1981 to 2011. The largest head residual of 21.5 m (i.e. simulated head is lower than observed) corresponds to a monitoring well located along a steep river terrace with a substantial elevation relief within the model cell, and is likely a result of inadequate model scale at this location.

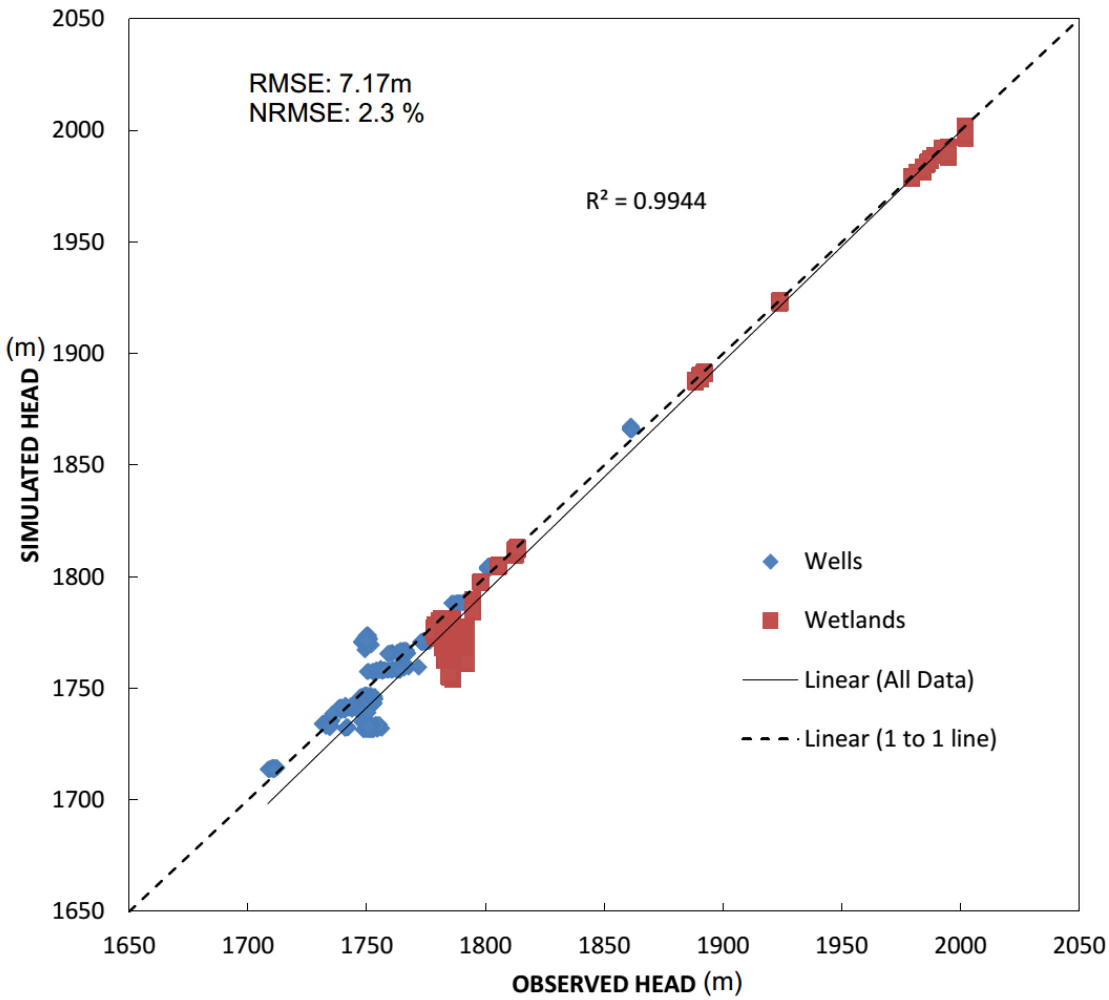

Figure 20. Transient GSFLOW calibration results to heads in wells and wetland cells

Recharge

The spatial distribution of steady state groundwater recharge from 1981 to 2011 indicates that the greatest groundwater-recharge rates occur near stream channels, mountain fronts, and across the alluvial aquifers, where the alluvium is relatively permeable as compared to the upland bedrock areas (Figure 22). Recharge occurs in the upland bedrock areas; however, deep percolation in these areas is restricted by the relatively low vertical hydraulic conductivity of the weathered bedrock in higher elevation areas (Figure 23). These results are consistent with recent findings from a noble gas and isotopic tracer study of recharge within the Martis Valley Basin (i.e. Olympic Valley / Squaw Creek), which suggests that most groundwater recharge to the alluvial aquifer occurs on the lower slopes of the catchment (Singleton et al., 2014; Singleton and Moran, 2010).

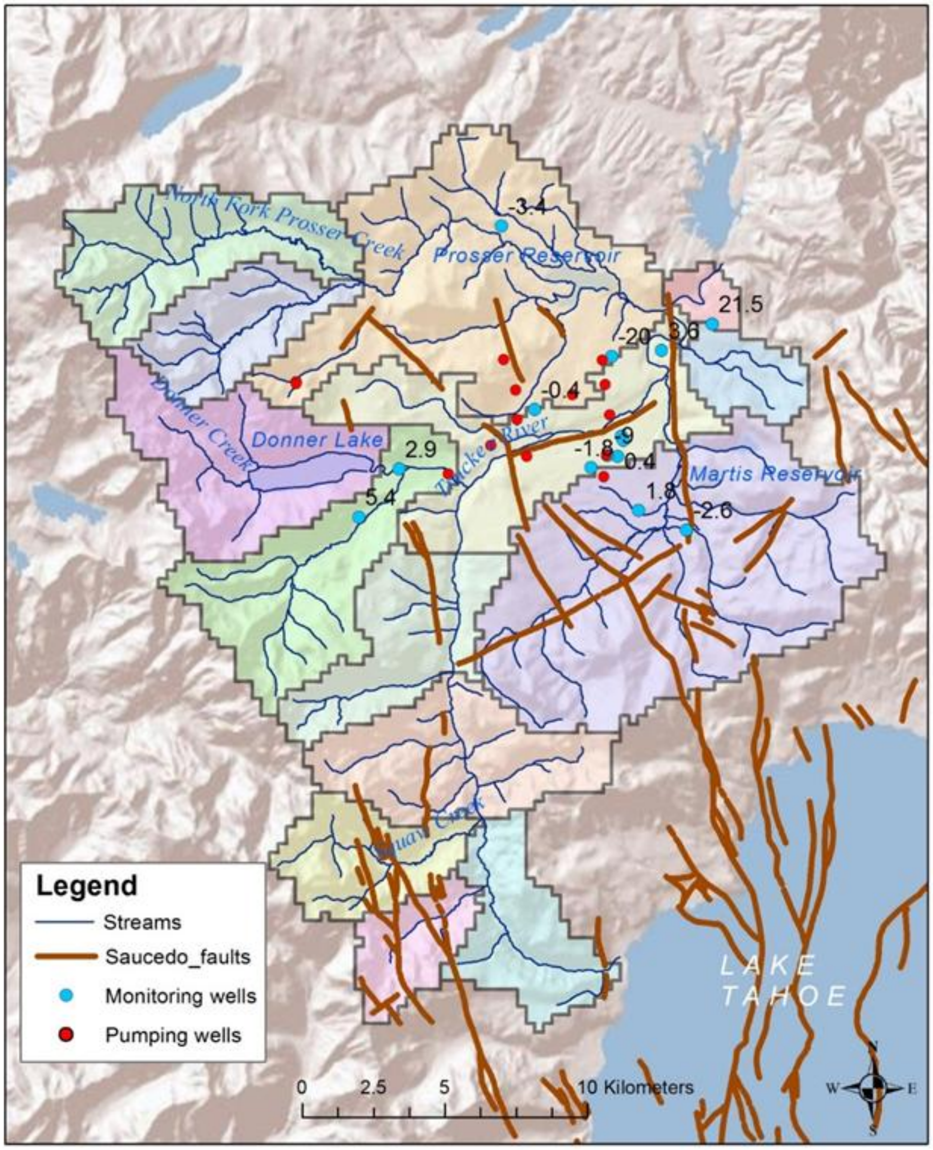

Figure 21. Fault map obtained by Brown and Caldwell overlain with simulated head residuals of the monitoring wells.

GSFLOW Simulations for Future Periods

Future climate impacts to the hydrology of the Martis Valley Basin were evaluated by forcing the calibrated GSFLOW model with historical and EI climate projections provided by CH2M HILL. The model was run with a continuous time series that included measured climate from 1981-2011 and future projection time series. Figure 24 illustrates Basin wide averages of different water budget components simulated by the model for the six different climate scenarios namely No Change, Q1-Q5 which by experimental design perturb the future precipitation by -15 to +15 percent and temperature by 0 to 1.5 deg C. From these simulations it can be observed that the precipitation change ranges from increases of

+7 percent to decreases of -15 percent for the last 30 years of the 21st century compared to the no change scenario. Despite scenarios that include increases and decreases in precipitation, there is always a decline in simulated SWE in the Basin. This occurs because all future climate scenarios have increases in temperature. Similar results have been reported for the Sierra and many snow dominated watersheds across the U.S. (Rajagopal *et al.*, 2014; Dettinger *et al.*, 2004; Huntington and Niswonger 2012; Gangopadhyay and Pruitt, 2011).

Another feature of Figure 24 is the decline in precipitation in the years 2020-2040. As mentioned in the Future Climate development section (above) it should be noted that the future No Change data is identical to the Livneh *et al.* (2013) historical reconstruction from 1913 to 2003, and the future projections of Q1-Q5 are essentially transient perturbations of this historical timeseries (see Appendix-I). Therefore the decline in precipitation from 2020-2040 is reflective of the well-known 1930's drought since the future (2010-2100) precipitation is simply the 1913-2003 timeseries appended to the historic data in 2010. Hence this decline should not be misconstrued to either climate model projections of the region or numerical spin up with the hydrological model. We re-emphasize that this is a result of the experimental design and especially the choice of how the future climate scenarios were constructed.

A key finding from this analysis is that irrespective of increases in precipitation as represented by scenario Q3, groundwater recharge and groundwater discharge to streams tends to decrease. This is a significant finding since it is anticipated that there will be more reliance on groundwater resources in the future due to the full appropriation of surface water resources. In addition to declines in projected groundwater recharge and discharge, runoff (infiltration excess) is projected to increase. This increase in projected runoff is partly responsible for the decline in groundwater recharge and is discussed further in the next section.

Martis Valley primarily relies on ground water sources and uses reservoirs for multiple purposes such as, flood control, water supply, and recreation. Therefore, it is important to evaluate how surface and groundwater inflow volumes into the reservoirs potentially change in the future. Figure 25 shows the cumulative inflows into Donner and Prosser reservoir for the historic and future period for the Q5 (ensemble median) scenario. This figure illustrates that over a 30 year period, the cumulative inflows are similar for historic and future periods in terms of total accumulated flows over the period. However, the duration of deficit is higher in the future for extended periods (i.e. the future (blue line) is lower than historical conditions (red line)). However, some future years have excessively wet periods that increase the future inflows above the historical inflow volumes. This is particularly important from a water management perspective since extended drought periods in the future shown in Figure 25 potentially pose threats to long term water storage and supply.

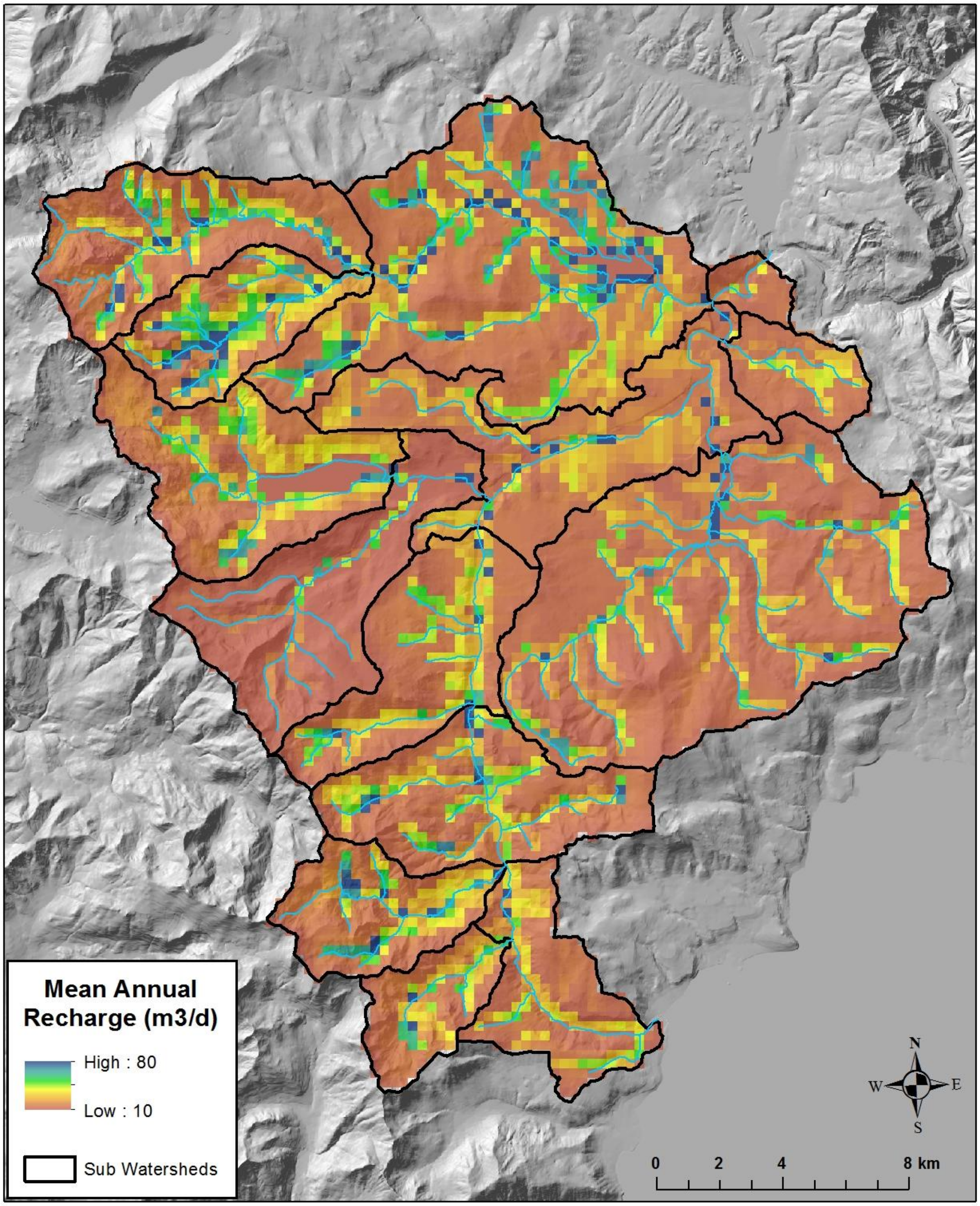

Figure 22. Mean annual recharge (simulated as flux to the saturated zone) over the historical simulation period from 1980 to 2011. From Gardner (2014).

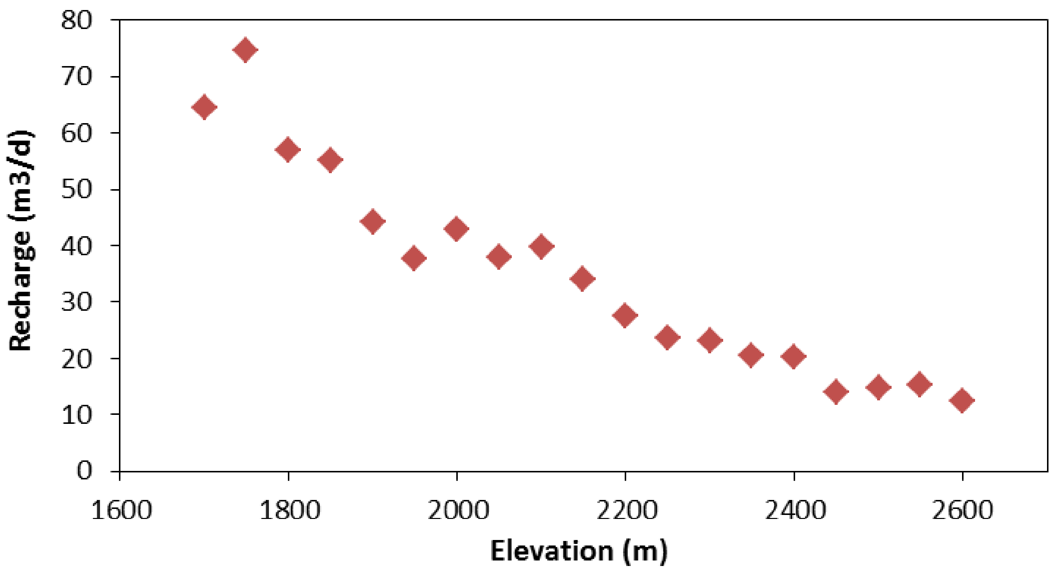

Figure 23. Distribution of recharge as a function of elevation within the Martis Basin. From Gardner (2014).

DISCUSSION

A moderate resolution (300m grid) physically based integrated surface and groundwater GSFLOW model was developed for the Martis Valley Basin. The GSFLOW model reasonably simulates various hydrologic fluxes and states in the Basin when compared to historical observations. The construction and application of GSFLOW in the Martis Valley Basin for historical and future climate periods provides a uniquely different way of assessing climate change impacts on surface and groundwater resources. Traditionally, climate change impacts assessments rely on a surface hydrology model or a groundwater model, separately. This is one of the first studies that integrates both surface and groundwater processes at the Basin scale for a climate impact assessment. Such integration allows for assessment of projected interactions between surface and groundwater such as groundwater discharge to streams and complementary streambed losses to groundwater shown in Figure 24.

One of the most significant findings from this study is the potential reduction of groundwater recharge and discharge to streams for future periods. It should be noted that for future periods, at least two (Q3 and Q4) of the five climate scenarios suggest an increased annual precipitation while declines in recharge are projected for these same scenarios. It should also be noted that for future periods, groundwater pumping was assumed to be constant at the 2011 rates of approximately $3 * 10^4$ m^3/d (24 ac-ft/d). Keeping these findings and assumptions in mind, the decrease in groundwater recharge and discharge to streams could be due to a combination of a change in precipitation form from snow to rain and

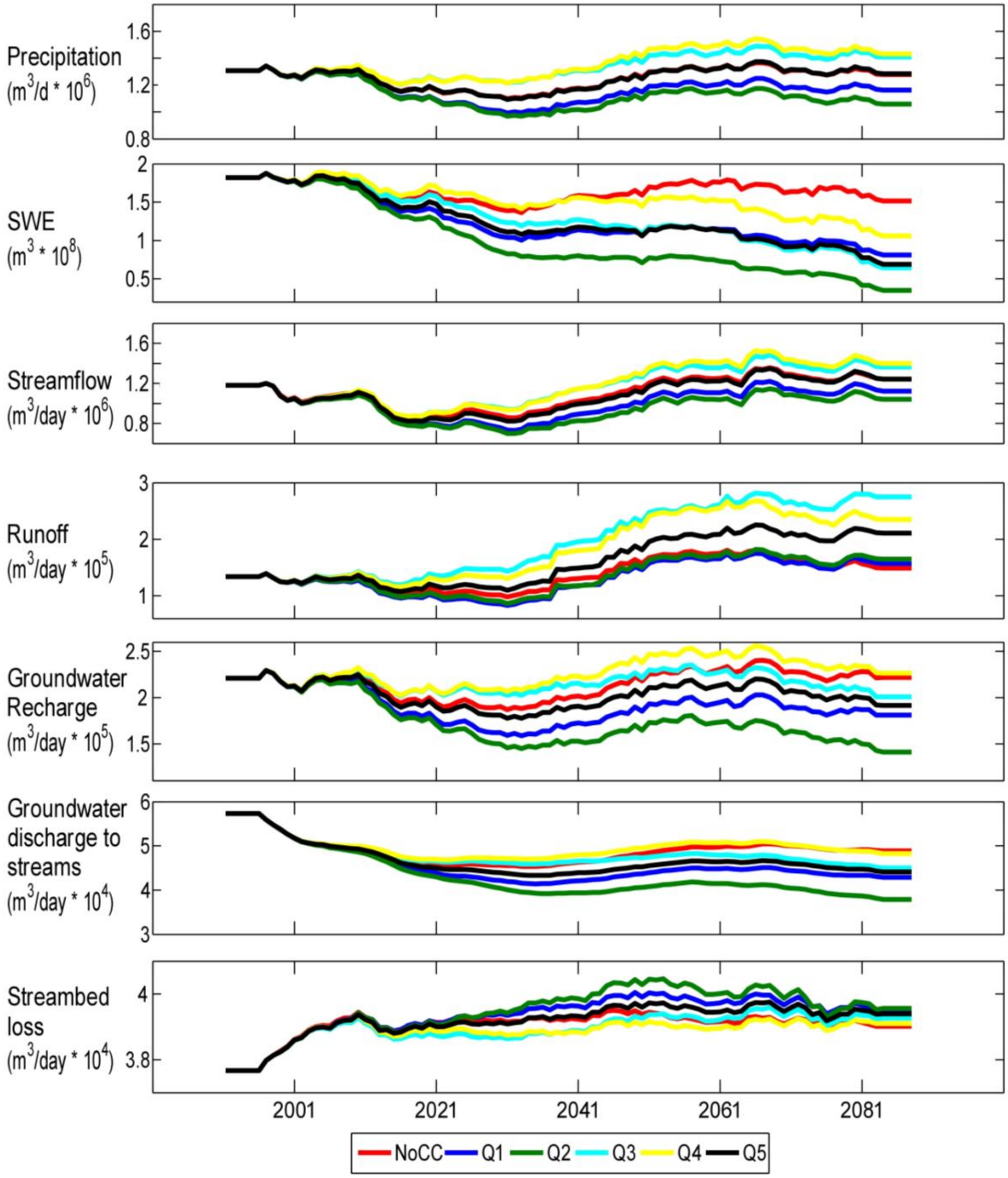

Figure 24. GSFLOW simulated historical and future climate impacts to hydrologic variables. Note: Values smoothed using 30 year moving average with the moving window centered on the 15th year.

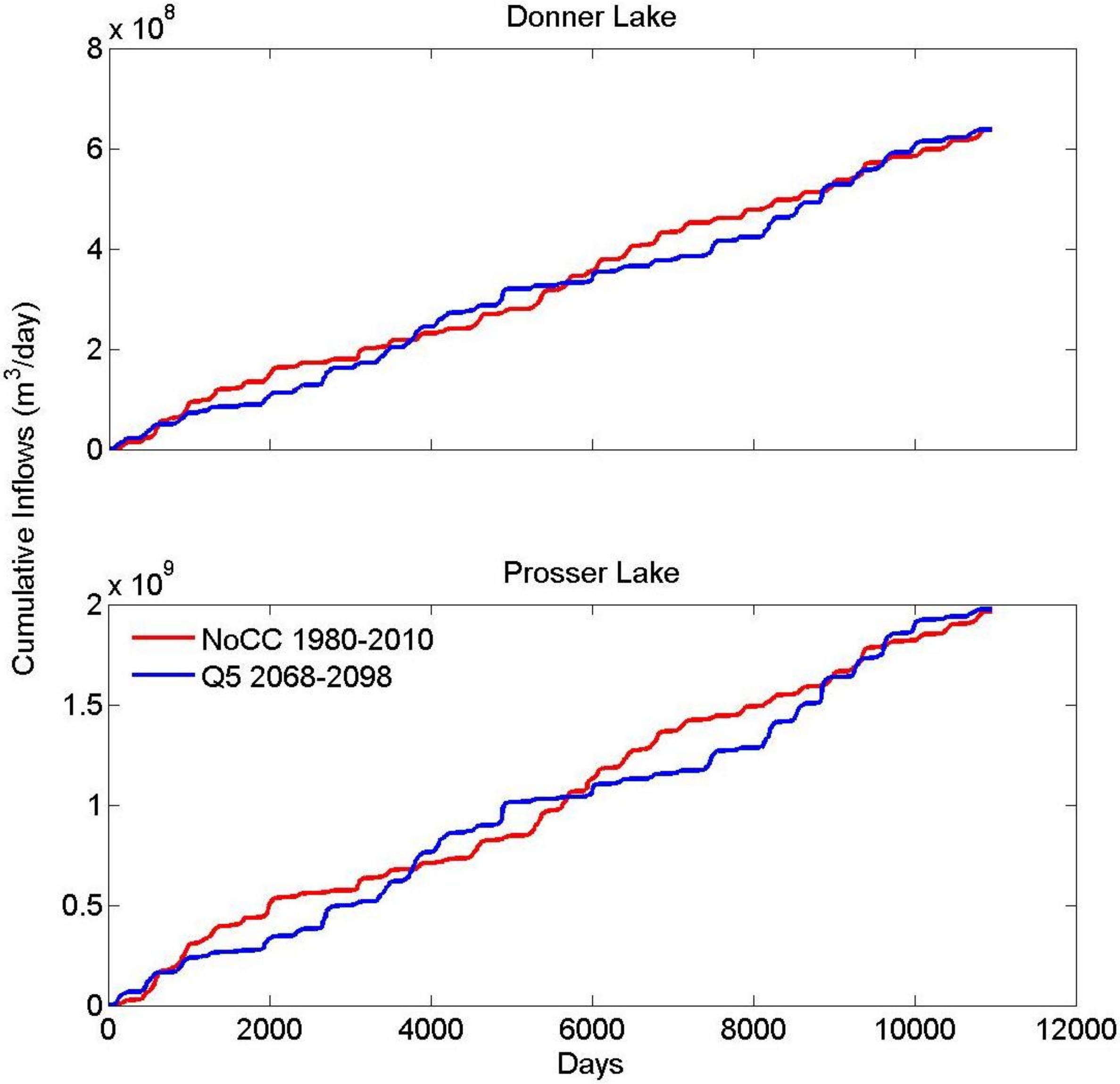

Figure 25. Cumulative inflows in to the reservoirs for historic and future climate conditions. Notice that over a 30 years total (represented by the last timestep on the x axis) inflows are approximately the same, but there are longer periods when the lake is in deficit storage. Intermittent high precipitation events bring the lake back to normal storage.

increased runoff, and capture of groundwater discharge to streams due to pumping. With a change in form of precipitation from more snow to more rain, there is more infiltration excess that quickly leaves the system which potentially could lead to less recharge. Historically, when the precipitation accumulates as snow and melts in spring, there are more diffuse and longer pathways for the water to recharge, whereas infiltration excess runoff provides a short and relatively shallow flow path and ultimately reduces groundwater recharge. It is plausible that the groundwater discharge to streams is reduced in the future due to increases in stream capture by groundwater pumping, however groundwater pumping is only 3% of the average flow of the Truckee River exiting the Martis Basin. As the period of pumping increases, the proportion of water captured by wells, transitions between capturing groundwater storage to capture of streamflow (Konikow and Leake, 2014). Thus, streamflow capture may increase during the future simulation period and cause decreases in groundwater discharge to streams, but again, will be a small fraction of the total river flow, and equates to about 33% of the estimated current groundwater recharge (assuming 30,000 ac-ft/yr; Table 1). Additional simulations that exclude groundwater pumping would clarify the contributions of decreased groundwater discharge to streams due to decreased ground recharge, increased runoff, and groundwater pumping.

Limitations

It is difficult to build physical models that aim to depict the numerous processes that control the movement of water over and below the land surface. There were many simplifications that were necessary for simulating integrated surface and groundwater processes, however, despite these simplifications, results shown in this report illustrate that the model reasonably captures the dynamics of water movement within the Martis Valley Basin. Through the process of model development and calibration, key insights were gained and are summarized below.

The Martis Valley Basin is smaller than mesoscale (100's of Km) atmospheric circulation patterns. Therefore it is reasonable to assume that the two climate stations can describe the general climate (especially precipitation) variability within the watershed. However, there are isolated and localized precipitation events that are not measured at climate stations, leading to errors in spatially distributed precipitation. Accurately capturing the temporal and spatial distributions of precipitation is a challenge in watersheds with complex topography such as the Martis Valley Basin. Accurately classifying precipitation as rain or snow is also a challenge and adds to model uncertainty. While it is clear from the figures of simulated and observed SWE and SCA that the model simulates snow accumulation and melt fairly well, it should be noted that on certain days, especially late fall to early winter, classifying rain and snow correctly is a challenge.

There are numerous stream gauges within the Martis Valley Basin, however they are all downstream of the reservoirs. These data are clearly useful for operations and management. However, due to the lack of gaged streamflow data upstream of reservoirs, it is difficult to accurately estimate reservoir inflows that are ultimately used for calibration of the surface water model. The lack of detailed lake and reservoir bathymetry information, especially for Donner Lake, could introduce significant errors in assumed stage volume relationships, and therefore simulated stages.

SUMMARY AND CONCLUSIONS

To better understand the hydrology of the Basin and its responses to climate change this study built a physically based coupled surface and groundwater model of the Martis Valley Basin. This model was built and calibrated/verified against observations of 1) streamflow, 2) snow water equivalent, 3) snow covered area, 4) groundwater heads and 5) lake stages. The model simulates the dynamics of the system reasonably well over a 30 year historical period. In addition to being consistent at the outlet of the watershed, this model also performs well at internal gauges and replicates the measured groundwater head distribution and flow direction.

Currently, groundwater is the primary water resource for municipal supply in the Martis Valley. It is yet unclear to what extent groundwater pumping and consumptive use will change in the future. However, with projected increased growth, groundwater pumping will likely increase. Increased groundwater pumping in the future will have the effect of lowering the groundwater table and capturing discharge (Konikow and Leake, 2014).

Climate projections provided by CH2M Hill were used to make future projections of hydrological change in the Basin. In addition, the climate elasticity of the system to precipitation was observed to be approximately 1:2 for the historical period meaning a reduction in precipitation of 10 percent would lead to a 20 percent reduction in streamflow. In all scenarios, there is a shift from a more snow dominated system to a rain dominated system, in other words the snowpack water equivalent is projected to reduce in the future. This is consistent with findings from other snow dominated watersheds. Water use from the Truckee River is seasonally dependent due to large fluctuations in temperature that increases water use in the summer, in addition to increased water use during the growing season by agriculture. Accordingly, the snowpack in the Martis Valley Basin effectively serves as a reservoir and the snowmelt period has conveniently corresponded to increased water demand. The significant loss in snowpack projected by the modeling herein will significantly reduce water storage for the Truckee River Basin. Accordingly, losses in snowpack storage will need to be replaced by other storage mechanisms, either by additional surface reservoirs or possibly artificial groundwater storage and recovery.

An interesting finding from the current study is the decline in future groundwater recharge and discharge to streams. There are two potential causal mechanisms that could explain this, 1) the current levels of pumping in the Basin are already high in comparison to the early 1980's and much of the pumping may have come from groundwater storage in the past that transitions to streamflow capture in the future, or 2) the transition from a snow dominated system to rain dominated system provides quicker pathways for water to exit the system and hence there is reduced recharge. The model shows that there is an increase in infiltration excess runoff which suggests that the latter mechanism could be the cause for future decreases in groundwater recharge. This hypothesis however needs to be investigated further, since there are many hydrological processes that interact at various scales both spatial and temporal. In the near future, we plan to conduct synthetic experiments with not only varied climate like in this study but also varied pumping rates in the future. Results of this study suggest that climate change potentially adds further stress to available surface and groundwater water resources in the Martis Valley. The results from this study will be archived at DRI.

Lastly, these simulations indicate there will be a significant reduction in snowpack, as indicated by other studies (Coats, 2010; Huntington and Niswonger 2012; Rajagopal et al., 2014). A reduction in snowpack affectively reduces reservoir storage due to the seasonality of water demand in the Truckee River Basin. Because rain and early snowmelt cannot be impounded by reservoirs due to flood risks, reductions in snowpack will need to be supplemented in the future by new surface reservoirs or artificial groundwater storage and recovery.

ACKNOWLEDGEMENTS

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Yapo P.O., Hoshin Vijai Gupta, Soroosh Sorooshian, Multi-objective global optimization for hydrologic models, Journal of Hydrology, Volume 204, Issues 1–4, 30 January 1998, Pages 83-97, ISSN 0022-1694, http://dx.doi.org/10.1016/S0022-1694(97)00107-8.

APPENDIX A: TECHNICAL NOTE ON CLIMATE CHANGE SCENARIOS

The future climate data used in this study was provided to DRI by CH2M HILL. The future climate data consists of six ensembles Q1, Q2, Q3 Q4, Q5 and No Climate Change. The ensembles approximately reflect the scenarios presented in the table below.

Table A1. Summary of climate change scenarios provided by CH2M HILL

	ΔP	ΔT (deg C)	Description
Q1	-15%	0.5	Warmer Drier
Q2	-15%	1.5	Hotter Drier
Q3	15%	1.5	Hotter Wetter
Q4	15%	0.5	Warmer Wetter
Q5	0%	1	Average Future
NoCC	0%	0	No Climate Change

They provided the following two documents as a reference of the method of developing the future Ensemble Informed (EI) ensembles.

1) Climate projections and methods described in http://www.usbr.gov/WaterSMART/wcra/docs/ssjbia/ssjbia.pdf

2) The applied method was based on the approach developed for California Department of Water Resources Bay Delta Conservation Plan, Draft Bay Delta Conservation Plan, Appendix 5.A.2 located at http://baydeltaconservationplan.com/PublicReview/PublicReviewDraftBDCP.aspx

Below is the technical note provided by CH2M HILL pasted verbatim that explains the EI Climate Scenarios method and how the future climate scenarios were developed for this study.

Climate Change Scenarios for the Truckee-Carson River Basins Technical Note

Prepared by CH2M HILL

November 12, 2013

Transient future climate scenarios were developed for selected locations over the Truckee and Carson River Basins using an Ensemble Informed Climate Scenarios (EI) method. The approach uses an ensemble of 112 climate projections used in the IPCC AR4, subsequently bias-corrected and statistically downscaled (BCSD). The downscaled climate projections were obtained from Lawrence Livermore National Laboratory under the World

Climate Research Program's (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3). This archive contains climate projections generated from 16 different GCMs developed by national climate centers and for SRES emission scenarios A2, A1b, and B1. One historical and five statistically representative future temperature and precipitations projections were developed to characterize the central tendency and the range of the ensemble uncertainty including projections representing drier, less warming; drier, more warming; wetter, more warming; and wetter, less warming conditions than the median projection. The observed natural variability in the historic climate between 1915 and 2003 was used to create the inter-annual variability in the projected climates.

The EI method is described in various project reports, including Bay Delta Conservation Plan, Central Valley Project Integrated Resource Plan, and Sacramento-San Joaquin River Basins Climate Impact Study. A manuscript describing the method is in preparation to be submitted to a peer-reviewed journal and should be referenced for these climate scenarios before publication of final Basin study document.

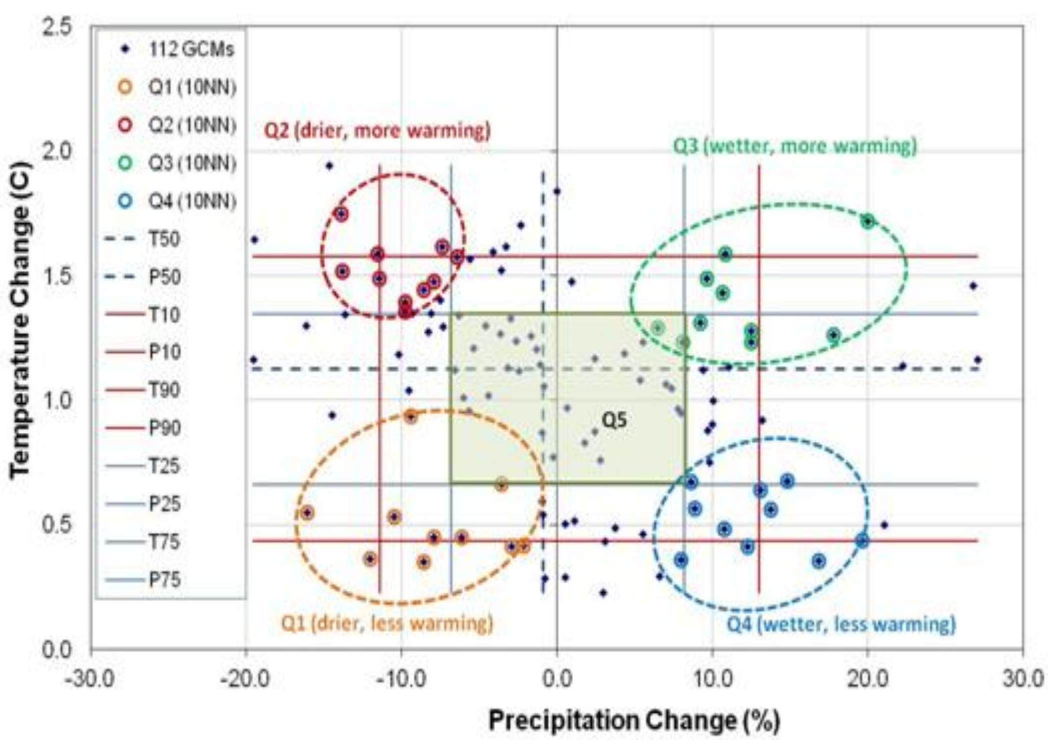


Figure A1. Ensemble Informed Climate Scenarios (EI) method

The Ensemble Informed method results in five climate scenarios labeled Q1 through Q5. The Q5 scenario is bounded by the 25th and 75th percentile joint temperature-precipitation change. Scenarios Q1-Q4 are selected to reflect the results of the 10 projections nearest each of 10th and 90th joint temperature-precipitation change bounds.

Some Specific Notes Related to the Truckee-Carson specifics are described below.

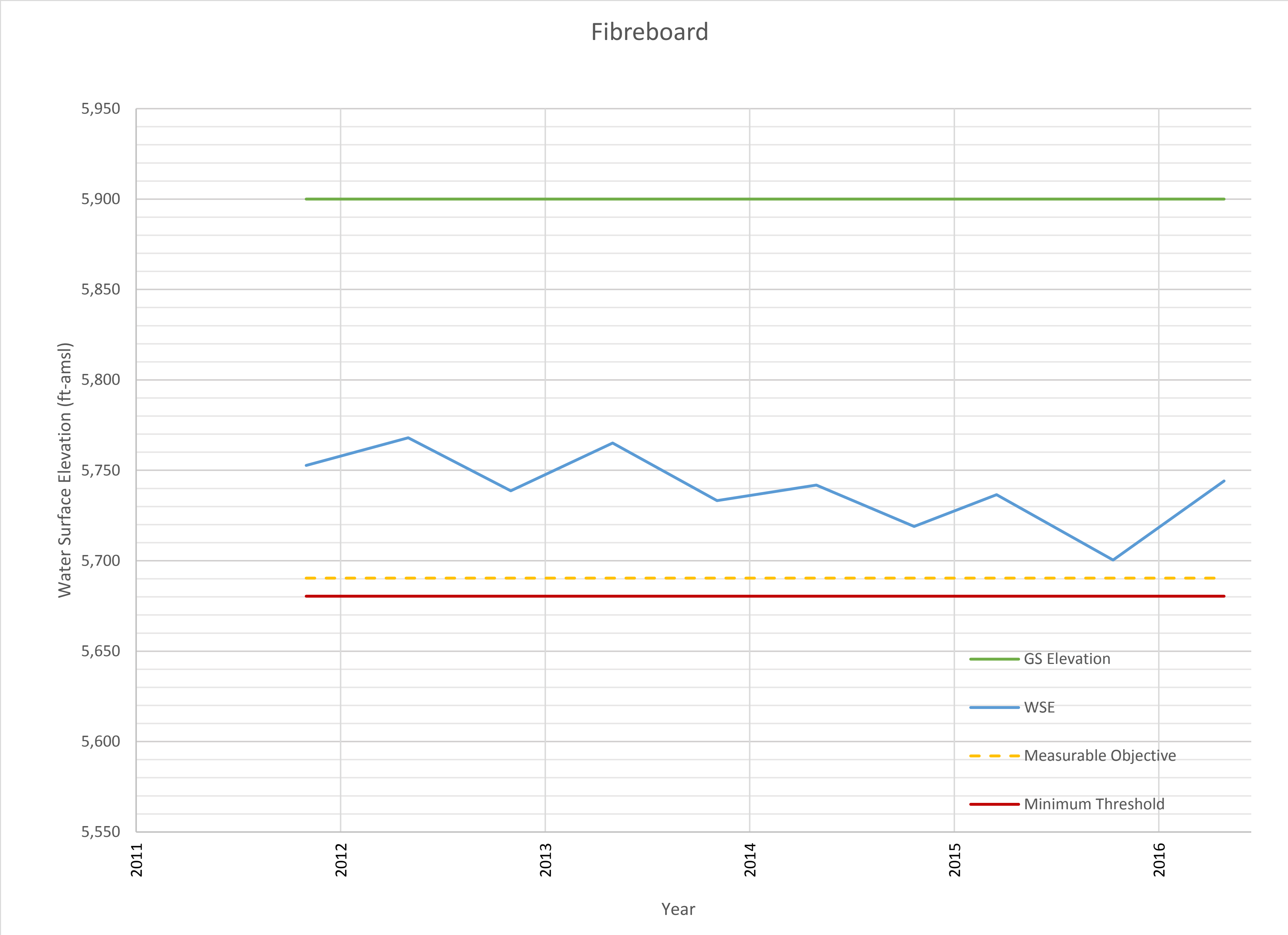
1. Climate forcing for the no climate change conditions were prepared over the period 1/1/2011 through 12/31/2099 by repeating the historical data over the period 1/1/1915 through 12/31/2003.
2. Historical precipitation, maximum and minimum temperature data at 1/16-degree spatial resolution were obtained from Livneh *et al.* forcing (2013). The 1/16-degree historical forcing was averaged to 1/8-degree spatial resolution to match the spatial resolution of the 1/8-degree BCSD data. BCSD downscaled data are used to develop the ensemble informed climate change scenarios as described previously. 1/8-degree closes grids are selected for each of the station locations identified by Desert Research Institute.
3. The projected changes in precipitation, computed based on the BCSD downscaled precipitation, were used along with the 1/8-degree historical precipitation to produce future precipitation scenarios. A wet bias was indentified in the historical Livneh *et al.* precipitation data prior to 1949 period. A simple approach, based on monthly scaling factors computed using the PRISM and Livneh precipitation data, were used to remove the wet bias over the period 1915-1949.
4. The projected changes in average temperature were used along with the 1/8-degree maximum and minimum temperature data to produce future temperature scenarios. A linear trend in the historical temperature was removed.
5. Five climate change scenarios bracket the ranges and median were developed over the future period 1/1/2011 through 12/31/2099.
6. The columns contain the variables (and units):
    - year
    - month
    - day (for a daily data file)
    - precipitation (mm/day for daily data file; monthly sum in mm for monthly data file)
    - maximum temperature (deg C)
    - minimum temperature (deg C)
    - average temperature (deg C)
    - average wind speed (m/s). [Please note the average wind speed is only listed in the data files in the folder named “No_Wetbias_Correction”; the average wind speed is averaged at 1/8-degree spatial scale taken from Livneh *et al.*, 2013; this is repetition of 1915-2003]
7. For some station locations, same 1/8-degree was identified (due to the spatial resolution of the 1/8-degree data). In such cases, precipitation for the overlapping grids, were scaled using monthly scaling factors computed using the Livneh precipitation and the station precipitation over the over lapping period 1981-2003.

Table A2. Climate stations for which climate change scenarios were provided

38.8125	-120.0625	ECHO PEAK	PRISM Station
38.9375	-120.0625	FALLEN LEAF	PRISM Station
39.0625	-119.9375	GLENBROOK #2	PRISM Station
38.8125	-119.9375	HAGAN'S MEADOW	PRISM Station
38.9375	-119.9375	HEAVENLY VALLEY	PRISM Station
39.1875	-119.9375	MARLETTE LAKE	PRISM Station
39.3125	-119.9375	MT ROSE SKI AREA	PRISM Station
38.9375	-120.1875	RUBICON #2	PRISM Station
Please Look at the folder "TAHOECITYCROSS"		TAHOE CITY CROSS	PRISM Station
Please Look at the folder "WARDCK3"		WARD CK 3	PRISM Station
39.3125	-120.1875	TRUCKEE #2	PRISM Station
39.1875	-120.3125	Squaw Valley GC	PRISM Station
39.4375	-120.1875	SAGEHEN CREEK	PRISM Station
39.4375	-120.3125	INDEPENDENCE CAMP	PRISM Station
39.1875	-120.1875	ET Tahoe City	Evaporation Station
39.4375	-119.0625	ET Lahontan Dam	Evaporation Station
Please look at the folder "ETDonnerMemSp"		ET Donner Mem Sp	Evaporation Station
39.4375	-120.0625	ET BOCA	Evaporation Station
Please look at the folder "ETTruckeeTahoeGSOD"		ET Truckee-Tahoe GSOD	Evaporation Station

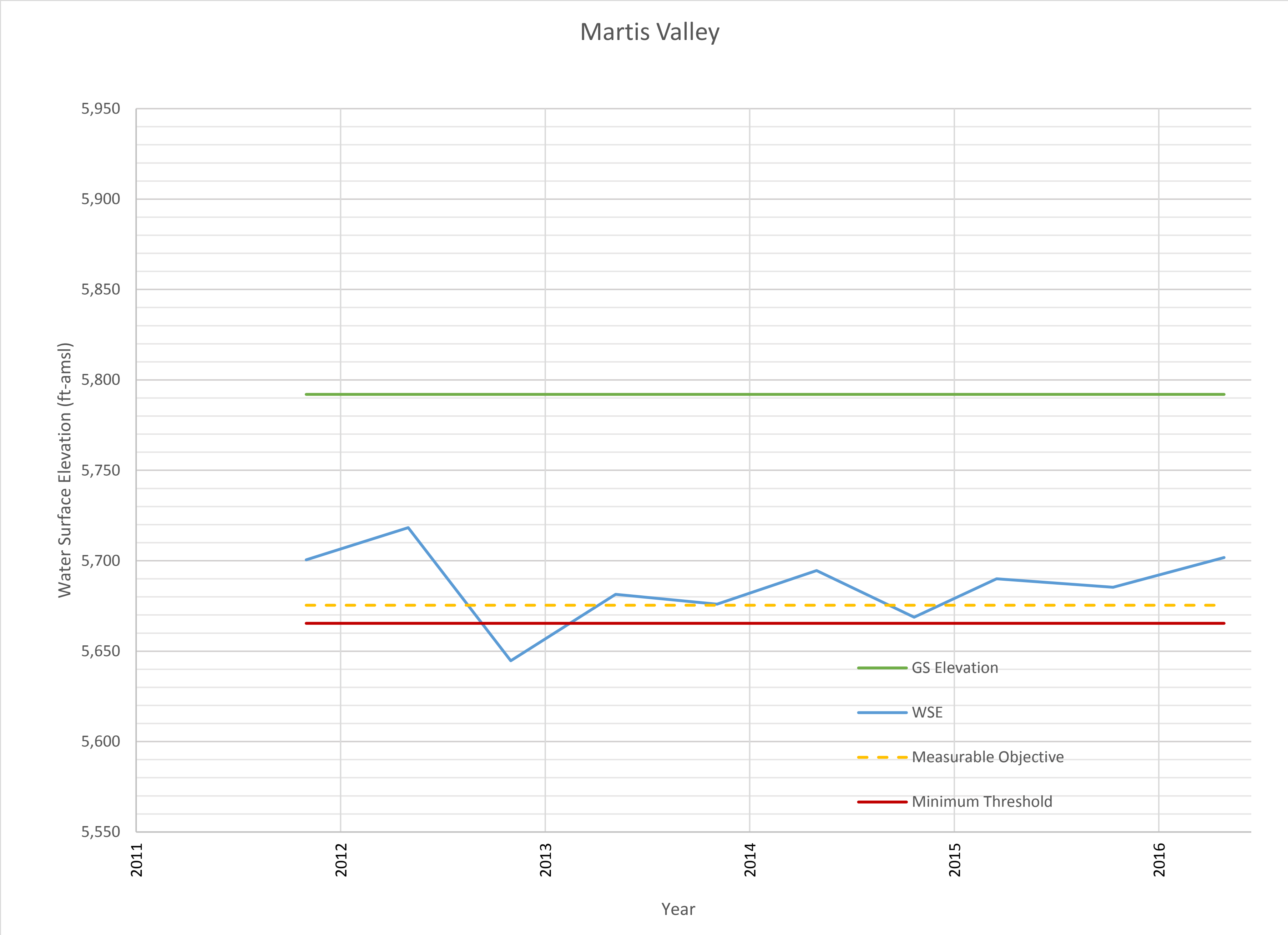
APPENDIX C

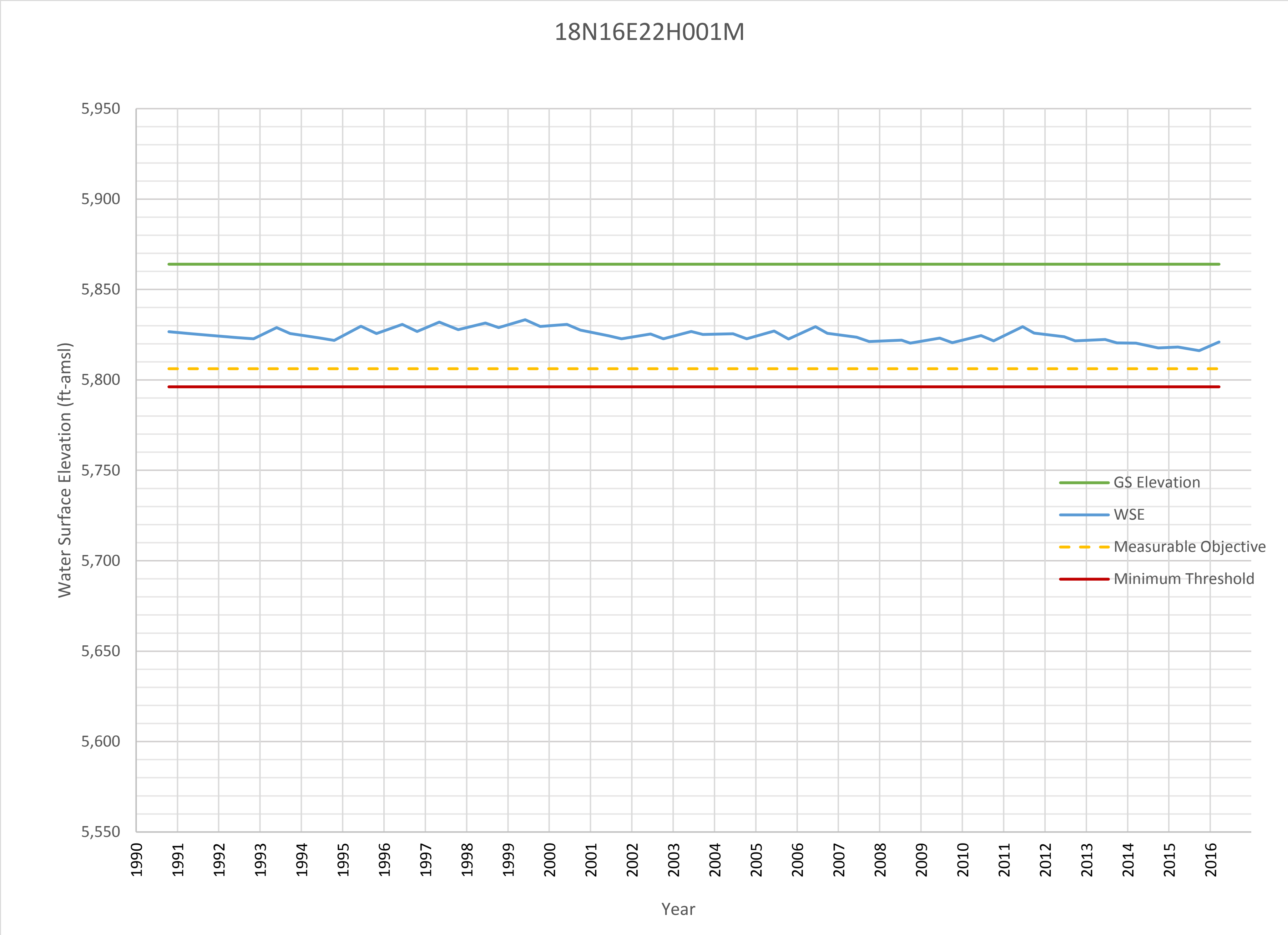
CASGEM Monitoring Well Hydrographs



Fibreboard
Water Surface Elevation (ft-amsl)
5,950
5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold

Prosser Village
Water Surface Elevation (ft-amsl)
5,950
5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold


Martis Valley
5,950
5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
Water Surface Elevation (ft-amsl)
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



18N16E22H001M
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5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
Water Surface Elevation (ft-amsl)
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
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2003
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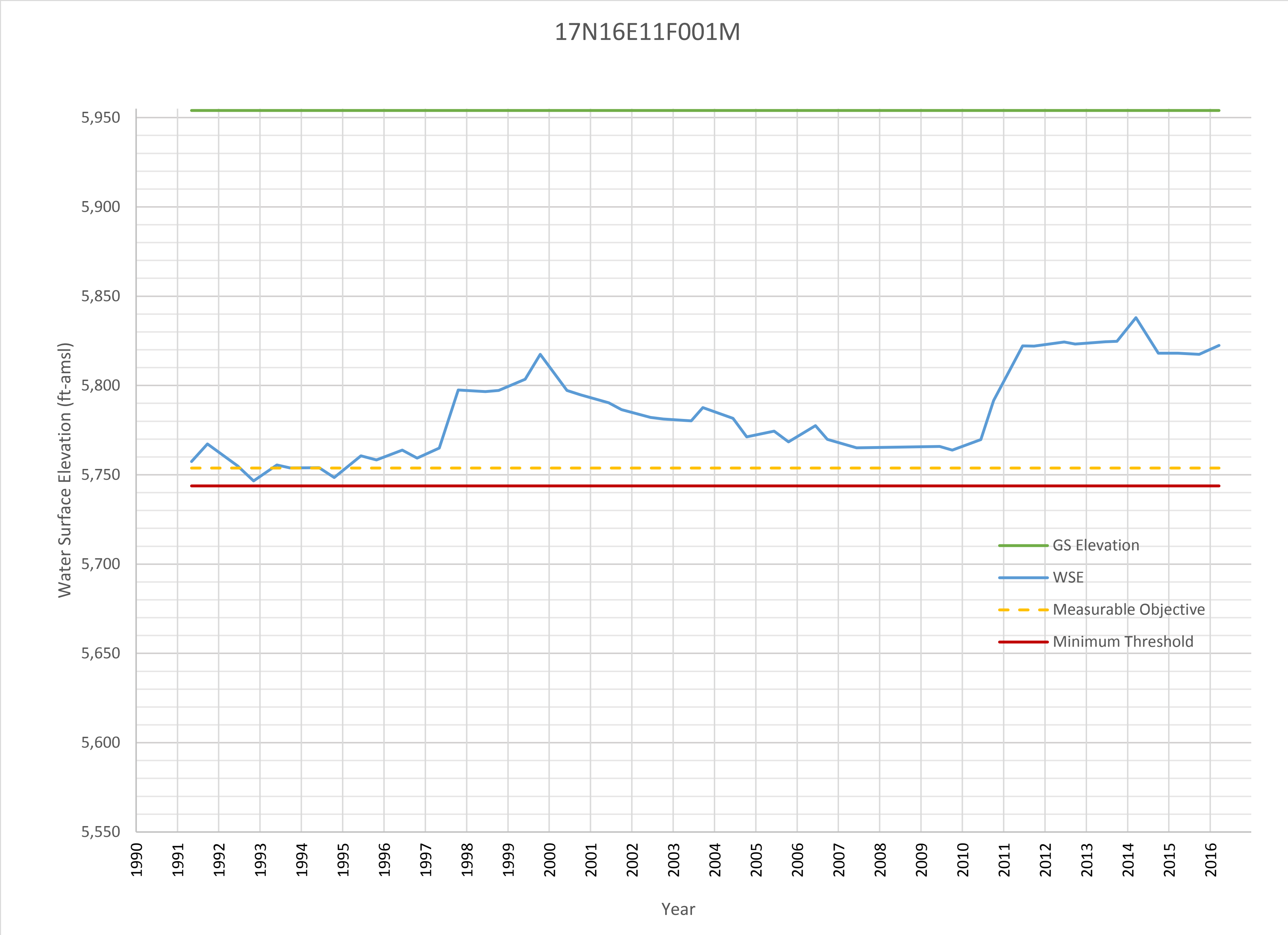
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



17N16E11F001M
Water Surface Elevation (ft-amsl)
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5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
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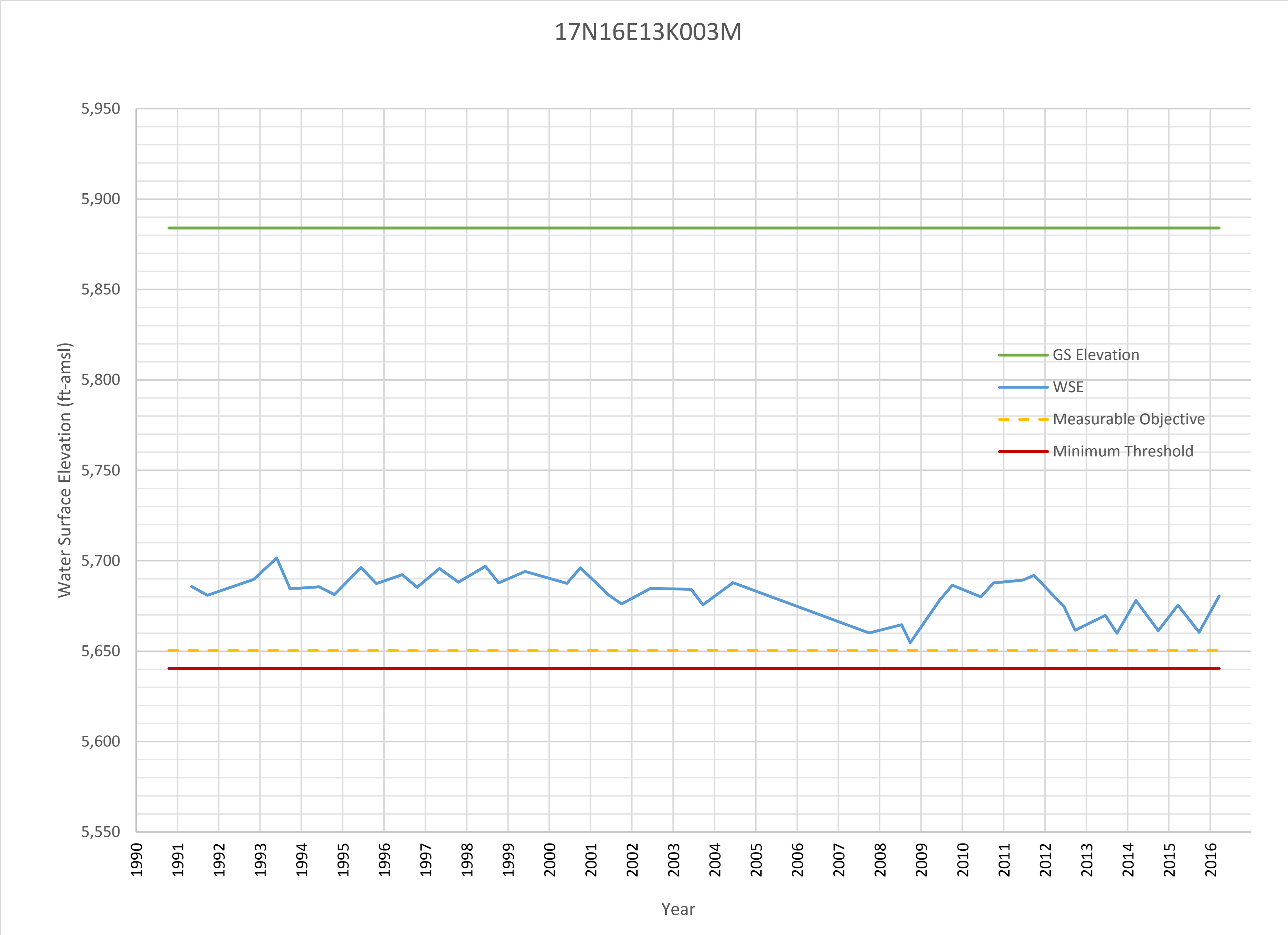
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold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Water Surface Elevation (ft-amsl)
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5,900
5,850
5,800
5,750
5,700
5,650
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5,550
1990
1991
1992
1993
1994
1995
1996
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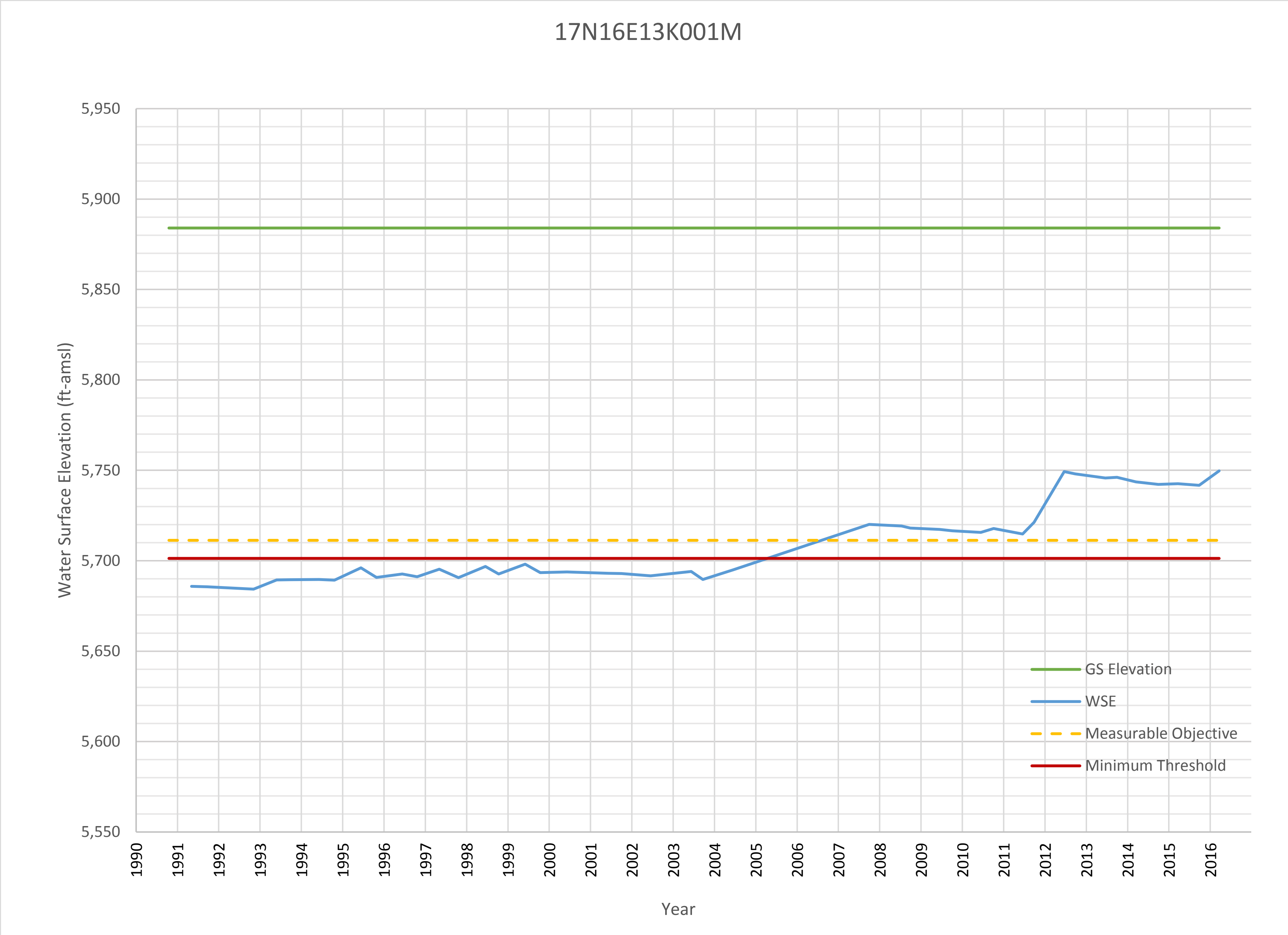
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



17N16E13K001M
5,950
5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
Water Surface Elevation (ft-amsl)
1990
1991
1992
1993
1994
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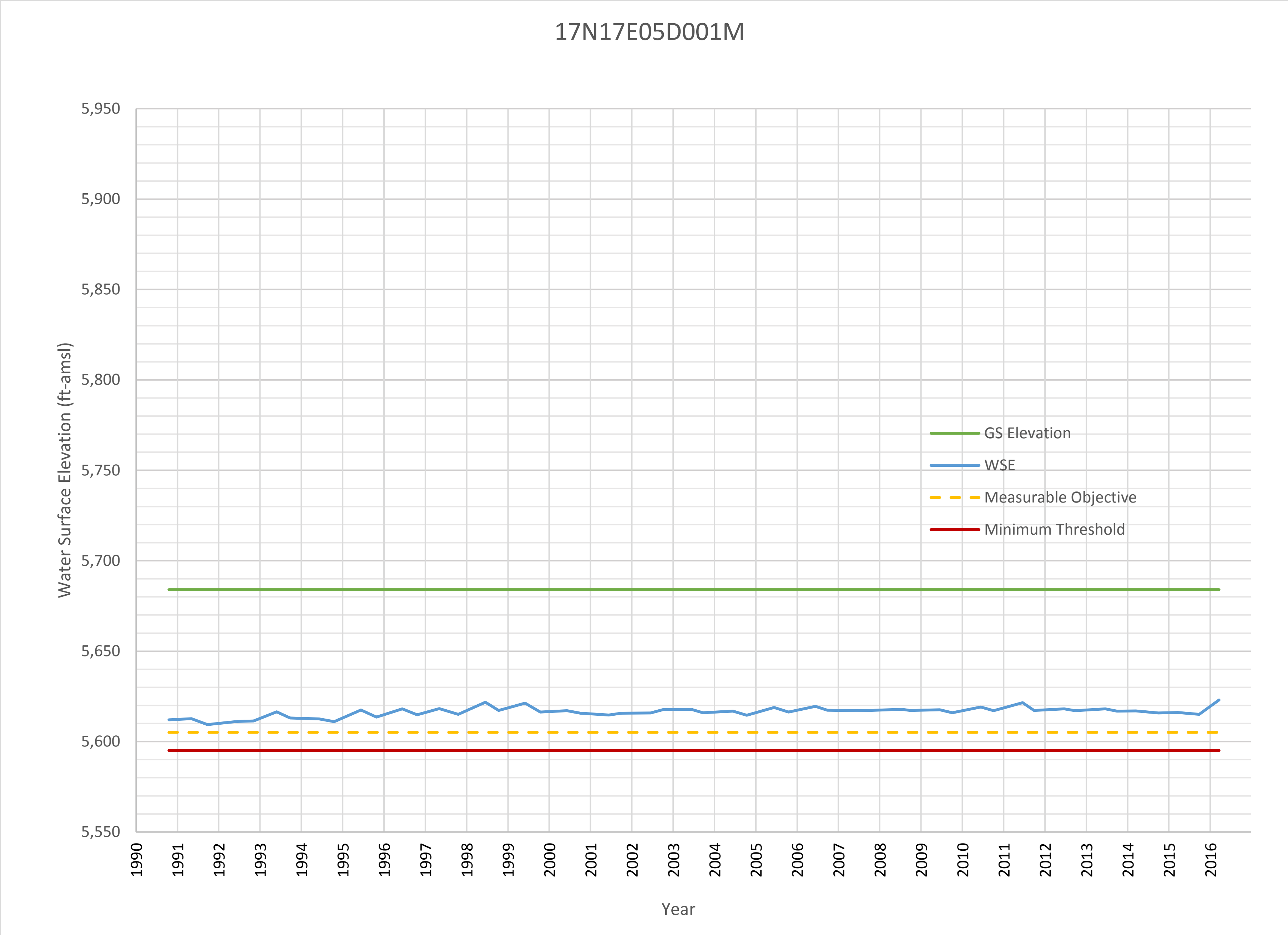
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



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Water Surface Elevation (ft-amsl)
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5,850
5,800
5,750
5,700
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5,550
1990
1991
1992
1993
1994
1995
1996
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2011
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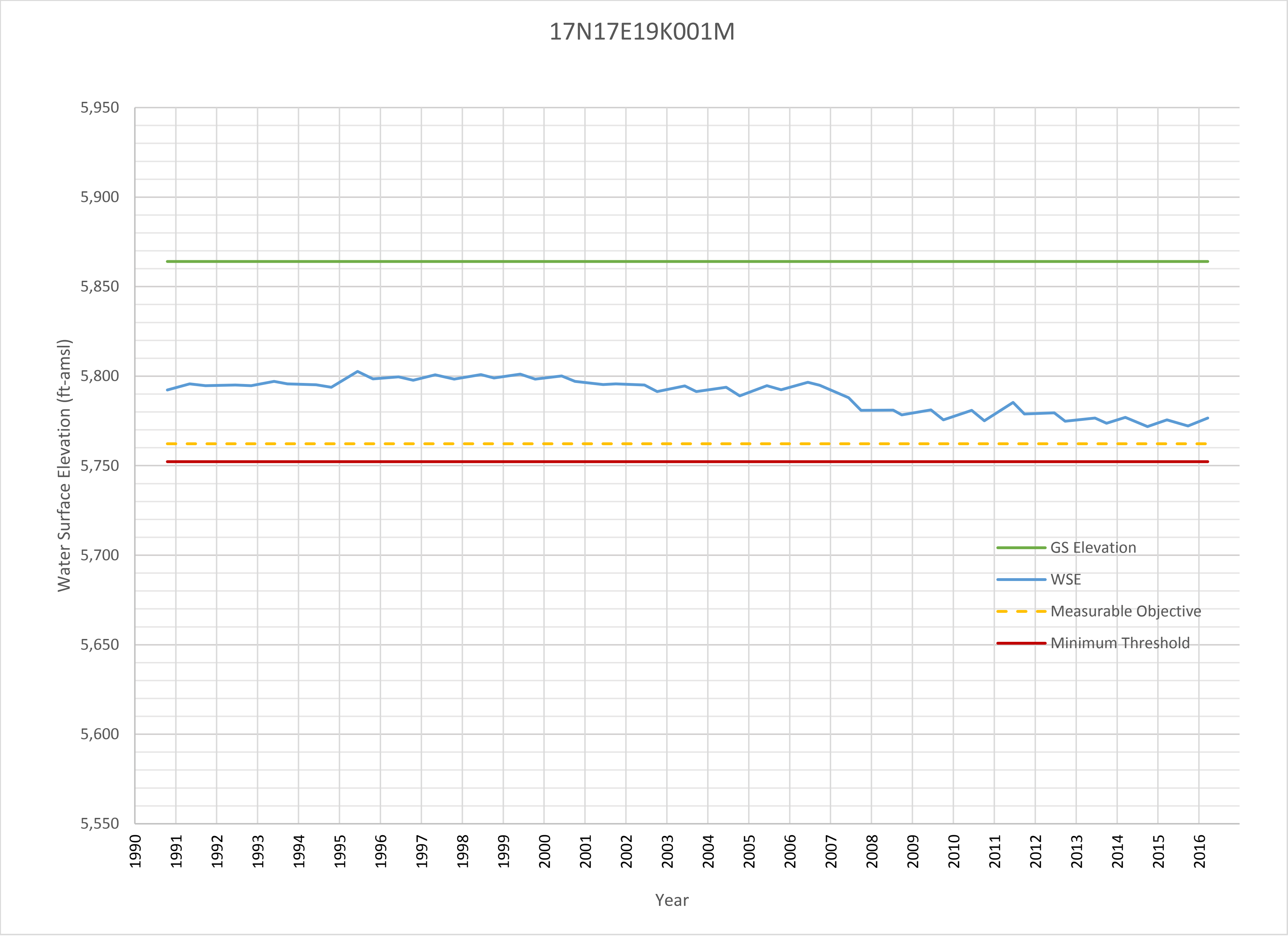
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



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Water Surface Elevation (ft-amsl)
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5,850
5,800
5,750
5,700
5,650
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5,550
1990
1991
1992
1993
1994
1995
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2011
2012
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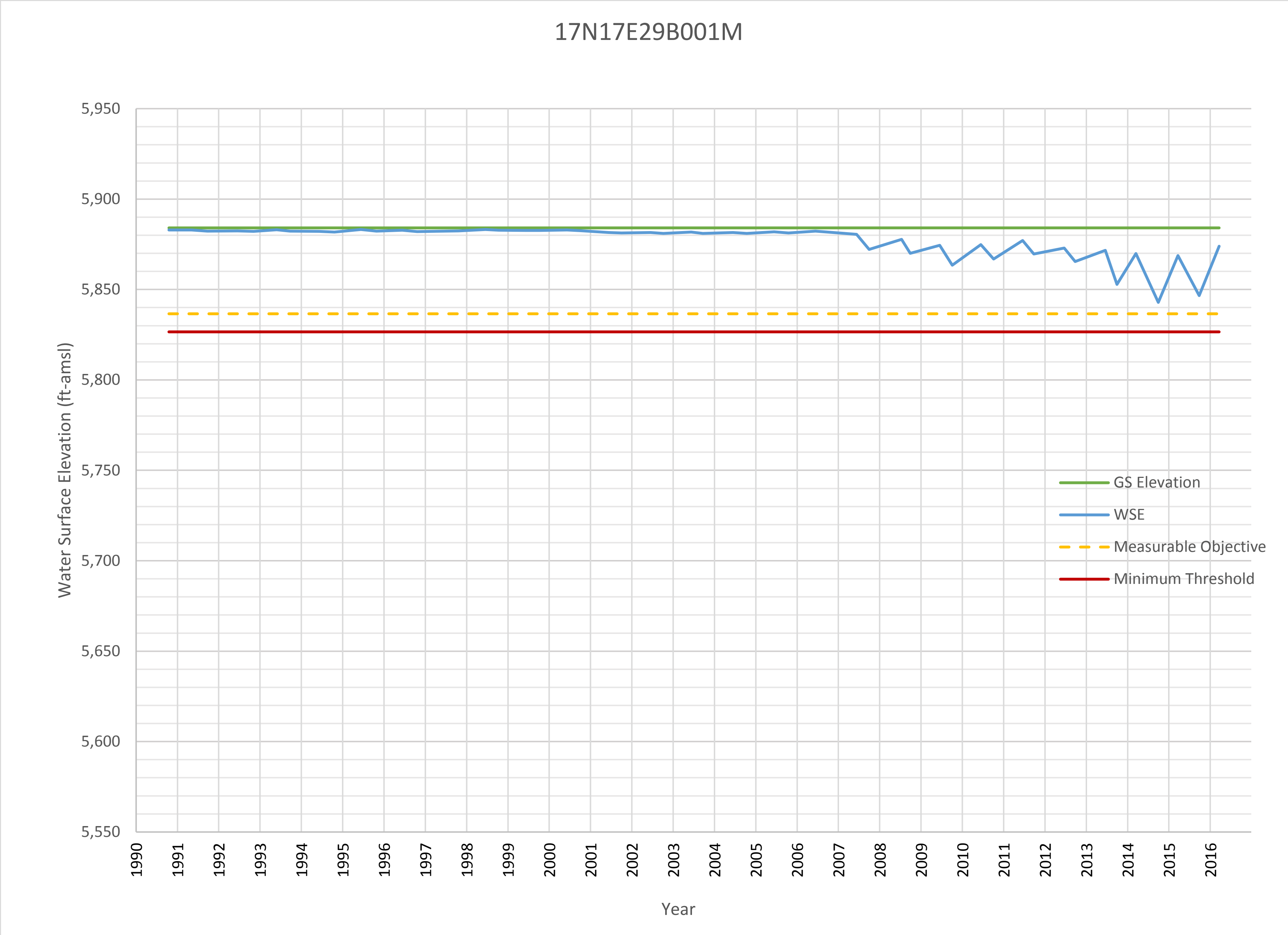
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



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5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
Water Surface Elevation (ft-amsl)
1990
1991
1992
1993
1994
1995
1996
1997
1998
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2010
2011
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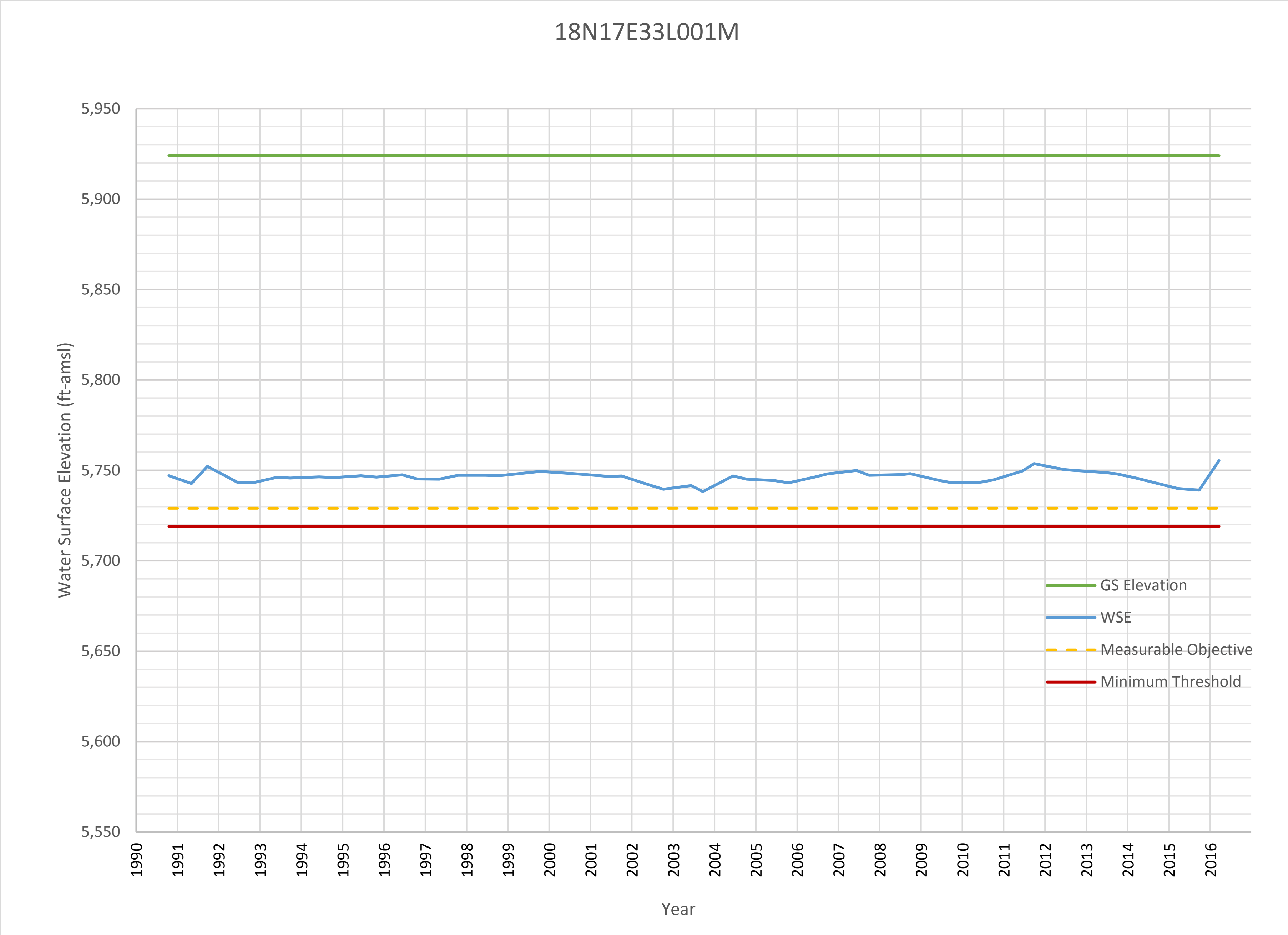
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold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5,850
5,800
5,750
5,700
5,650
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5,550
1990
1991
1992
1993
1994
1995
1996
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2011
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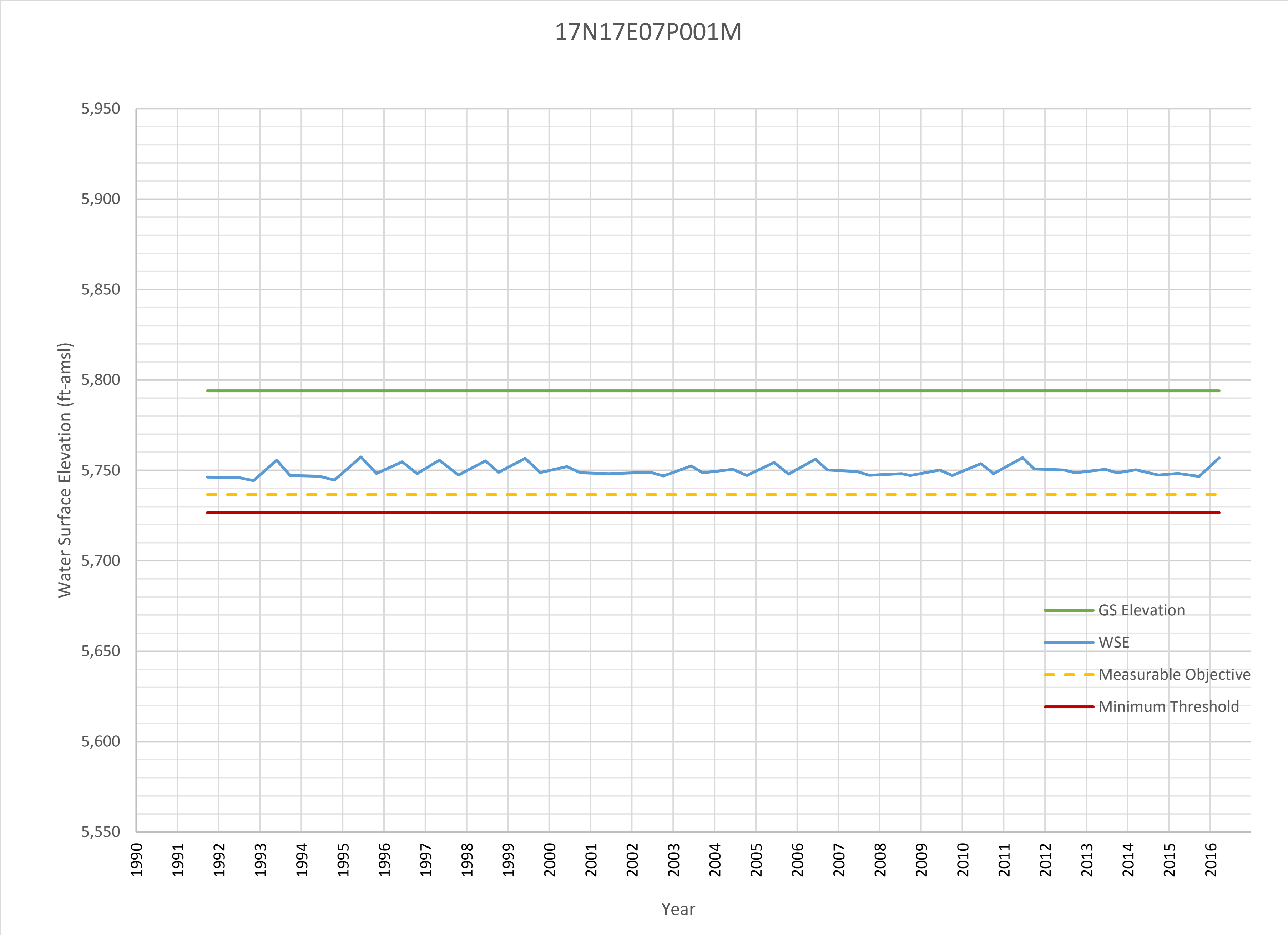
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold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5,850
5,800
5,750
5,700
5,650
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1990
1991
1992
1993
1994
1995
1996
1997
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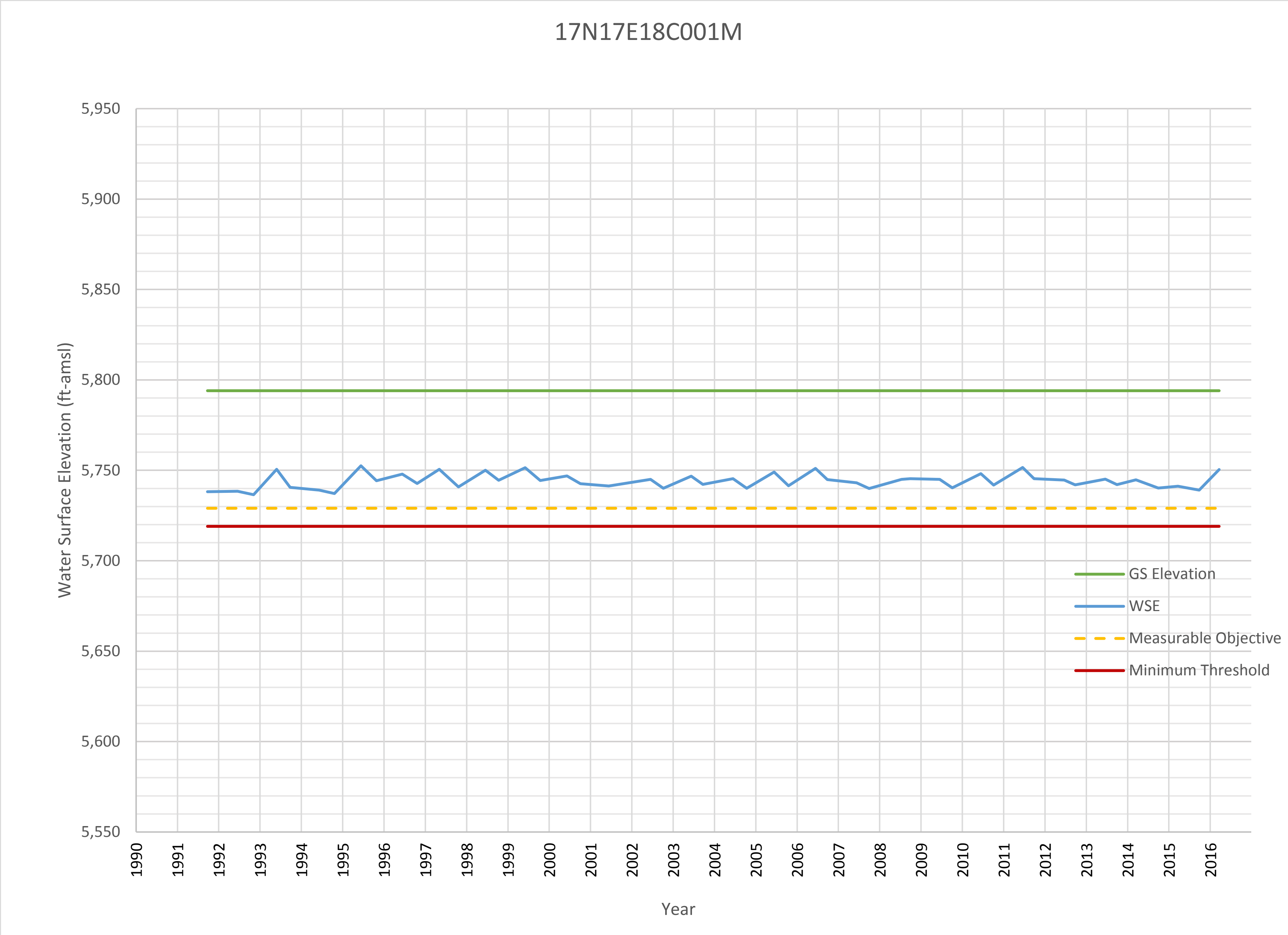
2010
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



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Water Surface Elevation (ft-amsl)
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5,900
5,850
5,800
5,750
5,700
5,650
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5,550
1990
1991
1992
1993
1994
1995
1996
1997
1998
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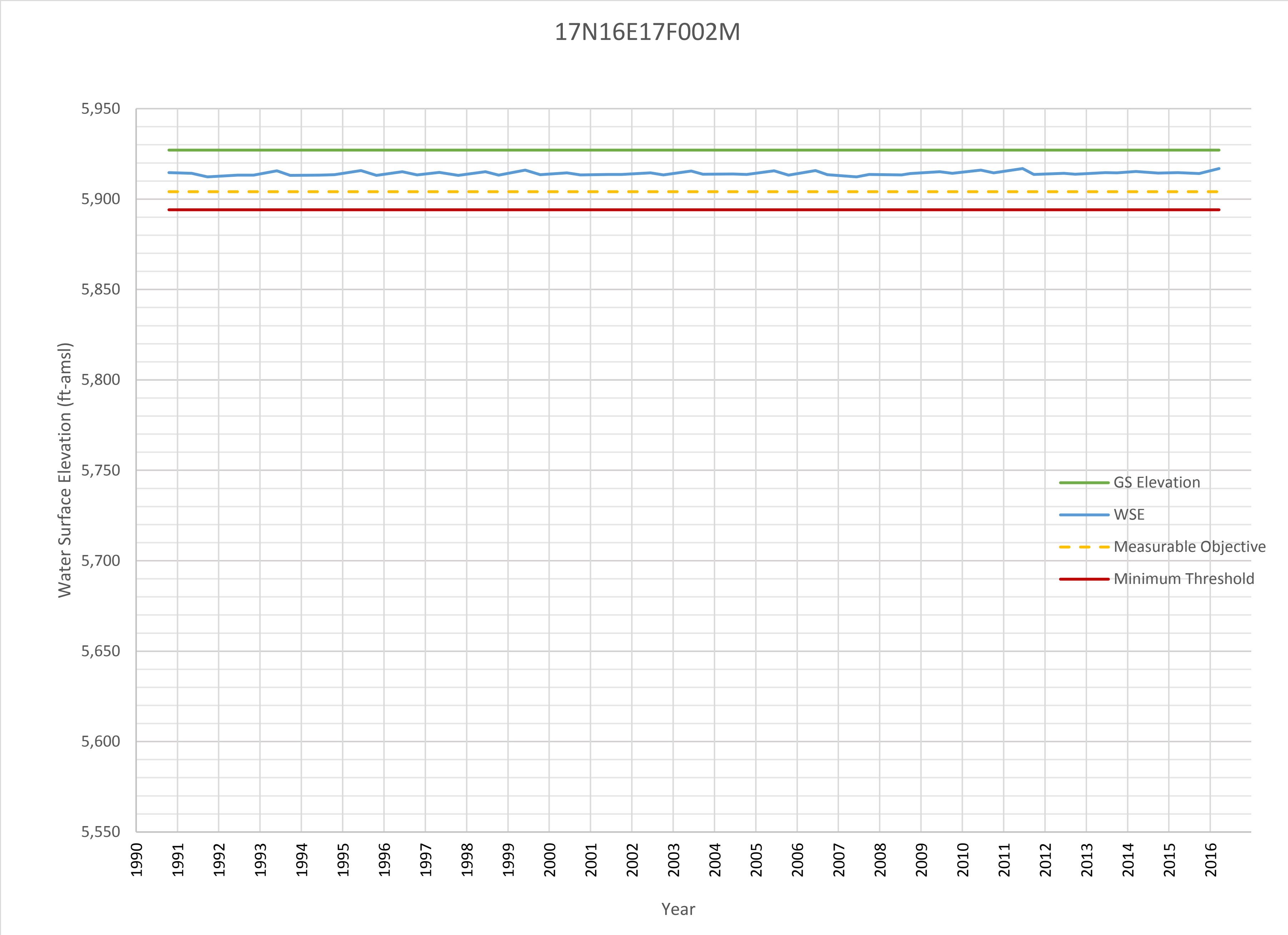
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold



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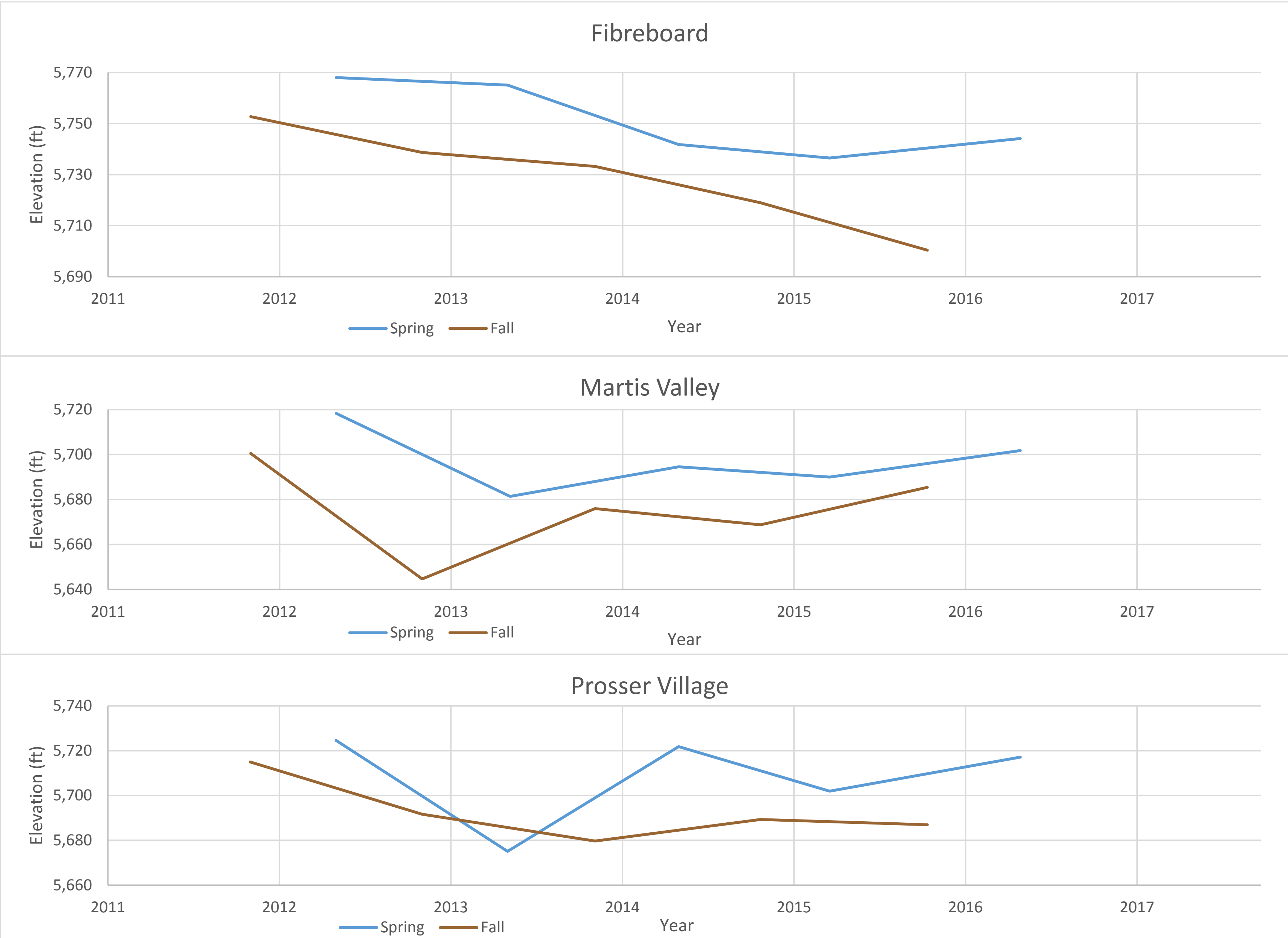
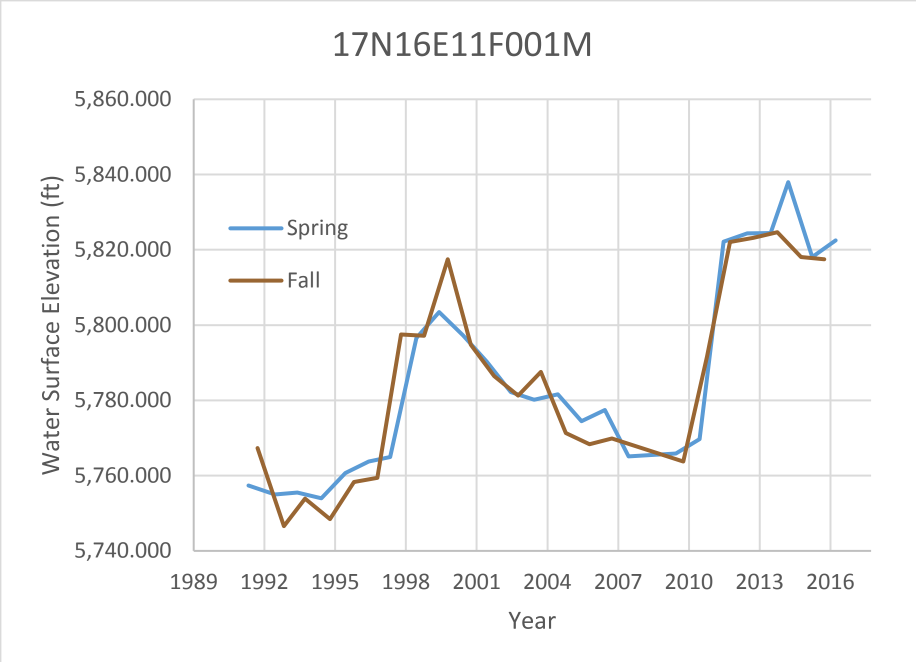
5,900
5,850
5,800
5,750
5,700
5,650
5,600
5,550
Water Surface Elevation (ft-amsl)
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
GS Elevation
WSE
Measurable Objective
Minimum Threshold


Fibreboard
Elevation (ft)
5,770
5,750
5,730
5,710
5,690
2011
2012
2013
2014
2015
2016
2017
Spring
Fall
Year
Martis Valley
Elevation (ft)
5,720
5,700
5,680
5,660
5,640
2011
2012
2013
2014
2015
2016
2017
Spring
Fall
Year
Prosser Village
Elevation (ft)
5,740
5,720
5,700
5,680
5,660
2011
2012
2013
2014
2015
2016
2017
Spring
Fall
Year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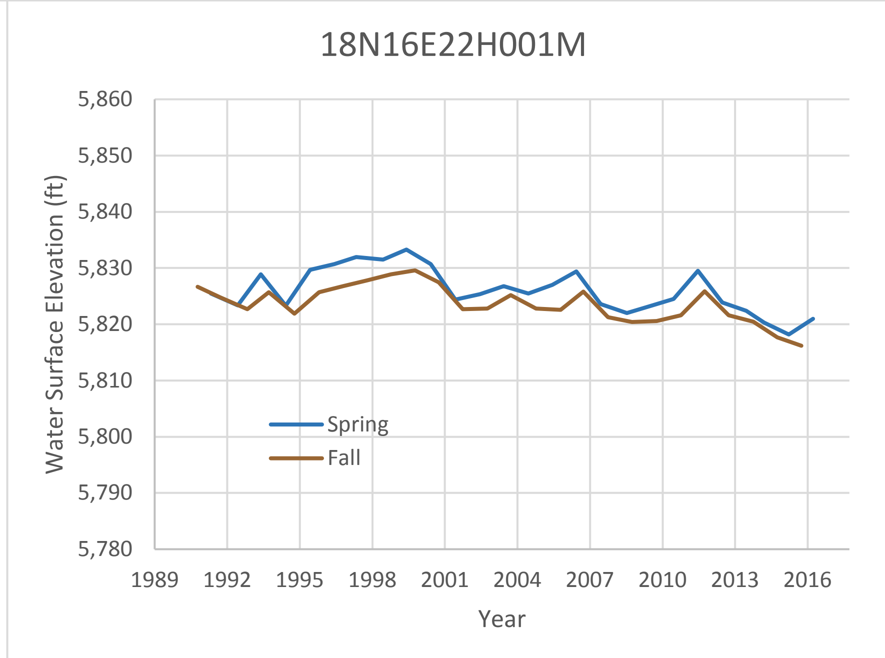
5,840.000
5,820.000
5,800.000
5,780.000
5,760.000
5,740.000
Spring
Fall
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Year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Water Surface Elevation (ft)
5,860
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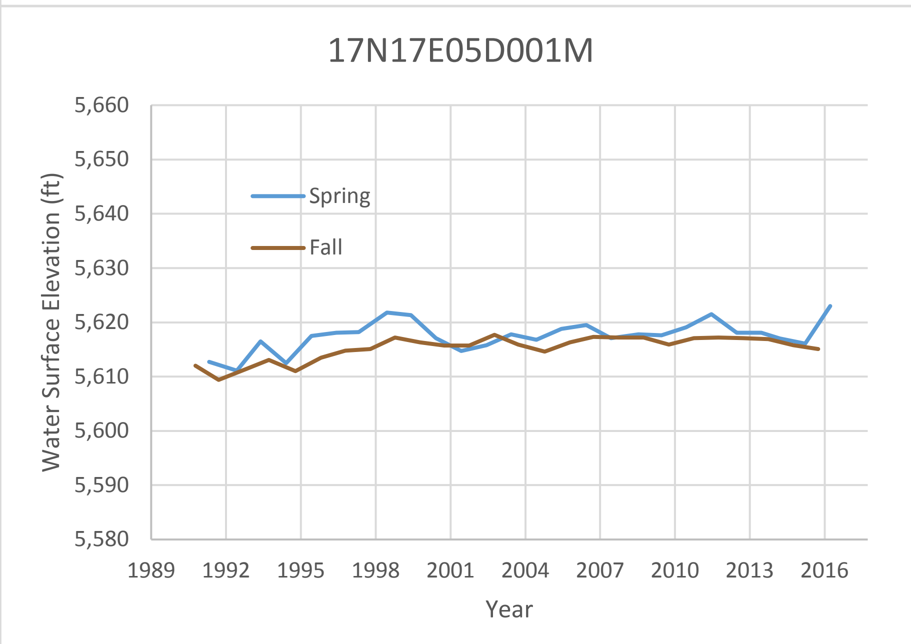
5,840
5,830
5,820
5,810
5,800
5,790
5,780
Spring
Fall
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Year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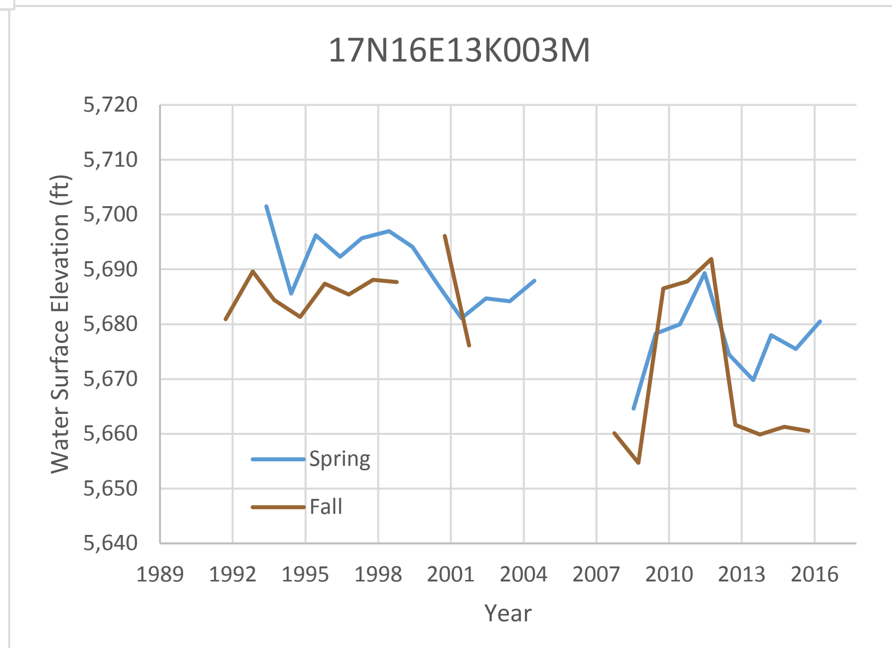
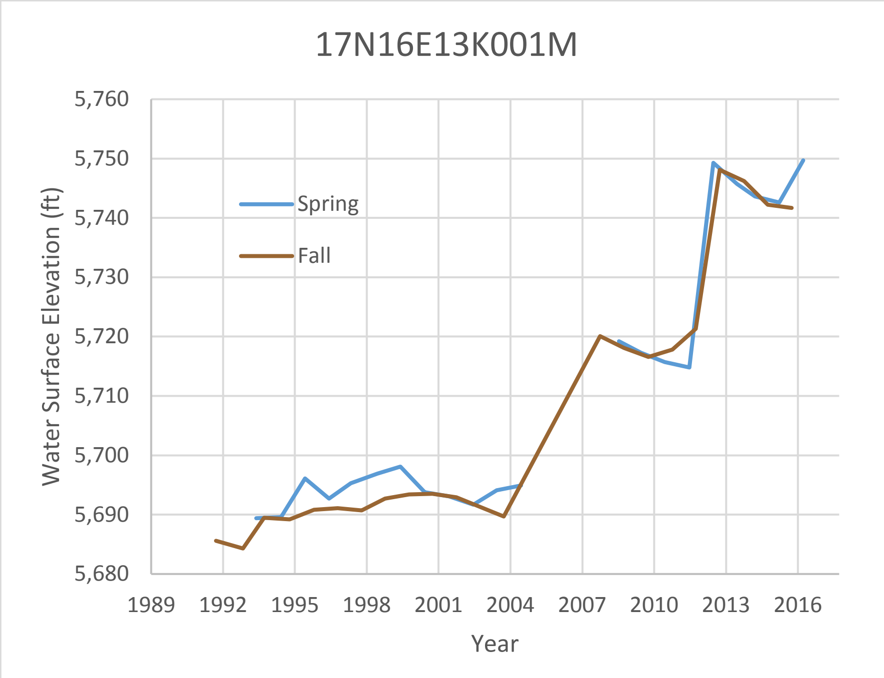
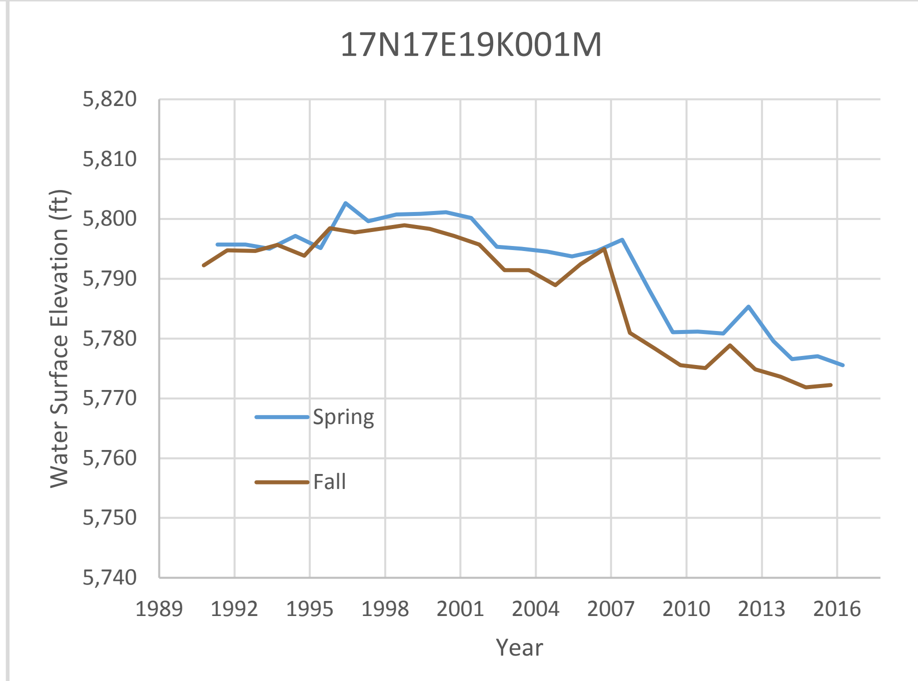
Water Surface Elevation (ft)
5,660
5,650
5,640
5,630
5,620
5,610
5,600
5,590
5,580
Spring
Fall
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Year


17N16E13K003M
Water Surface Elevation (ft)
5,720
5,710
5,700
5,690
5,680
5,670
5,660
5,650
5,640
Spring
Fall
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Year


17N16E13K001M
5,760
5,750
5,740
5,730
5,720
5,710
5,700
5,690
5,680
1989 1992 1995 1998 2001 2004 2007 2010 2013 2016
Year
Water Surface Elevation (ft)
Spring
Fall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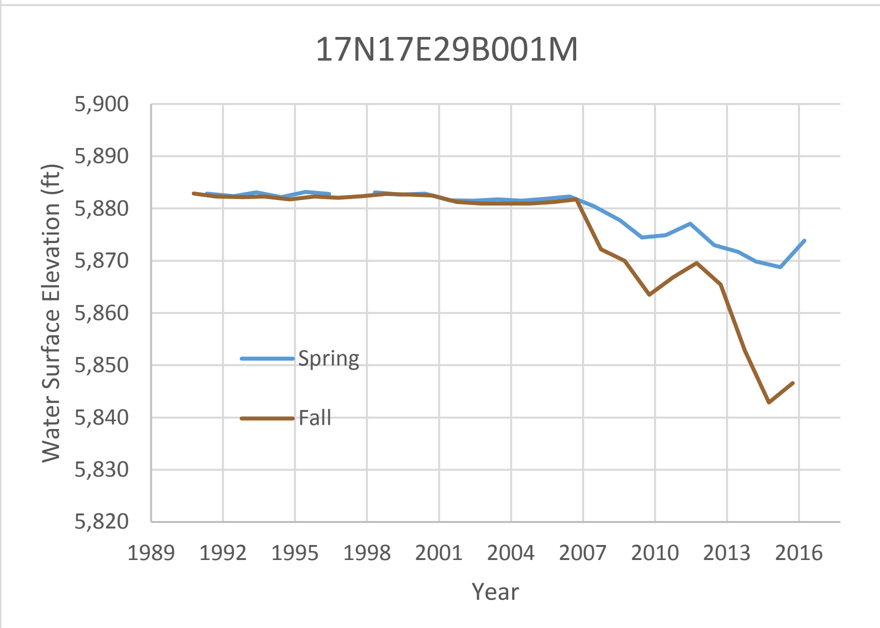
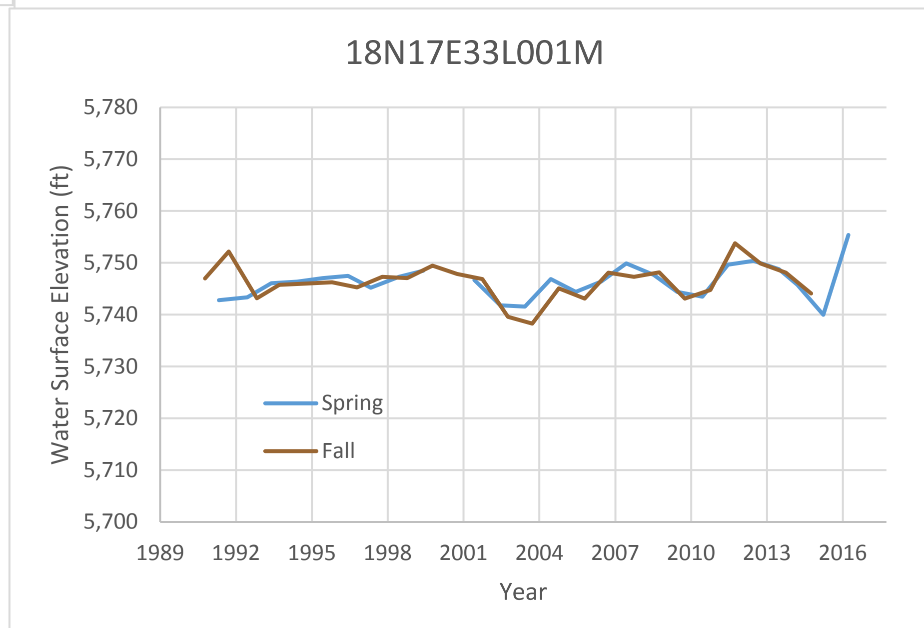
5,820
5,810
5,800
5,790
5,780
5,770
5,760
5,750
5,740
1989 1992 1995 1998 2001 2004 2007 2010 2013 2016
Year
Water Surface Elevation (ft)
Spring
Fall


17N17E29B001M
5,900
5,890
5,880
5,870
5,860
5,850
5,840
5,830
5,820
1989 1992 1995 1998 2001 2004 2007 2010 2013 2016
Year
Water Surface Elevation (ft)
Spring
Fall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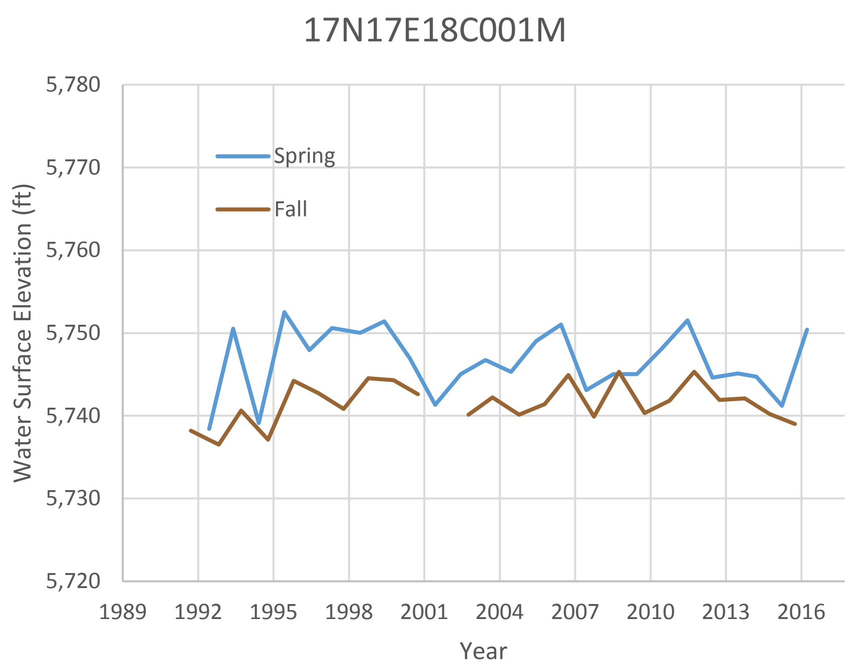
5,770
5,760
5,750
5,740
5,730
5,720
5,710
5,700
1989 1992 1995 1998 2001 2004 2007 2010 2013 2016
Year
Water Surface Elevation (ft)
Spring
Fall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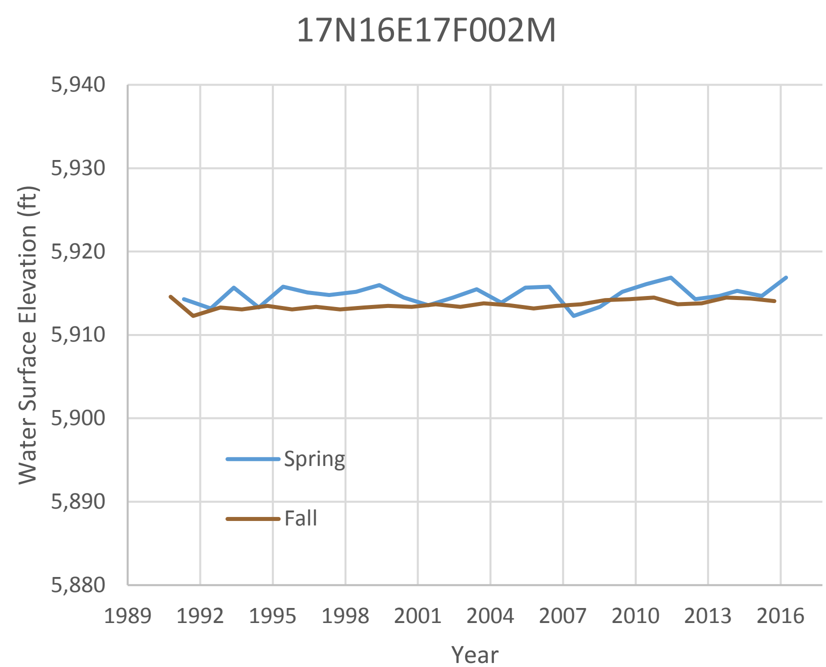
5,770
5,760
5,750
5,740
5,730
5,720
Water Surface Elevation (ft)
Spring
Fall
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Year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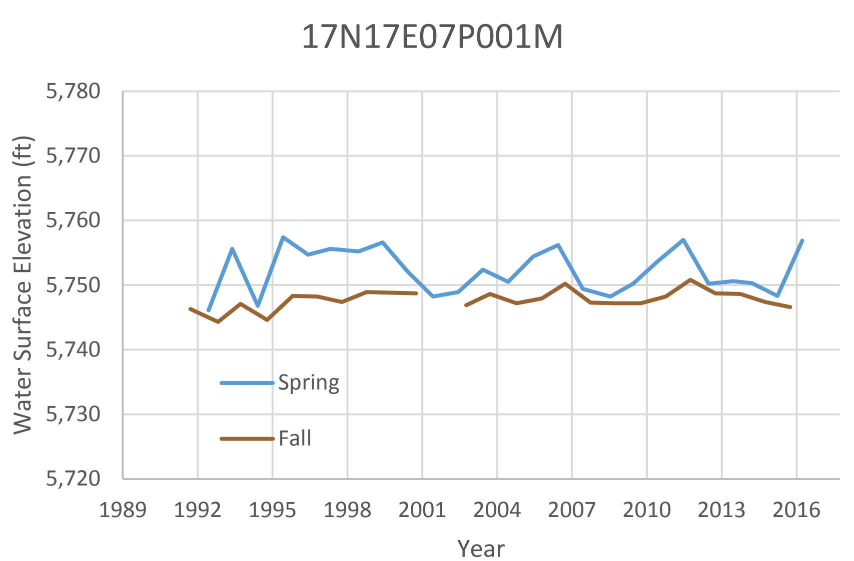
5,940
5,930
5,920
5,910
5,900
5,890
5,880
Water Surface Elevation (ft)
Spring
Fall
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Year


17N17E07P001M
5,780
5,770
5,760
5,750
5,740
5,730
5,720
Water Surface Elevation (ft)
Spring
Fall
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Year

APPENDIX D

Martis Valley Groundwater Basin
Sustainable Yield Estimate,
Placer and Nevada Counties, California.
Technical Memorandum for
Placer County Water Agency (GEI, 2016)

GEI Consultants
Bookman-Edmonston Division

Geotechnical
Environmental and
Water Resources
Engineering

June 10, 2016

Mr. Tony Firenzi, P.E.
Deputy Director of Technical Services
Placer County Water Agency
P.O. Box 6570
Auburn CA 95604-6570

Dear Mr. Firenzi:

**Re: Martis Valley Groundwater Basin
Sustainable Yield Estimate
Placer and Nevada Counties, California**

1.0 Introduction

GEI Consultants, Inc. (GEI) prepared this report for Placer County Water Agency (PCWA), Truckee Donner Public Utility District (TDPUD), and Northstar Communities Service District (NCSD) to assess the sustainable yield of the Martis Valley Groundwater Basin (MVGB). A Groundwater Management Plan (GMP) has been adopted and a groundwater model has been developed by the Desert Research Institute (DRI) of Reno, Nevada. The groundwater model was coupled with the Precipitation Runoff Modeling System (PRMS), a surface water routing model developed by the U.S. Geological Survey (USGS) that is used to predict runoff, but can also estimate the amount of deep percolation through the soils that becomes groundwater recharge. DRI prepared the PRMS model for the entire Martis Valley watershed then coupled it to provide input to the groundwater model, which only covers the MVGB. DRI prepared a Technical Note (Appendix F of the GMP) that briefly summarizes the amount of groundwater recharge by precipitation, predicted by the modeling, but did not provide a water budget for the groundwater basin. Additionally, several hydrogeologic and hydrologic investigations have been developed over the years for the MVGB. GEI reviewed these reports and extracted inflow and outflow components to develop a water budget and estimated the sustainable yield.

2.0 Background

GEI reviewed several reports that provide historic hydrogeologic and groundwater availability estimates, not necessarily sustainable yield, for the basin. Water balances were created by some of the studies, but had some slight differences in the terminology and approaches. Generally, with the procession of time the amount of what may be interpreted to be the sustainable yield has been revised upward. In summary:

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- Hydro-Search, 1995 – estimated a maximum groundwater withdrawal of 13,700 acre-feet per year (AFY).
- Nimbus, 2001 – estimated available groundwater is about 24,700 AFY, but could be higher.
- Antonucci, 2002 – made projections of 19,000 AFY of groundwater pumping needed at build-out.
- Kennedy Jenks, 2002 - generally agrees with Nimbus but suggests available groundwater is about 24,000 to 27,000 AFY.
- InterFlow Hydrology, 2003 - the estimated total amount of groundwater potentially available for use in Martis Valley on a long-term sustainable basis exceeds 34,000 AFY.
- DRI, 2013 - estimated groundwater recharge with MVGB to be about 33,000 AFY.

3.0 Martis Valley Groundwater Basin

The MVGB (Basin No. 6-67) is a 35,600-acre intermontane, fault-bounded basin east of the Sierra Nevada crest (DWR, 2006). The Truckee River crosses the basin from south to east in a shallow, incised channel. Principal tributaries to the Truckee River are Donner Creek, Martis Creek, and Prosser Creek. Major surface water storage reservoirs include Martis Creek Lake and Prosser Creek Reservoir. Donner Lake is outside of the groundwater basin as defined by the California Department of Water Resources (DWR). Figure 1 shows these features. Average precipitation is estimated to be 23 inches in the lower elevations of the eastern portion of the basin to nearly 40 inches in the western areas.

4.0 Hydrogeology

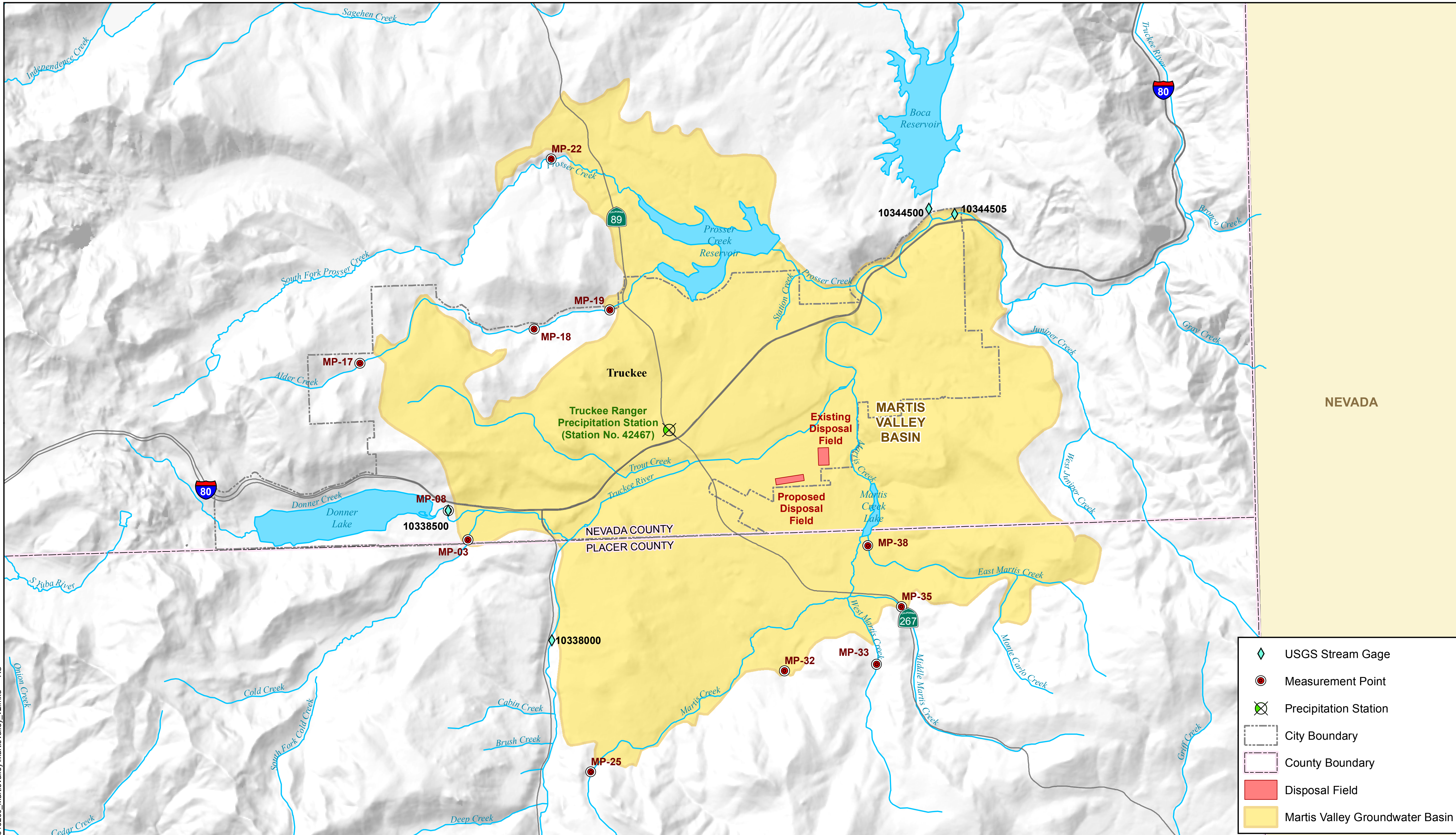
The MVGB is a valley that was etched into low permeability bedrock that has since been filled with sediments and volcanics of many different formations. The coarse-grained sediments and to some extent fractured volcanics comprise the aquifers used for domestic, commercial, industrial, and residential purposes.

There are multiple faults within the basin. The Polaris fault is deemed active (Hunter et. al. 2011). The faults may create compartments that may be isolated from the rest of the groundwater basin.

For purposes of developing the water budget, the entire basin was considered to be one single basin.

5.0 Water Budget

A water budget for the groundwater basin was developed and populated with existing information from various published sources. Many of the published sources span decades. The most recent source of information is from Precipitation Runoff Modeling System (PRMS) and coupled to GS ModFlow (a groundwater model) prepared by DRI. The model was developed for the watershed and only limited details have been published that cover just the groundwater basin. Results of the model as presented by DRI were



2 1 0 2

Miles

N W E S

Martis Valley Sustainable Yield
Nevada and Placer Counties, California

Placer County Water Agency

GEI Consultants

MARTIS VALLEY GROUNDWATER BASIN
WATER BUDGET PERTINENT FEATURES

MARCH 2016

FIGURE 1

30-Mar-2016 Z:\Projects\1513260_MartisValley\MartisValley_v2.mxd RS incorporated into this water budget; however, additional analysis using and running the model was not within the scope of this work.

A water budget was developed and identified all components of inflow and outflow. However, estimates for some components have not been quantified and therefore were left blank. In the future, depending upon their significance, additional investigations may be warranted to develop estimates. Figure 2 shows a schematic of the general water budget for MVGB.

Tables 1A and 1B provide the water budget. The water budget values are color coded to demonstrate whether the values were measured or have been previously estimated and have a higher level of certainty (black font). Where the values have not been measured or estimated the values are shown in a purple font. These values were typically copied from previous years where estimates were made. Where average annual estimates were calculated and distributed throughout the water budget the values are shown in a blue font.

The following sections describe the water budget inflow and outflow components and the sources of data. All data was compiled on an annual basis.

5.1 Inflow Components

Water entering the groundwater basin consists of precipitation, surface water, wastewater, and subsurface inflow. Table 1A provides the annual values and percent contribution to the water budget inflow components.

5.1.1 Precipitation

The long-term (1934 to 2014) average annual precipitation is about 30.41 inches based on measurements from the Truckee Ranger Station precipitation station (Station No. 42467). The location of the precipitation station is shown on Figure 1. Figure 3 shows the annual precipitation departure from the mean.

Precipitation (in AFY) that fell directly on the groundwater basin was obtained from DRI’s modeling for 1983 through 2011; however, their projections did not cover the complete period for water budgeting purposes. Therefore, those missing years were estimated using precipitation measurements from the Truckee Ranger Station precipitation station and selecting total precipitation in AFY from DRI for years with similar precipitation. Recharge from precipitation is about 22 percent of the total inflow to the basin, the second largest component of inflow in the water budget.

5.1.2 Surface Water

Surface water enters the basin from within the watershed and from nearby watersheds. Major creeks and rivers have gaging stations. The locations of the gaging station used for this study are shown on Figure 1. The measurements were obtained from the USGS website and are reported in calendar years. Minor tributaries are not gaged.

Figure 2

Martis Valley Groundwater Basin Water Budget Diagram

All Values in Acre-Feet per Year

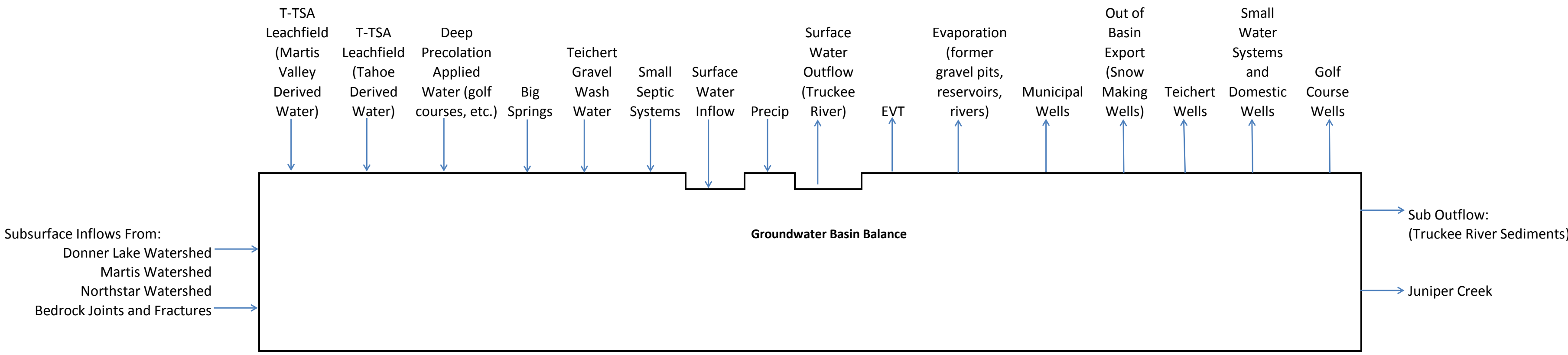
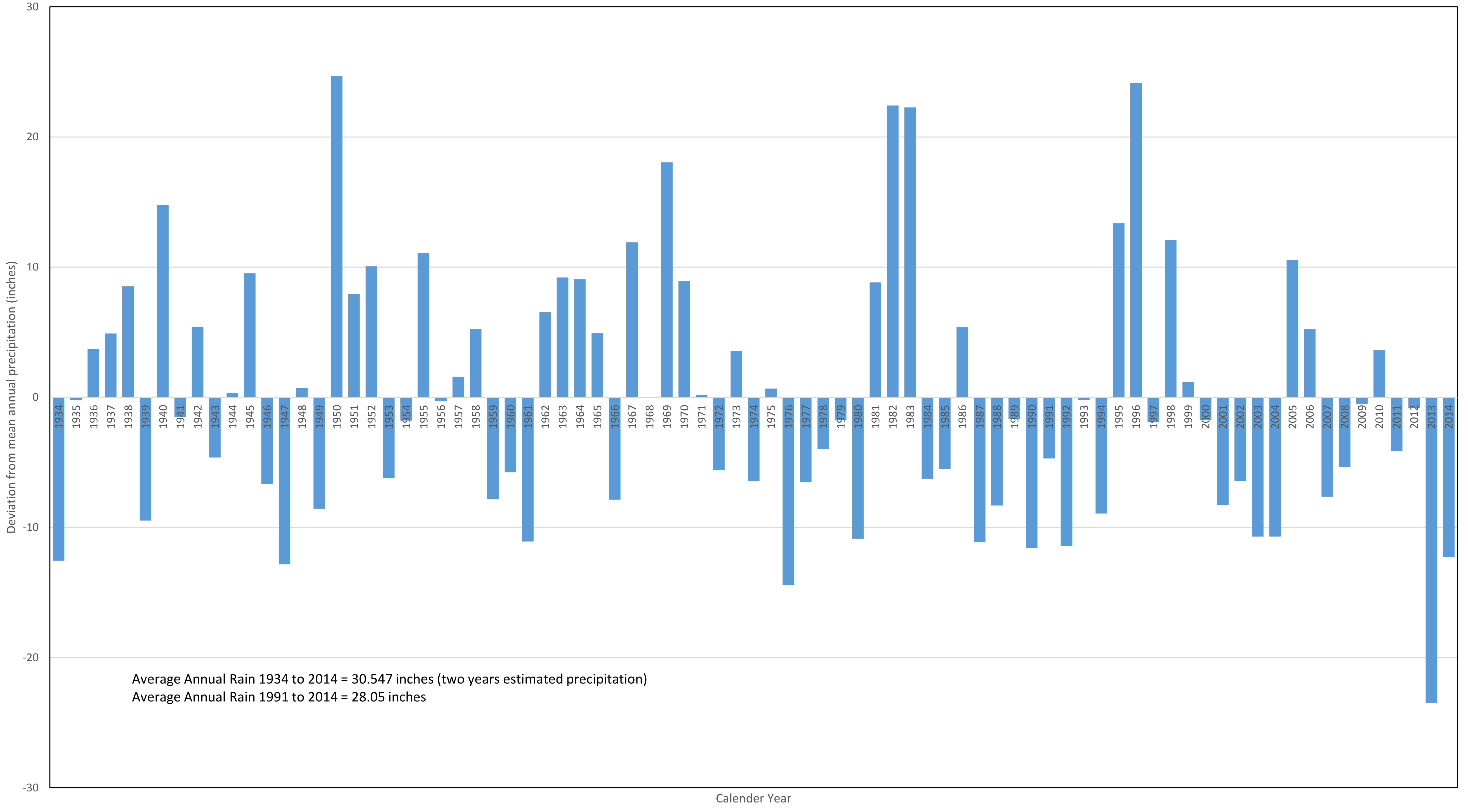


Figure 3
Deviation from Mean
Truckee Ranger Station No. 049343



The Truckee River conveys water from the Lake Tahoe watershed into the MVGB. The river is incised into bedrock from Lake Tahoe until it reaches Martis Valley. A USGS surface water gaging station (Station No. 10338000) is present near the edge of MVGB and has a relatively high level of certainty in the measurements; however, the gage only has a partial record, starting in about 1993, or for about 23 years.

Another USGS gaging station (Station No. 10338500) is located along Donner Creek that measures water released from Donner Lake into the MVGB. Over 85 years of records are available for this station.

Boca Reservoir is outside of the MVGB; however, releases from the reservoir join the Truckee River prior to the river leaving the groundwater basin. A USGS gaging station (Station No. 10344500) is present along this tributary. Over 44 years of records are available for this station.

These three sources of surface water into the basin account for over 50 percent of the inflow to the basin.

There are numerous small tributary drainages that convey water from the Martis Valley watershed into the groundwater basin. None of these tributaries have gaging stations. In 2003 an investigation was performed to quantify the runoff and in some instances make forecasts of average annual runoff (Interflow, 2003). Stations at the edge of the groundwater basin were used in the water budget. Their locations are shown on Figure 1. The small tributaries account for about 22 percent of the total inflow to the basin. Prosser Creek represents 15 percent of this inflow. With the surface water sources gaged by USGS and Prosser Creek over 90 percent of the inflow to the basin can be quantified.

5.1.3 Wastewater

Wastewater is returned to the groundwater basin through private septic systems and by large leach fields operated by the Tahoe-Truckee Sanitation Agency (T-TSA). The location of the T-TSA leach fields are shown on Figure 1.

Wastewater is collected by the T-TSA from the north shore communities surrounding Lake Tahoe and also from within the Martis Valley. Wastewater inflows to the treatment plant are measured through meters or weirs. After treatment the water is discharged to leach fields near the town of Truckee, south of the Truckee River. Annual effluent inflows to the treatment plant from the Lake Tahoe area and from within MVGB were obtained from T-TSA for 1981 through 2014, a 32-year period. The inflows from the Lake Tahoe increased rather significantly in 1987 and has remained rather stable since that time. The average inflow from the Lake Tahoe area between 1987 and 2014 was about 2,700 AFY and about 2,000 AFY is from within the MVGB. The inflow to the basin from the leach fields represents one percent of the total inflow to the basin.

Individual septic systems are present at rural cabins and residences throughout the basin and are difficult to quantify. One estimate was made in 2001 by Nimbus of 435 AFY and was distributed throughout the water budget. The small septic system represent only 0.1 percent of the total inflow to the basin.

5.1.4 Subsurface Inflow
Subsurface inflow to the groundwater basin occurs beneath some of the creeks and rivers. Previous authors considered subsurface inflow to the groundwater basin to occur from the Donner Lake, Martis Peak and Northstar watersheds (Nimbus, 2001). No details were available regarding how these estimates were derived. The estimates were distributed throughout the other water budget years. Subsurface inflow to the basin accounts for less than one percent of the total inflow to the basin.

Subsurface inflow to the basin from joints and fractures in the bedrock below ground surface likely occurs but cannot be quantified at this time. For the water budget we assumed zero contribution.

5.1.5 Other Inflow Sources
Teichert Aggregate operates a sand and gravel mine near the confluence of Martis Creek and the Truckee River. They pump groundwater to wash fines from the sand and gravel during processing. The water is then returned to basins where the water percolates back into the basin. GEI estimates 10 percent of the water may be lost to export of the finished material and due to evaporation. The volume of water returned to the basin was estimated based on the groundwater pumped (Brown and Caldwell, 2013).

Other inflow sources include deep percolation of applied water for irrigation of golf courses and residential irrigated landscape. One estimate was made and indicated the deep percolation was small.

Water from Big Springs, located outside of the groundwater basin, is captured and treated for potable water, raw water for irrigation of golf courses and snow making. The amount of water from this source and its distribution, whether within or exterior of the groundwater basin cannot be readily quantified.

5.2 Outflow Components

Water leaves the MVGB as surface water in the Truckee River, evaporation from surface water bodies, water consumed by plants, by groundwater pumping, subsurface outflow and pumping from the basin for snow making within the watershed. Table 1B provides the annual values and percent of contribution to the water budget outflow components.

5.2.1 Surface Water

Water from the groundwater basin leaves the basin along the Truckee River and is monitored by the USGS gaging station at Truckee River at Boca (Station No.10344505). The gage station location is shown on Figure 1. The gage was installed in 2003. It is downstream of the inflow from Boca Reservoir that collects and stores water from outside of the MVGB and watershed. The data was obtained from the USGS internet website and has a high degree of certainty; however, the gage only has a partial record, about 13 years. The missing years were scaled proportionately based on other gages. Runoff in the Truckee River accounts for 80 percent of the water budget outflow components.

5.2.2 Groundwater Pumping

Groundwater is currently being pumped from the basin by the TDPUD, NCSD, private well owners and until recently PCWA. Groundwater pumping values were obtained from these public water agencies on a calendar year basis. The wells are metered so the data is of high quality. Groundwater pumping, long term average is about 7,000 AFY but is only 1.3 percent of the total outflow components from the basin.

Historically, groundwater was pumped by the Glenshire Mutual Water Company and Donner Lake Mutual Water Company. TDPUD acquired both of these water districts in 2001 and accounts for a relatively large increase in their pumping records after 2001. TDPUD instituted a leak detection program in 2000 that reduced their overall groundwater pumping by repairing leaky water mains. Groundwater pumping by both Glenshire Mutual Water Company and Donner Lake Mutual Water Company are not available. One study reported water use by Glenshire Mutual Water Company to be about 830 acre-feet (AF) (Nimbus, 2001). This value was distributed in all years prior to 2001. The values have a high degree of uncertainty. The Donner Lake Mutual Water Company service area is outside of the MVGB and therefore represents an export from the basin. The amount delivered outside of the basin cannot be easily segregated and was not accounted for in the water budget. Groundwater pumping by municipalities accounts for over 92 percent of the groundwater pumping in the basin.

Private well owners (127 wells) include both domestic users and Teichert Aggregate. Their water use was estimated in 2001 (Nimbus, 2001) and were distributed throughout the water budget. The amount of water pumped by domestic wells were increased based on records that show about 40 new domestic wells were constructed between 2000 and 2007. The average annual production was increased for domestic wells during this period to account for the new wells, assuming a values of about 1.4 AFY (same rate as used by Nimbus, 2001). From 2007 to 2014 the pumping was held constant at the 2007 rate.

Between 2000 and 2014 four new large housing developments and golf courses were constructed. The source and amount of the water used during grading for the developments is unknown but could be significant and would lead to a potential higher sustainable yield.

5.2.3 Subsurface Outflow

Subsurface outflow from the basin may occur within sediments along the eastern boundary of the basin and in hydraulic communication with the Truckee River. Potentially, there may be some outflow through bedrock joints and fractures to the Juniper Creek watershed, south of the MVGB. Both are poorly quantified.

Subsurface outflow occurs along the eastern edge of the groundwater basin where older sediments from within the basin abut the Truckee River. The older alluvium was estimated a width of 7,600 feet, an estimated saturated thickness of 40 feet, a gradient based on the topographic land surface along the Truckee River of 0.01, and a permeability of 50 feet/day. An estimated 200 AFY leaves the basin.

In 2001, about 1,000 AFY was believed to leave the MVGB to the Juniper Creek watershed along joints and fractures (Nimbus, 2001). This value was used for all water budget years.

Subsurface outflow from the basin only represents 0.2 percent of the outflow from the basin.

5.2.4 Evapotranspiration

Plants uptake water and transpire it into the atmosphere (evapotranspiration or ET). A detailed analyses of the ET of vegetation within the groundwater basin was performed by DRI but the data was not available. Therefore, alternative methods to estimate ET were made.

In general, to estimate ET, crop factors are multiplied by the reference ETo (obtained from the California Irrigation Management Information System (CIMIS) station) and multiplied by the number of acres populated by different species. Crop factors are expressed as a percentage; however, no CIMIS stations are present in the MVGB. Annual average reference ETo have been established for 14 zones statewide by DWR. The MVGB is in Zone 13, which has an average reference ETo of 54.3 inches per year (DWR, 1999). Reference ETo (from a non-CIMIS station) at Tahoe City, which is only about 300 feet higher than Truckee, ranges between 35.5 and 42.5 inches per year over the (TetraTech, 2007), significantly less than average annual reference ETo estimates provided by the CIMIS zones. For this evaluation, we used the reference ETo from the CIMIS zone map of 54.3 inches per year which would potentially overestimate the amount of ET.

Martis Valley currently has nine golf courses with a total of over 2,000 acres. Most have been developed since 1998. Evapotranspiration of about 2,100 AFY from the turf areas were estimated for some of the golf courses in 2001, based on groundwater pumping (Nimbus, 2001). Four additional golf courses have opened since 2001. During the winter and spring months, ETo requirements are generally small and would typically be supplied by precipitation. During the summer and fall the water is supplied mostly by wells although some portion of the demand is made up by springs and precipitation. Because groundwater pumping is already accounted for as an outflow item in the water budget, ETo by golf courses was included in the water budget as an outflow component but values was assigned to prevent double counting. In a similar fashion turf areas at schools and decorative landscape ETo are also supplied by the wells and values are not included in the water budget.

Native vegetation also transpires water. The MVGB contains roughly 14,800 acres of evergreens forest and 19,400 acres of shrubland. Riparian vegetation is also present along narrow corridors of creeks and rivers. The areas of native vegetation were estimated from vegetation types from a figure contained in a report produced by DRI and therefore the acreage are gross estimates. A crop factor for evergreen forest was estimated in the Tahoe City area to be 1.2 (TetraTech, 2007). The estimated annual ETo for the evergreen forest in MVGB using a reference ETo of 54.3 inches per year the evapotranspiration is about 70,000 AFY, which by using the higher ETo would potentially overestimate the ET from the vegetation. No crop factors were available for shrubland. A study of actual ETo for sagebrush and rabbit brush made in Carson Valley for water year 2003-04 results in estimates of about 1.7 to 1.9 feet per year with depths of groundwater ranging from 2 to 6 feet below ground surface or 1.5 feet per year in an area where the depth to groundwater was about 60 feet below ground surface (USGS, 2005). Because Carson Valley is at a much lower elevation we used a lower ETo rate of 1.7 feet per year, due to Martis Valley being at a higher elevation. The estimated annual ETo for the shrubland is conservatively overestimated to be about 32,000 AFY. Riparian vegetation was not separated from the evergreen forest or shrubland due to the typical narrow distribution around creeks and rivers and time required to segregate these areas. Evapotranspiration represents about 18 percent of the outflow from the basin.

5.2.4 Evaporation

Water is also lost from the groundwater basin due to evaporation from surface water. The largest water bodies include Prosser Creek Reservoir, Martis Creek Lake and the Truckee River. Smaller ponds and reservoirs are also present in the area.

In 2011, a detailed evaporation study was performed that included Prosser Creek Reservoir, Boca Reservoir and Martis Creek Lake (Huntington, 2011). The evaporation rates from this study were used to estimate evaporation from water bodies in the MVGB. The surface area of the reservoirs (about 500 acres) were measured using Goggle Earth imagery taken in spring of 2015 and was distributed uniformly throughout the water budget. Evaporation was estimated to be about 0.1 percent of the outflow from the basin.

5.2.5 Snowmaking

Some groundwater is pumped from MVGB and used by Northstar ski resort for snow making. NCSD provided some limited data for the groundwater used for snowmaking. Groundwater used for snowmaking was estimated to be 0.1 percent of the outflow from the basin. According to TROA, snowmaking returns 84 percent of the water used back to the basin as groundwater subsurface inflow or as surface water inflow, with the balance leaving as evapotranspiration.

6.0 Water Budget Calibration Data

Calibration of the water budget needs to be based on groundwater levels or change-in-storage estimates developed from groundwater level contouring and specific yield estimates (the amount of groundwater that can drain from the sediment pores with gravity). Change-in-storage estimates have not been developed for the MVGB. Therefore, for this evaluation calibration was based upon groundwater level measurements.

Groundwater levels in the area have been measured by DWR in 16 wells within the MVGB. Of the 16 wells, nine wells had reasonably continuous groundwater level measurements beginning in 1990 to 1991 and continuing through 2015 (DWR, Water

Data Library, 2016). Figure 4 shows the location of some of these wells and groundwater level measurements from 1990 through 2012 (Brown and Caldwell 2013). More recent measurements are available for the wells extending through 2014. Groundwater levels in the MVGB, display a variety of patterns, but have little to no information available to understand whether the water levels are representative of different aquifers, are affected by pumping, or are affected by faults. Therefore, calibration of the water budget based upon groundwater levels will be subjective, based on which well is selected for calibration. Instead of selecting just an individual well, nine wells were selected that had less than three missing measurements and the average groundwater level was calculated. For those years with missing measurements from any well, the average was not calculated. Figure 5 shows the average groundwater level trends in the MVGB.

The plot of the average groundwater levels show that between 1990 and 2000 groundwater levels rose by about 14 feet. Between 2000 and 2009 groundwater levels declined by about 16 feet. Between 2009 and 2011 groundwater levels rose again but thereafter the groundwater levels began to decline. Overall the groundwater levels suggest there has been a positive change-in-storage from 1990 to 2014.

Based on the available groundwater level measurements that can be used to calibrate a water budget, the water budget was developed for the period of 1990 through 2014.

7.0 Water Budget 1990 to 2014

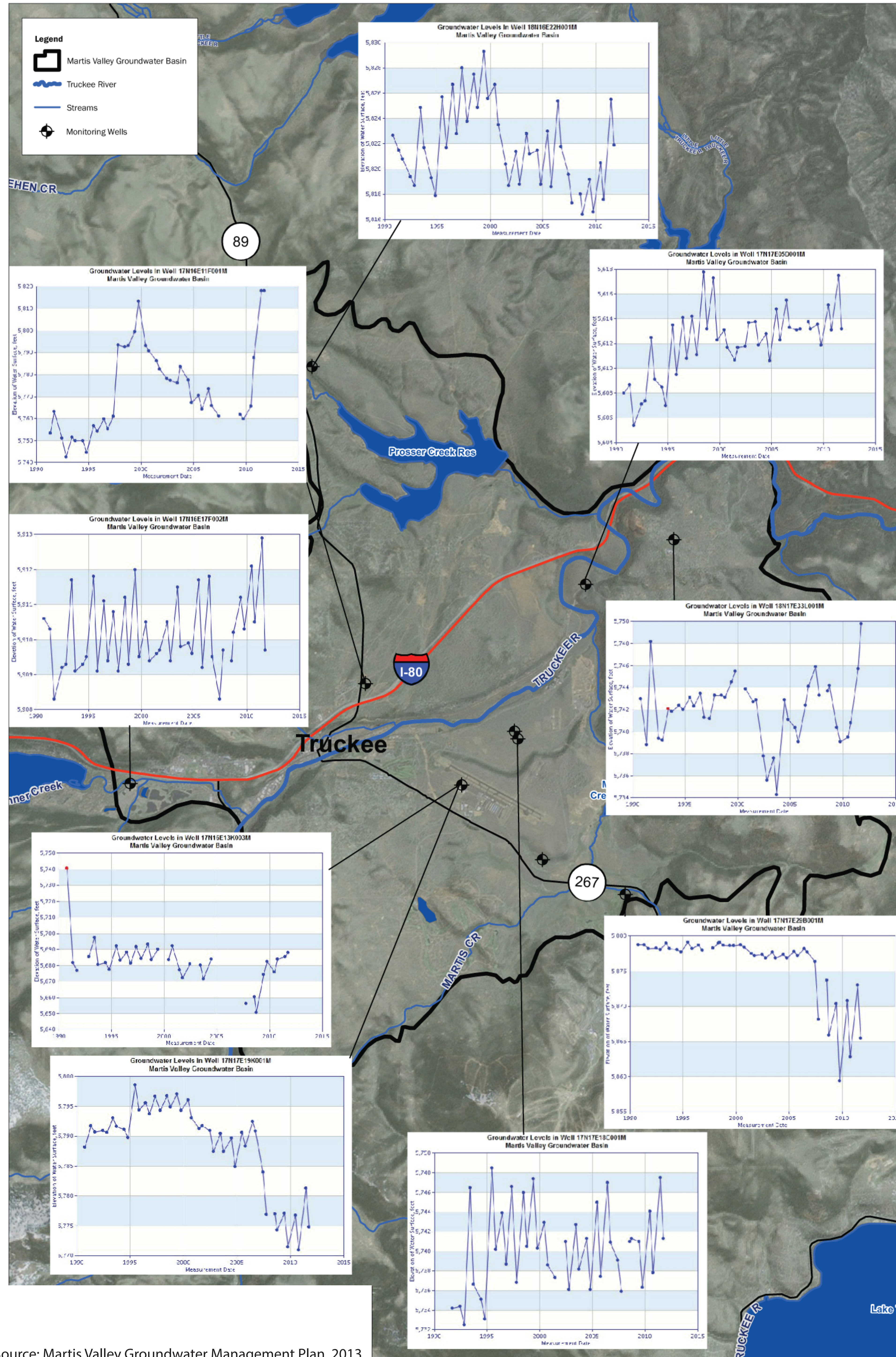
Annual water budgets were developed for 1990 to 2014. The water budget for this period is provided in Table 1.

The water budget shows the largest inflow component (about 53 percent) is from the Truckee River, Donner Creek, and Boca Reservoir. All of these sources have gaging stations. The next highest component of inflow is precipitation which was derived from the PRMS modeling. The next largest component is inflow into Prosser Creek, which is not gaged and was only measured once since 1990 (Nimbus, 2001). These five sources account for 92 percent of the inflow to the basin.

The water budget shows the largest outflow component (about 80 percent) is along the Truckee River which is gaged. The next highest component is evapotranspiration (18 percent), which was has a higher degree of uncertainty due to using average reference ETo values and rough estimates of acreage. Municipal groundwater pumping averaged about 6,200 AFY and represents less than 2 percent of the total outflow from the basin.

As illustrated in the water budget the flows in the Truckee River do not correlate to the water year classification but are due to managed releases from storage from Lake Tahoe.

The average annual groundwater change-in-storage based on the water balance is about 15,000 AFY. The annual range is rather a wide range and suggests further refinements of the water balance may be warranted. Because there are surface water reservoirs in the MVGB a change-in-storage in the reservoirs is also taken into account.



Source: Martis Valley Groundwater Management Plan, 2013

Brown AND Caldwell

Martis Valley Sustainable Yield
Nevada and Placer Counties, California

Placer County Water Agency

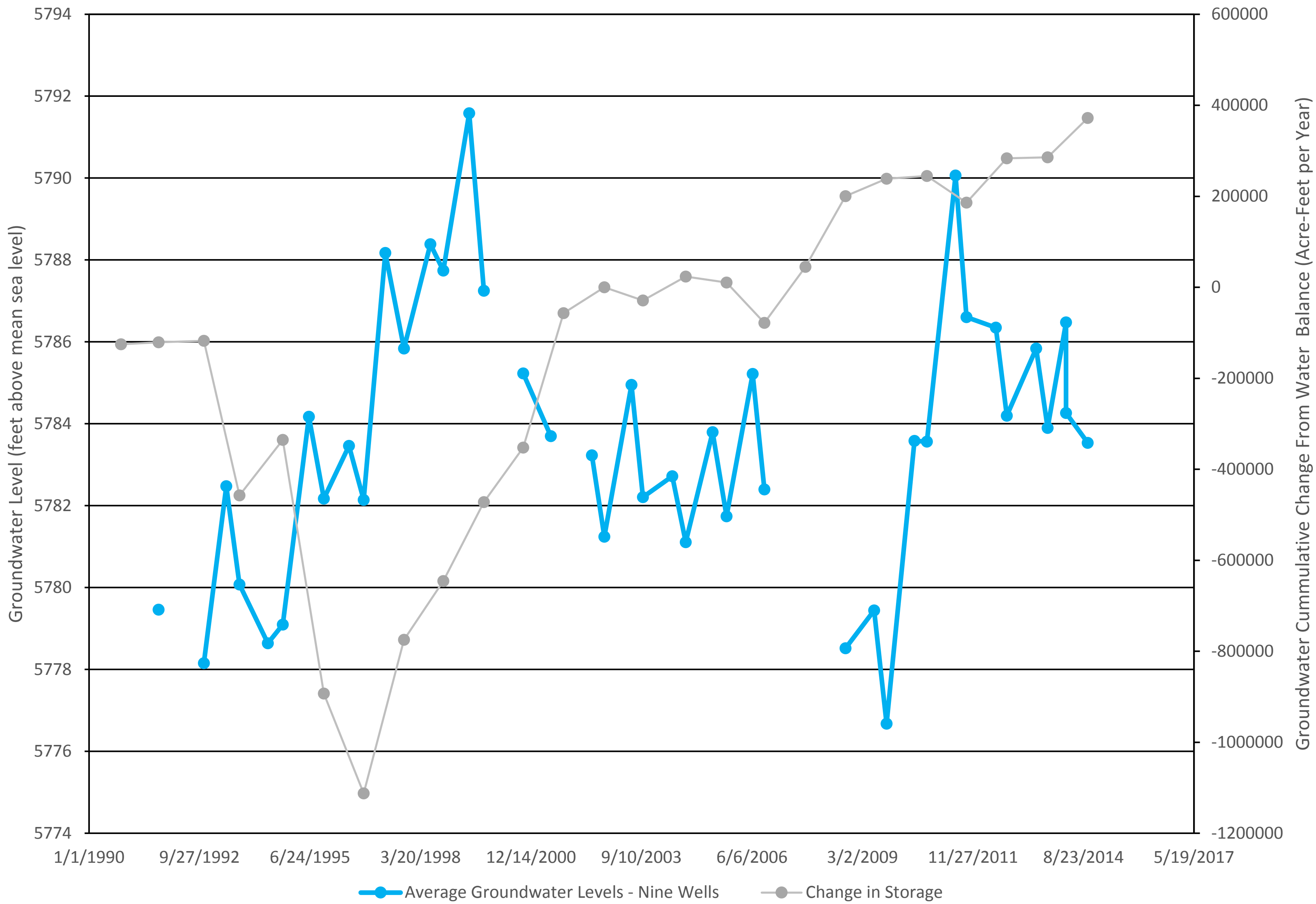
GEI Consultants

Monitoring Wells and Selected Hydrographs

MARCH 2016

FIGURE 4

Figure 5
Average Groundwater Levels versus Cumulative Water Budget Change-in-Storage



To calibrate the water budget average groundwater levels were used as a surrogate to attempting to quantify the groundwater change-in-storage. Figure 5 shows a plot of the cumulative change-in-storage in comparison to the groundwater levels. The change in groundwater levels corresponds fairly well with the cumulative water budget for years 1990 through 2000. The water budget does not replicate the change in groundwater levels from 2000 to 2014. The water balance is over predicting the amount of surplus water, which could be related to either too high of inflow into the basin or not enough outflow from the basin. This was during the time when most of the golf courses and housing developments were constructed. Further evaluation of the amount of construction water pumped could improve the model calibration and increase the sustainable yield for the basin.

The water budget inflow components are 74 percent quantified with high quality gaging data. Quantifying inflows from Prosser Creek would improve the inflow characterization to over 90 percent. The water budget outflow components are over 80 percent quantified with high quality gaging and metered flows from municipal water supplies. Better quantification of evapotranspiration, by obtaining this component from the DRI modeling, would improve the budget outflow certainty to close to 98 percent.

8.0 Sustainable Yield

The definition of sustainable yield varies somewhat throughout the historic literature and from state to state.

The Sustainable Groundwater Management Act of 2014, defined sustainable yield as “the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.” Undesirable result means one or more of the following effects caused by groundwater conditions occurring throughout the basin: chronic lowering of groundwater levels, depletion of interconnected surface water, significant and unreasonable loss of storage, subsidence, saltwater intrusion, and degradation of water quality.

The average annual groundwater extractions through the calibration period is on the order of 7,000 AFY. The water budget shows the basin has an average surplus of about 15,000 AFY, with a plus or minus uncertainty level of about 20 percent. Adding the surplus to the existing pumping would suggest the sustainable yield is about 22,000 AFY.

9.0 Conclusions

The water budget was developed to the extent of the available studies and measurements within the limited fiscal budget. The water budget is fairly well quantified with both inflow and outflow components having about 80 percent high quality data. The accuracy of the water budget can be improved to over 90 percent in both the inflow and outflow by improving the monitoring on Prosser Creek and quantification of native vegetation evapotranspiration.

The water budget shows the average total pumping is about 7,000 AFY. Wastewater returns are about 2,100 AFY, therefore about 4,900 AFY is being consumed, likely due to outside water use and mostly from irrigation of golf courses. However, the water loss is being compensated for by wastewater imported from outside the MVGB from the Lake Tahoe watershed and recharged to groundwater through T-TSA leachfields. An average of about 2,700 AFY is imported into MVGB, reducing the losses of groundwater due to pumping by about 2,200 AFY, on average.

Please contact Richard Shatz at (916) 631-4566 if you have any questions pertaining to this report.

Regards,

Richard W. Shatz, C.HG. 84
Principal Hydrogeologist

Mark S. Williamson, P.E. C35671
Vice President

Enclosure

12.0 References

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Table 1A
Martis Valley Groundwater Basin Water Budget
(in Acre-Feet per Calendar Year)

Groundwater Level Records - from Water Data Library

GSP Regulation Base Period for Evaluation (10 yr historic)

Water Year Type Based on Precipitation	C	BN	C	AN	BN	W	W	BN	W	AN	BN	BN	BN	C	C	W	AN	BN	BN	BN	AN	BN	BN	C	C		
Calendar Years	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**Average**	**Percent of Total**
Inflow																											
Precipitation Total	65,000	150,000	120,000	105,000	95,000	175,000	80,000	230,000	180,000	200,000	190,000	170,000	125,000	75,000	115,000	135,000	100,000	155,000	200,000	95,000	100,000	125,000	154,057	44,508	115,492	131,962	22.8%
Surface Water:																											
Truckee River (USGS 10338000)	16,755	152	101	95,061	23,602	22,171	203,284	597,807	462,057	433,097	201,996	205,109	134,157	135,388	90,645	169,633	216,331	176,656	149,072	111,713	133,650	180,638	196,856	148,348	89,486	167,751	29.0%
Donner Creek above Cold Creek (USGS 10338500)	14,118	13,901	9,484	35,404	8,326	53,431	44,743	39,024	39,096	33,738	22,806	9,412	20,851	25,992	18,172	34,318	44,454	12,742	15,421	22,734	28,598	42,499	22,734	10,426	12,887	25,412	4.4%
Boca Reservoir (USGS 10344500)	61,106	58,716	40,110	66,536	144,872	130,030	205,978	239,934	151,244	199,534	96,799	85,215	123,008	82,826	108,672	45,033	229,001	99,188	103,242	70,373	63,784	202,286	79,712	112,654	90,355	115,608	20.0%
Cold Creek (MP03)	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	2.2%
Adler Creek (MP-19)	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	2.4%
Prosser Creek (MP-22)	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	89,000	15.4%
Martis Creek (MP25)	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	0.1%
West Martis Creek (MP-33)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	0.4%
Middle Martis Creek (MP-35)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	0.4%
East Martis Creek (unknown)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	0.4%
Siller Ranch Springs Tributary (MP-32)	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	0.1%
Monte Carlo Creek (unknown)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0.2%
Ungaged surface inflow (small tributraries)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		0.0%
Groundwater Recharge - Adler Creek (MP-17 minus MP-18)	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	0.3%
Wastewater Recharge:																											
T-TSA Import from Lake Tahoe (NTPUD, TCPUD,ASCWD,SVPSD or Granite Flats)	2,364	2,084	2,308	3,226	2,745	3,686	3,652	3,551	3,461	3,697	3,305	2,509	2,689	2,644	2,543	2,733	3,069	2,263	2,016	1,972	2,084	2,487	1,994	1,871	1,692	2,666	0.5%
T-TSA Martis Valley Generated Wastewater (TSD)	1,400	1,624	1,512	1,378	1,176	1,826	1,725	1,927	2,050	1,770	1,949	2,005	2,173	2,543	2,532	2,543	2,722	2,610	2,689	2,677	2,689	2,801	2,420	2,431	2,296	2,139	0.4%
Martis Valley Septic Systems (small)	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	0.1%
Irrigation Deep Percolation	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		0.0%
Tiechert - gravel washwater discharges	319	319	319	319	319	319	319	319	319	319	318	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	0.1%
Import NCSD Big Springs collection system	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		0.0%
Subsurface Inflows:																											0.0%
Northstar Watershed	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220	0.6%
Martis Peak Watershed	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	0.2%
Donner Lake Watershed	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	1,008	0.2%
Joint and Fracture Granites beneath Alluvium	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Total Inflow	293,982	359,717	306,754	439,844	408,961	519,383	672,622	1,245,481	971,147	1,005,076	650,094	607,490	541,117	457,631	470,804	522,499	728,817	581,699	605,680	437,708	464,045	688,949	591,012	453,477	445,448	578,778	

Table 1B
Martis Valley Groundwater Basin Water Budget
(in Acre-Feet per Calendar Year)

Groundwater Level Records - from Water Data Library

GSP Regulation Base Period for Evaluation (10 yr historic)

Water Year Type Based on Precipitation	C	BN	C	AN	BN	W	W	BN	W	AN	BN	BN	BN	C	C	W	AN	BN	BN	BN	AN	BN	BN	C	C		
Calendar Years	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**Average**	**Percent of Total**
Outflow																											
Surface Water Outflow																											
Truckee River at Boca Bride Nr Truckee (USGS 10344505)	317,825	245,809	193,433	669,576	177,363	966,570	779,684	799,920	731,475	720,761	418,411	201,766	372,582	371,846	310,524	413,838	708,289	348,099	333,981	286,487	346,362	633,934	380,172	341,366	243,916	452,560	80.2%
Groundwater Pumping:																											
Truckee-Donner PUD (Total Potable)	3,206	3,221	3,258	3,272	3,653	3,389	3,758	3,930	3,949	4,566	4,859	5,208	6,423	6,454	7,128	6,668	7,426	7,195	6,978	6,639	5,722	5,313	5,727	5,674	5,149	5,151	0.9%
Truckee-Donner PUD (Irigation)	0	0	0	0	0	0	0	0	0	0	0	257	230	223	256	200	239	271	275	335	603	549	841	636	699	225	0.0%
PCWA Lahontan (Zone 4)	0	0	0	0	0	0	0	0	0	35	31	7	5	30	52	44	73	79	160	141	122	88	90	117	144	49	0.0%
Northstar Comm Services District	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	398	142	146	219	224	274	64	0.0%
Schaffer's Mill Golf Course	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	254	275	236	41	0.0%
Glenshire Mutual Water Co	835	835	835	835	835	835	835	835	835	835	835	835	0	0	0	0	0	0	0	0	0	0	0	0	0	835	0.1%
Donner Creek Mobile Home Park	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	0.0%
Tiechert	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	354	0.1%
Public Small Water Systems	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	0.0%
Domestic Wells	180	180	180	180	180	180	180	180	180	180	182	194	200	204	208	212	216	223	220	220	220	220	220	220	220	199	0.0%
Evapotranspiration (EVT)																											
Golf Courses:																											
Truckee Falls Golf Couse (now Coyote Moons)																											
Coyote Moon Golf Course																											
Lahontan Golf Club (2000 19 holes, 2015 27 holes)																											
Ponderosa Golf Course (openned 1961)																											
Northstar at Tahoe (approx. 1/3 out of basin)																											
Tahoe-Donner																											
Old Greenwood Golf Club																											
Martis Camp Club																											
The Timilick Club/Schaffer's Mill																											
The Golf Club At Gray's Crossing																											
Tahoe-Truckee Unified School District Turf Fields																											
Residential Landscapes																											
Native vegetation:																											
Forest	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	69,504	12.3%
Sagebrush	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	32,130	5.7%
Wetlands (vicinity Martis Creek)	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540	0.3%
Riparian																											
Evaporation (surface water bodies)																											
Prosser Reservoir	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	0.1%
Martis Creek Lake	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	0.0%
Truckee River	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	0.0%
Pond in Glenshire subdivision	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Dry Lake adjacent to Waddle Ranch Preserve	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Gooseneck Reservoir near Lahontan Golf Club	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	0.0%
Union Mills	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	0.0%
Tiechert - washwater pond	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	0.0%
Donner Quarry Ponds	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	0.0%
Subsurface Outflow																											
Juniper Creek	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0.2%
To Truckee River	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	0.0%
Groundwater Transfer out of Groundwater Basin (snow making)																						598	598	598	598	598	0.1%
Total Outflow	**427,521**	**355,520**	**303,181**	**779,338**	**287,506**	**1,076,449**	**889,932**	**910,340**	**841,914**	**831,852**	**529,791**	**313,742**	**484,915**	**484,232**	**423,642**	**526,437**	**821,717**	**461,341**	**447,288**	**399,696**	**458,646**	**746,582**	**493,597**	**454,585**	**356,711**	**564,259**	

Total Inflow - Outflow = Change-in-Storage	**-133,539**	**4,197**	**3,573**	**-339,494**	**121,455**	**-557,066**	**-217,310**	**335,141**	**129,234**	**173,223**	**120,302**	**293,748**	**56,202**	**-26,601**	**47,161**	**-3,938**	**-92,900**	**120,358**	**158,391**	**38,013**	**5,399**	**-57,632**	**97,415**	**-1,108**	**88,738**	14,519	
Groundwater	**-125,223**	**4,183**	**3,505**	**-339,702**	**121,756**	**-557,423**	**-219,524**	**337,551**	**129,360**	**173,082**	**120,285**	**295,423**	**56,676**	**-28,801**	**52,212**	**-12,772**	**-88,908**	**123,066**	**155,531**	**38,193**	**6,058**	**-58,318**	**97,245**	**2,141**	**86,408**	14,880	
Surface Water																											
Prosser Reservoir	-8,309	11	73	205	-298	347	1,222	-1,418	-131	146	20	-1,690	-470	2,210	-5,048	7,588	-2,750	-2,701	2,859	-185	-674	671	195	-3,300	2,305	-365	
Martis Creek Reservoir	-7	3	-5	3	-3	10	992	-992	5	-5	-3	15	-4	-10	-3	1,246	-1,242	-7	1	5	15	15	-25	51	25	3	
Truckee River	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Cumulative Groundwater Change-in-Storage	**-125,223**	**-121,039**	**3,573**	**-339,494**	**121,455**	**-557,066**	**-217,310**	**335,141**	**129,234**	**173,223**	**120,302**	**293,748**	**56,202**	**-26,601**	**47,161**	**-3,938**	**-92,900**	**120,358**	**158,391**	**38,013**	**5,399**	**-57,632**	**97,415**	**-1,108**	**88,738**		

Notes:

Black font = Are published values from USGS, historic reports, Partners files,

Purple font = Estimated values

Blue font = Average annual water balance components

---- = Water balance components that are considered to have neglible values or cannot be estimated reliabiably at this time

APPENDIX E

Technical Memorandum: Assessment of the Martis Valley Groundwater Basin (Stantec, 2016)

Stantec **Memo**

To: Mike Staudenmayer - NCSD
Steven Poncelet, TDPUD
Tony Firenzi, PCWA

From: Thomas W. Butler, PG, CHG, CEG
Associate Hydrogeologist

Stantec, Walnut Creek California

Date: October 20, 2016

Reference: Assessment of the Martis Valley Groundwater Basin

EXECUTIVE SUMMARY

- The recently discovered Polaris Fault forms a hydraulic barrier to groundwater flow, with the eastern side of the fault having groundwater elevations 30 to 40 feet higher than groundwater elevations on the western side of the fault.

- The most recent assessment of the MVGB sustainable yield is around 22,000 acre-feet per year. Of this 7,000 acre-feet is currently being used, leaving about 15,000 acre-feet for potential future use.

- Total water use at buildout was estimated to be 12,941 acre-feet per year or about 59% of the total estimated amount of available groundwater within the basin.

- Review of available shallow groundwater elevation and spring flow data does not provide evidence to conclude that pumping from NCSD or TDPUD's wells is having a direct or substantial influence on stream flows in the basin.

- Measured water level declines at DWR Monitoring Well 17N17E19K001M appear to be controlled by the onset of the decadal climate variations and not local groundwater pumping.

- Review of DWR Monitoring Well 17N17E29B001M water level data suggest hydraulic communication with Northstar production wells TH-1 and TH-2, with the spring time potentiometric surface generally recovering and stabilizing since around 2011, with some influences potentially associated with the drought. Stable spring groundwater levels indicate that recharge is occurring and that a new equilibrium has been reached. This trend indicates that a chronic lowering of the water table is not occurring.

- Review of groundwater elevation data indicates that pumping of Northstar's production wells TH-1 and TH-2 has resulted in a new pressure equilibrium in that portion of the valley, influenced in part by the drought. Water levels at these locations appear to have stabilized and may even be recovering after the near normal precipitation year in 2015-2016. Additional information is needed to ascertain long term water level changes at newly acquired (formally PCWA) wells Well 1 and Well 2.

- Water level measurements at TDPUD wells indicate certain wells influenced by drought but overall stable groundwater levels.

- Monitoring of both Northstar and TDPUD wells indicates that there is not a chronic lowering of the water table, as it relates to SGMA. However, continued monitoring is recommended to further assess potential longer term trends, particularly for wells with a short history of water level measurements.

- The stable groundwater levels in the MVGB is sufficient to conclude that an "unreasonable loss of storage" has also not occurred.

HYDROGEOLOGY

MARTIS VALLEY AQUIFER SYSTEM

According to the California Department of Water Resources, Bulletin 118, the Martis Valley Groundwater Basin (MVGB) is an intermontane (lying between mountains), fault-bounded basin east of the Sierra Nevada crest. According to this source, the Martis Valley is about 35,600 acres in size. The floor of Martis Valley is terraced with elevations between 5,700 and 5,900 feet above mean sea level, while the valley is punctuated by round hills rising 1,000 feet or more around the perimeter. Mountains along the southern margin of Martis Valley rise dramatically to elevations in excess of 8,000 feet above mean sea level. Surface water within the basin includes the Truckee River, which crosses from south to east in a shallow, incised channel. The principal tributaries to the Truckee River are Donner Creek, Martis Creek, and Prosser Creek. Major surface water storage reservoirs include Donner Lake, Martis Creak Lake, and Prosser Creek Reservoir. The average precipitation is estimated to be 23 inches in the lower elevations of the eastern portion of the basin to nearly 40 inches in the western areas. A photo taken from Martis Peak overlooking the Martis Valley is illustrated above.

The major groundwater bearing formations within the MVGB consist of basin fill volcanic and sedimentary deposits. The volcanic basin fill material consists of basaltic andesite lava, tuff breccias, and volcaniclastic deposits ranging in age between 0.75 to 7 million years. The sedimentary basin fill was deposited in the late Miocene-Pliocene and includes interbedded sediments of stream and lake origin, laterally extensive clay and silt layers of glacial origin, and recent alluvial material. Basement rocks within the basin are older than the basin fill sediments and volcanic units and include Cretaceous-Jurassic plutonic and metamorphic rocks and Miocene volcanic units. According to Hunter et. al. (2011), the Polaris Fault, an active fault, was recently discovered within the Martis Valley traversing the valley in a north northwesterly directly from about 3 miles south of and near the western side of Martis Creek Dam Reservoir, past the western edge of Prosser Creek Reservoir, and terminating just north of Kyburz Flat. Figure 1 illustrates the location of the fault (per Hunter et. al. (2011). The hydrogeologic significance of the fault is that it acts as a hydraulic barrier to groundwater flow, with the eastern side of the fault having groundwater elevations 30 to 40 feet higher than groundwater elevations on the western side of the fault (Interflow, 2014).

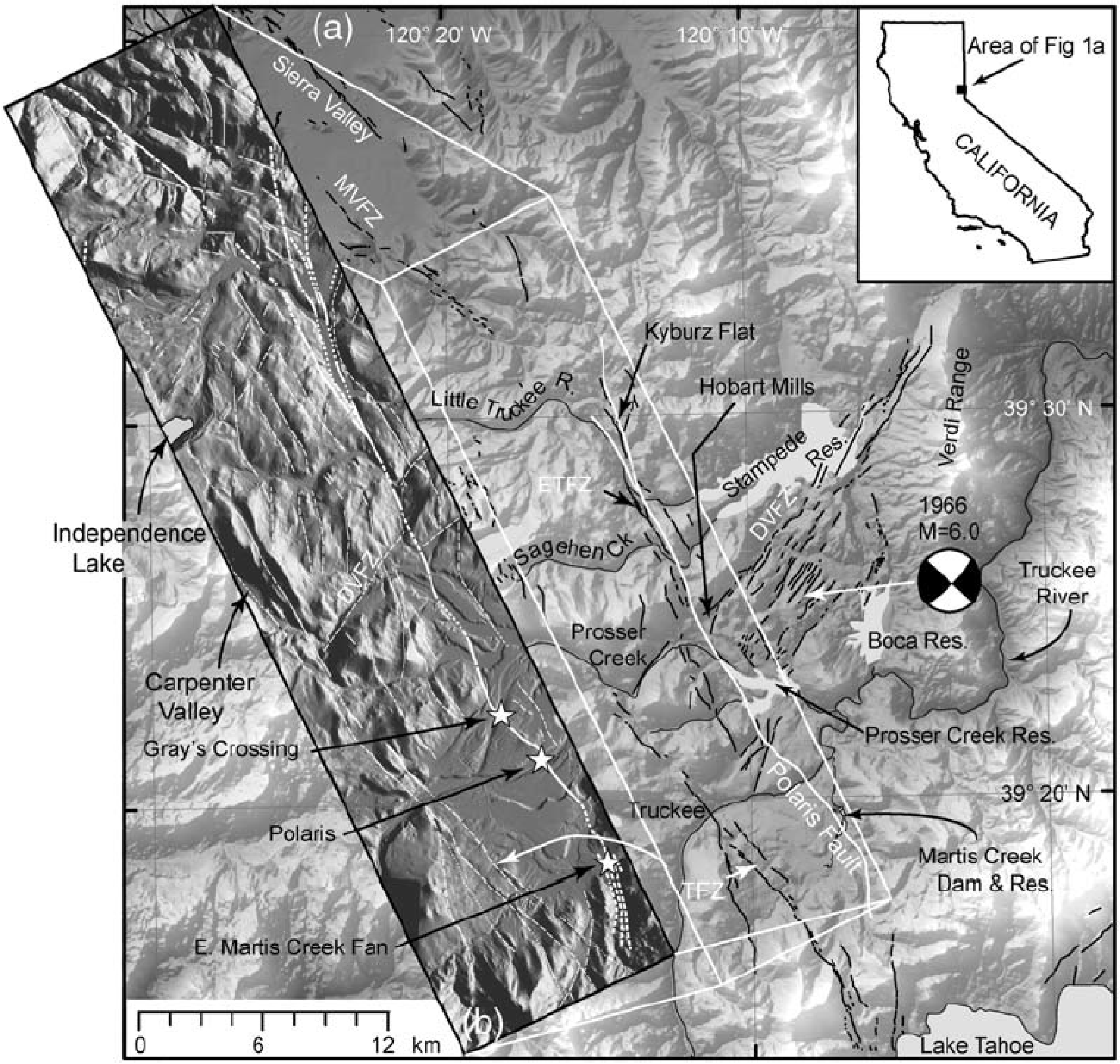

Figure 1: Location of the Polaris Fault.

GROUNDWATER RECHARGE AND AVAILABLITY

According to the MVGB Groundwater Management Plan (2014) the average groundwater *recharge* to the MVGB was estimated to be about 33,000 acre-feet per year, based on a 2012 Desert Research Institute (DRI) Study. The concept of groundwater recharge is different than what is available for extraction/potable use on an annual basis (sustainable yield) in that other processes/factors rely on groundwater, particularly shallow groundwater. These processes generally include plant uptake (evapotranspiration), stream base flow, and basin groundwater outflow. Accordingly and in contrast, the California Bulletin 118 summarized estimates provided by

Nimbus Engineers (2001) at approximately 24,700 acre-feet per year of groundwater that is available for extraction on an annual basis with the MVGB. Several studies including Kennedy Jenks (2002) and InteFlow Hydrology (2003) have suggested that between 24,000 and 34,000 acre-feet may be available for extraction on a sustainable basis. The most recent analysis was conducted by GEI Consultants in 2016 (GEI), incorporating data and modeling efforts from the previous assessments into an overall water budget for the basin. Their findings suggest that the sustainable yield of the MVGB is around 22,000 acre-feet per year, with about 7,000 acre-feet currently being used. The total amount of inflow of water to the basin was found by GEI to be approximately 580,000 acre-feet per year. The amount of groundwater currently estimated by GEI to be available for future development is about 15,000 acre-feet per year.

GROUNDWATER USE

The 2016 GEI report found that the total groundwater extraction for the MVGB is around 7,000 acre-feet per year. The current use is 32% of GEI's estimate of available groundwater and only 1.2% of the total basin inflows. At basin build out, the Truckee Water System 2015 Urban Water Management Plant (UWMP) found that all users in the MVGB may account for up to 12,941 acre-feet per year or about 59% of GEI's estimate of what is available on a long term basis. It is important to note however that build out demand estimate provided by Kaufman (2011) is likely biased high as it assumes that 100% of the available entitlements will be utilized and an average domestic use of 400 gallons per day per equivalent dwelling unit (gpd/EDU), for single family homes. For comparison the actual average 2012-2013 domestic use in the community of Northstar was substantially less (approximately half) at 209 gpd/EDU for single family homes, and even less for condos.

SUSTAINABLE GROUNDWATER MANAGEMENT ACT OVERVIEW

SGMA defines the following as it relates to the sustainable yield of a groundwater basin:

Sustainable Yield: The maximum quantity of water, calculated over a base period representative of the long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an *undesirable result*.

***Undesirable Results*:** an effect caused by groundwater conditions occurring throughout the basin such as chronic lowering of groundwater levels, depletion of interconnected surface water, significant and unreasonable loss of storage, subsidence, saltwater intrusion, and degradation of water quality.

Of these potential undesirable results, subsidence, saltwater intrusion, and degradation of water quality are generally not regarded as significant concerns for the MVGB.

Depletion of interconnected surface water, chronic lowering of groundwater levels, and significant and unreasonable loss of storage, as they may apply to SGMA as undesirable results due to pumping, are principal factors that are the focus of this evaluation.

ASSESSMENT OF POTENTIAL UNDESIRABLE RESULTS

DEPLETION OF INTERCONNECTED SURFACE WATER

There are two principal aquifers within the MVGB generally consisting of shallower sedimentary and volcanic fill deposits (shallow aquifer) and deeper igneous and metamorphic rocks (deep aquifer). The shallow aquifer can be further divided into discrete water bearing strata, separated by silt and clay confining layers. The shallowest water bearing strata located within approximately 20 feet of land surface is the zone where surface water channels are most likely to bisect and be influenced by, or influence, groundwater levels. In contrast, public water wells operated by the Northstar Community Services District (NCSD) and Truckee Donner Public Utility District (TDPUD) have been designed to target deeper groundwater resources, with tops of well screens ranging anywhere from 100 to 460 feet below ground surface (see Tables 1 and 2). Review of pumping and static water levels provided by NCSD and TDPUD and stream flow data suggest that there is no direct evidence that the operation of the public water wells has or is influencing stream flow or significantly affecting groundwater levels in the overlying upper portions of the shallow aquifer.

Supporting the conclusion of a lack of depletion of interconnected surface water is a recent study conducted by Balance Hydrologics and summarized in their 2016 technical memorandum. That memorandum documented monitoring from a near continuous stream flow gaging station on Middle Martis Creek, a non-instrumented stream stage monitoring station just west of the Northstar golf course and between NCSD wells TH-1 and TH-2, as well as six new shallow groundwater monitoring wells installed at depths up to 18 feet below ground surface. The wells and the stream gauging stations were installed in the spring of 2013 and have been monitored since their construction. The locations of the wells and stream monitoring stations are illustrated in Figure 2 (Balance Hydrologics, Inc., 2016). The findings from three water years of monitoring, conducted during a multi-year drought, are that shallow groundwater monitored by the piezometers was in direct connection with stream flow in Middle Martis Creek with levels varying from 4.6 to 11.5 feet below ground surface. They found that groundwater levels responded directly to periods of snowmelt runoff, recharge, and cessation of stream flow in Middle Martis Creek. They also found persistent perennial flows in East Martis Creek, West Martis Creek, and Martis Creek, however Middle Martis creek was intermittent during the dry season. Figure 3 (Balance Hydrologics, Inc., 2016) illustrates the stream flow (solid dark blue line) and shallow groundwater level data (dashed lines). What is evident from these data is that seasonal variations in groundwater levels are typically less than 12 feet, they recover each year (despite the drought), and fluctuate in direct response to flows in Martis Creek, with groundwater levels increasing following increases in stream flow.

Reference: Assessment of the Martis Valley Groundwater Basin

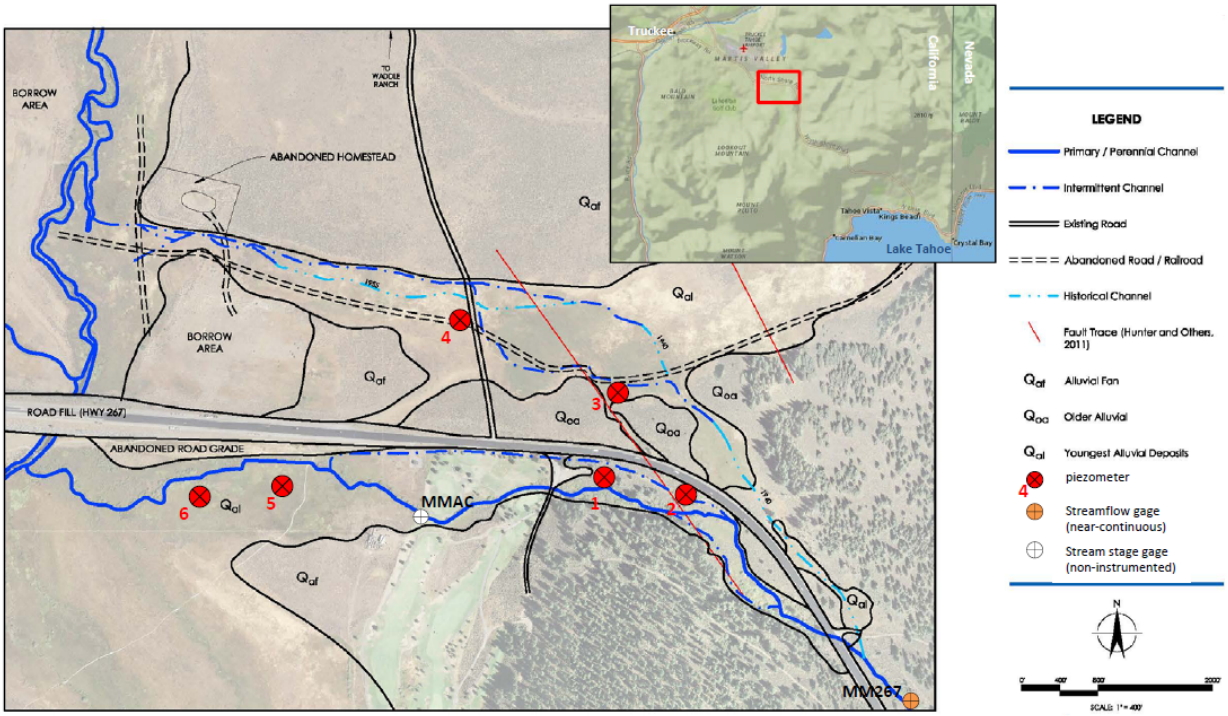

Figure 2: Balance Hydrologics, Inc. (2016) figure illustrating the location of shallow monitoring wells (piezometers) and stream gauging stations.

Reference: Assessment of the Martis Valley Groundwater Basin

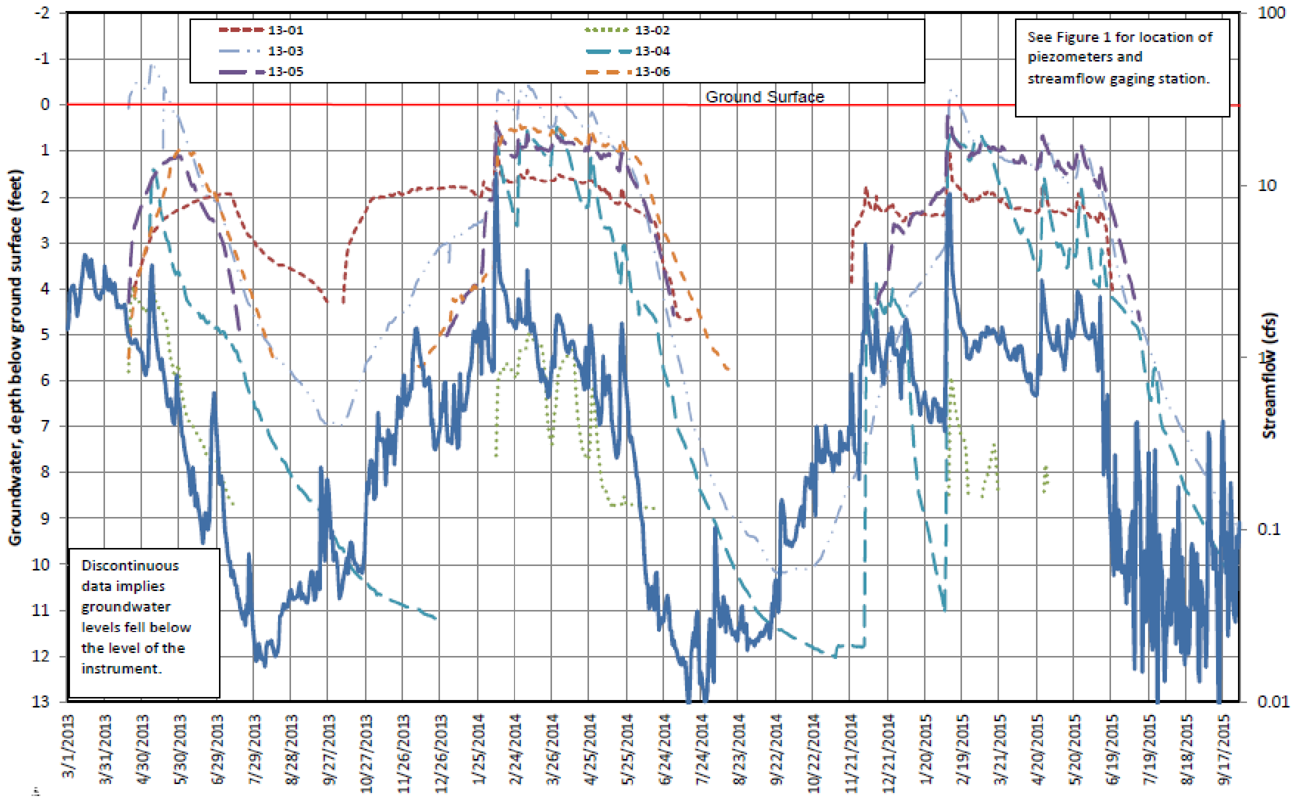

Figure 3: Balance Hydrologics, Inc. (2016) Martis Creek stream flow and shallow groundwater levels.

Reference: Assessment of the Martis Valley Groundwater Basin

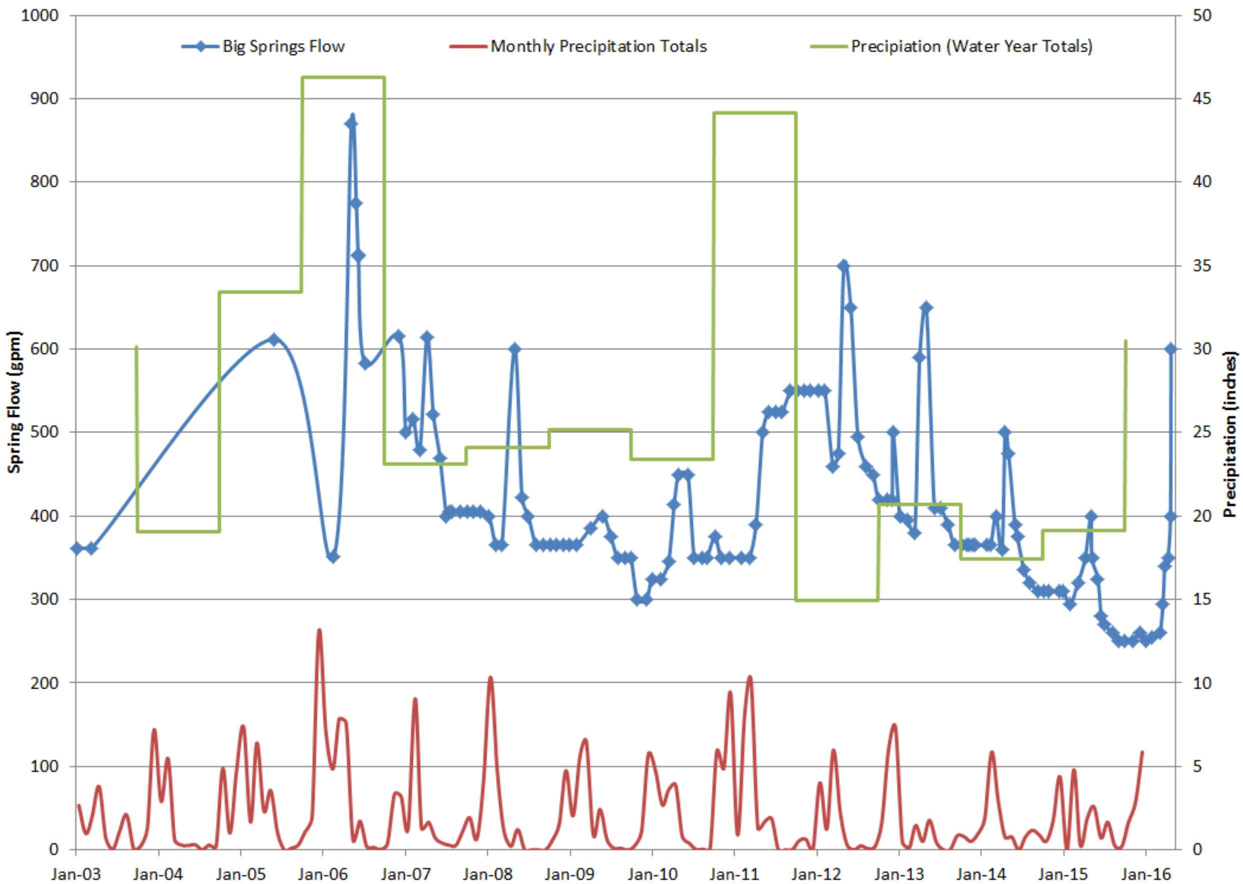

Figure 4: Comparison of Big Springs Flow and Precipitation.

In addition to shallow piezometer groundwater and surface water data, Stantec also evaluated production from NCSD Big Spring. Springs often have shallower sources of recharge and may qualitatively reflect the relative availability of groundwater for deep recharge potentially occurring in a groundwater basin. Figure 4 illustrates flow (blue line) monitored from the Big Springs going back to around 2005. Additionally, both monthly precipitation totals (red line) and total water year accumulations (green line) are also illustrated for comparison. What can be seen from this figure is that the Big Springs flows are heavily influenced by the magnitude of precipitation with an approximate two to three month lag from peak precipitation periods to peak seasonal spring flows. Also, trends in spring flow since around 2012 have generally correlated with water year totals and in response to the significant most recent multiyear California drought. It is important to note that, despite the significant and prolonged drought, Big Springs flows did not drop below historically low production until 2015, the third year of one of California's worst, multi-year droughts on record. Despite decline in spring flow it took only one year of approximate normal precipitation (water year 2015-2016) to cause flows to recover to normal conditions.

Accordingly, review of available data indicates that shallow groundwater elevations are generally stable year to year, however are influenced by precipitation patterns including the multi-year drought. Review of these data do not however provide evidence to conclude that pumping from

NCSD or TDPUD's wells is having a direct or substantial influence on stream flows in the basin. Given that the period of record for shallow groundwater monitoring is relatively small, continued monitoring of precipitation, surface water, spring(s), shallow groundwater (piezometers), and groundwater pumping is however recommended in order to establish a more robust record through periods of precipitation excesses and drought. With time, these data may provide sufficient information in order to make more quantitative conclusions regarding the influence of potential stressors, including shorter term weather, climate, and future groundwater development, and management practices on shallow groundwater and surface water.

CHRONIC LOWERING OF GROUNDWATER LEVELS

As previously noted, the near surface shallow groundwater zones are unconfined to semi-confined and controlled in part by flows in Martis Creek and based on monitoring data assessed have remained stable year to year. Water levels in an unconfined aquifer represent the actual water level in the subsurface. In contrast deep groundwater generally occurs in confined aquifers and is often recharged over longer periods of time. Groundwater elevations in a confined aquifer are not the actual water surface but represented by an imaginary surface that characterizes the confining pressure (potentiometric surface) in that aquifer. For instance, when a well is drilled into a confined aquifer that has a confining pressure greater than land surface it would result in flowing artesian conditions (flowing well). However the confining layer, usually silt, clay, or competent rock prevents the water surface from actually reaching the surface without the aid of a conduit, e.g. a well.

The Department of Water Resources has two monitoring wells installed in Martis Valley (17N17E29B001M and 17N17E19K001M) that have shown water level declines over the past decade or more. The location of these two wells is illustrated in Figure 5, along with NCSD and TDPUD production wells for reference. Figure 6 provides a hydrograph of the potentiometric surfaces for these two monitoring wells along with the water year precipitation totals for the Truckee, California (TKE) climate station (see California Data Exchange for more information). Note that the DWR monitoring wells are intermittent in depth with the top of screen for each respective well illustrated in Figure 6. Both of the DWR wells screen very thin discrete 10 foot intervals of a confined aquifer as indicated by the potentiometric surface being much higher than the top of the well screen. A discussion of each monitoring well is as follows.

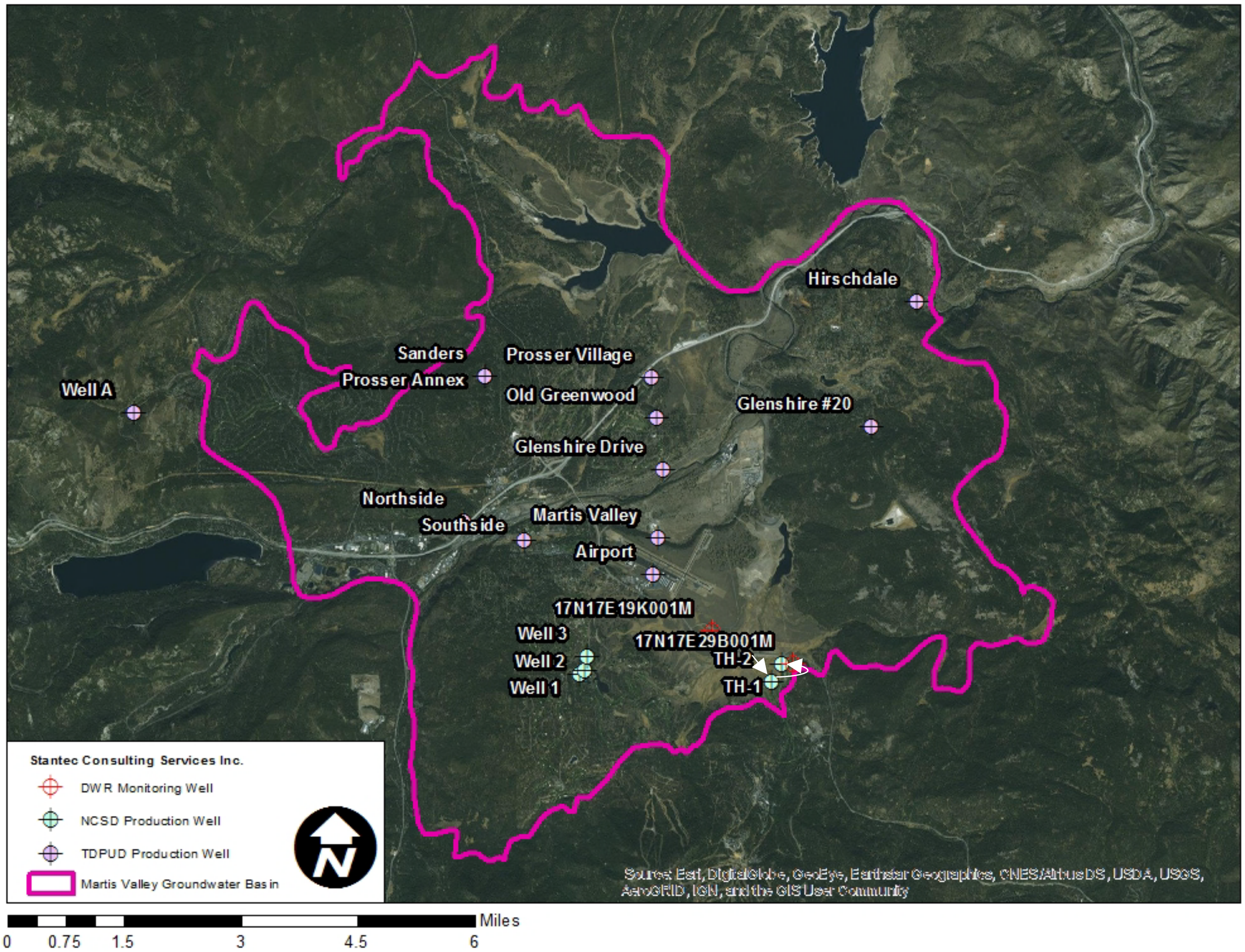

Figure 5: Martis Valley NCSD and TDPUD Well Location Map

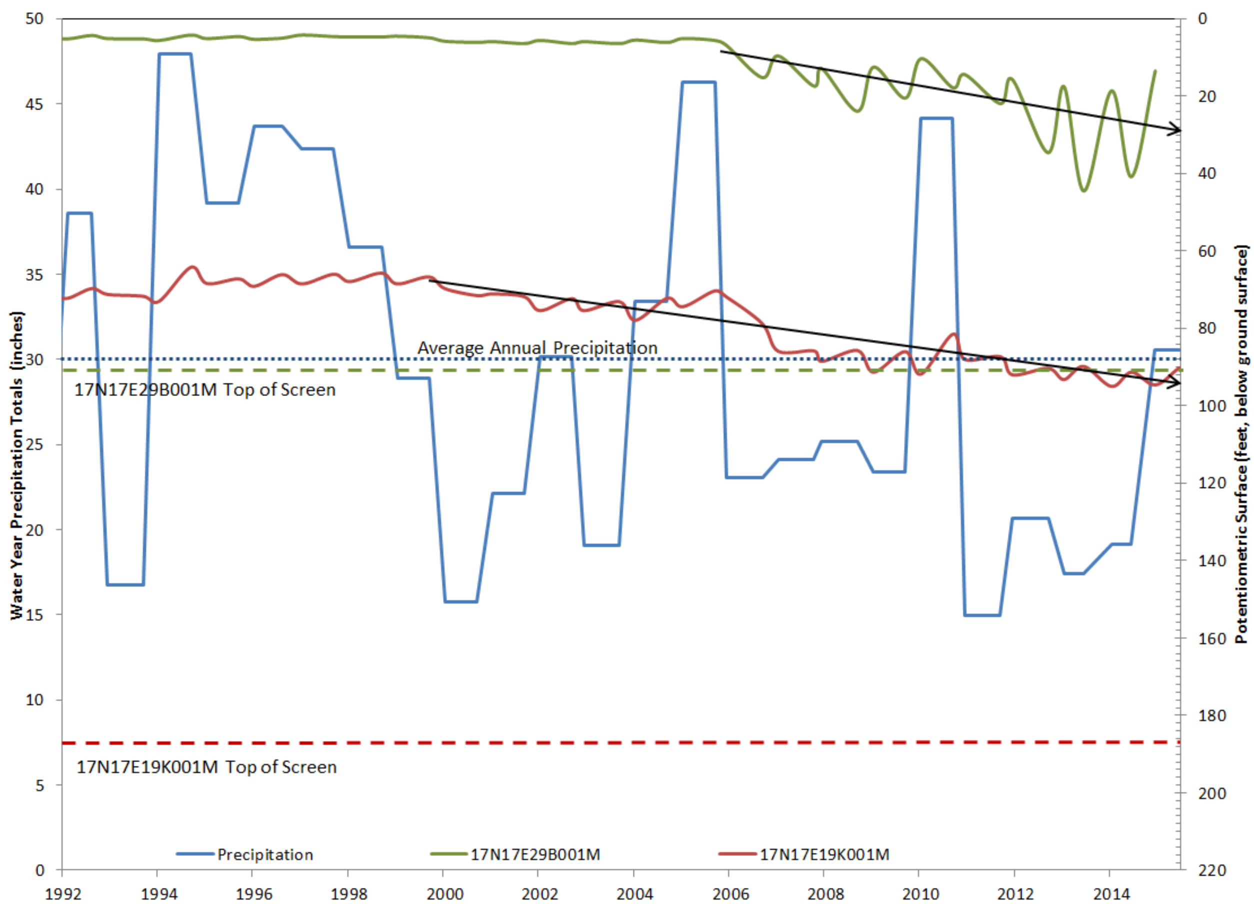

Figure 6: DWR Well Hydrograph and Precipitation Totals

DWR Monitoring Well 17N17E19K001M

DWR Monitoring Well 17N17E19K001M (red hydrograph) was installed to a total depth of 201 feet with a screen from 187 to 197. The potentiometric surface for this well indicates that water levels began to decline around 1999, the first year of what will turn out to be the beginning of three multi-year droughts that have occurred since 1997. Additionally, during that period the hydrograph indicates that water levels began to recover during the rare wetter than normal water years of 2006 and 2010. The only main production wells in the near vicinity of this well include NCSD's TH-1 and TH-2 as well as TDPUD's Airport Well. The closest of these wells (TH-1 and TH-2) were not put into operation until 2014 and 2006, respectively and thus are not likely having a significant influence on the declining water levels, that appear to have begun much earlier. Furthermore, the Airport Well, although operating much longer, has stable year to year water levels. Accordingly, the water level declines at this location appear to be controlled by the onset of the decadal climate variations and not local groundwater pumping.

DWR Monitoring Well 17N17E29B001M

DWR monitoring well 17N17E29B001M (green hydrograph) is a shallower monitoring well, having a well screen from 90 to 100 feet below ground surface and located near one of the splays of the Polaris Fault. This well is also very close to NCSD's TH-1 and TH-2, with TH-2 being put into production near the time that this monitoring well's water levels began to decline (circa 2006). It is important to note that both TH-1 and TH-2 were installed with seals specifically designed to isolate the shallower water bearing strata screened by this well, with cement seals extending to depths of 205 (TH-2) and 206 (TH-1) feet, respectively (Table 1). The next closest well is TDPUD's Airport Well, with a top of screen around 100 feet below ground surface. Although water level declines do correlate with recent drought (since 2006), the monitoring record prior to this period shows only minor groundwater level responses to precipitation and thus other factors are likely controlling water levels at this location.

Review of the geophysical and lithologic logs (Figure 7) for TH-1, the closer of NCSD's two production wells, indicates two zones of relatively thick clay and silt (a minimum of 20 to 30 feet each) are present that should inhibit water level responses due to pumping of TH-1 or TH-2. However, it is possible that pumping of TH-1 or TH-2 has influenced this well through a preferential conduit (another nearby well screening both zones, fault, etc) or that the cone of depression from these wells has reached an area near the alluvial basin boundary where shallower and deeper water bearing zones may be in hydraulic communication. Additionally, pumping of the TDPUD's Airport Well may have the potential to influence this well as its screen begins at a similar depth and at 100 feet bgs. Note however that long term monitoring of water levels for the Airport Well suggest otherwise and stable conditions. Another possible scenario is that the water bearing strata screened by this monitoring well is thin and discontinuous/finite in areal extent and thus affected to a greater degree compared to the actual aquifer proper.

Regardless of the exact cause, if the well is in hydraulic communication with the pumped wells it would be expected to show water level responses due to pumping. Pumping in a fully confined aquifer has an immediate pressure response throughout the aquifer with the magnitude proportional to the log of the distance of similarly screened wells. Based on review of the water level responses at this location, the spring time potentiometric surface appears to have stabilized since around 2011, with some minor influences associated with the drought from 2012 - 2014. For instance the September 2011 water level was 14.4 feet bgs, while the September 2015 water level had recovered past this level and to 13.5 feet bgs, despite the drought. In any case, the water level changes at this location are not significant and could not be considered "chronic". Furthermore, these water levels appear to have equilibrated to the new aquifer pressure at this location, possibly due to pumping, have stabilized, and may be further recovering. Future monitoring of this well is however recommended in order to assess potential longer term trends.

Reference: Assessment of the Martis Valley Groundwater Basin

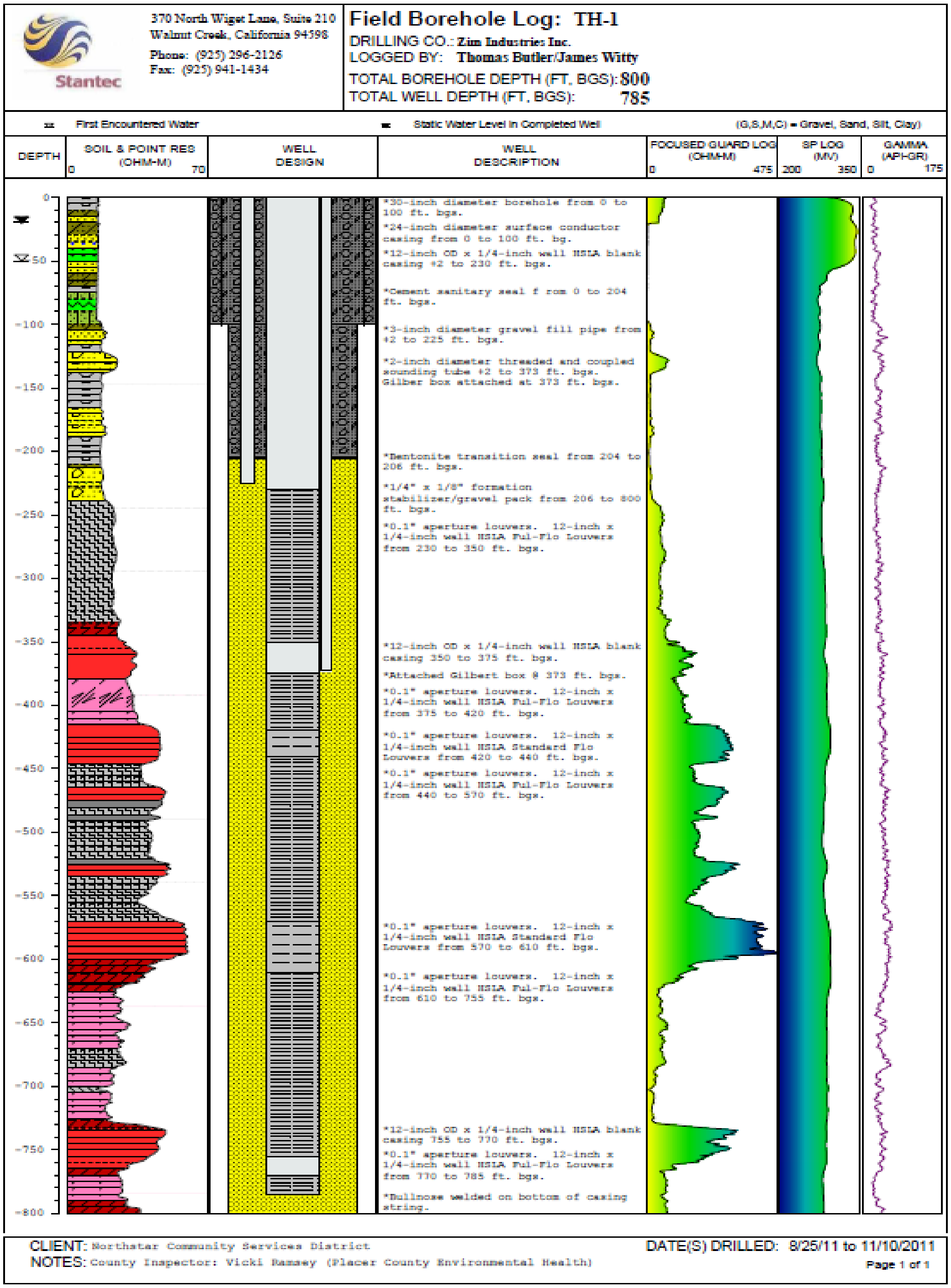

Figure 7: Geophysical, Lithologic, and Well Construction Log for NCSD Well TH-1

NCSD Production Wells

Stantec acquired water level data from NCSD for their production wells (Figure 8). As can be seen from Figure 8 there has been a pressure level decline in TH-2 immediately after it was put into operation (circa 2006), however since 2010 – 2012 the water levels in this well appear to have stabilized. This observed initial water level decline is likely due to pumping of the new well and, as a result, the aquifer reaching a new state of equilibrium (pressure). Additionally, newly acquired (from Placer County Water Agency) Well 1 and Well 2 also show some potentiometric surface changes, which have occurred during the most recent drought. The period of record for these two wells is however limited and it is unknown whether the recent normal water year (2015-2016) has resulted in water level recovery at these locations. Note that water level monitoring in TH-1 only began in 2014 thus a prolonged record of water pressure levels have not been recorded, for comparison.

Also plotted in Figure 8 is the water year precipitation totals for the Truckee TKE precipitation station. For comparison, the long term average water year precipitation totals for this climate station is 30.1 inches. As can been seen from this figure, the water levels at TH-2, TH-1, Well 1, and Well 2 appear to be influenced in part by the prolonged drought, with TH-1 and TH-2 showing evidence of recovery after the near normal water year of 2015-2016. As previously stated, although some historical water levels for Well 1 and Well 2 are available, recent data for these wells, including Well 3, are not available for comparison. Given the more recent stable to recovering water levels at TH-1 and TH-2 and correlation to in part the water year precipitation there no evidence to conclude that there is currently a chronic lowering of the water table, as it relates to SGMA. Instead, the water levels are more likely controlled by initial establishment of a new pressure equilibrium due to increased pumping in this portion of the aquifer and by climate, with water level responses also reflecting less than normal recharge during drier than normal drought years, as would be expected. Continued monitoring of water levels at all of NCSD's well is however recommended, in order to ascertain if any longer term trends are evident, particularly for Well 1 and Well 2 where recent data are unavailable. Should water levels be found to show year over year decline, different well operations should be considered and/or new wells installed. Table 1 provides a summary of the construction and operational attributes of NCSD's water supply wells.

Reference: Assessment of the Martis Valley Groundwater Basin

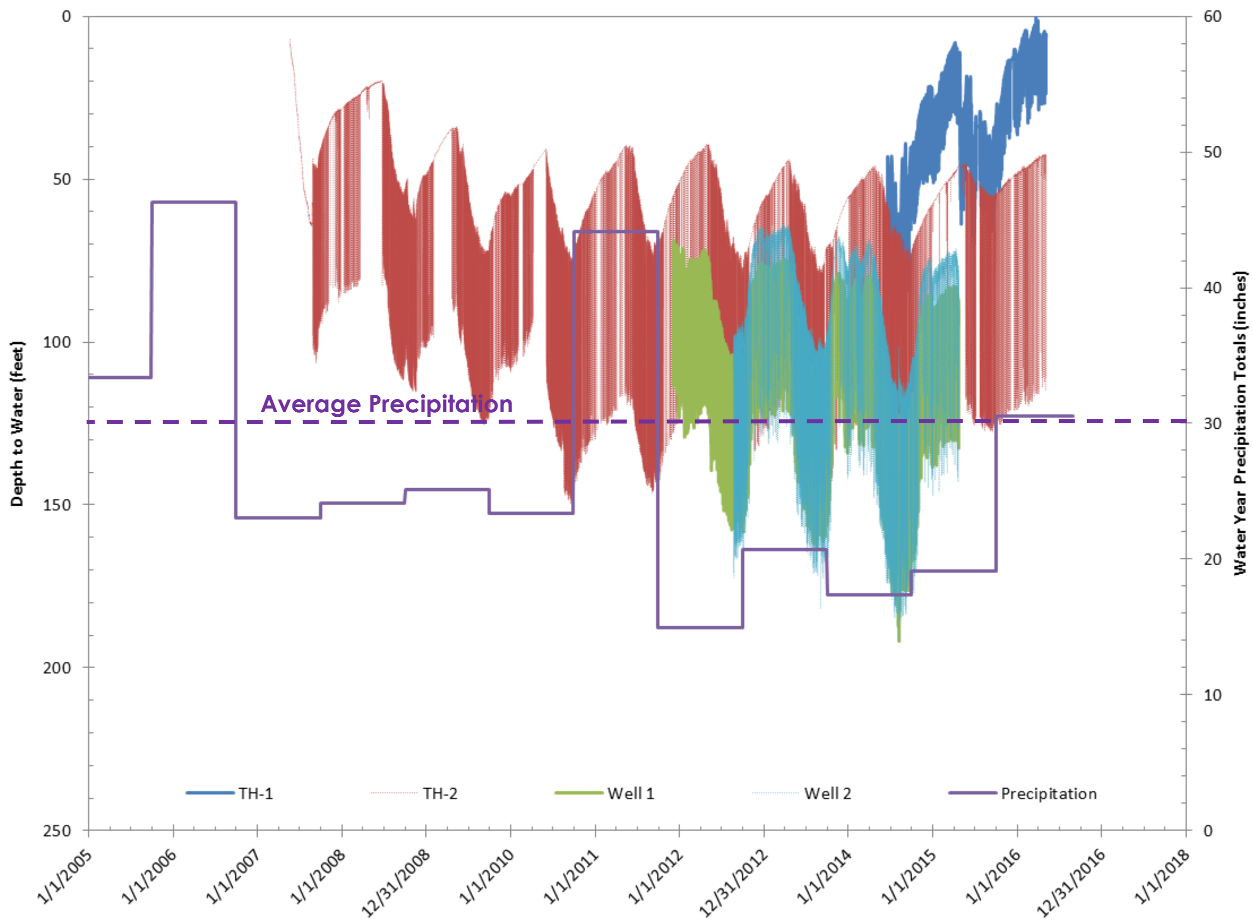

Figure 8: Water Levels for NCSD Wells in Martis Valley Groundwater Basin

Feature	TH-1	TH-2	Well 1	Well 2	Well 3
Well Depth (ft, bgs)	785	800	902	740	550
Screen Intervals (ft, bgs)	230 – 350; 375 – 755; 770 - 785	217 – 538; 558 – 800	114 – 637; 667 – 902	140 – 220; 240 – 280; 320 – 740	260 – 340; 360 – 440; 460 – 500; 510 – 550
Gravel Pack Interval (ft, bgs)	206 – 800	205 – 810	102 – 912	103 – 761	110 – 550
Seal Depth (ft, bgs)	206	205	102	103	100
Approximate Yield (gpm)	800	800	1200	1200	210
Status and Approximate Operation	Active (All Year)	Active (All Year)	Active (All Year)	Active (All Year)	Active (All Year)
Well Type	Public	Public	Public	Public	Public

Table 1: NCSD Potable Well Construction Summary

TDPUD Production Wells

Stantec acquired water level measurements from Truckee Donner Public Utilities District (TDPUD) to assess apparent trends in water levels at their water supply wells (Figure 9). The location of TDPUD wells is illustrated in Figure 5, while a summary of their construction features is provided as Table 2. The hydrographs for these wells (Figure 9) indicates that although some declines have occurred at discrete locations, particularly around the 2012 to 2015 timeframe and likely associated with the drought (and have generally been recovering since 2015-2016), longer term water levels in the aquifer from which these wells were installed have remained stable. Given the stable water levels at the TDPUD wells there is no evidence to support a "chronic" lowering of the water table, as it relates to SGMA.

Reference: Assessment of the Martis Valley Groundwater Basin

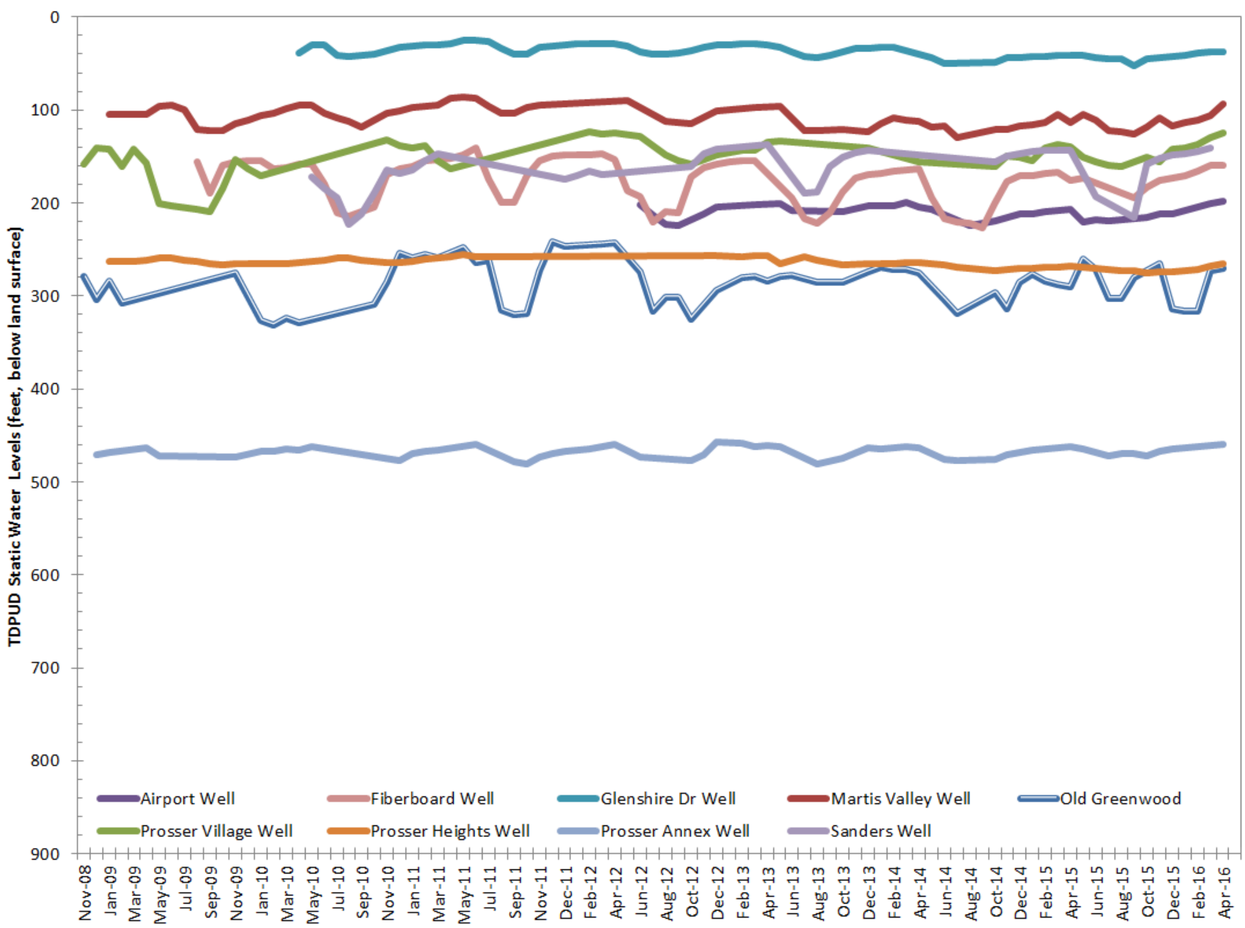

Figure 9: Water Levels for TDPUD Wells in Martis Valley Groundwater Basin

Reference: Assessment of the Martis Valley Groundwater Basin

Feature	Airport Well	A-Well	Fiberboard Well	Northside Well	Martis Valley Well	Old Greenwood
Well Depth (ft, bgs)	1027	?	?	927	940	1380?
Screen Intervals (ft, bgs)	100 – 1027	285 - ?	?	100 – 460; 465 – 925	287 – 732; 796 – 836; 865 – 930	460 – 620; 720 – 1000; 1130 – 1150; 1160 – 1200; ?
Gravel Pack Interval (ft, bgs)	60 – 1026	?	?	54 – 873	280 – 925	260 – 1360
Seal Depth (ft, bgs)	60	?	?	54	320?	260
Approximate Yield (gpm)	2000-2700	125 – 150	?	550	1800-2000	800
Status and Approximate Operation	Active (All Year)	Active (June – September)	Active (June – September)	Active (June – September)	Active (All Year)	Active (All Year)
Well Type	Public	Public	Irrigation Non-Potable	Public	Public	Public

Table 2: TDPUD Potable Well Construction Summary

Feature	Prosser Annex Well	Prosser Heights Well	Prosser Village Well	Sanders Well	Southside Well	Glenshire Well
Well Depth (ft, bgs)	900	405	1110	612	400	900
Screen Intervals (ft, bgs)	460 – 860	385 – 405	280 – 400; 460 – 720; 760 – 880; 920 – 980; 1000 – 1040; 1060 – 1110	125 – 600	90 – 200; 210 – 275; 310 – 400	270 – 290; 510 – 530; 570 – 650; 720 – 740; 800 - ?
Gravel Pack Interval (ft, bgs)	50 – 750	None	250 – 1102	53 – 612	50 – 400	140 – 900
Seal Depth (ft, bgs)	50	105	250	53	50	140
Approximate Yield (gpm)	?	?	800	500	200	1500
Status and Approximate Operation	Active (June - September)	Active (June - September)	Active (All Year)	Active (June - September)	Inactive	Active (All Year)
Well Type	Public	Public	Public	Public	Public	Public

Table 2: TDPUD Potable Well Construction Summary (continued)

Unreasonable Loss of Storage

The previous discussion above documents the pressure head in the confined aquifer from which potable supply is provided by the main water purveyors in the MVGB, including NCSD and TDPUD. Storage (S) in groundwater is defined as a sum of the specific yield (S_Y), e.g, the volume of water released from storage per unit surface area of aquifer per unit decline in the water table, and the specific storage (S_s), which is the volume of water that a unit volume of aquifer releases due to a decline in head. These two terms are however significantly different in that the specific yield is the dominant factor for unconfined aquifers, is driven by gravity drainage from the aquifer, and is much higher in volume than the specific storage for the same decline in head. In confined aquifers, the specific yield is not considered and storage is governed by aquifer thickness and the specific storage, which is controlled by fluid density, porosity, aquifer compressibility, and fluid compressibility). Typical unconfined storage values are 0.01 to 0.3, while confined aquifers typically range from 10^{-5} to 10^{-3}. Confined fractured bedrock aquifers have been known to have even lower storage values. The previous documentation provided above regarding the stable groundwater levels in the MVGB is sufficient alone to conclude that an “unreasonable loss of storage” has not occurred. Give that storage of a confined aquifer is much less than that of an unconfined aquifer only further exemplifies this finding.

CONCLUSION AND RECOMMENDATIONS

Review of relevant information provided to Stantec for review and regarding the hydrogeology and state of the MVGB indicates that under current operational conditions the use of groundwater within the basin has not caused an “undesirable result” under the definitions provided by the Sustainable Groundwater Management Act. Additionally, only about 32% of the estimated available groundwater supply, and only 1.2% of the total basin inflows, has been captured for use in the MVGB. Projections of recharge and available supply for the basin are sufficient to meet the additional potable demands at build-out of the valley. It is important to also underscore the fact that these projected demands at buildout are likely biased high as they were based on (1) 100% of the entitlements being leveraged and (2) water usage per EDU that is much higher than actual usage. For instance, the community of Northstar has an actual single family home water usage that is approximately half that used in the buildout projected water demands. The biggest unknown factors that could influence the conclusions regarding basin hydrogeology and groundwater availability is likely the effects of climate change and water levels from wells where recent or historical data are unavailable. Accordingly, continued monitoring of shallow and deep groundwater by the major water purveyors is recommended. The current shallow (~upper 20 feet or so) monitoring network is largely confined to the area around and just north of the community of Northstar. Additional groundwater monitoring wells may be necessary within this shallow zone to provide better coverage throughout the MVGB in order to further evaluate long term shallow groundwater trends and the potential influence of/on surface water. Should future downward trends be identified changes in groundwater management practices and or well location/design should be considered.

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