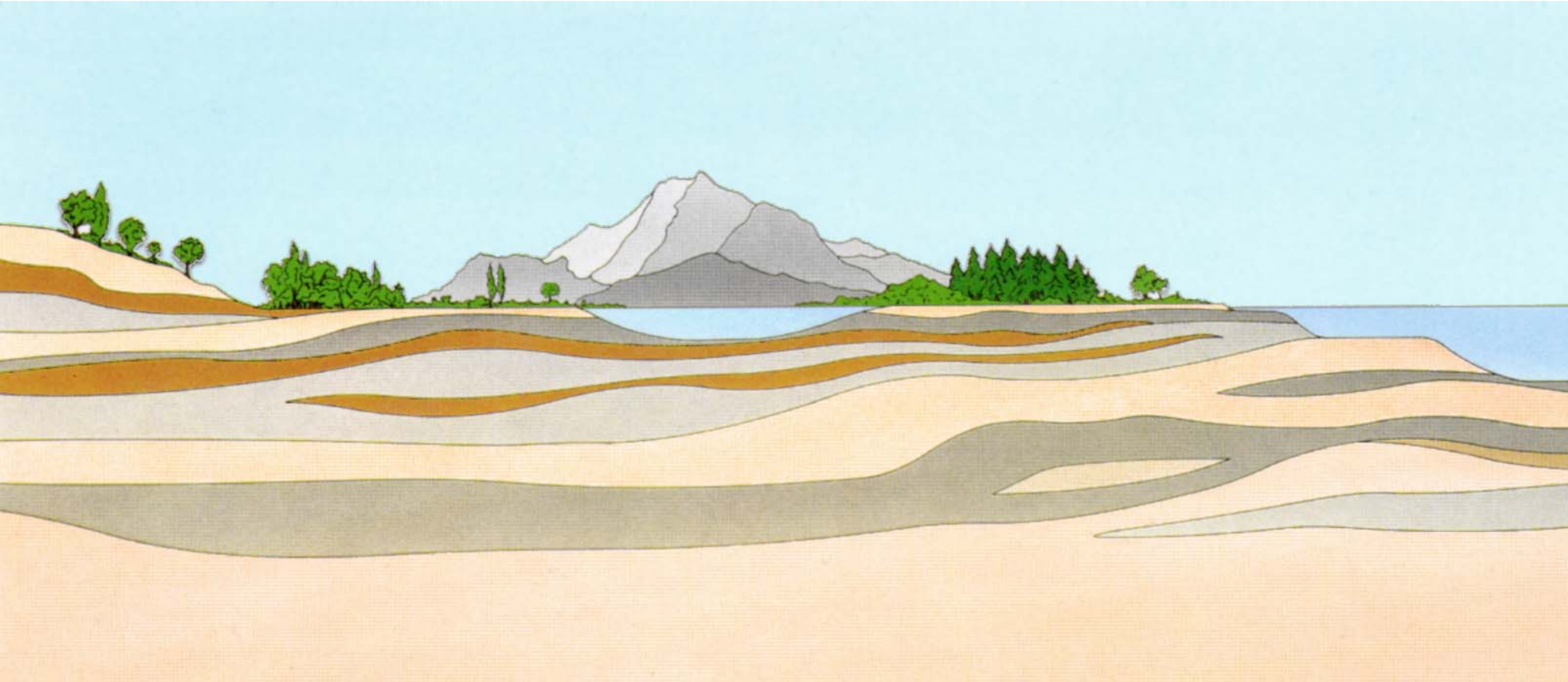
FUGRO WEST, INC.

DRAFT

TASK 1 INTERIM REPORT, DATA COLLECTION AND CONCEPTUAL HYDROGEOLOGIC MODEL, TEHACHAPI GROUNDWATER BASIN STUDY

Prepared for:
TEHACHAPI-CUMMINGS COUNTY WATER DISTRICT

February 2007



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Project No. 3267.003.01

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Attention: *Mr. Glenn H. Mueller*
General Manager

DRAFT
Task 1 Interim Report,
Data Collection and Conceptual Hydrogeologic Model,
Tehachapi Groundwater Basin Study

Dear Mr. Mueller:

Fugro West Inc. is pleased to submit this DRAFT Task 1 Interim Report of the Tehachapi Groundwater Basin study. The objective of the overall study is to assess the hydrogeologic conditions of the basin, estimate the perennial yield, and evaluate future trends in groundwater levels and quality in response to current and future operations in the basin.

The purpose of this initial task is to compile existing reports and maps, assemble data necessary to develop the conceptual and numerical model, and develop a conceptual understanding of the basin, including the occurrence and movement of groundwater, aquifer geometry, and hydraulic characteristics. It is important to understand that this Task 1 Interim Report is a compilation of our current understanding of the basin. It represents the results of our efforts to gather data to be used in the development of the numerical model and, as such, is subject to refinement as the study continues.

If you have any questions, please do not hesitate to contact us.

Sincerely,

FUGRO WEST, INC.

Paul Sorensen, PG, CHg
Principal Hydrogeologist

Shawn Roberts, Ph.D.
Project Hydrogeologist

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EXECUTIVE SUMMARY

This Interim Report presents the findings of Task 1 of the Tehachapi Groundwater Basin study. The task is the first of five tasks that will conclude with the development of a numerical basin model and a final hydrogeologic basin report. The study is intended to provide the Tehachapi-Cummings County Water District, the City of Tehachapi, Golden Hills Community Services District, and overlying agricultural users and landowners an understanding of the basin by calculating the quantity of groundwater storage in the basin, the hydraulic movement of groundwater through the basin, sources and volumes of recharge, and trends in water quality.

The purpose of Task 1 is to:

- Compile existing geological and hydrogeological reports, maps, and geologic cross-sections;
- Assemble available data necessary for development of the conceptual and numerical models, including groundwater elevations, aquifer tests, geologic logs, precipitation records, well locations, well pumping records, and water quality data;
- Obtain and develop base maps of the basin; and
- Review reports, maps, and data to develop the conceptual hydrogeologic model including the occurrence and movement of groundwater, hydrogeologic budget including estimates of basin recharge and discharge, aquifer geometry and hydraulic characteristics, hydrogeologic stresses, and spatial and temporal trends in groundwater quality.

Data were collected from the District and other cooperating landowners and stakeholders across the basin. Compiled data sets included precipitation records, driller's logs, groundwater level data, production records, imported water records, land use maps, water and wastewater treatment facility records, aerial photographs, and water quality analyses. The data were assembled to develop a conceptual understanding of the hydraulic conditions of the aquifer.

The Tehachapi Groundwater Basin is an alluvial basin comprised of approximately 25,600 acres, surrounded by bedrock watersheds comprising another 34,000 acres. The

preparation of hydrogeologic cross-sections generally indicated no consistent layering or zonation of aquifer materials across the basin. The basin consists essentially of a heterogeneous mixture of discontinuous layers, with regions of coarser and finer sediments, which is best represented as one unconfined to semi-confined aquifer.

For the purposes of this evaluation, it is necessary to establish a base period that defines a specific time, based on rainfall patterns, over which elements of recharge and discharge in a groundwater basin may be compared. From the perspective of a water balance calculation, it was decided that the best period to use for the Tehachapi Groundwater Basin was 1986 to 2004.

Groundwater hydrographs and groundwater level contour maps show relatively stable to rising trends in groundwater elevations over the base period throughout most of the basin. Over the same period, the southwestern corner of the basin has displayed stable to falling trends in groundwater elevations. This difference in groundwater elevation trends is probably a combination of pumping distribution, combined with the effect of restricted water movement caused by faulting of the sediments in the southwestern portion of the basin.

The hydrological data indicate that the basin, when considered as a whole, has not been in a state of long-term overdraft and has accumulated groundwater storage over the period from 1986 to 2004. Over the 19-year base period, water level contour maps show a slight shift of pumping centers and resulting pumping depressions across the basin, in response to changing trends in agricultural uses, municipal demands, and the use of imported water.

Contoured groundwater elevation maps were used to calculate the change in groundwater storage between Fall 1986 and Fall 2004. Assuming an overall basin specific yield of eight percent, these calculations showed a groundwater storage increase of approximately 28,000 acre feet (AF) for the Fall 1986 to Fall 2004 time period.

The inventory method (water budget equation) was also used to calculate the change in storage. This involved the compilation of the data and allowed for the calculation of a hydrologic budget, which is simply a statement of the balance of total water gains and losses from the basin. In very simple terms, the hydrologic budget represents Total Inflow equal to Total Outflow plus or minus Change in Storage.

Using the inventory method of calculating each component of recharge and discharge, the sum of all components of inflow exceeded outflow by approximately 38,000 AF over the 19-year base period, or an average of approximately 2,000 acre feet per year (AFY). Calculation of the change in storage by the two methods differed by approximately 10,000 AF, which is remarkably close considering the size of the basin, the complexity of the geology and hydrogeology, and the lack of data in some parts of the basin. There are numerous reasons for the slight differences in the two approaches, which could be resolved by adjusting slightly the values of some of the individual components that required rather significant assumptions. The review process and numerical modeling will be used to further refine the basin water balance.

INTRODUCTION

The Tehachapi Groundwater Basin is located at the junction of the Sierra Nevada and Tehachapi mountain ranges, in the area surrounding the City of Tehachapi, California (Plate 1). Land use in the area includes both agriculture and residential uses. Prior to 1970 the Tehachapi Groundwater Basin was subject to groundwater overdraft, resulting in basin adjudication (boundary displayed on Plate 1) and subsequent importation of supplemental water supplies. The time from about 1974 to 1980 was characterized by a relatively stable period of groundwater levels, and from 1980 to 2004 by stable to increasing trends in groundwater levels in most areas of the basin. This was due to the groundwater management policies implemented by the Tehachapi-Cummings County Water District (TCCWD) (basin watermaster), including the balancing of imported water with use of local groundwater supplies. However, several groundwater related issues and concerns have arisen in recent years that require basin-wide cooperation including continued growth in municipal and domestic water demands, and degradation of groundwater quality due to increased nitrate levels as well as potential Methyl tertiary Butyl Ether (MtBE) contamination.

The purpose of this report is to provide a hydrogeologic conceptual model to serve as the basis for constructing a numerical model of the basin. Data generated as part of the conceptual model (e.g., water balance) may be subject to modification during the numerical model calibration process.

PREVIOUS STUDIES

Some of more important previous studies pertaining to Tehachapi Groundwater Basin used in this investigation include:

- Michael-McCann Associates (1962);
- Hill and Arkley (1966);
- Tehachapi Soil Conservation District (1969);
- Tehachapi-Cummings County Water District Annual Reports (1974 to 2004);
- Geoconsultants (1994); and
- Knauss (2002).

These previous studies were reviewed and provided important data used in this investigation. Pertinent data and information from the reports listed above are incorporated in various sections of this report.

BACKGROUND

TOPOGRAPHY

The Tehachapi Groundwater Basin underlies a relatively flat valley, bounded on the north by the Sierra Nevada Mountains and on the south by the Tehachapi Mountains (Plate 1). The basin is bounded on the west by the foothills of a low-lying ridge connecting the two ranges, and on the east by a ridge of the Sierra Nevada and Tehachapi mountains, separated by Proctor Gap.

The valley floor elevation ranges from approximately 3,920 to 4,200 feet above mean sea level (AMSL) with a mean elevation of 4000 feet. It is surrounded by hills and mountains, with the highest mountains on the north side of the basin reaching an elevation of approximately 6,400 feet MSL, and on the south side approximately 7,800 feet MSL. The Tehachapi valley generally is oval in shape with an east-west orientation, and is about 10 miles long and five miles wide at its widest point (TCCWD, 2003).

CLIMATE

Precipitation occurs primarily as rainfall on the valley floor and a combination of rain and snow at higher elevations in the surrounding hills and mountains. The majority of precipitation (85%) occurs between November and April in association with frontal storms. A portion of the remaining precipitation occurs as convection-type thunderstorms of relatively high intensity--short duration during the late summer and early fall. In the upper watersheds, much of the precipitation occurs as snow, with average snowfall totals of 65 to 70 inches. During high precipitation years, snow packs of four to six feet accumulate and remain on north-facing slopes until late spring (Tehachapi Soil Conservation District [TSCD], 1969). On the valley floor, average precipitation is 11.45 inches per year over the historical record (1921 to 2005; Table 1); during the 19-year base period from 1986 to 2004 used in this investigation, precipitation averaged 12.03 inches per year (Table 1). The location of the Tehachapi rain gauge is shown on Plate 1.

Average monthly temperatures range between 40 degrees Fahrenheit in January to 73 degrees in July, with extremes of -8 degrees up to 105 degrees. Class A pan evaporation rates range from 80 to 90 inches per year. The typical growing season lasts 156 days, with the last freezing day in the spring being at the end of April, and the first freezing day in the fall occurring around mid-October (TSCD, 1969).

PREVIOUS WATER BALANCE STUDIES

The Tehachapi Soil Conservation District estimated that in 1967 the average annual natural replenishment for the Tehachapi Basin was 3,600 acre-feet per year (AFY). The calculated total demand for the basin was 11,004 AFY, with a change in net storage of 5,067 AFY. The calculated safe yield was estimated at 5,937 AFY (TSCD, 1969).

Sources of recharge to Tehachapi Basin include precipitation on mountainous areas surrounding the basin and associated surface inflow from several intermittent streams and creeks during wet years (Plate 2), percolation of precipitation into the alluvium that comprises the basin aquifer, irrigation return flows, and domestic return flow. Surface outflow from Tehachapi Basin in Tehachapi Creek occurs during storm events and the wet season. Outflow from Cache Creek, to the east of the basin, occurs occasionally during storm events (Michael-McCann Associates, 1962). Additional studies included test drilling to determine the eastern boundary of the basin and to examine the relationship between Tehachapi Valley and Sand Canyon to the east (Plate 1). Groundwater flow from Sand Canyon was interpreted to move south and east, and not into the Tehachapi Basin. Also initiated was the monitoring of six key wells in the Tehachapi Basin (32S/33E-27N2, 32S/33E-28E2 and 28M1 prior, 32S/33E-28L2 and 28K1 prior, 32S/33E-20P1, 32S/33E-21P1 and 32S/33E-24P1), thereby allowing the recordation of more accurate trends in groundwater elevation though the basin. This resulted in the refinement of the calculated safe yield to 5,500 AFY, which was established in the 1971 Tehachapi Basin Judgment (TCCWD annual reports).

LAND USE

Agriculture

Land use in Tehachapi Basin has historically been agricultural, which has slowly been shifting towards a more urban and domestic setting with the growth of the City of Tehachapi and Golden Hills residential areas. However, significant agricultural land use still occurs in parts of the basin. All irrigation water before the 1970's was pumped from the basin, but is now principally derived from imported state water. Presently, imported water is delivered for irrigation purposes from the TCCWD main line at specific turnout locations. The line runs east to west across the center of the basin.

Irrigated cropland in Tehachapi Valley in 1986 totaled 1,354 acres. The primary crops were tree fruit (974 acres) and turf sod (230 acres) (Table 2). By 2004, irrigated cropland had declined to 572 acres, with vegetables (324 acres) and tree fruit (178 acres) comprising 88% of the total land in irrigation. Other irrigated crops in Tehachapi Valley have included pumpkins, home gardens, lilacs, alfalfa hay, Korean radish, and nurseries. Land under irrigation in the valley from 1986 to 2004 has ranged from 1,354 to 484 acres. The location of agricultural land irrigated over the period of 1986 to 2004, for each crop type, was determined by air photograph interpretation, with the results displayed in Appendix A.

Residential

Residential areas of Tehachapi Valley include the City of Tehachapi, Golden Hills Community Services District (GHCSD), Monolith in the eastern part of the valley (near Proctor Lake), and other isolated residences throughout the valley. The water supply for domestic residences has historically come from groundwater pumped from the basin. These wells were either large diameter wells such as those supported by the City of Tehachapi and GHCSD or small diameter wells for individual household supply.

BASIN CHARACTERISTICS

Basin Geometry

The Tehachapi Groundwater Basin is located at the junction of the Sierra Nevada and Tehachapi mountains. The basin aquifer materials consist of alluvium and encompass and area of approximately 26,000 acres. The basin is surrounded by bedrock watersheds comprising another 34,000 acres (Plate 2). These area estimates differ slightly from those of TSCD (1969) due to the inclusion of all alluvial deposits in the above calculations, including those along the Tehachapi Creek. The alluvium consists of a mixture of clay, silt, sand, and gravel deposited by streams draining bedrock areas and flowing into the basin. The basin alluvium has a reported average thickness of 220 feet in Tehachapi Valley (TSCD, 1969). Bedrock consists primarily of igneous rocks such as diorite, quartz diorite, granodiorite, and quartz monzonite.

Water well drillers reports obtained from TCCWD were evaluated to develop maps showing depth to the base of alluvium and weathered bedrock (Table 3; Plates 3-5). The thickness of alluvium ranges from a few feet at the edges of the basin to approximately 600 feet in the center of the basin. In the southwest part of the basin, faulting offsets the alluvium with a throw of as much as 200 feet. Additionally, a fault that cuts the eastern part of the basin appears to have a maximum throw of approximately 300 feet.

The areal boundary of the alluvium was derived from Michael-McCann Associates (1962) and a review of United States Geological Survey (USGS) topographic and geological maps. The depth to bedrock maps were used in combination with surface elevation data to develop maps showing elevation of the base of the alluvium and weathered bedrock surfaces (Plates 4 and 6). The elevations of the bedrock surfaces provide a basis for determining layer boundaries for the model.

The thickness of the weathered bedrock was found to be quite zonal, as displayed on Plate 7. At the base of the alluvium, the thickness of weathered bedrock varies from 0 to 10 feet in the central and eastern areas, to 10 to 50 feet in the western part of the valley. In the southwestern part of the basin, south of the fault that cuts the basin, the thickness of weathered rock is as much as 100 feet.

Soils

Several different soil types are present in the valley, each with slightly differing composition, texture, drainage patterns and permeability. Each soil type is a product of a specific physiographic section or landform, including alluvial fans and flood plains, basin areas, low terraces, high terraces, uplands, and other miscellaneous land types.

Pertinent characteristics of the major soils in the valley are summarized in Table 4. The Visalia-Oakdale (alluvial fan and flood deposits) and Tehachapi-Chualar (low terrace deposits) associations cover the majority of the Tehachapi Basin alluvial surface, and the other soil types are present typically in the high terraces or uplands.

The Tehachapi-Chualar association is typically found in the western part of the basin, and as an isolated section near Monolith and Proctor Lake in the east. On the south side of Highway 58, these soils were developed on alluvium from granitic sources. North of Highway 58, and northeast of the City of Tehachapi, medium textured alluvium from metamorphic rock predominates.

In the central to eastern parts of the basin, the Visalia-Oakdale soils are present. The Visalia soil lacks an accumulation of clay in the soil horizons, whereas the Oakdale soil has a horizon slightly enriched with clay. This soil type has been used to grow potatoes, pears, apples, alfalfa, and sod (Hill and Arkley, 1966).

Other soils types are present irregularly, typically in the highland areas. These include the Brite-Terrace escarpment association in the northwestern part of the basin, the Auberry–La Posta association in the southwestern uplands, the Coarsegold-Monolith association in the northeastern uplands, mixed alluvial land-Tujunga in the east, and rock-rough broken and stony land in the northeastern highlands.

Infiltration tests conducted on various soil types indicate relatively high infiltration rates of up to 10 inches per hour (TSCD, 1969). These tests show that the alluvial deposits are capable of absorbing large runoff volumes, and suggest that a major component of recharge to the Tehachapi Basin occurs within alluvial fan and foothill areas along the perimeter of the basin (TSCD, 1969).

Geology

Previous reports describe Tehachapi Valley as a semi-graben with a relatively thick accumulation of alluvial sediments on the valley floor. The surficial deposits present in Tehachapi Valley include alluvial fan deposits and finer-grained stream deposits/floodplain silts. Coarser materials tend to occur near mountain slopes, with finer sediments in the center of the basin. The basin sediments consist of heterogeneous, discontinuous layers of varying permeability, with limited hydraulic continuity (Michael-McCann, 1962; TSCD, 1969).

A simplified geologic map of the area is shown on Plate 8, showing the basin alluvium and other alluvium in the area not hydrologically connected to Tehachapi Basin, older Tertiary sediments, and pre-Tertiary bedrock. Rock types include volcanic deposits, sedimentary deposits, and metamorphosed rock types. The area has experienced significant faulting, of which the major faults are portrayed on Plate 8. Several of these faults bisect the basin and offsets as much as 300 feet in the alluvium are noted. The faults typically strike northwest to southeast, with the exception of the active Garlock fault in the southwest part of the basin that strikes southwest to northeast.

Geologic cross sections portray the distribution of alluvial sediments across the basin (Plate 8; Plates 9-13). Lithologic descriptions from water well drillers reports were used to develop the geologic cross sections, and previous reports were used to help interpret fault locations and lithology at depth.

The distribution of alluvial sediments throughout the basin generally shows no consistent layering. Many well logs describe layered sediments, however there was no apparent trend of lithologic layers across the basin. The basin is best described as a heterogeneous mixture of discontinuous layers, and is best represented as a single unconfined to semi-confined aquifer. The presence of interbedded clay layers indicates a relatively low vertical permeability compared to horizontal permeability.

Cross section A-A' (Plate 9) runs east-west across the valley and displays an abundance of clay and gravelly clay in the western portion of the section (T32S/R32E sections 26 and 25), with more alternating clays and sandy clays in the central area (T32S/R33E sections 28, 29 and 30), becoming more sand and gravel rich in the eastern portion of the basin (T32S/R33E sections 27, 28, 29, and T32S/R34E 30), corresponding to stream deposits.

The alluvium within the central part of the basin is approximately 600 feet thick and appears to be bisected by two faults. The westernmost fault on this section has a throw of approximately 200 feet on this section. Overall, the lithologic correlation between any two adjacent well logs was poor, except for identifying the base of the alluvium/bedrock contact.

Cross section B-B' (Plate 10) trends southwest to northeast and runs across the middle of Tehachapi Valley. Well logs along this section show primarily clays to the south becoming interbedded clay and sandy clay in the central and northern areas. No distinctive lithologic correlations appear to be present on this cross section.

Cross section C-C' (Plate 11) runs sub-parallel to the strike of many of the faults that cross the basin. This cross-section shows alluvial fan deposits, with occasional stream deposits to the northwest, with older alluvial deposits to the southeast. Interbedded clays and sandy clays with occasional gravel layers dominate in the northwestern area, whereas the southeastern part of the section becomes more clay and gravelly clay-rich. Overall, the lithologic correlation between any two adjacent well logs is poor, except for the alluvial/bedrock boundary. Previous reports indicate significant offset of the bedrock by faulting in the southern part of the basin, with an offset of more than 300 feet.

Cross section D-D' (Plate 12) crosses the basin in the northwestern end of the valley. It shows an abundance of interbedded clay and sandy clays, becoming more sand rich to the north. Alluvial thickness consisting of stream deposits along this section is as much as 150 feet thick.

Cross section E-E' (Plate 13) is oriented across the basin in the southeastern end of the valley. Along the section interbedded clay and sandy clay predominate, although gravel is present in the central portion of the section (as noted in borehole T32S/34E-30N1). Alluvial thickness along this section is up to approximately 300 feet thick.

SURFACE WATER

Several streams feed the Tehachapi Basin, including Water Canyon, Brite, Chino Hill, Antelope, and Blackburn creeks from the south, and Whiterock Creek from the north. The respective sub-watershed units are displayed in Plate 2, the numbering corresponding to that reported for sub-watersheds in TSCD, 1969 for cross reference. This map also displays the alluvial boundary, which typically marks the point at which most streams tend to percolate into the subsurface, thereby creating recharge to the basin.

A drainage divide exists within the basin, running approximately north-south in the middle of the valley. Surface runoff east of the divide drains to Proctor Lake. Drainage west of the water divide includes Water Canyon and the through-flowing Brite Creek that joins Tehachapi Creek. Limited stream gauge data is available for Tehachapi Creek to record surface water flow out of the basin. Typically, surface water flows out of Tehachapi Valley only under storm conditions (TSCD, 1969), with the majority of flow (>60%) occurring in one year out of ten. Under extreme storm conditions, surface water can flow out of the basin via Cache Creek to the east (Plate 1).

GROUNDWATER

Background

The distribution of wells with water level data is shown on Plate 14, and groundwater level measurements are presented in Appendices B and C. A high concentration of wells exists to the southwest of the City of Tehachapi and also in the northwestern part of the basin, in the area of Golden Hills. Depth to water across the Tehachapi Basin has varied considerably over time depending upon the concentration of irrigation and municipal wells, volume of water pumped, thickness of permeable alluvium and surface elevation.

Prior to agricultural development, groundwater levels in the Tehachapi Basin were within a few feet of ground surface and some artesian (flowing) wells were observed at lower elevations. Moreover, groundwater reportedly discharged to stream channels prior to 1950 (Michael-McCann Associates, 1962; TSCD, 1969). Groundwater level declines began around 1933, following increased agricultural activity. Water levels apparently dropped an average of 70 feet in Tehachapi Valley between 1951 and 1961. The most affected wells were in the vicinity of the City of Tehachapi where groundwater levels declined by approximately 110 feet.

The decrease in water levels continued through to the mid-1970's, when the basin was subject to an adjudication action, thereby establishing water rights and a defined groundwater management program. This included the integration of the use of imported water for irrigation purposes, replacing and/or supplementing the use of groundwater, which has resulted in a widespread recovery of groundwater levels, as shown on water well hydrographs (Plate 15, Appendix B). The hydrographs shown on Plate 15 and Appendix B represent data from the "key" wells, from which TCCWD has collected groundwater measurements since the 1950's to the present.

Groundwater Hydrographs

Hydrographs over the period from 1986 through 2004 for several wells other than the key wells are presented on Plate 16. Hydrographs and water level measurements for all wells with available data are presented in Appendix C. The hydrographs typically show relatively stable to rising trends in groundwater levels in the central part of the basin over the base period (1986-2004). The data indicate that the basin as a whole has not been in a state of long-term overdraft, and has accumulated groundwater storage since 1986. Stable trends were typically observed in wells in the eastern and northwestern parts of the basin, and declining trends were observed in wells in the southwestern part of the basin (e.g. 32S/32E-35G1).

Groundwater Flow Patterns and Water Levels

Prior to the start of significant pumpage from the basin, groundwater movement was generally toward the center of the valley floor. By 1961, the movement of groundwater had shifted to the east of the City of Tehachapi. During this period, groundwater elevations reached a low of 3,800 feet AMSL in the area with the most intense pumpage.

For purposes of the basin analysis and development of a numerical groundwater flow model, this study focuses on a base period from 1986 to 2004, which commences more than a decade after the implementation of the current groundwater management practices. By the start of the base period (1986), the basin had already significantly recovered from the prior overdraft condition.

Several groundwater level contour maps were constructed (Plates 17-22). Inspection of the series of water level contour maps shows that, in recent years, groundwater flow is predominantly towards an area southwest of the City of Tehachapi (32S/33E Sections 29 and 30), where the lowest water levels in the valley occur (water level elevations of 3,820 to 3,860 feet AMSL).

South of the faults that bisect the basin, water levels are as much as 180 feet lower than is measured in wells north of the fault (Plates 17-22). This condition was also noted by Michael-McCann (1962), who reported a difference of 130 feet in water level elevations within a horizontal distance of 200 feet from measurements taken in 1961.

Change in Groundwater Storage

A water level elevation change map shows the difference in groundwater levels over the base period (Plate 23). This map shows that over the period 1986-2004, water levels generally recovered in the central portion of the basin, with water levels increasing up to 40 feet in elevation. The greatest increase was observed in the central portion of the basin. The northern, eastern and northwestern edges of the basin typically remained relatively stable over the base period. However, in the southwestern part of the basin, water levels declined over the same base period, particularly in 32S/32E-Section 25 and 32S/33E-Sections 30 and 32.

The portions of the basin that show declining water levels are located in a part of the basin just south of the fault zone, which restricts flow between the southwestern and central parts of the basin. A combination of this flow restriction combined with apparent increased pumping in the area appears responsible for this trend. A second region of decrease in groundwater decline exists just to the north of the same fault, in a region containing a large number of wells (Section 32S-33E-30, Plate 23).

The volume of the change in groundwater in storage over the 19-year base period was calculated by three different methods, and compared for reasonableness and accuracy. First, water level changes of the six key wells (Plate 23 and Appendix B) were reviewed. Given the portion of the basin area represented by the key wells of approximately 19,000 acres, an aquifer specific yield of eight percent, and an average water level change in the key wells of 24.3 feet from Fall 1985 to Fall 2004, the data suggests an overall increase in groundwater in storage in the basin of approximately 37,000 AF. It should be noted that the key wells are all typically located in the central portion of the basin, represent the portion of the basin that has experienced groundwater level increases, and do not take into account the outer fringes of the basin that have displayed declining water levels, such as those to the southwest behind the fault zone.

A second method of calculating change in storage utilized GIS to calculate the volumetric change between water levels in wells from Fall 1986 to Fall 2004. The GIS method of calculations was based on groundwater elevation contour maps constructed from all available water level data for the basin. Assuming an overall basin specific yield of eight percent, these calculations showed groundwater storage increases of approximately 28,000 AF for the Fall 1986 to Fall 2004 period.

The third method of calculating the change in groundwater in storage was via the inventory method (or water balance equation), where the sum of basin inflows and outflows was calculated for the base period (Table 6). Using this method of calculation, groundwater in storage increased by approximately 38,000 AF over the base period. A detailed description of the water balance equation and methodologies used to generate Table 6 is presented in the following chapter – Water Balance.

The three methods of calculating change in groundwater in storage result in estimates of 37,000 AF, 28,000 AF, and 38,000 AF. This remarkable agreement of calculated changes in groundwater storage suggests that the basic dynamics of the basin are understood and represented in the water balance equation (which will be described in detail in the following chapter). The slight discrepancy in the calculated volumes is normal and understandable, considering the necessary assumptions of groundwater inflows and outflows. A primary aim of the review and modeling phases will be to refine the components of the water balance.

Artificial Recharge Operations

The use of groundwater for as the primary water supply for users in the Tehachapi Basin is supplemented with imported State Water Project water. Although most of the imported surface water is used directly for irrigation, a portion is recharged by GHCSD and TCCWD through streamflow percolation and recharge ponds (Plate 1). The streambed release area for GHCSD is located at 32S/33E Sections 25 to 31 and the percolation ponds are at Antelope Dam, 32S/33E Section 33, as shown on Plate 1. The Golden Hills recharge project allows the services district to gain credits to be able to withdraw additional water from the basin via pumpage.

Aquifer Parameters

Aquifer transmissivity (T) values are tabulated in Table 5 and shown on Plate 24. Transmissivity values were derived from specific capacity data taken from Southern California Edison pump efficiency tests. The specific capacity data were converted to transmissivity values using a method described by Driscoll (1986). Specific capacities for wells in the basin averaged 12.1 gpm/ft and ranged from 0.1 to 60.5 gpm/foot.

The highest transmissivity values, greater than 25,000 gallons per day per foot of aquifer (gpd/ft), are found in the eastern central region of the basin in T32S/R33E-26, and parts of T32S/R33E-25/27/28/35 and 36 (Plate 24). The next highest range of values of 15,000-25,000 gpd/ft is in the central to western region of the basin. Lower transmissivity values of 5,000-15,000 gpd/ft are found in the northwestern part of the basin (Golden Hills area), with the lowest values of <5,000 gpd/ft along the fringes of the basin.

The higher transmissivity values (15,000 to 75,000 gpd/ft) represent hydraulic conductivity (K) values of 10 to 50 feet/day (ft/d), whereas the lower T values (2,500 to 15,000 gpd/ft) likely represent K values of 1.7 to 10 ft/d. These K values represent horizontal hydraulic conductivities, with vertical conductivity likely to be considerably lower (0.001 to 0.5 feet/day) due to the presence of interbedded clay layers.

No aquifer test data were available to evaluate aquifer storativity values. Specific yield values used in previous reports to calculate changes in groundwater storage ranged from seven to eight percent (TSCD, 1969).

WATER BALANCE

BASE PERIOD SELECTION

Precipitation data were obtained for the Department of Water Resources rainfall station in Tehachapi, located at a surface elevation of 3,975 feet MSL (Plate 1). The station includes data from 1921 to 2004 (Table 1), which has been tabulated by water year, such that the water year for 2004 comprises October 2003 through September 2004.

Average annual precipitation in Tehachapi Valley was 11.45 inches per year from 1921 to 2005. The data were used to plot the long-term cumulative departure from mean (Plate 25). These data were then used to help select the base period for calculation of the water balance equation. In general, the cumulative departure curve indicated that the best base period for calculating the water balance, in terms of the cycle of wet to dry periods, corresponded to 1986 to 2004 (Plate 26). This period is also the best time frame when considering both the nitrate and MTBE contaminant transport aspect of the numerical model. During the base period, the average annual precipitation in Tehachapi Valley was 12.03 inches/year, which was 0.58 inches/year more than the long-term average.

PRECIPITATION RECHARGE

Precipitation data were collected for the Tehachapi Station located at 32S/33E-Section 21 (Plate 1; Table 1). The data were used to estimate the amount of water that recharges the basin from deep percolation from rainfall that falls on the valley floor. It was assumed as an initial gross estimate that 10% of total precipitation over the entire base period went to deep percolation. This assumption resulted in an average percolation of 1.2 inches per year (10 percent of 12.03 inches), or 1,910 AFY (based on a basin area of 19,050 acres, the “active” portion of the basin). However, the amount of deep percolation from precipitation on a year-to-year basis is not necessarily 10 percent of precipitation in that particular year. Soil moisture budget approaches to calculating the amount of deep percolation each year tend to indicate higher percentages of deep percolation during wetter years and lower percentages of deep percolation in drier years. Table 6 and Appendix D provide yearly estimates of precipitation recharge based upon varying annual percentages of precipitation recharge. The yearly precipitation recharge distribution was based upon methodologies and results developed by Fugro (2003).

Each base period water year in Tehachapi Valley from 1986 to 2004 was ranked from driest to wettest based on total annual precipitation. The results of soil moisture balance studies by Fugro (2003) were reviewed to obtain a distribution of the proportion of total base period precipitation recharge that occurred in each year of that study. The annual proportion of precipitation recharge was assigned to each year of the Tehachapi Valley base period (with the driest year having the lowest proportion and the wettest year having the highest proportion) and multiplied by the total base period precipitation recharge in Tehachapi Valley (36,290 acre-feet) to derive the quantity of precipitation percolation for each year. Thus, the amount of precipitation recharge for the driest year in Tehachapi Valley (472 acre-feet; 6.37 inches of rainfall in 1990) amounted to 4.7% of total precipitation (0.30 inches). The wettest year (23.78 inches in 1998) resulted in an estimate of precipitation recharge (5,189 acre-feet) equal to 13.7% of total precipitation for that year (3.27 inches). An estimated volume of precipitation recharge for the remaining years in Tehachapi Valley was assigned based on the same methodology.

STREAM FLOW RECHARGE

The major streams contributing flow into Tehachapi Valley are Water Canyon, Brite, Chino Hill, Antelope, and Blackburn creeks on the south side of the valley, and Whiterock Creek on the north side of the valley. In addition, several minor drainages contribute stream flow from the surrounding hills and mountains, as shown on Plate 2. Review of available stream flow data, previous reports, and calculations for this study suggest that a significant volume of stream flow coming into Tehachapi Valley percolates through streambeds and does not exit the valley via stream flow. The remaining portion of stream flow is lost from the basin as surface water outflow in Tehachapi Creek, by evaporation from Proctor Lake, and surface water outflow to Cache Creek.

Stream flow records were available only for Tehachapi Creek, at a gauging station just outside the Tehachapi Basin, at map reference 32S/33E-Section 6 (Plate 1). The station was managed by the USGS until 1986, after which Kern County Water District (KCWD) started collecting intermittent readings. From discussion with staff at KCWD it is evident that the gauging station may be more reliable for high flow rates, due to the need for a better calibration between stage and flow at lower flow rates.

TSCD (1969) indicated that the major watersheds on the south side of Tehachapi Valley have an average annual runoff equal to 2.1 inches of precipitation. A review of individual watershed mean annual runoff amounts (as provided in TSCD 1969) indicates that individual watersheds had mean annual runoff of 0.6 to 3.8 inches/year. The individual watersheds flowing into Tehachapi Valley that were not included in the TSCD (1969) analysis were reviewed with respect to general location, orientation, and topographic elevations in comparison to watersheds evaluated by TSCD (1969). It was conservatively (i.e., perhaps underestimated) assumed that the watersheds not specifically evaluated by TSCD (1969) had a mean annual runoff of 0.6 inches/year.

Total runoff into Tehachapi Valley was calculated as the sum of individual watershed mean annual runoff amounts (derived either from TSCD (1969) or by multiplying 0.6 inches of mean annual runoff by the individual watershed area). The total average annual runoff into Tehachapi Valley equals approximately 3,562 AFY. This average is biased towards extremely wet years (about two years in ten), which display considerably higher stream flow than the other years. The total average annual runoff of 3,562 AFY is divided into those watersheds that ultimately drain to the Tehachapi Creek basin outlet (2,042 AFY) and those watersheds that drain to Proctor Lake and the Cache Creek basin outlet (1,520 AFY), as calculated in Appendix D.

The Tehachapi Creek stream gauging station is located downstream of the Tehachapi Creek basin outlet. Thus, stream flow recorded at the Tehachapi Creek station is a combination of stream flow exiting the basin and runoff from the mountains between the basin outlet and the gauge station. The amount of mean annual runoff from the watershed area between the basin outlet and the gauge station was estimated at 150 AFY, based on 0.6 inches of annual runoff.

Thus, the amount of average annual stream flow exiting Tehachapi Valley via the Tehachapi Creek outlet was calculated to be 1,609 AFY (1,759 AFY – 150 AFY).

No data were available for use in directly calculating runoff losses from the basin due to evaporation in Proctor Lake or outflow to Cache Creek. It was assumed that Proctor Lake (about 320 acres) has an average annual evaporation of 6 inches from runoff that terminates in the lakebed (160 AFY). Anecdotal information and the surface topographic contours indicate that surface water outflow (essentially overflow from Proctor Lake) to Cache Creek only occurs in the wettest years. The assumption used to account for Tehachapi Basin surface water outflows to Cache Creek was to establish a maximum amount of stream flow percolation of 3,000 acre-feet for the entire basin in any given year.

Year-to-year stream flow percolation varies considerably from the average annual value depending on the amount of rainfall. The yearly distribution of stream flow in Tehachapi Valley was based on stream flow records for Tehachapi Creek, as shown in Table 7. Review of stream gauging data for this station indicates that the majority of stream flow in a given watershed is likely to occur in only one or two out of every ten years. Stream flow data exists for 1963 to 2005, but it does not completely cover the base period due to data gaps in the period of 1986-1989 and for 1992. However, missing stream flow data for a given year within the base period were estimated based upon the amount of precipitation that occurred in that year and stream flow that occurred in one or two other years with similar amounts of precipitation.

In order to calculate yearly stream flow percolation, the first step was to calculate the potential total stream flow available for percolation over the entire study period. This amount was calculated as the average annual runoff into the entire basin (3,562 AFY) minus the basin outflow via Tehachapi Creek (1,609 AFY) and evaporation from Proctor Lake (160 AFY). The resulting amount of potential stream flow available for percolation was 1,793 AFY on an average annual basis or 34,067 AF over the entire study period.

The annual proportion of this total potential stream flow percolation occurring in each year in Tehachapi Valley was assumed to be equal to the annual proportion of stream flow recorded at the Tehachapi Creek stream gauge station over the base period (Appendix D). For example, the least amount of potential annual stream flow percolation (32 AF) occurred in 1994, a relatively dry year with very little stream flow. The greatest amount of potential annual stream flow percolation (11,786 AF) occurred in 1995, the wettest year in the base period. The calculated potential stream flow percolation for each year of the base period is provided in Appendix D.

The calculated potential stream flow percolation for each year does not account for the runoff losses via the Cache Creek basin outlet. Runoff losses to Cache Creek were accounted for by using a maximum annual stream flow infiltration capacity of 3,000 acre-feet. This stream flow recharge cap only limits stream flow percolation in the wettest years (1993, 1995, 1998, and 2001), when it is reasonable to assume that overflow from Proctor Lake may have occurred. The total amount of runoff lost via the Cache Creek basin outlet over the entire study period amounts to 16,641 acre-feet, which translates to annual average of 876 AFY.

The stream flow recharge analysis described above results in an annual average stream flow percolation amount of 917 AFY. The yearly distributions of stream flow recharge ranges from 32 AF to 3,000 AF, as shown in Table 6.

AGRICULTURAL IRRIGATION RETURN FLOWS

Location of Irrigated Land

Aerial photos were reviewed for each year of the base period and irrigated acreages were tabulated by crop and township/range/section (Appendix A). The distribution of irrigated acreage for areas that were not fully covered by aerial photographs was assumed to be similar to previous and future years. Tabulation by section (one mile by one mile) was deemed an appropriate level of detail in terms of model input. A summary of yearly acreage use is given in Table 2.

An additional means by which to locate irrigated land was through a review of records of imported water use, which detail the amount of water and turnout location along the TCCWD main distribution line where the imported water was delivered each year. Typically, the imported water was applied directly to acreages adjacent to the turn out. Additionally, irrigation water was also derived from groundwater pumpage. In these cases, the location of the pumping wells was determined via map research and consultation with TCCWD staff. The distribution of agricultural and municipal/industrial wells are shown on Plate 27. The application of the irrigation water was then attributed to adjacent farmland.

Calculated Return Flow

Applied irrigation water for agricultural land has typically been derived from two sources, including groundwater pumpage and imported water supply. The TCCWD has kept annual, and in most cases monthly, records of the volume of water used for irrigation by both pumpage and imported water use, as summarized in Tables 8 and 9, respectively, with details provided in Appendices E, F and G. Water applied via imported water use over the base period totaled 23,799 AF, or an annual average of 1,252 AFY during the 19-year base period. Groundwater pumpage used for agricultural irrigation during the same period totaled 7,174 AF, or 378 AFY.

TCCWD has historically assumed an average irrigation return flow of 15% based on work previously conducted by Mann (pers. comm., John Otto). Therefore, 15% was used in this study to calculate return flows from agricultural irrigation. The 15% return flow factor was applied to all irrigation water (imported and groundwater). Over the base period, agricultural irrigation return flow amounts to a total of 4,646 AF, with an annual average of 245 AFY (columns 7 and 8, Table 6).

WASTEWATER RETURN FLOWS

Municipal Wastewater Treatment Plant Return Flow

The City of Tehachapi operates wastewater treatment facilities in T32S/R32E-20 (Plate 1). According to City staff, the facility treats an average of approximately 810,000 gallons of effluent per day, as of 2004. Treated discharge is stored in retention ponds during the wet season (October 1st through April 30th), and used as supplemental irrigation water in the dry summer months. Losses from the retention ponds lead to recharge to the basin of approximately 43 to 48 AF per month, or about 567 AF of treated effluent percolation in 2004 (Boyle Engineering, 2005). Additionally, 354 AFY of treated effluent were applied to cropland (alfalfa and pasture at 43 and 19 acres, respectively), of which there is assumed 70% irrigation efficiency. Assuming a 15% return flow of the applied wastewater irrigation water equates to an additional 53 AFY recharge (in 2004). The known volume of treated wastewater from 2004 data was adjusted for previous years of the base period to generate estimated percolation of wastewater discharge shown in columns 2 and 3 of Table 6.

Domestic Private Return Flow

Most domestic water users overlying the basin are on private individual septic systems, with the exception of the City of Tehachapi and a few residences (about 40 homes) served by Golden Hills community wastewater treatment facilities. Return flows from domestic water users with septic systems are assumed to average 50% of total water use (50% of total water demand is used as outdoor irrigation, with an estimated 20% of outdoor irrigation as return flow; 50% of water demand is used indoor, with 80% of indoor use as return flow through the septic system).

The number of private domestic residences overlying the basin was estimated using aerial photographs and personal communication with GHCSD staff. Residences were divided into small residences (R), occupying less than one acre of land, and large residences (LR) occupying equal to or greater than one acre of land. The volume of return flow from private domestic residences was then calculated on a section-by-section basis to allow later input to the numerical model, with data provided in Appendix D. Return flow volumes were based on a 50% return flow from annual water demand (Fugro and ETIC, 2003). Within GHCSD, a 50% return flow was applied to District domestic demand (rather than counting properties), as shown in Appendix D. In total (rural domestic, plus GHCSD) domestic return flow for residences outside of the City of Tehachapi totaled approximately 11,300 AF for 1986 through 2004, averaging 596 AF per year (Table 6 and Appendix D).

ARTIFICIAL RECHARGE

Since 1993, the GHCSD has used imported water, taken from turnout T5AN, to conduct artificial recharge operations. The water is recharged over a half-mile stretch of Water Canyon Creek bed, extending from 32S/33E-Sections-25 to 30 (Plate 1). Annual recharge volumes range from 0 to 364 AFY (Table 10). The total water recharged over the base period was 2,625 AF, averaging 138 AFY.

The TCCWD has also engaged in trial recharge operations periodically recharging imported water since 1995 at the Antelope Dam site. A total of 493 AF of water has been recharged during six recharge seasons (Table 10).

BEDROCK GROUNDWATER INFLOW

Bedrock groundwater inflow to the basin was estimated based on Darcy's Law, which requires a bedrock hydraulic conductivity, hydraulic gradient, and cross sectional area of flow. The cross sectional area of flow was estimated using the periphery of the north and south sides of the valley (approximately 20 miles) times a flow depth of 100 feet. The average hydraulic gradient was based on surface topography and estimated at 0.1 feet/foot. The average hydraulic conductivity for bedrock was estimated at 0.1 feet/day. This calculation results in an average annual contribution of 885 AFY (column 1 of Table 6). Bedrock groundwater inflow is assumed not to vary significantly with rainfall from year to year. Given a bedrock watershed area of 34,000 acres, 885 AFY of bedrock groundwater inflow equates to 0.3 inches/year of precipitation recharge over bedrock areas.

GROUNDWATER PUMPING

The distribution of agricultural and municipal groundwater pumping was determined by water year (October to September) and well, and is summarized in Table 8, with detailed data presented in Appendices E and F. The locations of both agricultural and municipal pumping wells are displayed on Plate 27.

The average annual agricultural groundwater pumping over the base period was 378 AFY, with a range from 153 to 797 AFY (column 12 of Table 6). The greatest volume of agricultural groundwater pumping (797 AF) occurred in 1995, and the second highest total was 771 AF in 2004. The average annual municipal and industrial groundwater pumping from Tehachapi Basin over the base period amounted to 2,806 AFY, ranging from 1,819 AFY to 3,702 AFY (column 11 of Table 6). The highest total groundwater use (3,702 AF) was recorded in 2004.

The majority of water for residential use is typically pumped from only a few areas in the basin. As much as 46% of total municipal pumpage for the City of Tehachapi was pumped from 32S/33E Sections 21 and 29, with 1,694 AF extracted in 2004. The main areas of pumpage for GHCSD is 32S/32E Section 13, and 32S/33E Sections 19, 25 and 30, with 1,382 AF being pumped for 2004, or 37% of total municipal pumpage for the basin.

Over the past 19 years, residential demand has steadily increased (Table 8). Domestic water demand has risen from approximately 1,900 AFY in the mid 1980's, to 3,700 AFY by 2004. This trend looks set to continue with a steady growth of population in the area.

Private residences not served by the City or by GHCSD were assumed to use private wells, or private community wells, for their water supply. The number and locations of these residences were counted through the use of aerial photographs, on a section-by-section basis (Appendix D). The residences were divided into small residences (R), occupying less than one acre of land, and large residences (LR) occupying equal to or greater than one acre of land. Duty factors of 0.5 AFY for small residences and 0.75 AFY for large residences were applied. Groundwater pumpage for residences outside of the City of Tehachapi and Golden Hills was therefore estimated to be 452 AF per year (Appendix D). This volume compared remarkably close to TCCWD estimates of rural unmetered pumpage.

STREAM FLOW DISCHARGE

Surface water outflow from the basin occurs via Tehachapi Creek to the north of the basin in virtually all years, and to Cache Creek to the east of the basin only in very wet years. Stream flow records were only available for Tehachapi Creek, at a gauging station just outside the Tehachapi Basin (Plate 1). Year-to-year stream flow varies considerably from the average annual value depending on the amount and intensity of rainfall.

Stream flow in Tehachapi Creek (and therefore out of the basin) is given in Table 7. Data were available for 1963 to 2005, with data gaps for the period of 1986 to 1989 and for 1992. Based on a review of available stream flow data, 68% of the total stream flow for a 38-year period was recorded in only four wet years, with the remaining 32% recorded in the other 34-years.

Over the years for which data is available (1963 to 2005), the average flow for Tehachapi Creek was 1,406 AFY. For the base period (1986 to 2004), not including the data gaps, the average flow was 2,314 AFY. Stream flow during the base period included a low flow of 31 AF in 1994 and a high flow of 11,562 AF in 1995. As described previously in the section on stream flow recharge, annual stream flow for the missing years was correlated to years with data, and resulted in an estimated average annual stream flow in Tehachapi Creek of 1,759 AFY over the base period. Stream flow from the basin via Cache Creek was indirectly estimated to be 876 AFY as described in the previous section on stream flow recharge.

SUBSURFACE GROUNDWATER OUTFLOW

Estimates of subsurface groundwater outflow were based on Darcy's Law, which requires a hydraulic conductivity, hydraulic gradient, and cross sectional area of flow. Potential areas of subsurface groundwater outflow from Tehachapi Basin include Tehachapi Creek alluvium and an area to the east of Proctor Lake adjacent to Cache Creek. The cross sectional area of flow for Tehachapi Creek alluvium was estimated as 500 feet in width at the basin outlet times a flow depth of 50 feet. The average hydraulic gradient was estimated to be 0.005. The average hydraulic conductivity for Tehachapi Creek alluvium was estimated at 5 feet/day. This calculation results in an average annual subsurface groundwater outflow of 5 AFY for Tehachapi Creek alluvium.

A similar subsurface outflow calculation was made for the basin outlet east of Proctor Lake. The parameters used in the calculation included a width of 2,500 feet, saturated thickness of alluvium of 200 feet, hydraulic conductivity of 2 feet/day based on transmissivity of 2,900 gpd/ft at well 32S/34E-29P1, and a hydraulic gradient of 0.004 (20 feet/5,000 feet). The calculated subsurface groundwater outflow east of Proctor Lake was 35 AFY. The total estimated groundwater outflow from the basin of 40 AFY was assumed to be constant from year to year (column 13 of Table 6).

SUMMARY OF RECHARGE AND DISCHARGE COMPONENTS

Groundwater recharge in Tehachapi Basin is derived from several different sources, including precipitation, stream flow, return flows, bedrock inflow, and artificial recharge. The majority of groundwater discharge from Tehachapi Basin is via pumping with a minor component of subsurface groundwater outflow. The yearly and average annual contribution of each component is displayed in Table 6.

The data summary shown on Table 6 suggests that, over the 19-year base period from 1986 to 2004, basin recharge (inflow) is greater than average annual groundwater demand (outflow) by approximately 2,000 AFY, or approximately 38,000 AF over the 19-year base period. The inventory method storage change value of 38,000 AF compares extremely well with the specific yield method increase in groundwater storage of approximately 28,000 AF. The slight difference in groundwater storage change as determined by the water balance inventory method versus the specific yield method is due to a number of uncertainties and assumptions, each of which will be refined and accounted for in the review phase, and during development and calibration of the numerical model.

WATER QUALITY

INORGANICS

Inorganic chemistry analyses were available from two specific wells and for blended Golden Hills and City of Tehachapi water within the Tehachapi Basin, combining several sources each. The majority of the inorganic chemical analyses included major cation and anion concentration totals. The groundwater chemistry data from the wells are presented in Table 11, and are also displayed in Plate 28. The piper diagram plot shows a calcium-bicarbonate type water for all samples, with slight variations in sodium, potassium, and sulfate content. Iron content was typically one (1) mg/L or less, chloride ranged from 10 to 45 mg/L, and total dissolved solids ranged from 276 to 385 mg/L. The parameters of pH (7.80 to 8.20) and electrical conductivity (470 to 620 µohm/cm) displayed slight variations both spatially and temporally. Most parameters were consistently within regulated guidelines for drinking water quality, with the occasional exception of iron that has the secondary standard of 0.3 mg/L, which can be treated before distribution.

NITRATE

The presence, distribution, and increasing concentrations of nitrates in the Tehachapi Basin are a growing issue. The potential sources of nitrate within the basin include historic nitrate based agricultural fertilizer application and wastewater disposal.

Nitrate data were available from 13 individual wells, and two blended sources (City of Tehachapi and Golden Hills supply water) within the Tehachapi Basin. Nitrate (as NO_3) concentrations ranged from 0 to 51 mg/L (the maximum contaminant level (MCL) is 45 mg/L), but most readings were less than 25 mg/L (Appendix H). The spatial distribution of nitrate in the basin is presented on Plate 29. Nitrate concentrations in samples collected from three separate wells had nitrate concentrations at or above the MCL of 45 mg/L. These wells, T32S/R33E-21K1 (Snyder Well), T32S/R33E-21R2 (Dennison Well) and T32S/R33E-30K1 (Iriart Well), had maximum nitrate concentrations of 51.1, 45.0 and 46.9 mg/L, respectively. The Snyder Well has consistently exceeded the MCL since 2001, and the Dennison well has displayed increasing concentrations since the 1990's. Both of these wells are located in the vicinity of the City of Tehachapi. The Iriart Well, located southwest of the City, recorded its highest concentration in 2000 and has since displayed a trend of declining nitrate concentration to 21.5 mg/L in 2005.

MTBE

MtBE has previously been found associated with the underground storage tank(s) located at the Old Town Trading Post, located at 20917 South Street in the City of Tehachapi. The concentrations of MtBE recorded were between 200 and 500 micrograms per liter (µg/l) (CVQCB, 2006). This remediation project is now closed. There were no other projects noted for the Tehachapi Basin area. However, MtBE was detected in samples collected from a blended source for Golden Hills Community Services District between 1999 and 2005, with concentrations ranging from 0 to 0.917 µg/l (MCL of 13 µg/l), as shown in Appendix H.

NUMERICAL MODEL APPROACH

The primary objective for the numerical model is to develop a tool to enhance the District's ability to manage and protect the groundwater resource in Tehachapi Valley. The numerical model provides a mechanism to evaluate existing and future trends in groundwater levels. In addition, the model can be used to evaluate impacts of management practices on the groundwater resource. The model will be developed using MODFLOW-2000 (Harbaugh et. al., 2000) and MT3DMS (Zheng and Wang 1999). These codes were developed by the USGS and are industry standards for this type of work. The software package Groundwater Vistas (ESI 2006) will be used as a pre- and post-processor to more efficiently set up and calibrate the MODFLOW/MT3D numerical model.

To develop the numerical model, the model area is subdivided into a grid. An early technical decision will be to define the appropriate model grid spacing. Adding more grid cells increases the model resolution, but it also increases the time required to manage and run the model. Transport modeling for compounds such as nitrate typically requires smaller grid spacing than groundwater flow alone, because contaminant concentrations vary significantly across smaller distances. It is anticipated that a variable spacing grid will be used to balance the need for higher model resolution in the nitrate-impacted areas versus developing an efficient groundwater flow model to evaluate groundwater resources in the rest of the basin.

The model will rely upon the aquifer parameters and water budget presented in this Task 1 Interim Report as the initial model input. The water balance data will be input as boundary conditions in the model for the period 1986 to 2004. The groundwater flow model will be calibrated by varying the model input parameters to match the observed groundwater elevations in the basin. Model calibration will consist of a statistical comparison of model simulated and observed groundwater elevations, a visual comparison to groundwater elevation maps, and an evaluation of hydrographs for a select set of key wells in the area. It is anticipated that model calibration will require multiple simulations that vary the aquifer parameters within a reasonable range to improve the comparison of the simulated to observed conditions.

The calibration may require multiple adjustments to the model input data. During the model calibration process, the model input parameters may require significant adjustment to match the observed groundwater elevations. Such a result may indicate a data gap that may require future investigation to resolve. In this manner, the model results may provide new insights into the defining the appropriate water balance and safe yield for the groundwater basin.

Once the model is considered reasonably calibrated, it will be used to conduct simulations. Some of the possible scenarios that could be simulated with the numerical model include:

- Simulation of water level impacts associated with localized intensive pumping in the valley;
- Optimization of well field operations;
- Simulation of water level impacts associated with potential increased pumpage in different parts of the basin;
- Simulation of potential impacts associated with a future increase in groundwater pumpage across the entire basin, including effects of droughts; and
- Simulation of potential migration of nitrate in groundwater toward water supply wells.

SUMMARY AND CONCLUSIONS

The alluvial aquifer that comprises the Tehachapi Basin covers approximately 25,700 acres. The surrounding bedrock watershed draining into Tehachapi Valley consists of 34,000 acres. An extensive review of previous reports, water well drillers reports, and construction of geologic cross sections suggests there is no distinct, continuous aquifer layers present in the alluvium. Therefore, for purposes of the numerical model, the basin will be treated as a single aquifer with relatively low vertical hydraulic conductivity due to an abundance of discontinuous clay layers. Aquifer transmissivity values typically ranged from 1,000 to 25,000 gpd/ft, although values as high as 75,000 gpd/ft were noted in individual wells.

The appropriate hydrologic base period was determined to be 1986 to 2004. Recharge or inflow to Tehachapi Basin is derived from percolation of precipitation, stream flow, irrigation return flows, domestic return flows, artificial recharge, and bedrock inflow. Discharge or outflow from Tehachapi Basin is derived from groundwater pumping and subsurface outflow. A net increase in groundwater in storage of approximately 28,000 AF was calculated over the base period, based on changes in water level data for wells in the area and using an overall average specific yield of eight percent. This value compares extremely well with an increase in groundwater storage derived from the water balance inventory method of 38,000 AF, over the base period. The slight discrepancy between groundwater storage changes calculated from the two different methods amounts to slightly more than 500 AFY. The review process and numerical modeling will be used to further refine the basin water balance.

Evaluation of major cations and anions indicate relatively uniform calcium-bicarbonate type groundwater quality for most wells. Nitrate concentrations range from 0 to 51 mg/L, although concentrations for most wells are less than 25 mg/L. MtBE related to the Old Town Trading Post operations and concentrations found in Golden Hills blended water supply (up to 0.9 µg/l) are a minor concern in terms of water quality. The numerical model will be used to evaluate the potential groundwater quality impacts to the basin related to increasing nitrate concentrations.

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