Prepared for:
TOWN OF SILVER CITY
P.O. Box 1188
Silver City, NM 88062

SUPPLEMENT ON WATER USE AND WELLFIELD SERVICE – TOWN OF SILVER CITY WATER PLAN

FEBRUARY 2006

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SUMMARY

The Town of Silver City supplies its municipal water system from groundwater supplied by the Frank's and Woodward wellfields, and the Anderson and Gabby Hayes wells. The aquifer that supplies the wells is the Gila Group aquifer. The Town of Silver City is interested in sources for future water use and wellfield service life. An evaluation of wellfield service life based on the widely-applied MODFLOW program is used to estimate future wellfield conditions. The model was developed by the New Mexico Office of the State Engineer and includes hydrogeologic details of the Gila Group aquifer in the Mangas and Mimbres subbasins. The model accounts for water use to supply the Town of Silver City water system, the Towns of Bayard and Central and mining uses at Chino, Tyrone and Cron Ranch. The Town of Silver City water system includes the local water associations of Pinos Altos, Tyrone, Rosedale and the Arenas Valley. We compiled information on domestic wells and added it to the model so that regional domestic well water use could be accounted for.

We upgraded the model with a well hydraulics package developed for MODFLOW that accounts for wellfield production based on the lowest practical pumping water levels in individual wells. For planning purposes, we specify a general well water column requirement of 120 feet to allow for pump submergence under operating conditions. The well hydraulic package accounts for individual well efficiency that relates feet of head loss in the well to the rate at which it is pumped. The constant we specify for each well is based on the specific capacity that was observed

during a field-testing program in the summer of 2002. Wellfield service life is expressed in terms of a schedule of producible water from existing and alternative wells sites during a 40-year planned period of use.

Town groundwater diversions have grown from about 500 acre feet per year in the 1950's to an average of about 2,800 acre feet per year in the last five years. The Town of Silver City is currently permitted with the New Mexico Office of the State Engineer to divert up to 4,566.64 acre feet per year from the wells that supply its municipal water system. We evaluated data on trends of expansion to the Town of Silver City water system and developed, for planning purposes, two growth schedules of water use (low and high) based on observed annual growth rates (1.2 and 2.9 percent) in the number of connections to the Town of Silver City water system. The scheduled growth is intended to account for the demand required to supply all connections to the Town of Silver City water system while recognizing trends that have been observed. Future water demand is uncertain. The high and low estimates of growth indicate that there is a range of time (within the next 16 to 38 years) over which future demand exceeds the Towns permit for use.

We evaluate the capacity of the Town of Silver City wellfield to meet the high annual rate (2.9 percent) of growth in water demand. The analysis indicates that as presently configured, the Town of Silver City wells can supply the growth in demand for about the next 30 years until yield of some wells begins to decline. As presently configured, the Town of Silver City wells can supply a medium growth rate of 1.45 without any loss in yield for the next 40 years. We also evaluate the hydrologic effects associated with three new well sites. With regard to wellfield interference, potential replacement wells for the Anderson and Gabby Hayes wells are preferable to a new Continental well located between the existing Frank's and Woodward wellfields.

The New Mexico Office of the State Engineer model simulates 15,900 acre feet per year of groundwater flowing through the Gila Group aquifer in the study area. In the long term, the Town of Silver City wells can divert a portion of the estimated 15,900 acre feet per year at the expense of depleting flow that otherwise would flow into Mangas Spring, the Gila River and would discharge to vegetation on the Mimbres River and to playas in the Mimbres Basin. That condition represents an inevitable future equilibrium for the Town of Silver City wells in which groundwater levels cease to decline. In the long term, the Town of Silver City wellfield as presently configured can sustain a yield of 4,200 acre feet per year. Well deepening would increase the sustainable yield. Long term use of others in the study area has an effect on the sustainable yield of the Town wells.

INTRODUCTION

Water for use by the Town of Silver City (Town) is supplied by Frank's wellfield (three wells in production), the Woodward wellfield (five wells in production), the Anderson well and the Gabby Hayes well. The wells are located about five miles southwest of the Town in Grant County, New Mexico. The groundwater resource that supports the Town wells is the Gila Group aquifer. A locality map of the wells operated by the Town and the area of interest (study area) are shown on Figure 1. The Town diverted an average of 2,800 acre feet per year (AFY) in the last five years from the wells supplying its municipal water system.

Records from the New Mexico Office of the State Engineer (OSE) indicate that the Town is permitted to divert up to a combined total of 4,566.64 AFY from the wells supplying the Town's municipal water system. The OSE administers groundwater diverted from the Town wells in two declared underground water basins: the Gila-San Francisco Basin and the Mimbres Basin (Figure 1). Frank's wellfield is permitted to divert 1,120.14 AFY from within the Gila-San Francisco Basin, while the Woodward wellfield (1,572.8 AFY), the Anderson well (440.7 AFY) and the Gabby Hayes well (1,433 AFY) are permitted for diversions from the Mimbres Basin.

Purpose and Scope

The Town is interested in sources for future water use and wellfield service life. On August 15, 2005, the Town authorized Balleau Groundwater, Inc. (BGW) to evaluate, for planning purposes, the service life of the wells that supply its municipal water system. The objectives of the analysis are (1) to compile records on current levels of Town water use and of OSE permitted use, (2) to develop a projection of future Town water demand for the next 40 years and (3) to use a groundwater model (the model) developed by the OSE to evaluate the Town's wellfield service life and to analyze alternative wellfield locations and source water options. The analysis is intended to combine information from databases available to BGW with data and analyses from previous studies on the Gila Group aquifer so that an interpretation of wellfield service life can be made. The report is designed to be an addendum to the Town's 40-Year Plan (the 40-Year Plan) (Engineers, Inc. and Geohydrology Associates, 1993) with regard to projected water use and wellfield service life.

Previous Work

Wellfield service life of the Town wells has been studied. Koopman and others (1969) evaluated Town well water columns and water use at that time and estimated that selected well water columns in Town wells would reach half of their initial water column within a range of time from years 1970 to 2000. They identified alternatives to extend wellfield service life by limiting production and expanding wellfields. Projected levels of water use were based on demand projections and analytical methods for calculating rates of water-level drawdown (Theis, 1935).

Trauger and others (1980) used methods similar to Koopman and others (1969) to revise earlier estimates and conclusions as a result of new findings associated with additional records of wellfield use and observations. They used a generalized computer model to make 40-year projections of drawdown in Town wells and to indicate that development of new wells and wellfields would extend the useful life of existing wells.

At the request of the New Mexico Interstate Stream Commission, the OSE (Johnson and others, 2002) evaluated the hydrologic effects of continued groundwater pumping to meet estimated future water demands for users of the Town of Silver City water system and the Towns of Central and Bayard. The evaluation of groundwater supplies is based on the OSE model of the Town of Silver City area. Future water demand for the Town is based on population projections and is estimated to be about 4,800 AFY by year 2045 (Wilson, 2001). Remaining water columns for individual wells operated by the Town are reported for model scenarios in which Town wells supply future demand for the Town, for Central and Bayard and for Grant County commercial and industrial uses. The report does not specifically address individual well lifetime, but reports remaining well water columns for planning purposes in a regional assessment.

For this analysis, we evaluate past trends of Town water system expansion to develop a future water use schedule intended to account for the demand required to supply all Town connections. We also upgrade the OSE model with a well hydraulics component to account for the declining yield associated with individual wells as future pumping water levels reach the lowest level allowed for operation. Finally, we analyze the sustainable yield of the Town wellfields.

SETTING

Geohydrology

Geology in the area of interest has been reported in previous studies (Paige, 1916; Koopman and others, 1969; Trauger, 1972; Hanson and others, 1994 and Hawley and others, 2000). A geology map of the area is shown on Figure 2 (adapted from Hawley and others, 2000). The area of interest is dominated by a northwest-trending structural feature described as the Mangas Trench (Trauger 1972, p. 22) and also known as the Mangas and San Vicente Subbasins (Hawley and others, 2000). The eastern boundary of the trench is marked by a fault trend along the Silver City Range. The western edge is bounded by the Precambrian uplift of the Burro Mountains. The principal aquifer that supplies the Town water system is the late Tertiary to early Quaternary Upper Gila Group (Woodward wellfield area) and the late Tertiary Middle Gila Group (Frank's wellfield area) (Hawley and others, 2000, Plate 1).

The continental divide runs through the study area and is the topographic divide between the Frank's and Woodward wellfields. Southeast of the continental divide is the Mimbres Basin. In the study area, the principal drainage in the Mimbres Basin is San Vicente Arroyo, which is ephemeral throughout most of its length (Hanson and others, 1994). Groundwater in this area generally flows southeast along the axis of San Vicente arroyo until it discharges to vegetated portions of the Mimbres River and to playas in the Mimbres Basin outside of the study area.

Northwest of the continental divide is the Gila Basin. The principal drainage of the study area is Mangas Creek, which becomes perennial at Mangas Spring about 12 miles from the continental divide. Mangas Spring is produced from the intersection of the water table with the land surface, where groundwater is generally flowing northwest within the Mangas Trench toward the Gila River.

Aquifer Resource Volume

The amount of water stored in the Gila Group aquifer within the Mangas Trench can be calculated. The trench surface area, the volume of drainable storage in the aquifer and the saturated thickness are known. The OSE model of the Mangas Trench provides a means to estimate the volume of that stored water. The wells operated by the Town are drilled from 550 feet to over 1,000 feet deep and currently penetrate 200 to 600 feet of the Gila Group aquifer. In the top 100 feet of the aquifer, the storage of groundwater in the OSE model area is 2.53 million acre feet (AF). The top 600 feet contains six times as much or about 15.2 million AF. These quantities of water give a perspective on the stored water resource, but do not include the water that is available for use in the sustainable long term. Diversions from wells in the study area ultimately capture groundwater that otherwise would flow through the aquifer and discharge to the Mimbres Basin to the southeast and the Gila Basin to the northwest. That captured amount is in addition to the stored water in the aquifer.

The OSE model simulates about 15,900 AFY flowing through the Gila Group aquifer; approximately 9,800 AFY provides underflow to the Mimbres Basin and the remaining 6,100 AFY discharges to Mangas Spring (1,300 AFY) and to the Gila River (4,800 AFY). In the long term, the Town wells can divert a portion of the estimated 15,900 AFY at the expense of reducing baseflow to Mangas Spring, the Gila River and the Mimbres River, and at the expense of salvaging evaporative losses from alluvial flats and playas in the north Deming area of the Mimbres Basin (Hawley and others, p. 39). That condition represents an inevitable future equilibrium for the Town wells in which groundwater levels cease to decline. The question at hand is the schedule and rate at which a portion of the estimated 15,900 AFY can be captured by the Town wells and managed with the large volume of aquifer storage to meet future demand. The model provides a means to evaluate that schedule and rate of depletion of each source.

EXISTING WELLFIELD FACILITY

In the summer of 2002, BGW conducted a field survey of the wells operated by the Town. Photographs of the Town wells and detailed maps of well locations are shown on Figures 3 and 4. Yield and drawdown in wells with existing pumps were measured to quantify individual well specific capacities. For some of the wells, we monitored water level recovery after well pumping was shut down so that aquifer transmissivity for individual well completions could be calculated. A summary of information regarding the Town wells and findings during the field survey of 2002 is shown on Table 1. Although Woodward Well 1 needs treatment for iron bacteria and is currently not in production, we simulated its use in future projections of wellfield service life. We assume that the well will be either treated or replaced in the future. Appendix A contains charts with plots of residual drawdown for the wells in which the water level was monitored after the pump was shut down.

Figures 5, 6 and 7 schematically show individual well water columns remaining in each of the Town wells relative to elevation and water levels at the time that each well was completed. Evident on the figures is the drawdown that has been observed between the time that each well was completed and the BGW field survey of 2002. Regional water-level drawdown in the aquifer reduces individual well water columns. Well deepening increases individual well water columns. Figures 5, 6, and 7 indicate a reserve of water column at the bottom of each well for pump setting. We use that estimated reserve as a basis to project existing wellfield service life as described below.

WELLFIELD EVALUATION METHOD

The OSE developed a groundwater flow model of the Mangas Trench to evaluate hydrologic effects associated with Town well diversions (Johnson, 2000, p. 8). The model is based on the widely-used U. S. Geological Survey (USGS) model MODFLOW (Harbaugh and McDonald, 1996). The model was calibrated by the OSE and a description of model parameters is detailed in Johnson (2000) and Johnson (2002).

The historical water-level trends simulated by the model at the wellfield sites indicate the model fits observed drawdown trends at the Town wellfields. There are two USGS groundwater site inventory (GWSI) observation wells with data available to locally monitor water levels for the Frank's and Woodward wellfields. Figures 8 and 9 show observed and simulated water levels at Frank's Well 2 and at an observation well for the Woodward wellfield. The simulated water levels match observed trends, even though the simulated head at Frank's Well 2 is offset by about 25 feet. The monitoring well data on Figures 8 and 9 provide a means to monitor overall aquifer water-level changes at the Town wellfields. The Town maintains records on static water levels at each of its wells, but water levels are affected by residual recovery from pump shutdown and interference effects from other wells in the same wellfield. Charts showing modeled and observed water levels for each of the Town wells are included in Appendix B. The model is an acceptable match with observed water levels.

The OSE model simulates well diversions as specified flows based on estimated or metered groundwater withdrawal rates. We upgraded the OSE model with the drawdown-limited, Multi-node Well (MNW) package for the USGS groundwater flow model MODFLOW (Halford and Hanson, 2002). The MNW package allows users to simulate wells that are production-limited based on lowest practical pumping water levels in individual wells. The user specifies a desired pumping rate and an amount of drawdown to the well water column that maintains acceptable pump submergence. The minimum water column (reserve) we chose for each of the Town wells is indicated on Figures 5, 6 and 7.[1] The model then calculates the declining yield that occurs to individual wells when pumping water levels reach the lowest levels necessary for operation. Wellfield service life is expressed in terms of a schedule of producible water from existing and alternative well sites during a 40-year planned period of use. Figure 10 illustrates the terms treated in the MNW package.

The MNW package accounts for individual well efficiency with a constant that relates feet of head loss in the well to the rate at which it is pumped. The constant we

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[1] We used a general reserve of 120 feet (except on Woodward Well 2) at the bottom of each well to account for setting a pump above any sediment backfill that may have occurred in any of the wells during the past service period. A downhole camera was sent into wells Frank's 7A (1994) and Woodward 2 (1997), 5 (2001) and 6 (2001). Frank's 7A had 36 feet of sediment at the casing bottom; Woodward 2, 5 and 6 had 15, 254 and 77 feet of sediment.

specify for each well is based on the specific capacity that was observed during the field-testing program in the summer of 2002 (Table 1). The observed drawdown in the well during conditions of operation accounts for well efficiency effects resulting from water flow through the screen and from partial penetration of the aquifer. The technique calibrates the MNW package to observed well hydraulic conditions. For example, if a well is observed to produce 75 feet of drawdown when 500 gallons per minute (gpm) is pumped for one day, then a coefficient for well pumping is set up in the MNW package to produce the same condition. If the simulated well yield is greater than 500 gpm, then the simulated well will exhibit more than 75 feet of drawdown; if the yield is less, then the simulated drawdown is less. The theory and components of well head loss addressed by the MNW package are discussed in Walton (1962, p. 26).

We examine the potential of the existing Town wells to meet a projected future growth in water use over the next 40 years. We also examine hydrologic effects associated with three alternative well locations and an imported water option to supplement the yield of existing wells. We then analyze and discuss the factors that affect our estimate of wellfield service life.

HISTORY OF WATER USE

Records on Town water use have been compiled by the Town and by the OSE. Groundwater development by the Town began in 1945 with the completion of Frank's Wells 1, 2 and 3. The OSE has compiled records on Town water use based on a report by Geohydrology Associates, Inc. (1981) from years 1945 to 1970 and from OSE meter records supplied by the Town since that time. The schedule of historical Town groundwater diversions is shown on Figure 11; the graphic is a stacked area chart illustrating the total annual diversion and the contribution from the Frank's and

Woodward wellfields, and the Anderson and Gabby Hayes wells. Town groundwater diversions have grown from about 500 AFY in the 1950's to an average of about 2,800 AFY in the last five years.

The Town has a wastewater treatment plant (WWTP) that discharges water to San Vicente arroyo in the Mimbres Basin (Figure 1). A portion of the WWTP discharge is used for irrigation of fields at a local ranch and at the Town golf course. Discharge to San Vicente Arroyo has been estimated by others (Trauger, 1972; Engineers, Inc. and Geohydrology Associates, 1993) and metered by the Town. A breakdown of the return flow component of Town water use is shown on Figure 12. Metered discharge to San Vicente arroyo averaged 34 percent of groundwater diversions from years 1995 to 2000. We estimate that one percent of discharge to the arroyo is consumed by evapotranspiration[2]; the remaining portion provides recharge to groundwater in the Mimbres Basin[3].

We added the Town WWTP return flow to the historical period of the OSE model to account for return flow to the Mimbres Basin aquifer. For modeled projections 40 years into the future, we assume that return flow is 34 percent of wellfield diversions as observed from years 1995 to 2000.

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[2] The Town WWTP has been reported to discharge at a rate of 1.4 cubic feet per second (1014 AFY) and to infiltrate within a half mile downstream (Hanson, et al, 1994, p. 16). In this area, potential evaporation that is not supplied by the soil moisture increase associated with precipitation is estimated to be 3.75 feet/year (OSE, 2002, Plate 7). Assuming an active channel 40 feet wide by a half mile long, potential evaporation produces 9.1 AFY of evaporative loss, which is less than one percent of 1014 AFY.

[3] Groundwater levels have been observed to rise in the McCauley well downstream of the Town WWTP along San Vicente Arroyo (Trauger 1972, Figure 40); from 1954 to 1970, the water level rose 15 feet.

PERMITTED WATER USE

The Town's permitted municipal water use is composed of one file in the OSE-declared Gila-San Francisco Basin (GSF-1014) and three files in the Mimbres Basin (M-2735, M-2903 and M-2675). A summary of the files is in the table below.

OSE File No.	Name	Diversion (AFY)	Comment
GSF-1014	Frank's Wellfield	1,120.14	The OSE approved a transfer of 102.72 AFY on 1/29/03. The OSE approval was appealed and finally approved on 12/5/05.
M-2735	Woodward Wellfield	1,572.8	--
M-2903	Gabby Hayes Well	1,433.0	--
M-2675	Anderson Well	440.7	The OSE approved a transfer of 33 AFY on 2/16/94.
	Total:	4,566.64	

OSE records on file for the Town indicate a permit to divert up to a total of 4,566.64 AFY for municipal use.

Increasing the Town's permitted diversion requires transferring water rights to the Town's water system. The processing and acquisition of water rights in the State of New Mexico can take many years to complete with an uncertain outcome. For example, in April of 2000, the Town filed an Application with the OSE to transfer 574.71 AFY of adjudicated water rights to Frank's wellfield to increase permitted diversions. In January of 2003, the OSE approved less than 20 percent (102.72 AFY) of the applied-for quantity. The approval was appealed to the State of New Mexico District Court until finally an order approving the OSE's decision (transfer of 102.72 AFY into the Town's water system) was filed in the State Court of Appeals on December 5, 2005. In this case, over five years elapsed before the Town received a final decision on its water rights transfer and less than 20 percent of the applied-for (adjudicated) quantity was approved by the OSE.

PROJECTED DEMAND

We developed a 40-year projection of Town water demand after considering and evaluating recent studies on projections of population growth used 1) in the Town's 40-Year Water Plan, and 2) in the Southwest New Mexico Regional Water Plan (SRWP) (Daniel B. Stephens & Associates, 2005), and 3) after evaluation of data on trends of expansion to the Town water system by means of increased water taps. Projected growth is compared to the Town's current permitted level of water use. Our findings are described below.

The projection of water use in the Town's 40-Year Water Plan is based on population (Engineers, Inc. and Geohydrology Associates, 1993, Table 12). The plan projects the population of the Town service area from 1990 to 2030. We analyzed the growth trend of that projection and found it increases at a rate of 1.31 percent per year. Per capita water use is estimated to be about 155 gallons per day (gpd). The Town's average water use in the last five years is 2,842.4 AFY. Projecting a 1.31 percent per year growth in water use for 40 years indicates demand would be 4,800 AFY by year 2045. On this schedule of growth, the Town's projected demand exceeds its permitted water use (4,463.92 AFY) in 35 years by year 2040.

The projection of water use in the SRWP also is based on population. The SRWP estimates future water use by projecting that the population of Grant County and of the Town will decrease until about year 2010 and after that time will increase at rates of

1.0 percent in Grant County and 1.2 percent in the Town.[4] In the last five years (2000 to 2004), the populations of Grant County and the Town have decreased[5], so the projected decline is not unreasonable. Applying the SRWP method of projecting future water use provides an estimated Town demand of about 4,000 AFY by year 2045. For planning purposes, the SRWP further applies a safety factor of 20 percent to account for the possibility of underestimating population projections. The 20 percent factor increases the projection of Town demand to 4,800 AFY by year 2045. On the SRWP schedule of growth with a 20 percent factor of safety, the Town's projected demand exceeds permitted water use (4,463.92 AFY) in about 35 years by year 2040.

We inspected data[6] maintained by the Town on the number of water taps per year that are added to the Town water supply system. The data include a breakdown of in-town and out-of-town connections as shown on attached Figure 13. We analyzed growth trends for the number of water connections and found that during most of the 1990s (through 1998), the number of connections grew at a rate of 2.9 percent. After that time, the rate of growth decreased to about 1.2 percent. These results indicate that although the local population has declined over the last five years, the demand required to supply all connections to the Town water system has increased due to system expansion. The rate of hook-ups has outpaced the rate of population decline. It follows that demand for the Town water system is not only dependent on population trends, but also on changes to the service area reflected by an increasing number of water connections in an expanded service area. As long as the Town continues to expand its service area with an increasing number of connections, then the demand required to supply all the connections will grow. If the Town intends to increase its permitted

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[4] This is described in Appendix E4, pg. 4 of the SRWP. The projected decrease in population is described to reflect the effects of mine layoffs and general economic downturn.

[5] The Bureau of Business and Economic Research at the University of New Mexico reports Grant County population decreased from 31,002 to 29,443 from years 2000 to 2004. Over the same years, the Town population decreased from 10,507 to 9,911 (see www.unm.edu/~bber/, accessed December 8, 2005).

[6] The Town of Silver City maintains data on the number of water taps added to its system. The data are available at www.townofsilvercity.org (accessed December 4, 2005).

water use to a level at or above the demand associated with supplying all connections to its system, then a growth trend for future planning should account for expansion of the water system as well as population growth. Development of a projected schedule based on growth trends of water connections inherently accounts for population changes because new water system connections reflect new areas requesting water service.

For planning purposes, we developed two growth schedules of water use (low and high) based on the observed growth rates (1.2 and 2.9 percent) in the number of connections to the Town water system. Although the past growth trends are not a certain indicator of future conditions, the scheduled growth is intended to account for the demand required to supply all connections to the Town water system while recognizing trends that have been observed. The growth schedules are projected from the average Town water demand over the last five years (2,842.4 AFY) and are shown on attached Figure 14. The trends on Figure 14 indicate that on the low growth projection, the Town's water demand exceeds permitted water use in about 38 years (year 2043); on the high projection, the Town exceeds its permitted water use in about 16 years (year 2021).

The Town's current OSE permit for municipal water use exceeds current levels of demand. In order to meet future demand requirements, the Town's permitted diversion must grow in increments ahead of future demand. Future water demand is uncertain. The high and low estimates of growth shown on Figure 14 indicate that there is a range of time (within the next 16 to 38 years) over which future demand exceeds permitted use. The timeline associated with acquisition of water rights in New Mexico is a factor that must be considered with any water-rights acquisition program because of the delay and uncertain outcome associated with decisions on applied-for transfers. For planning purposes, it is reasonable to begin seeking water rights to transfer into the Town water system. Planning now will provide time to account for the uncertainty of future demand and the timeline associated with water-rights acquisition. Chapter 72 of the New Mexico Statutes Annotated 1978 (NMSA, 72-1-9) allows a period up to 40 years for development and use of water resources by municipalities, so the earliest time to begin a water-rights acquisition program is within 40 years of the time that the Town's demand may exceed permitted use.

SCENARIOS

The model scenarios are designed to examine drawdown impacts to the Gila Group aquifer in the area of the Town well fields. We examine the superimposed hydrologic effects caused by other water uses besides the Town's. We evaluate the capacity of the existing Town wellfield to meet the high growth rate (2.9 percent) intended to account for the demand required to supply all connections to the Town water system. Finally, we evaluate the hydrologic impacts associated with three alternative well sites and with imported source water to meet demand.

Other Water Use

The OSE model accounts for other major water uses besides the Town, including the Towns of Central and Bayard, and mining uses at Chino, Tyrone and Cron Ranch (Johnson, 2002). The OSE projection of mine water use is based on information regarding an 18-year reserve of copper at the mines (Wilson, 2001, p. 4) and results in reducing mining use to nil by year 2035 (Wilson, 2001, Table 12). We adapted the OSE projection of mine use in the model to simulate a reduction rate of one percent per year from 7,600 AFY in year 2000 to 7,000 AFY in year 2010. After that time, we simulate mining water use to grow at a rate of one percent per year, reaching about 10,000 AFY by year 2045. We simulate more use than that projected by the OSE because of the uncertainty in future use and to avoid understating future water use in the Mangas Trench region.

The OSE model does not account for domestic well use. We added domestic wells to the model area based on files recorded in the OSE Water Administration Technical Engineering Resource System (WATERS) database.[7] We estimated domestic well diversions to average 0.3 AFY with a return flow factor of nil where depth to water is greater than 30 feet, but 2/3 if depth to water was less than 30 feet at the domestic well site. Water use by others as simulated in the model is shown on Figure 15; the graphic is a stacked area chart illustrating other water users besides the Town of Silver City in three categories: Domestic use, use by the Towns of Central and Bayard, and mine use. Figure 15 shows that in the 1990's, groundwater diversions by others exceeded 10,000 AFY with most of the use attributed to mining.

The aquifer impact caused by other water users is shown on Figures 16 and 17 for historical and future (next 40 years) conditions. Historically, other water users have lowered aquifer water levels by an average of about five feet at Frank's wellfield and about ten feet at the Woodward wellfield (Figure 16). By year 2045, continued groundwater pumping by other users adds about another five feet of drawdown at the Frank's and Woodward wellfields. The total drawdown from years 1945 to 2045 caused by other users is the sum of that shown on Figures 16 and 17, or about ten feet at Frank's wellfield and 15 feet at Woodward wellfield.

Existing Wellfield Facility and Other Water Use

We used the model to evaluate historical and future aquifer impacts caused by the combined use of the Town wells and other water users. The water-level drawdown

[7] Electronic communication to Balleau Groundwater, Inc. from the OSE (www.ose.state.nm.us/water-info/gis-data/index.html) data accessed July, 2000.

from year 1945 to year 2005 is shown on Figure 18. Historical drawdown in the area of the Town wellfields ranges from 60 to over 100 feet. The modeled aquifer condition in year 2005 provides a starting point for future projections of water use.

We examined the potential of the existing Town wellfield to supply the future growth rate of 2.9 percent by specifying that rate of growth as input to the model. The model then simulates that rate of growth in yield until local water levels decline below the minimum depth necessary for pump submergence under operating conditions. Once local water levels reach that minimum depth, the model calculates the declining yield of individual wells.

Figure 19 shows that the existing Town wells support a growth rate of 2.9 percent until about year 2032, when yield at some wells begins to decline. At that time, the gap between demand and wellfield yield can be supplied with another well or an alternative source of water. The drawdown to the aquifer from all users between years 2005 to 2045 is shown on Figure 20. From years 2005 to 2045, there is generally an additional 140 feet of drawdown around the Frank's and Woodward wellfields. Evident in the drawdown pattern is the influence of the Silver City Range and the Little Burro mountains, which store less water than the Gila Group aquifer. These mountains have the effect of causing aquifer drawdown around the Town wellfield to be greater due to the barrier boundary to the cone of influence.

Alternative Town Well Sites

As previously described, alternative well sites can supply the unmet demand shown on Figure 19. We examined three alternative well sites based on recommendations by Geohydrology Associates, Inc. in 1997 (attached as Appendix C). The alternative wells include a new Gila Basin well (Continental well), a replacement for the Anderson well and a replacement for the Gabby Hayes well. The three well locations are shown on Figure 21.

We used the model to analyze the three well locations with regard to drawdown effects on other Town wells. The drawdown caused by supplying the water necessary to fill in the gap between demand and yield on Figure 19 for the three well sites is shown on Figures 22, 23 and 24. The model results indicate that the Continental well causes the most drawdown (interference) on other Town wells and exhibits the most drawdown at the location of the new well in comparison to the other two sites. The Continental well location is most influenced by the Silver City Range, the Little Burro Mountains, and the Frank's and Woodward wellfields, as it is in the center of those features.

At the replacement well sites for the Anderson and Gabby Hayes wells (Figures 23 and 24), the drawdown from use of those wells is similar. With regard to interference effects on existing Town wells, the replacement well locations exhibit less interference than does the Continental well.

Imported Water

Surface water imported to the Town water system for future use is a potential option for meeting demand requirements. Possible options include use of water made available to New Mexico under the recent Gila Settlement (140,000 AF of water in any ten years) and surface water rights purchased from Tyrone mine if full use of the permit is not needed for mining. With regard to the groundwater simulation, where the water comes from is not as pertinent as whether or not it is actually made available for use in the Town system. For the simulation of imported source water, we assume that one-half of the future growth in demand is supplied by the new source (i.e. future growth is projected at 2.9 percent per year, so 1.45 percent per year is supplied by a new surface water source piped to the Town) and the remaining demand is supplied by the existing Town wellfield.

The future yield projection for the town wells as presently configured if surface water were made available for half of the growth in demand is shown on Figure 25. The results show not only that portion of demand supplied by imported water, but also indicate that the wellfield as configured is capable of supplying 1.45 percent growth in water use over the next 40 years. Figure 26 shows the reduction of drawdown with a 1.45 percent rate, in comparison to drawdown that otherwise would occur if the Town wells were used to supply the full future growth rate of 2.9 percent. It is that reduction in drawdown (savings of aquifer storage) that maintains aquifer water levels above the estimated lowest depths necessary for pump submergence in the existing Town wells.

MODEL RESULT AND LONG-TERM YIELD

Sensitivity of Wellfield Yield to Drawdown Reserve

We have evaluated the potential of the existing Town wellfield to produce future growth in water use at a rate of 2.9 percent per year and a general reserve of 120 feet at the bottom of the well casings.[8] The model indicates that in about 27 years (by 2032), yield at some wells begins to decline. Clearly, the estimated depth of reserve that is necessary for pump submergence in the existing Town wells is an important factor in projecting future wellfield yield.

[8] Except for Woodward Well 5 which has a 270 foot reserve based on the previously described sediment backfill at the bottom of the well casing.

We analyzed that factor by performing a sensitivity analysis of Town wellfield yield to pump setting necessary for pump submergence under operating conditions; the results are shown on Figure 27. The red (diamond) symbols on Figure 27 illustrate the yield of Town wells with 120 feet of water column reserve. In this case, wellfield yield begins to peak at about year 2032. If 50 feet less of reserve were necessary, then the yield of the Town wells can maintain 2.9 percent growth for another five years and the yield levels off with an additional 1,000 AFY (blue symbols (squares) on Figure 27). The sensitivity results indicate that to produce an additional 1,000 AFY, about 50 feet of additional drawdown is necessary in the existing wellfield layout. It should be noted that if more than 120 feet of reserve is necessary, then wellfield yield would level off at some time sooner than the estimated year of 2032 at the 2.9 percent rate of growth in use. The entire wellfield can be deepened to increase capacity at the rate of 2000 AFY at 40 years per 100 feet of deepening.

Long-Term Wellfield Yield

As previously described, the OSE model simulates about 15,900 AFY of groundwater flowing through the Mangas and Mimbres subbasin regions of the Gila Group aquifer. A portion of that estimated quantity is available for long-term sustainable use by others and by the Town with its wellfield as presently configured in location and depth. Other uses in the area would develop another portion of the estimated 15,900 AFY also at a sustainable rate. We used the model to estimate the long-term yield of the Town wellfields under two conditions: wells as presently configured and wells deepened by 300 feet. For each condition, we also show the model-derived sustainable use for others besides the Town. Long-term analyses such as this exceed the horizon of a future 40-year planning period; it actually takes hundreds of years for wells situated as those operated by the Town to reach their sustainable yield. The analysis addresses the question of sustainable water availability for a particular configuration of wells in the study area. However long it takes, wells operated in the study area will inevitably capture groundwater that otherwise would flow to discharge regions of the study area, namely Mangas Spring, the Gila River, and alluvial flats and playas in the Mimbres Basin. When a well reaches its sustainable yield, the water level in it ceases to decline because it is no longer drawing on water stored in the aquifer. It is instead supplied by capturing the groundwater that otherwise would discharge from groundwater at other areas.

Wells as Configured

The model scenario for Town wells as located and configured is designed to simulate growth in groundwater use for the Town and for other users over the next 60 years. After that time, the model is set up to determine the long-term sustainable yield for both categories of use. The result is shown on Figure 28. Growth for other water users is at the previously described growth rates. Growth for the Town is at the previously described rate of 2.9 percent per year; the declining yield of Town wells at year 2032 is evident on Figure 28 (as on Figure 19). Return flow from the Town WWTP adds 1,200 AFY of recharge to the Mimbres Basin in the long term. By year 2060, the model begins to solve for a declining rate of yield that approaches the long-term sustainable yield for wells as located in the study area. The long-term sustainable yield for the Town wells is estimated at 4,200 AFY (which is more than has historically been diverted); for others, it is 3,600 AFY. Together the Town and other users show a sustainable yield of 7,800 AFY. This results in reducing flow in Mangas Spring and the Gila River by 1,000 AFY and 600 AFY. Evaporation in the Mimbres Basin is reduced 6,200 AFY by the wellfield, but increased 1,200 AFY from the WWTP recharge. Wells can be deepened to increase the sustainable yield.

Wells Deepened

The model scenario for deepened Town wells simulates the same rates of growth (as the previous sustainability scenario) for others and for the Town; the only difference is Town wells are simulated 300 feet deeper. The result is shown on Figure 29. The deepened Town wells maintain a 2.9 percent per year rate of growth until year 2060 when yield begins to drop off. By year 2060, other users and the Town are each producing about 12,000 AFY for a total over 24,000 AFY. That rate of groundwater withdrawal is nearly twice that estimated to discharge into the Gila and Mimbres Basins (15,900 AFY). After year 2060, the model solves for the sustainable rate that is less than 15,900 AFY. In the long term the deepened Town wells produce 6,600 AFY and other users produce 1,900 AFY for a total sustainable yield of 8,500 AFY. To sustain that yield for the long term, Mangas Spring is depleted by about 1,200 AFY, baseflow to the Gila River is reduced by 700 AFY and groundwater flow through the Mimbres Basin is reduced by a net quantity of 5,400 AFY. Inspection of Figures 28 and 29 indicates that deepening the Town wells has the effect of increasing their yield and reducing the yield of other users, so the two categories of use interfere with each other. The wells of other water users could also be deepened to increase their yield, which would ultimately reduce the yield of the Town wells.

The two long-term scenarios address the sustainability of the Town wells and, in a general sense, the water use of other users in the study area. They do not address priority of water rights with respect to hydrologic impacts caused either by the Town to other water users or by other water users to the Town. The depletion to Mangas Spring and the Gila River and the reduced evapotranspiration to the Mimbres Basin described in the two paragraphs above is caused by all uses (The Town of Silver City, the Towns of Central and Bayard, the mines and domestic wells) included in the model of the study area.

MODEL RELIABILITY

The OSE model provides a mathematical representation of the hydrogeologic system of the study area. Comments on factors that affect model reliability are discussed below.

- The OSE model simulates a groundwater flow budget that is compatible with previous studies and observations in the Mangas and Mimbres subbasins. The model simulates 9,800 AFY flowing into the Mimbres subbasin; previous studies estimate 10,800 AFY and 10,000 AFY (Trauger, 1972, p. 64; Hawley and others, 2000, p. 39). The model simulates Mangas Spring flowing at 1,300 AFY; observed flow has been 1,160 AFY (Trauger, 1972, p. 49).

- The OSE groundwater flow model provides a means to evaluate the aquifer drawdown trends of the Mangas and Mimbres subbasins. The historical water-level trends simulated by the model at the observation wells for the Town well sites fit observed drawdown trends. For individual Town wells in which the model simulated elevation head is offset (high or low) from observed conditions, we adjusted the simulated water column from year 2005 conditions to reflect the actual observed water column. The adjustment is made in the MNW package and improves the model representation of projected well water-column changes.

- The OSE model provides an acceptable match of previously studied and observed quantities of regional groundwater flow. The model also matches observed changes in water-levels at the Town wellfield over the last 50 years while taking into account metered and estimated levels of use for the Town and for other users. Although the model is not a perfect representation of the actual hydrogeologic system, it provides a tool suitable to assess wellfield service life for planning purposes.

- Unforeseen changes in future uses in the study area could reduce or increase the estimated service life of the Town wellfield as presently configured. Some of the wells are 40 to 50 years old. Well rehabilitation or replacement may be necessary to restore the yield of deteriorating wells.

- If the Town proceeds with plans for well replacement and deepening, we recommend an associated program of exploratory drilling and aquifer testing to confirm, validate and, if necessary, adapt the OSE model (or possibly develop another) to account for new findings that may affect the estimates of resource lifetime.

CONCLUSIONS

1. The Town of Silver City wellfield is capable of producing water to supply the high growth rate of 2.9 percent per year for about the next 30 years. After this time, an alternative source of water, well deepening or replacement wells would be necessary to maintain that high growth rate after a 40-year planning period.

2. The Town of Silver City wellfield is capable of producing water to supply a medium growth rate of 1.45 percent per year for the next 40 years.

3. Future water demand for the Town of Silver City is uncertain, but for planning purposes, high and low growth rates (2.9 and 1.2 percent) account for the demand required to supply all connections to the Town water system, while recognizing trends of service area expansion and population change that have been observed in the past.

4. Town of Silver City groundwater diversions have averaged about 2,800 acre feet per year in the last five years. High and low estimates of growth in water demand indicate a range of time (within the next 16 to 38 years) in which future water demand exceeds the Town's permitted use of 4,566.64 acre feet per year.

5. With regard to wellfield interference, potential replacement wells for the Anderson and Gabby Hayes wells are preferable to a new Continental well located between the existing Frank's and Woodward wellfields.

6. Imported water would provide a new water source to the Town of Silver City municipal water system and would extend the life of the Gila Group aquifer stored resource.

7. There is an estimated 15,900 acre feet per year of groundwater flowing through the Mangas and Mimbres subbasins of the study area. In the long term, the

Town of Silver City wellfield as presently configured can sustain a yield of 4,200 acre feet per year. Configured at a 300-foot deeper pumping water level, the wellfield can sustain 6,600 acre feet per year. The long-term yield of other users in the Mangas and Mimbres subbasins has an effect on the sustainable yield of the Town wellfield.

RECOMMENDATIONS

1. Consider the option of developing groundwater versus an alternative source to supply demand above the current permitted use of 4,566.64 acre feet per year. If groundwater development is preferable, then begin a water rights acquisition program that involves seeking potential rights for transfer into the Town water system. Considering the timeline and uncertain outcome associated with acquisition of water rights in New Mexico, it is reasonable to begin the acquisition program within a 40-year planning period.

2. Prepare to deepen the wellfields in future years to extend the service lifetime to meet required levels of demand.

3. Planned wells should be constructed, developed and maintained to maximize efficiency. Incorporate a plan of field testing for wellfield expansion or replacement wells so that observed field conditions and as-built well conditions can be applied to wellfield simulations.

4. Identify wellfield capture zones so that areas that contribute water to the wellfield can be part of a wellhead protection program.

5. Track adjacent wellfield withdrawals to intervene with large-scale changes that could impact the Town sources.

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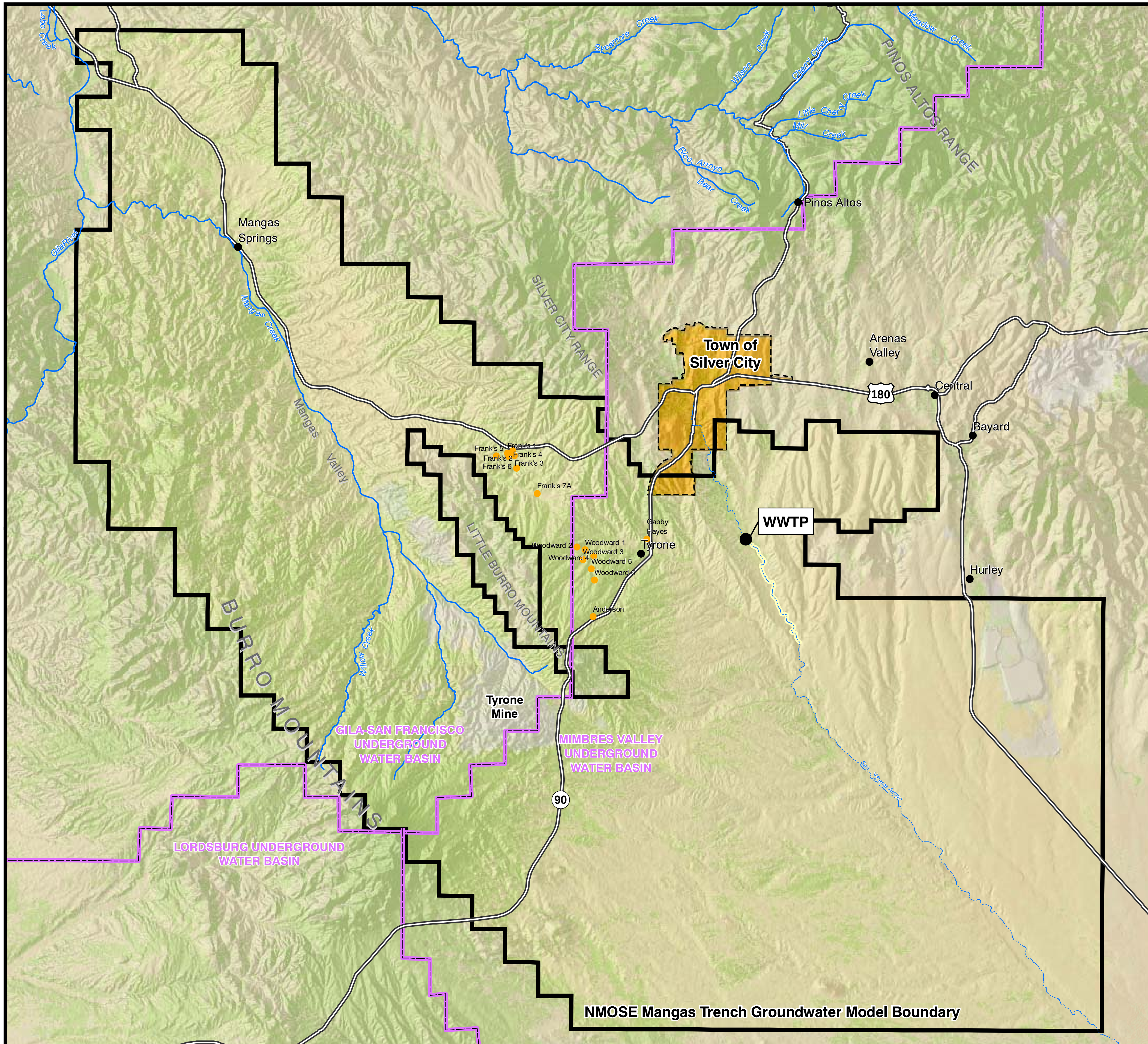
TABLE 1. SUMMARY OF TOWN WELLFIELD STATUS AND CAPACITY

City Well	Date Drilled[1]	Land Elevation[1] (ft)	Well Depth[1] (ft)	Reported Well Yield[1] (gpm)	DTW When Drilled (ft)	Water Column When Drilled (ft)	Well Pumping Test (Summer 2002)					Specific Capacity (gpm/ft)	T (ft^2/d)[2]	K (ft/d)[3]	Pumping Water Column on Date of Test (ft)[4]	Remark
							Date	Measured Non-Pumping DTW (ft)	Measured Pumping DTW (ft)	Drawdown (ft)	Pumping Rate (gpm)					
Frank's																
1	03/1945	5820	597													Not in production
2	03/1945	5830	558													Not in production
3	03/1945	5830	580													Not in production
4	03/1966	5820	547	400												In production, well water level not measured.
5	06/1955	5800	860	325			6/27/02	252.8								Not in production, well needs treatment for algae.
6	11/1974	5860	865	500	323	542	6/26/02	369.3	387.8	18.5	420	22.7	1744	3.7	477	Pumping DTW measured after approximately 60 minutes of pumping. Static DTW measured after 45 minutes of recovery (projected 3 feet higher in long term).
7A	09/1982	5940	1095	800	330	765	6/26/02	413.7	486.0	72.3	740	10.2	2612	4.6	573	Pumping DTW measured after approximately 30 days of pumping. Static DTW measured after 30 minutes of recovery (projected 32 feet higher in long term).
Woodward																
1	04/1954	5892	895	300	341	554									445	Not in production, well needs treatment for iron bacteria.
2	06/1954	5907	800	300	319	481	6/24/02	473.7	553.6	80.0	303	3.8	1445	6.2	231	Pumping DTW measured after 36 minutes of pumping. Static DTW measured after approximately 48 hours of recovery (projected 10 feet higher in long term). Well redeveloped in 1997.
3	08/1957	5908	835	500	348	487	7/17/02	463.0	530.5	67.5	420	6.2	--	--	305	Pumping DTW measured after 25 hours of pumping. Static DTW measured after 24 hours of recovery.
4	07/1965	5883	954	500	284	670	6/25/02	473.3	506.5	33.2	342	10.3	1006	2.2	448	Pumping DTW measured after approximately 49 hours of pumping. Static DTW measured after 47 minutes of recovery (projected 22 feet higher in long term).
5	11/1971	5941	1030	500	359	671	6/24/02	507.0	553.0	46.0	473	10.3	--	--	223	Pumping DTW measured after 32 minutes of pumping. Static DTW measured after approximately 49 hours of recovery. Well redeveloped in 2001.
6	03/1972	5988	1030	500	414	616	6/26/02	542.3	596.3	54.0	587	10.9	1883	5.3	357	Pumping DTW measured after approximately 4.9 days of pumping. Static DTW measured after 67 minutes of recovery (projected 22 feet higher in long term).
Anderson	02/1967	6060	900	250	455	445	6/26/02	628.8	680.6	51.8	230	4.4	854	3.9	219	Pumping DTW measured after approximately 70 hours of pumping. Static DTW measured after 60 minutes of recovery (projected 16 feet higher in long term).
G. Hayes	02/1970	5800	680	1100	260	420	6/24/02	355.0	373.0	18.0	950	52.8	--	--	307	Pumping DTW measured after approximately three days of pumping. Static DTW measured after 18 hours of recovery.

[1] Data from Town of Silver City 40-Year Water Plan, final report dated October, 1993.
[2] Transmissivity (T) from well recovery data on attached Figures A1 through A6 in Appendix A.
[3] Hydraulic conductivity (K) is calculated by assuming that each well is perforated over the pumping water column that was present during the June and July, 2002 field survey. The assumption minimizes the reported K.
[4] A downhole camera was sent into wells Frank's 7A (1994) and Woodward 2 (1997), 5 (2001) & 6 (2001). Frank's 7A had 36 feet of sediment at the casing bottom; Woodward 2, 5 & 6 had 15, 254 & 77 feet of sediment. The reported pumping water column on the date of the test takes into account the sediment fill.
DTW = Depth to water below measuring point at top of casing.

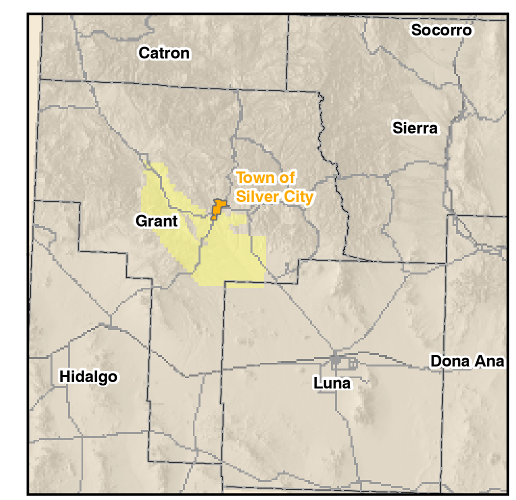


EXPLANATION

- TOWN OF SILVER CITY WELL LOCATIONS -- BGW GPS location data
- NMOSE UNDERGROUND WATER BASIN BOUNDARIES (2005) -- Adapted from NMOSE digital data and maps.

0 5 Miles

Map Projection: New Mexico West, NAD83.



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TOWN OF SILVER CITY / WATER USE

LOCALITY MAP WITH MODEL AREA

DATE: 1/6/2006
PRODUCED BY: SES
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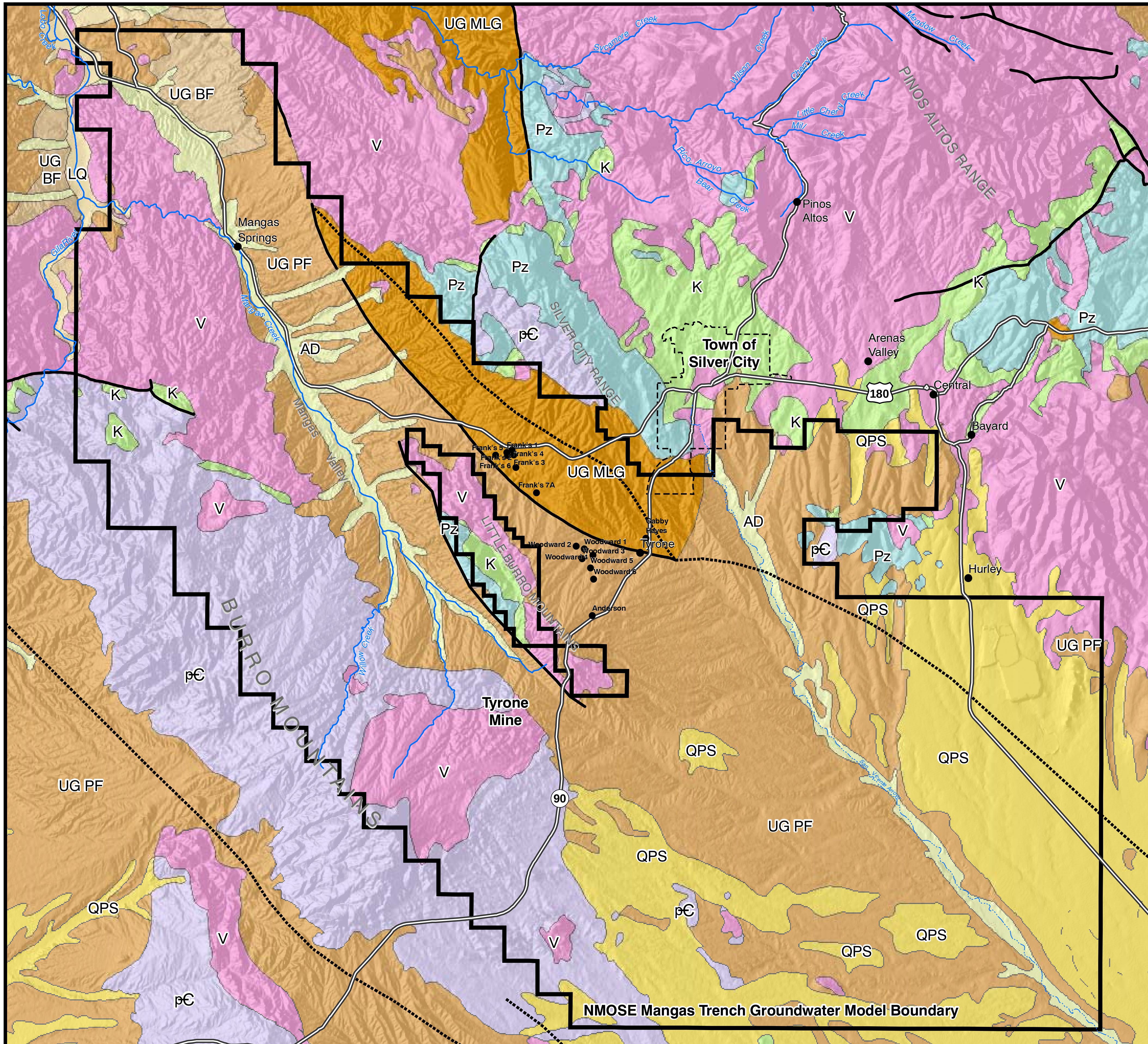
FIGURE 1

BALLEAU GROUNDWATER, INC.



EXPLANATION

- AD Alluvial deposits of major ephemeral streams
- QPS Quaternary piedmont slope hydrostratigraphic units
- LQ Late Quaternary fluvial hydrostratigraphic units
- UG BF Upper Gila Group hydrostratigraphic units - Basin-floor facies
- UG MLG Upper Gila Group hydrostratigraphic units - Middle and Lower Gila
- UG PF Upper Gila Group hydrostratigraphic units - Piedmont facies
- K Cretaceous rocks
- Pz Paleozoic rocks
- pЄ Pre-Cambrian
- V Volcanics
- Fault (dashed where approximated)

Adapted from:
Hawley, J.W, Hibbs, B.J., Kennedy, J.F, Creel, B.J.,Remmenga, M.D., Johnson, M., Lee, M.M. and Dinterman, P., 2000, Trans-International Boundary Aquifers in Southwestern New Mexico (Plate 1 – Surface Geology and Hydrostratigraphic Units of the Southwestern New Mexico Region) New Mexico Water Resources Research Institute, Technical Completion Report.

0 5 Miles

Map Projection: New Mexico Central, NAD83.

N W E S

TOWN OF SILVER CITY / WATER USE

GEOLOGY OF SILVER CITY AREA

DATE: 1/6/2006
PRODUCED BY: SES
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FIGURE 2

BALLEAU GROUNDWATER, INC.

FIGURE 5
WELL WATER COLUMNS IN WOODWARD WELLFIELD

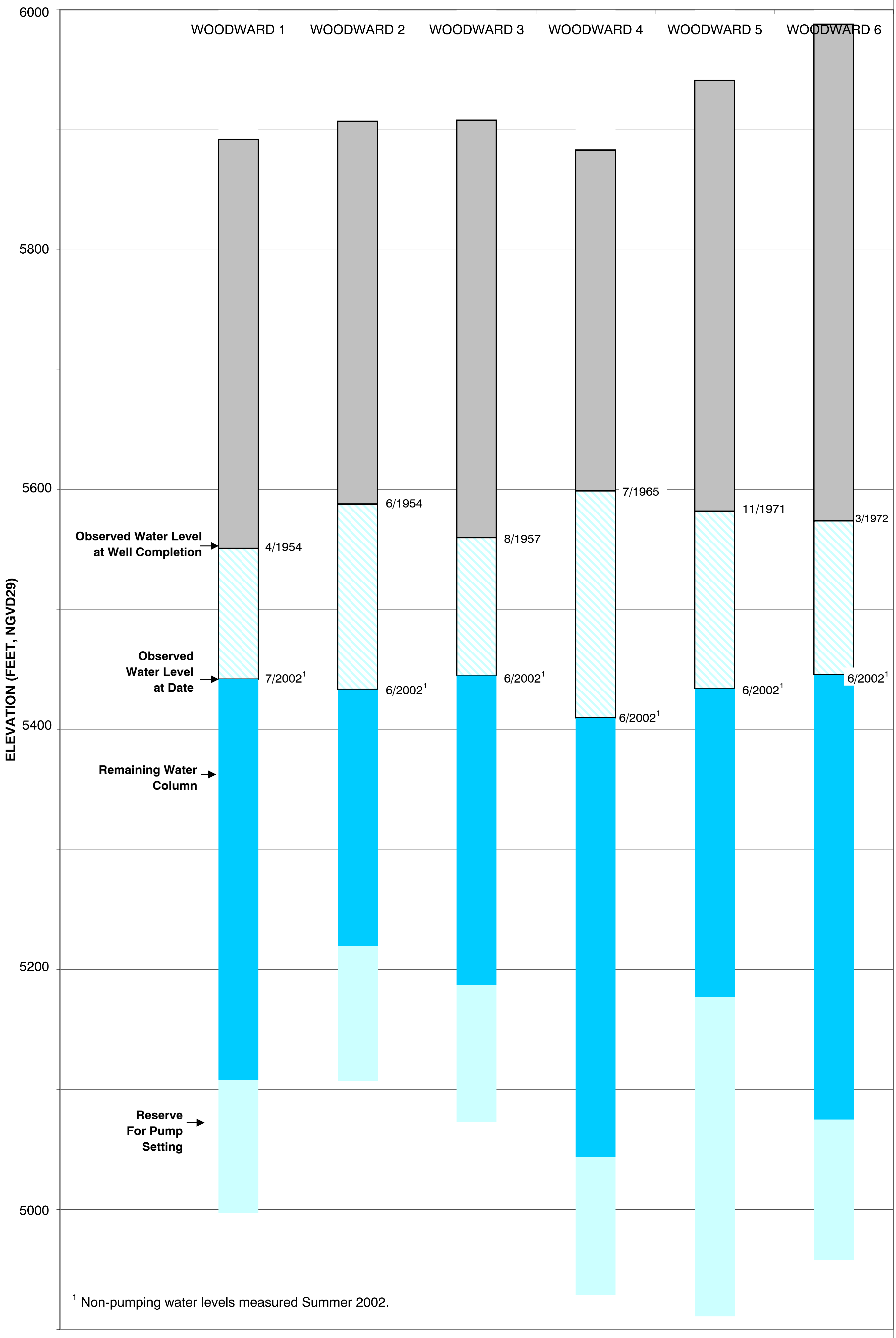
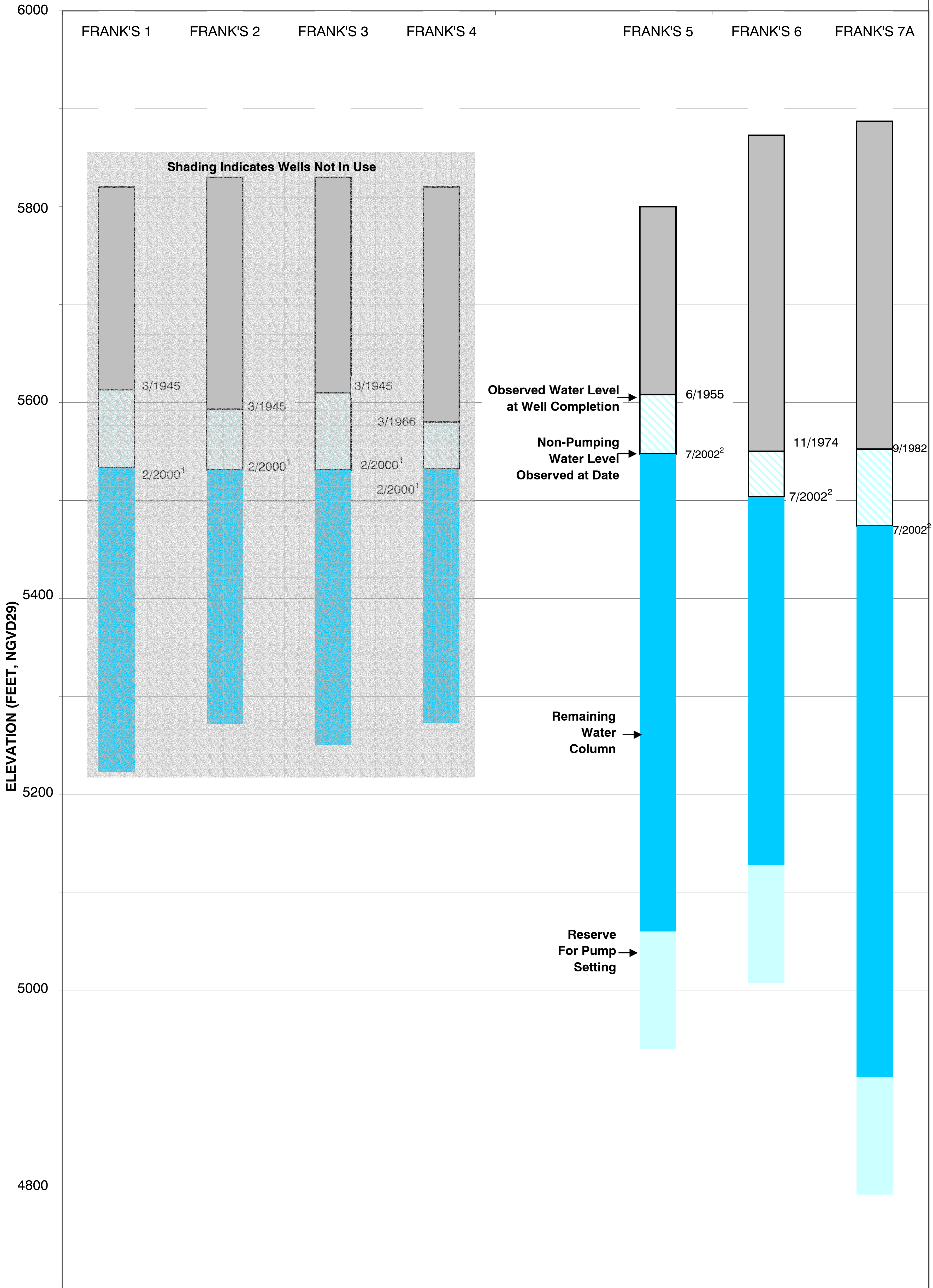


FIGURE 6
WELL WATER COLUMNS IN FRANK'S WELLFIELD



[1] Non-pumping water level assumed equal to Observation Well Frank's 2.
[2] Non-pumping water levels measured Summer, 2002.

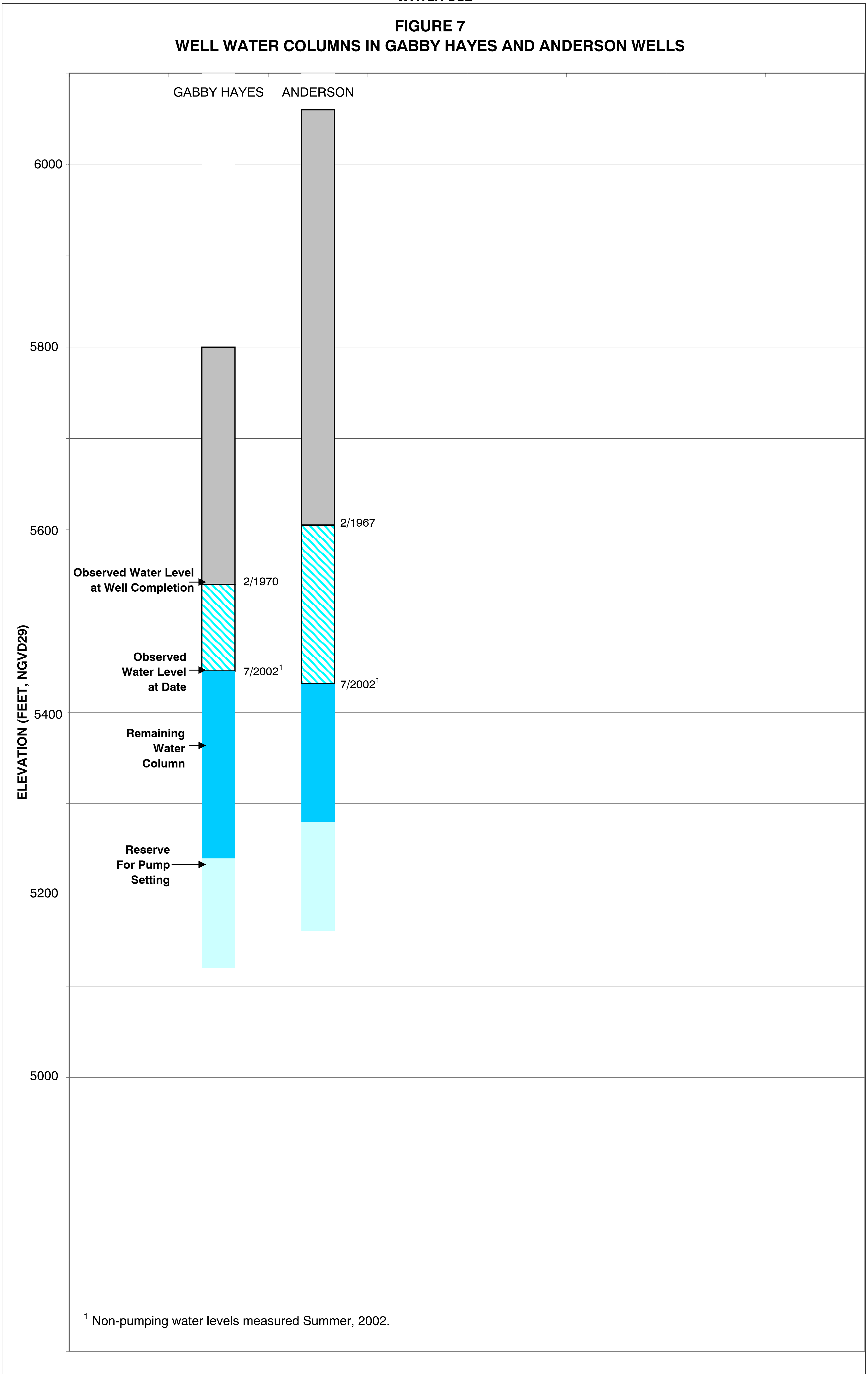
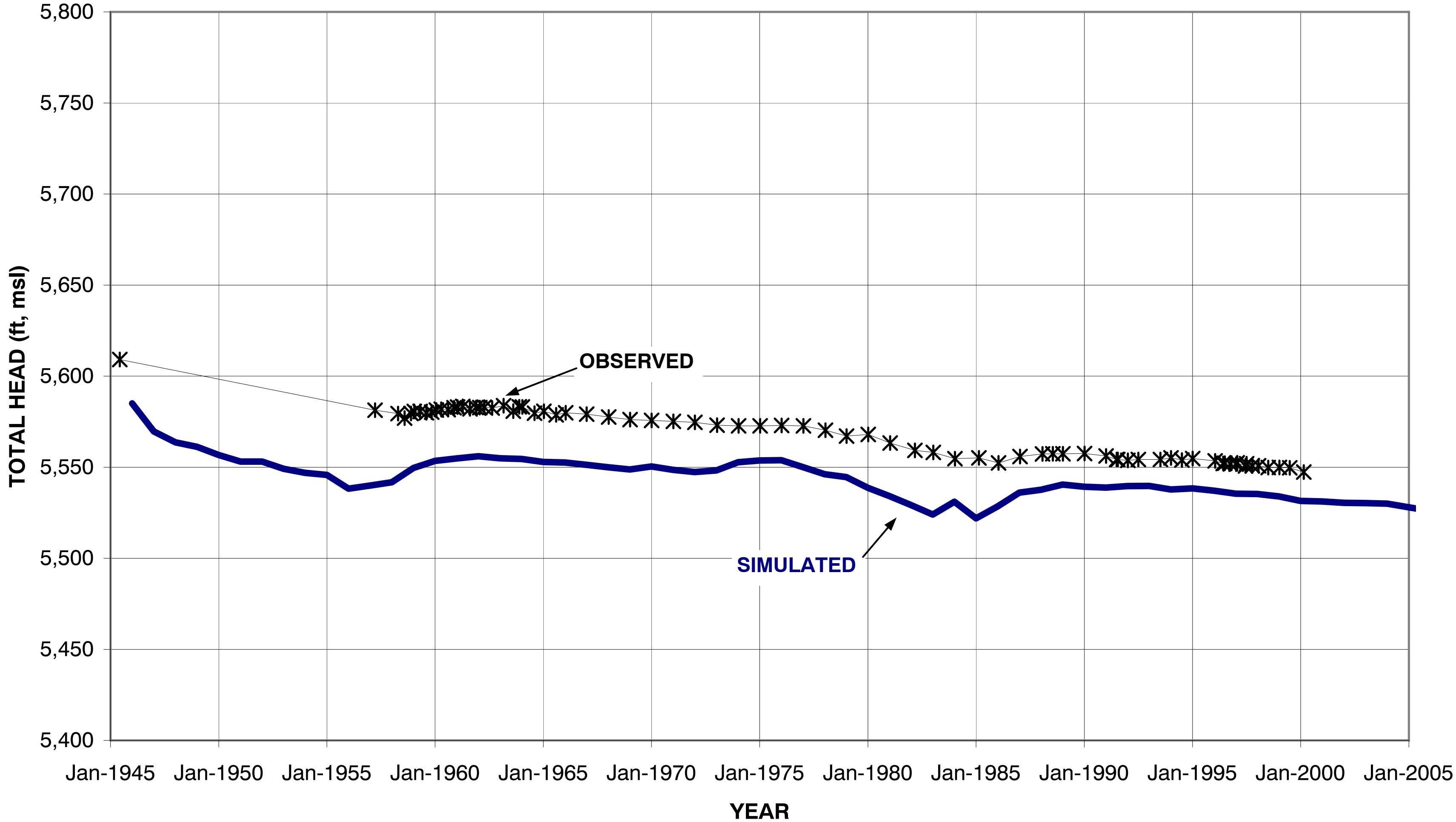


FIGURE 7
WELL WATER COLUMNS IN GABBY HAYES AND ANDERSON WELLS
GABBY HAYES
ANDERSON
6000
5800
5600
5400
5200
5000
ELEVATION (FEET, NGVD29)
Observed Water Level at Well Completion
2/1970
2/1967
Observed Water Level at Date
7/2002[1]
7/2002[1]
Remaining Water Column
Reserve For Pump Setting
[1] Non-pumping water levels measured Summer, 2002.

FIGURE 8
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S WELLFIELD



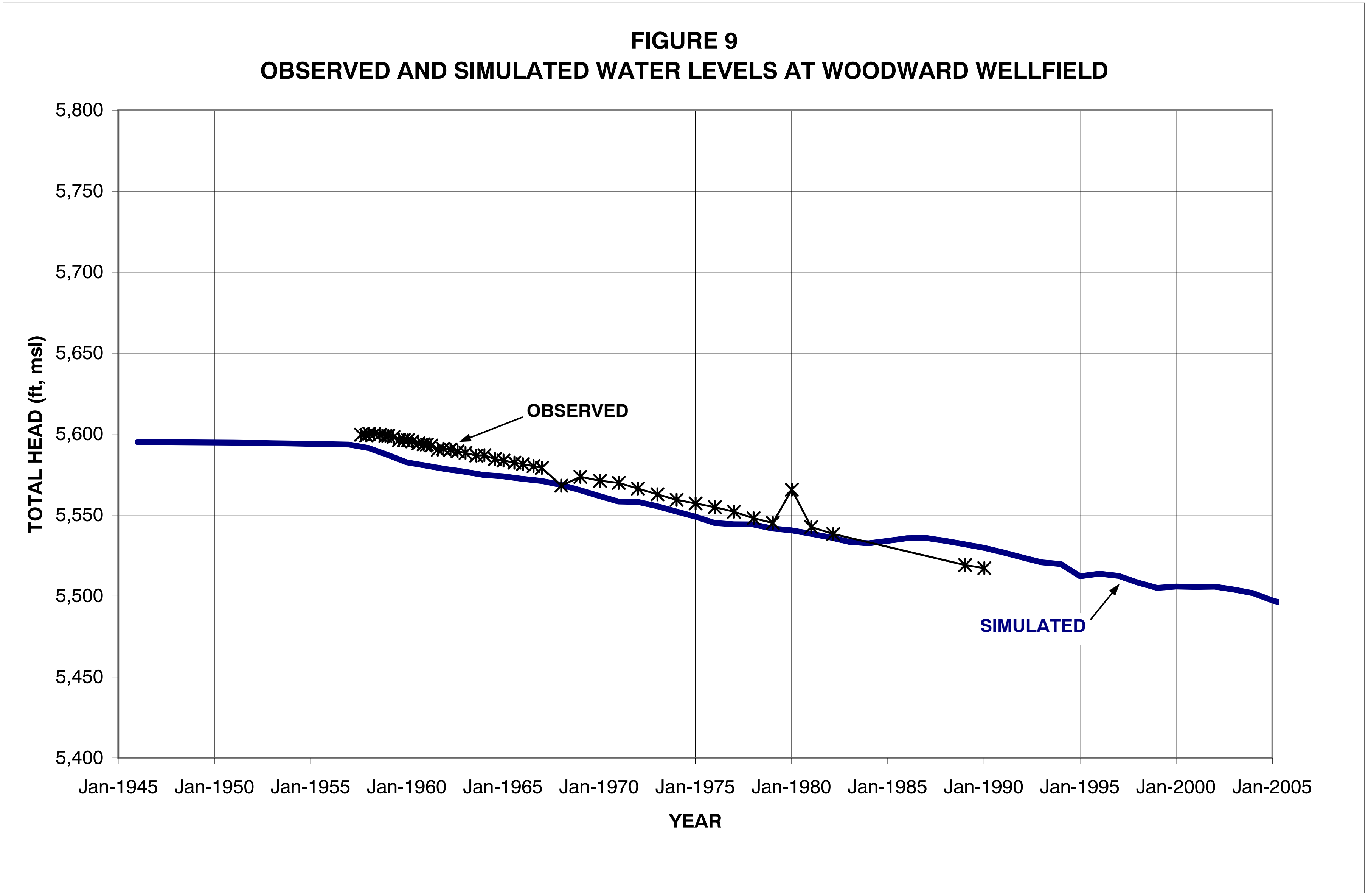
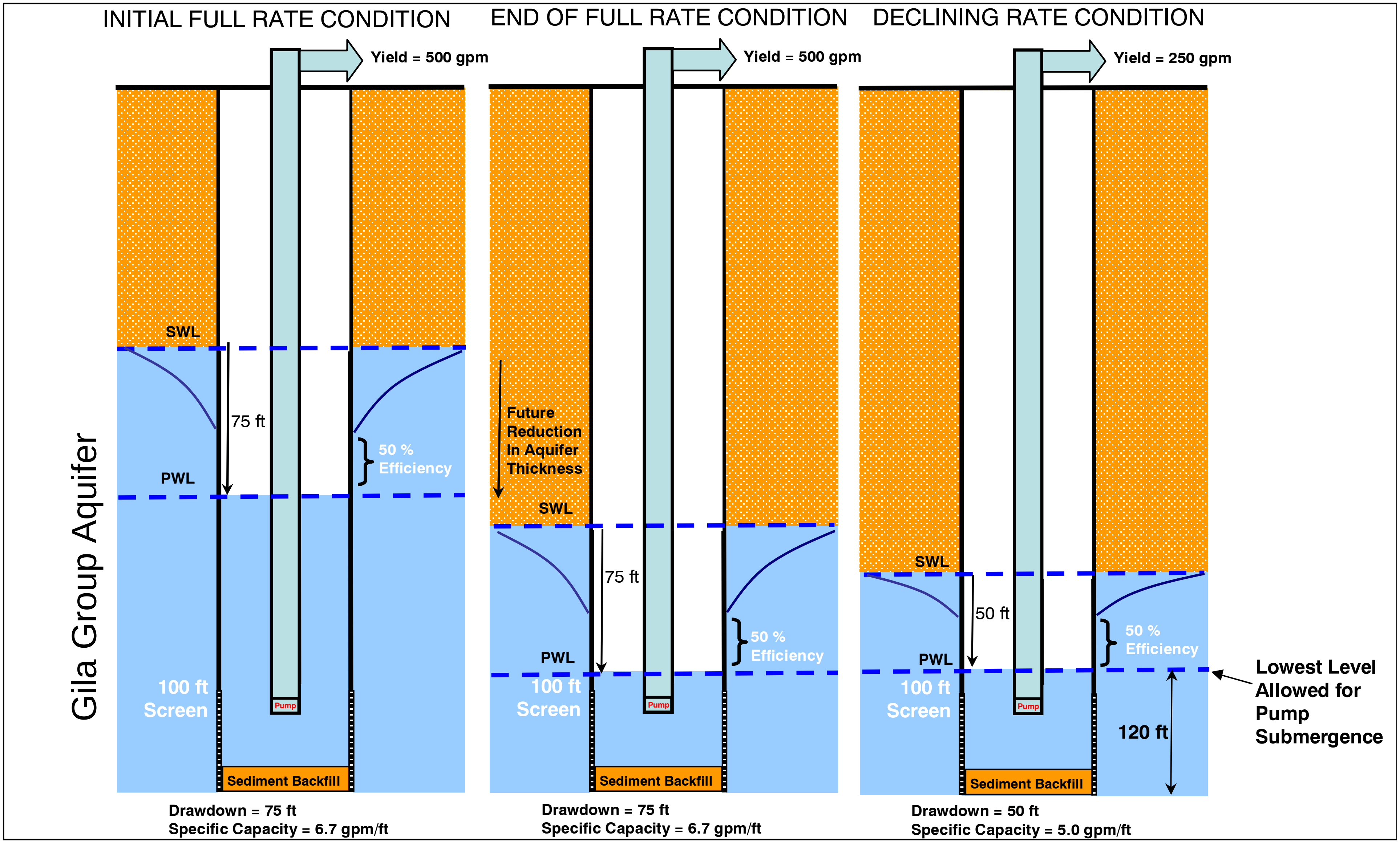


FIGURE 9
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD WELLFIELD
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
Jan-1945
Jan-1950
Jan-1955
Jan-1960
Jan-1965
Jan-1970
Jan-1975
Jan-1980
Jan-1985
Jan-1990
Jan-1995
Jan-2000
Jan-2005
YEAR
OBSERVED
SIMULATED

FIGURE 10
WELL SERVICE - LIFE PLANNING FACTORS



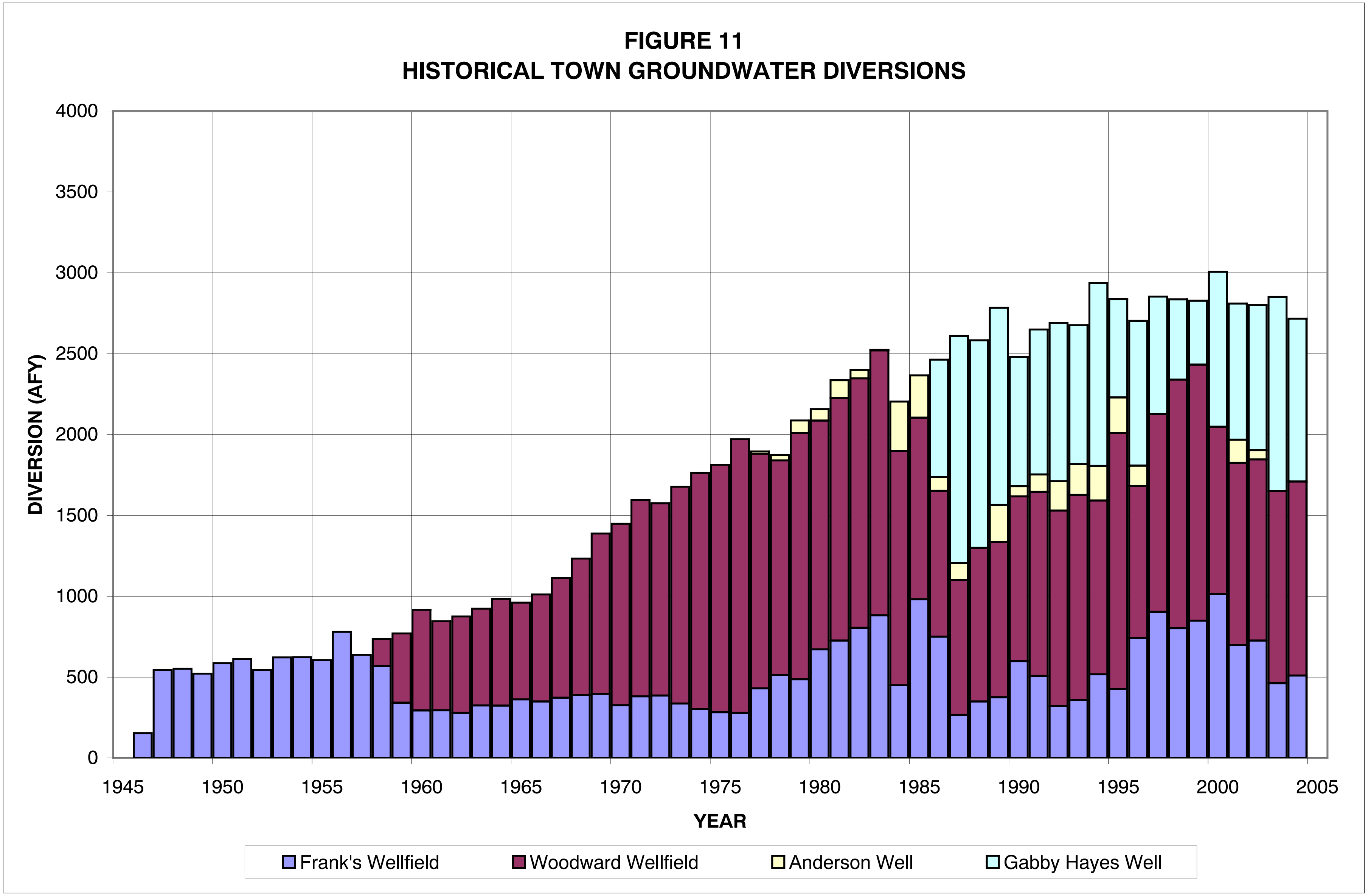


FIGURE 11
HISTORICAL TOWN GROUNDWATER DIVERSIONS
DIVERSION (AFY)
0
500
1000
1500
2000
2500
3000
3500
4000
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
YEAR
Frank's Wellfield
Woodward Wellfield
Anderson Well
Gabby Hayes Well

FIGURE 12
TOWN GROUNDWATER DIVERSION AND RETURN FLOW

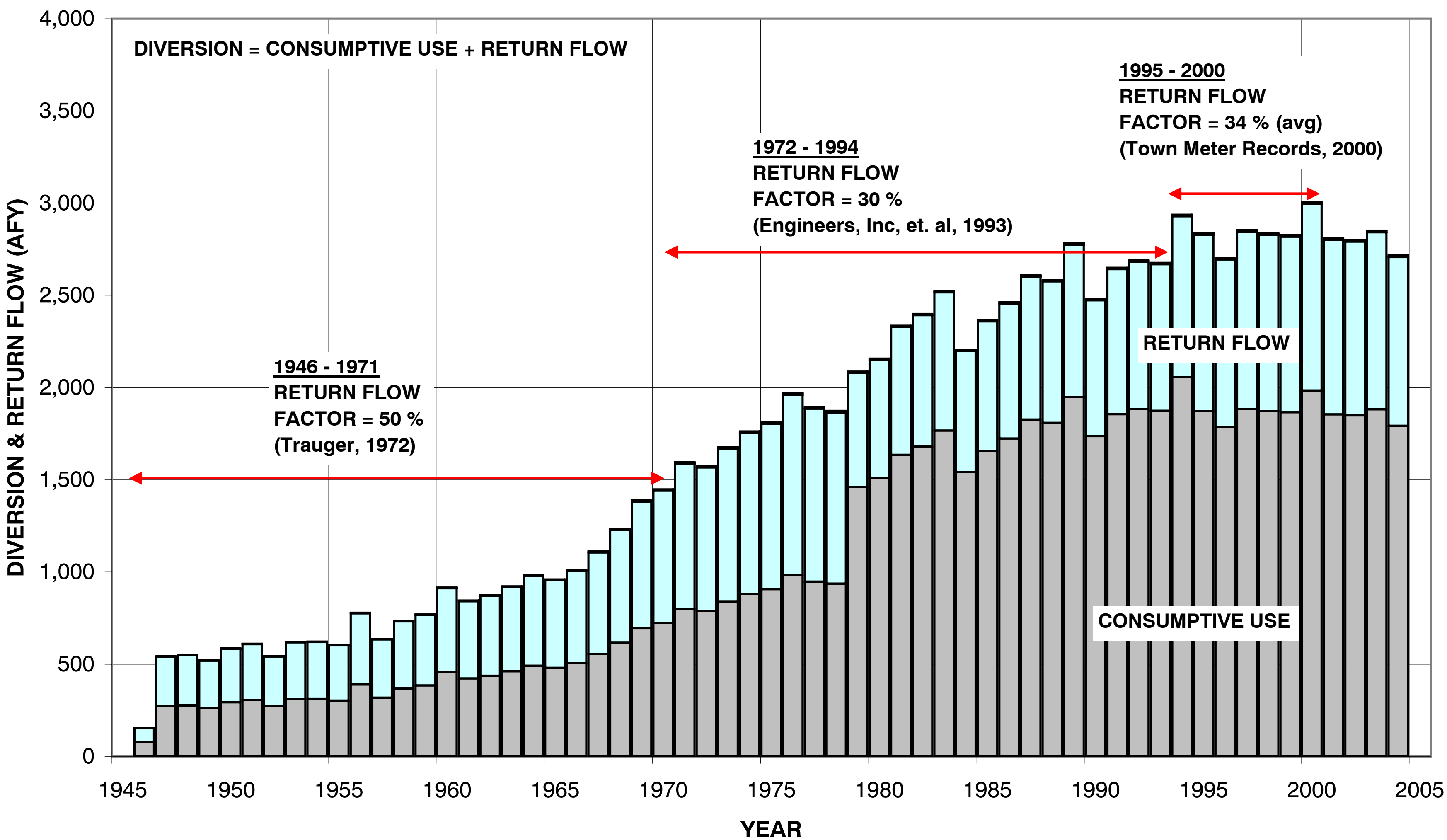


FIGURE 13
NUMBER OF IN-TOWN AND OUT-OF-TOWN TAPS ADDED TO TOWN WATER SYSTEM

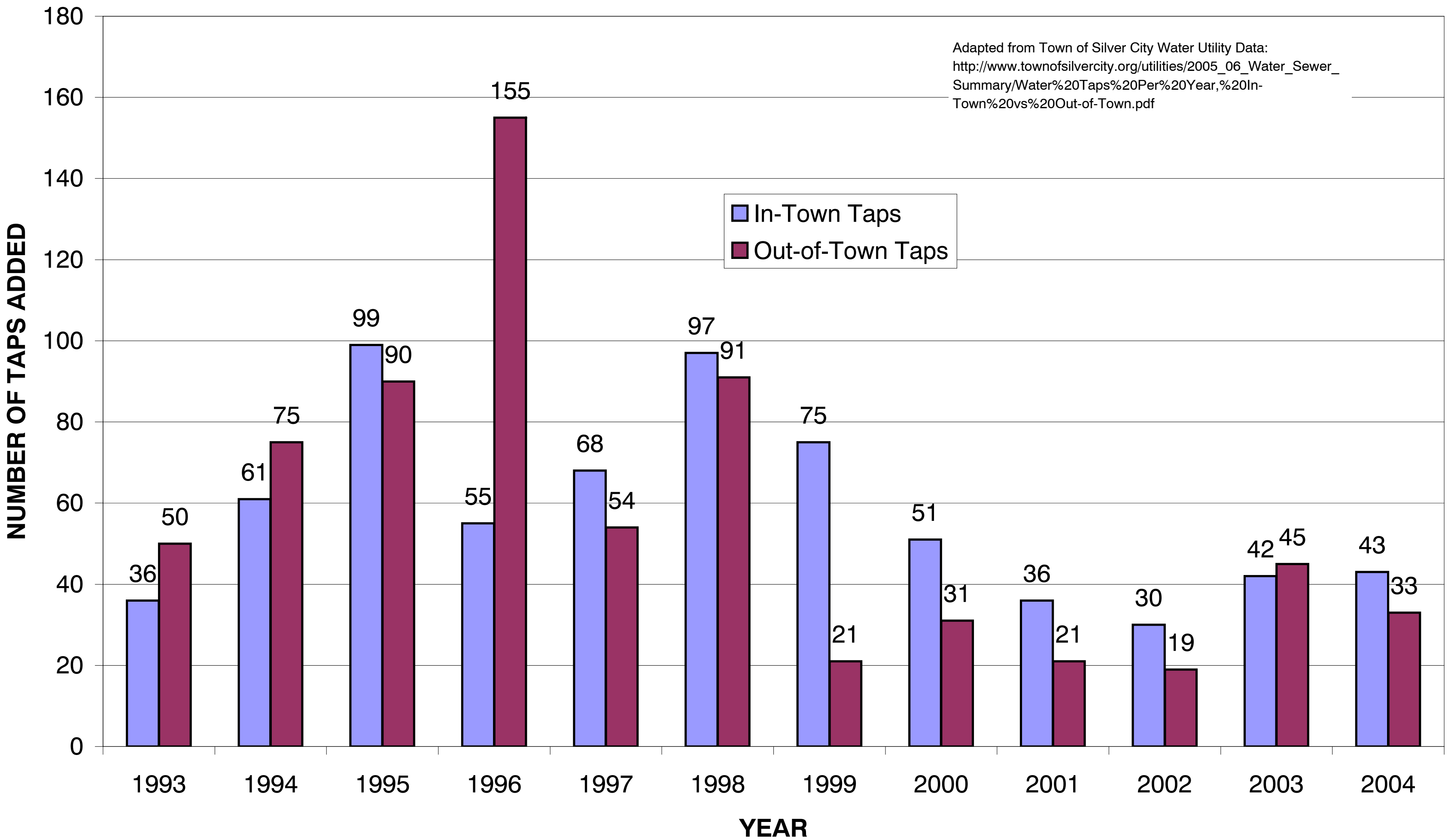
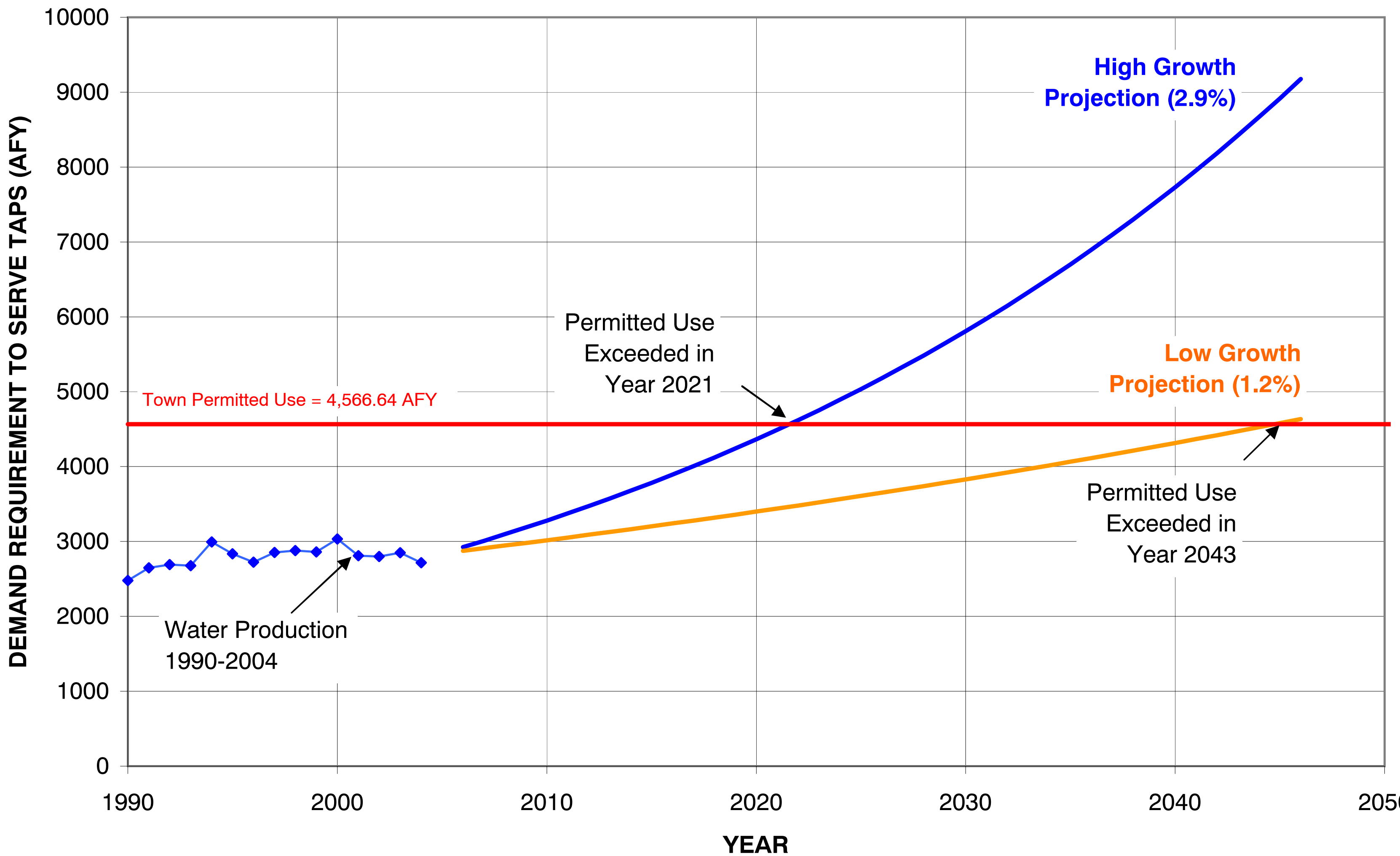
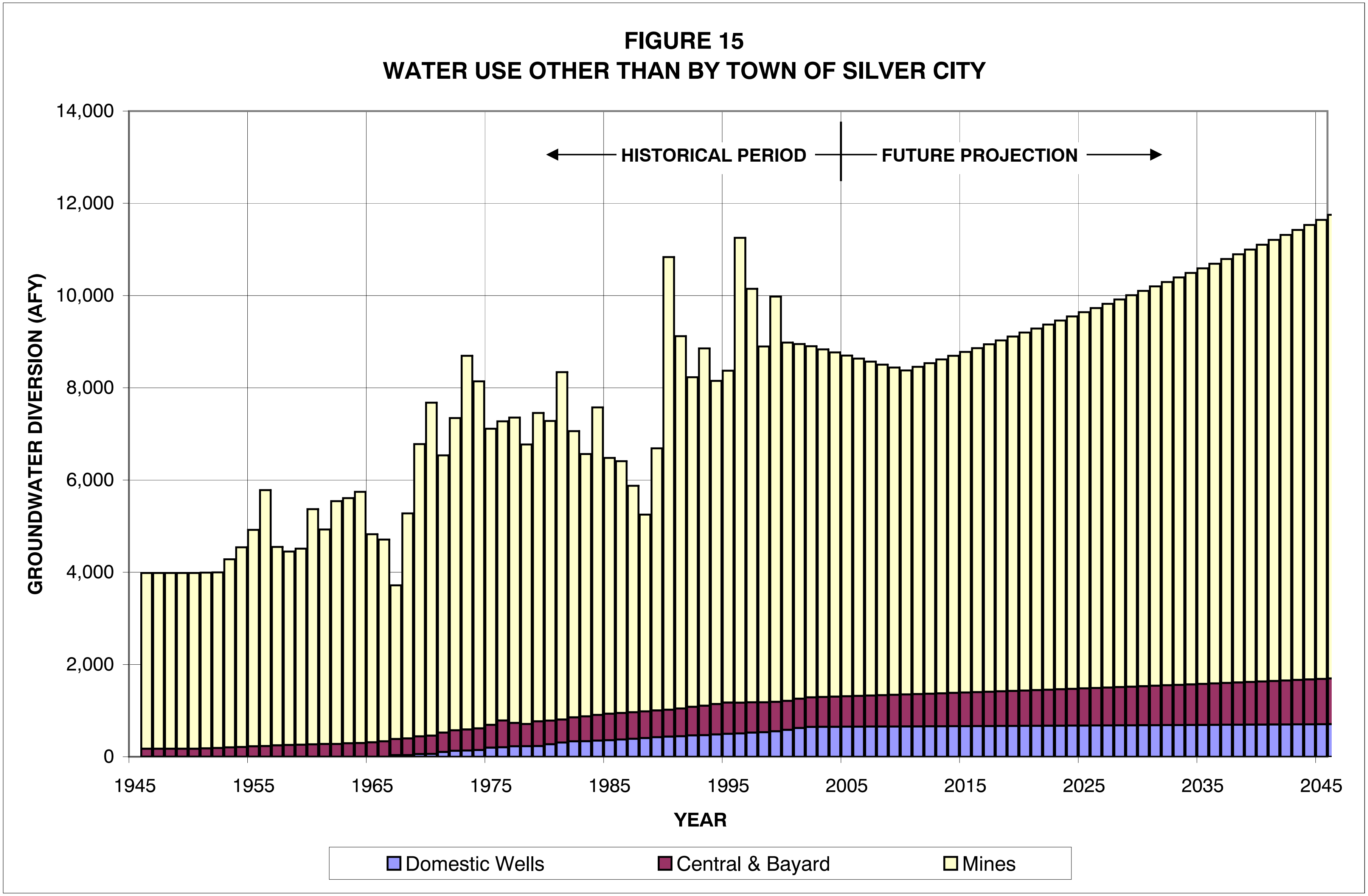
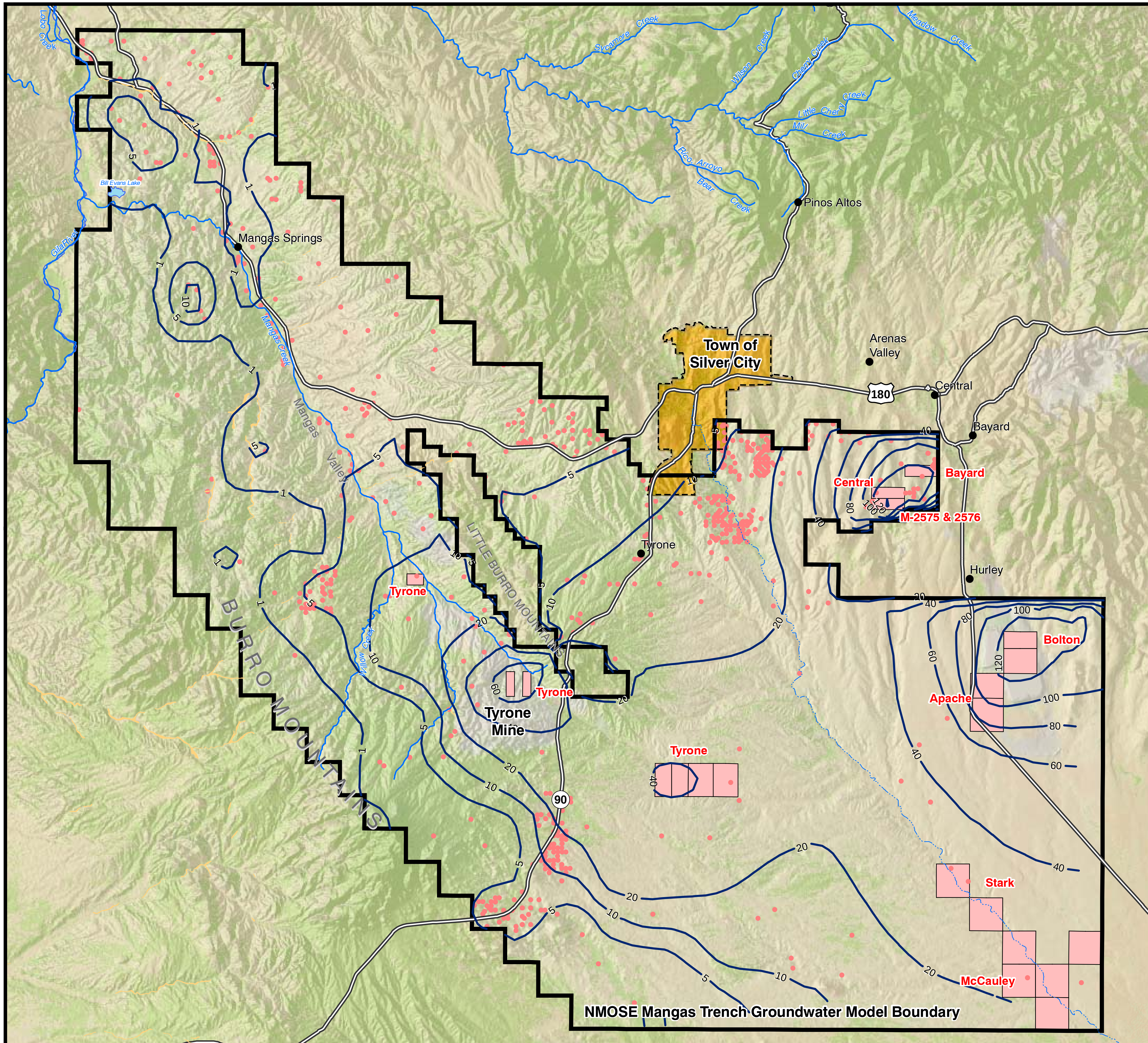


FIGURE 14
PROJECTED GROWTH OF TOWN WATER SYSTEM DEMAND





MakeWEL_RF.xls
DMR
2/3/2006



EXPLANATION

DRAWDOWN (FT)

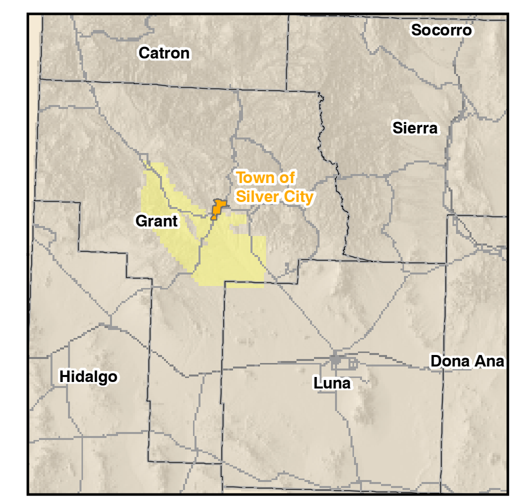
Tyrone = Wellfield Name

MODEL CELL WITH SIMULATED PUMPING

LOCATIONS OF SIMULATED DOMESTIC AND OTHER 72-12-1 WELLS -- Adapted from NMOSE digital data.

0 5 Miles

Map Projection: New Mexico West, NAD83.



N
W E
S

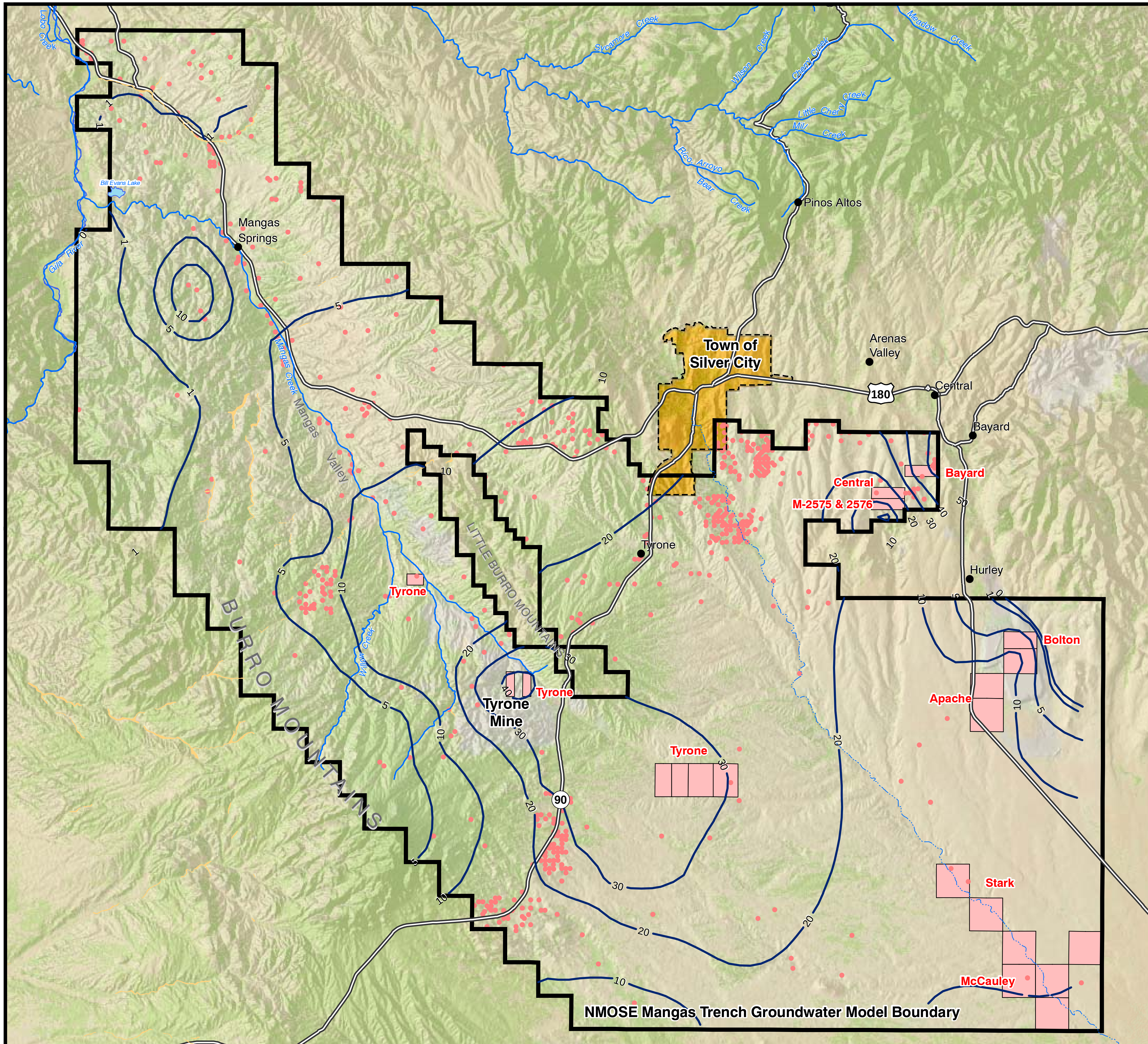
TOWN OF SILVER CITY / WATER USE

HISTORICAL AQUIFER IMPACT FROM OTHER WATER USES

DATE: 1/30/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE16.MXD

FIGURE 16

BALLEAU GROUNDWATER, INC.



EXPLANATION

100 DRAWDOWN (FT)

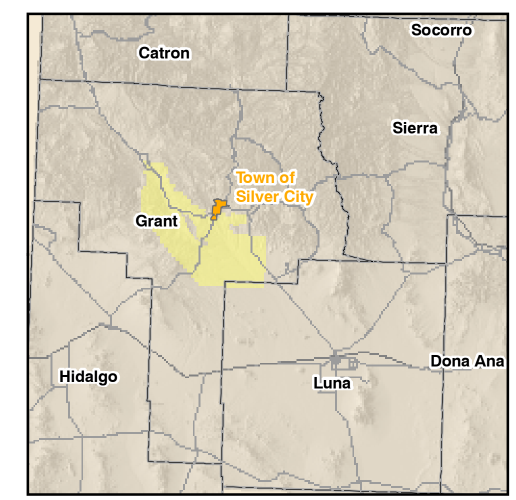
Tyrone = Wellfield Name

MODEL CELL WITH SIMULATED PUMPING

LOCATIONS OF SIMULATED DOMESTIC AND OTHER 72-12-1 WELLS -- Adapted from NMOSE digital data.

0 5 Miles

Map Projection: New Mexico West, NAD83.



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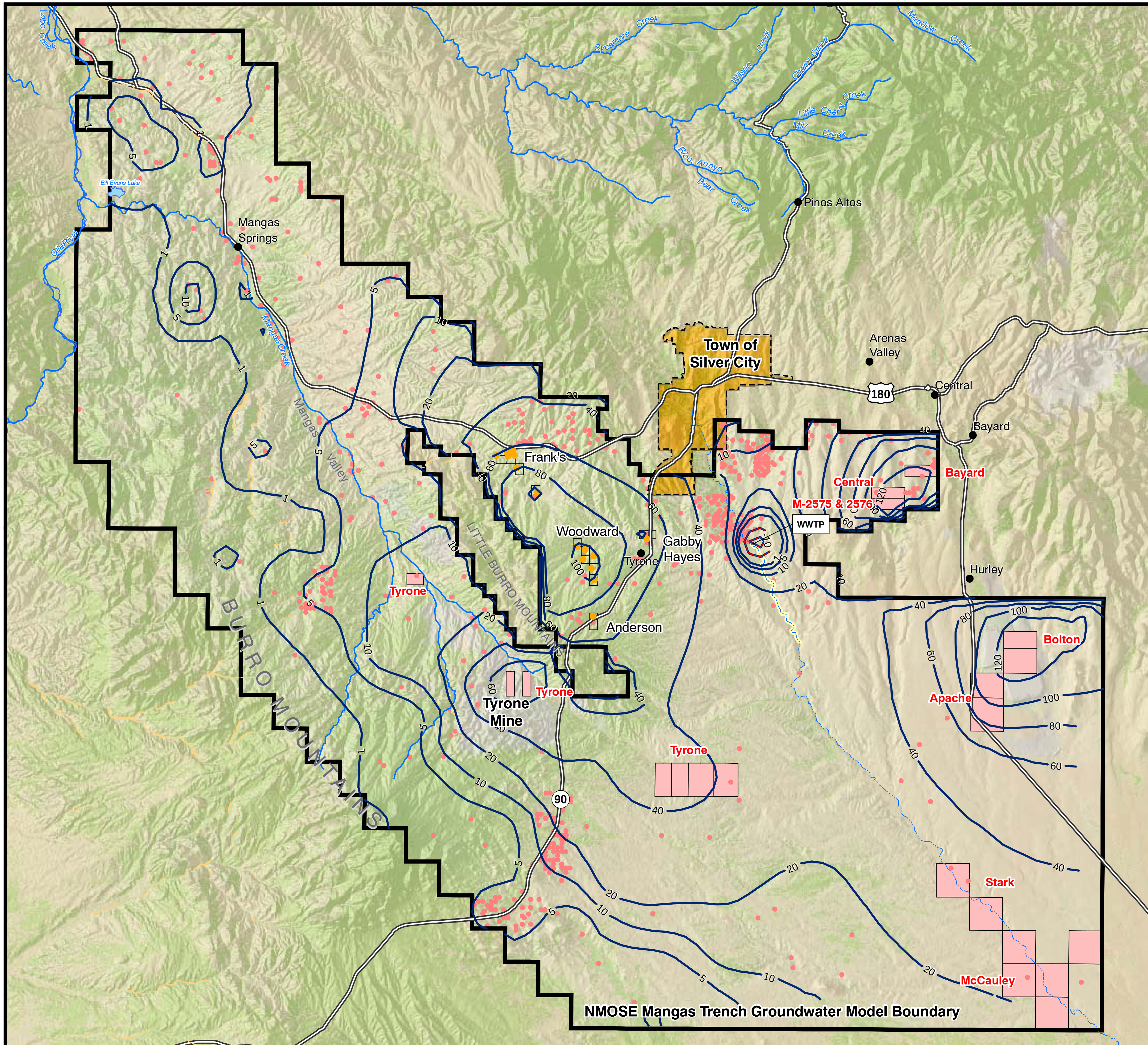
TOWN OF SILVER CITY / WATER USE

FUTURE 40-YEAR AQUIFER IMPACT FROM OTHER WATER USES

DATE: 1/30/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE17.MXD

FIGURE 17

BALLEAU GROUNDWATER, INC.



EXPLANATION

BUILD-UP FROM WWTP DISCHARGE (FT)

DRAWDOWN (FT)

Tyrone = Wellfield Name

MODEL CELL WITH SIMULATED PUMPING

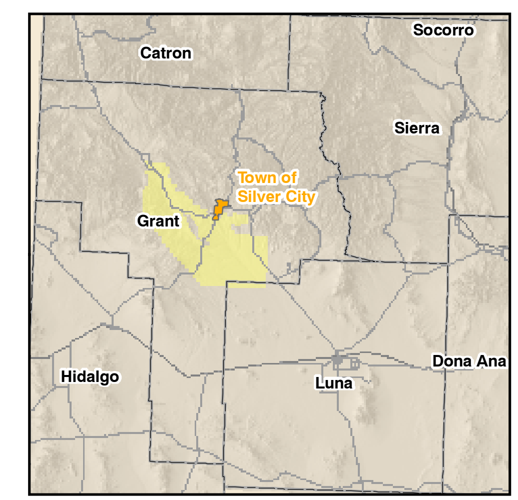
LOCATIONS OF SIMULATED DOMESTIC AND OTHER 72-12-1 WELLS -- Adapted from NMOSE digital data.

Frank's = Well or Wellfield Name

simulated TOWN OF SILVER CITY WELL LOCATIONS -- BGW GPS location data.

0 5 Miles

Map Projection: New Mexico West, NAD83.



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TOWN OF SILVER CITY / WATER USE

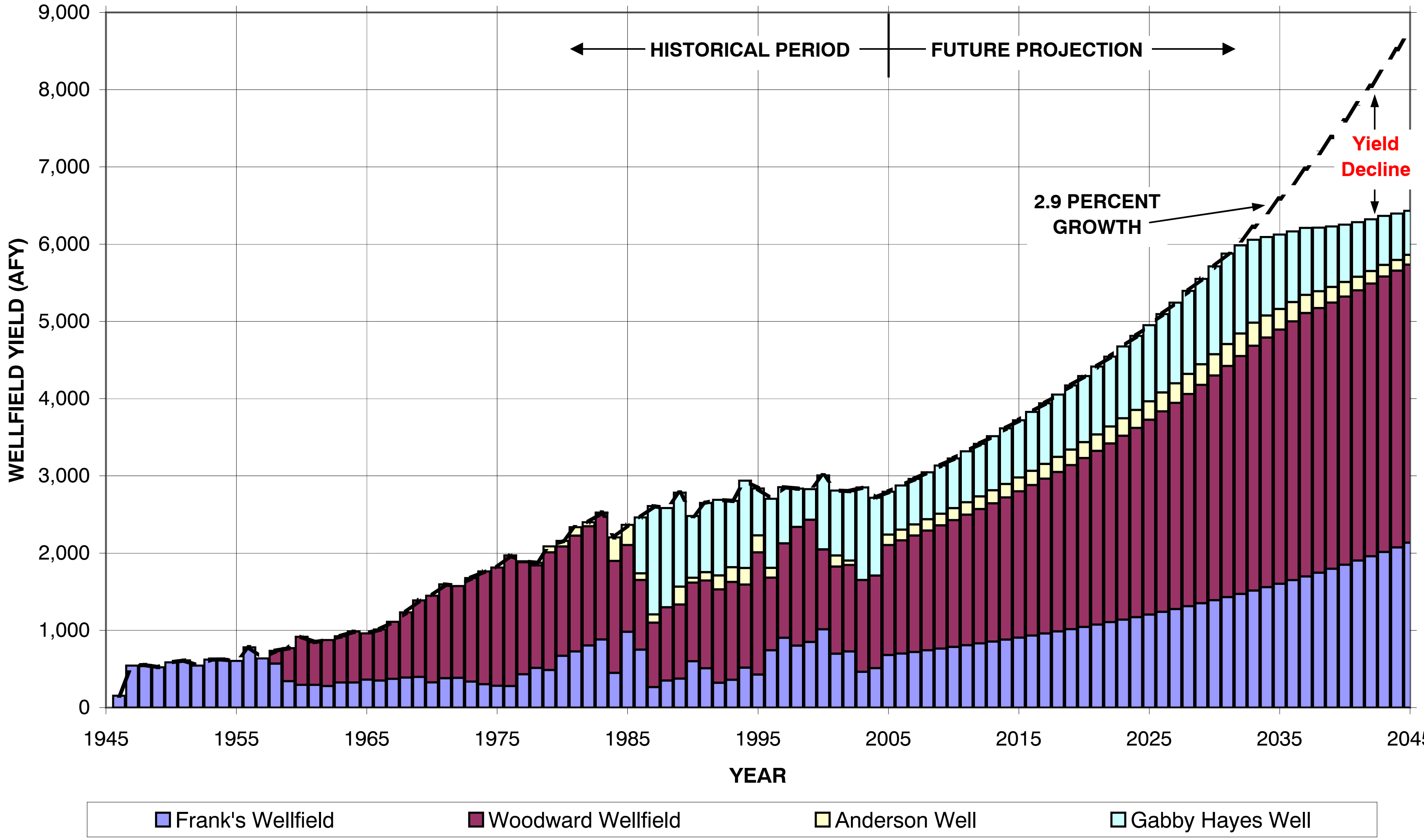
HISTORICAL AQUIFER IMPACT FROM ALL WATER USES

DATE: 1/30/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE18.MXD

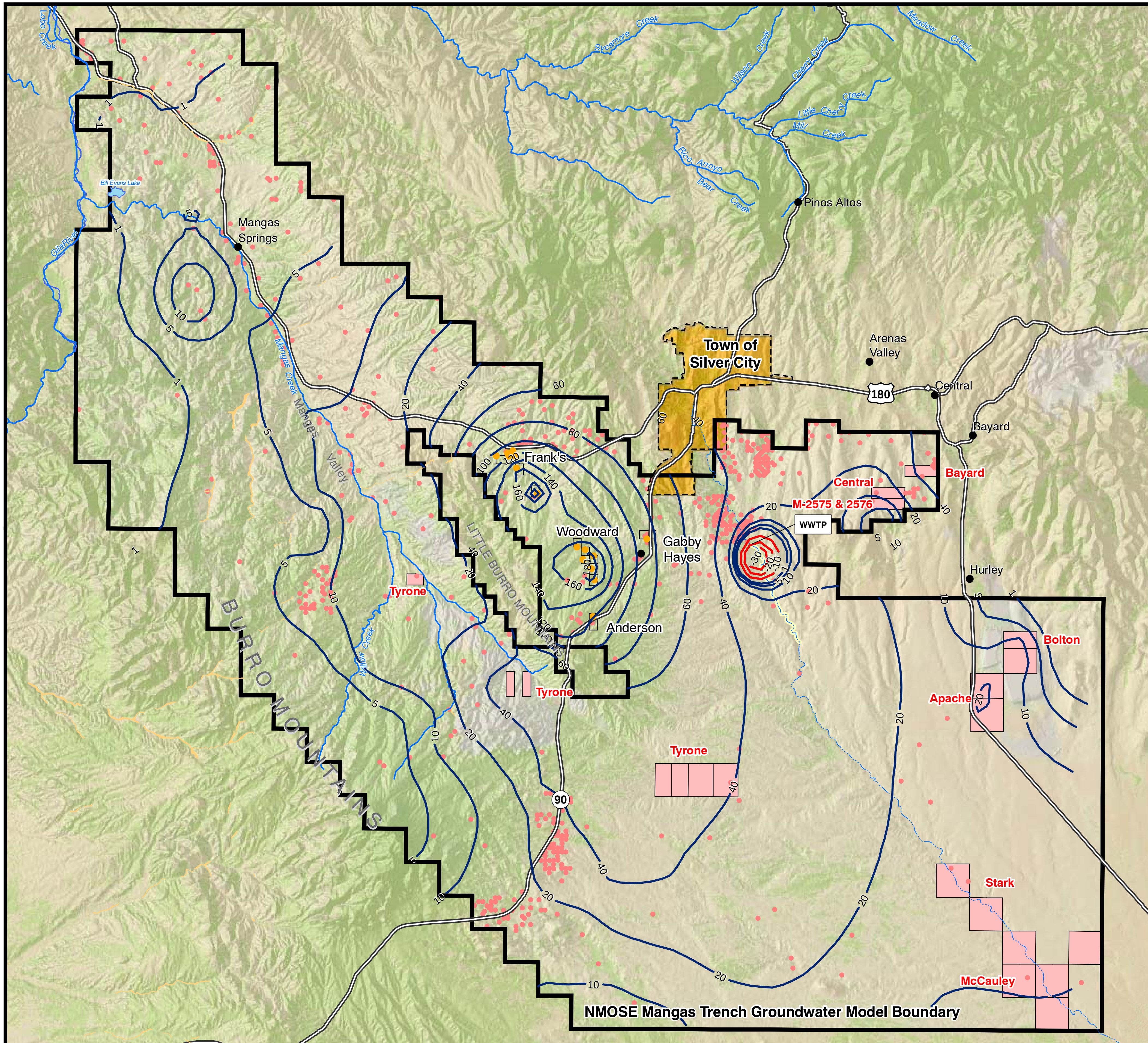
FIGURE 18

BALLEAU GROUNDWATER, INC.

FIGURE 19
YIELD FROM TOWN WELLS AS CONFIGURED WITH MAXIMUM DEMAND GROWTH



MaxGrowWellYieldHead.xls
DMR
2/3/2006

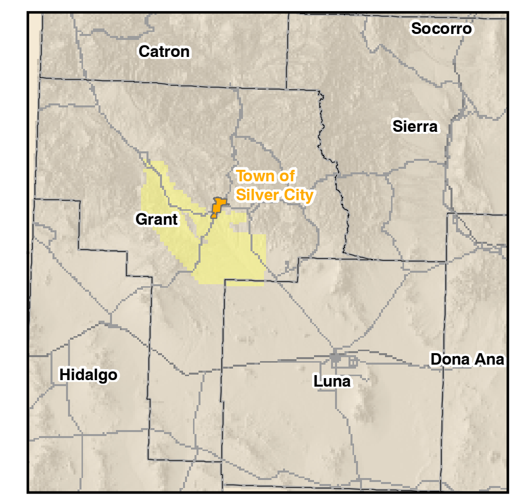


EXPLANATION

- BUILD-UP FROM WWTP DISCHARGE (FT)
- DRAWDOWN (FT)
- Tyrone = Wellfield Name
- MODEL CELL WITH SIMULATED PUMPING
- LOCATIONS OF SIMULATED DOMESTIC AND OTHER 72-12-1 WELLS -- Adapted from NMOSE digital data.
- Frank's = Well or Wellfield Name
- SIMULATED TOWN OF SILVER CITY WELL LOCATIONS -- BGW GPS location data.

0 — 5 Miles

Map Projection: New Mexico West, NAD83.



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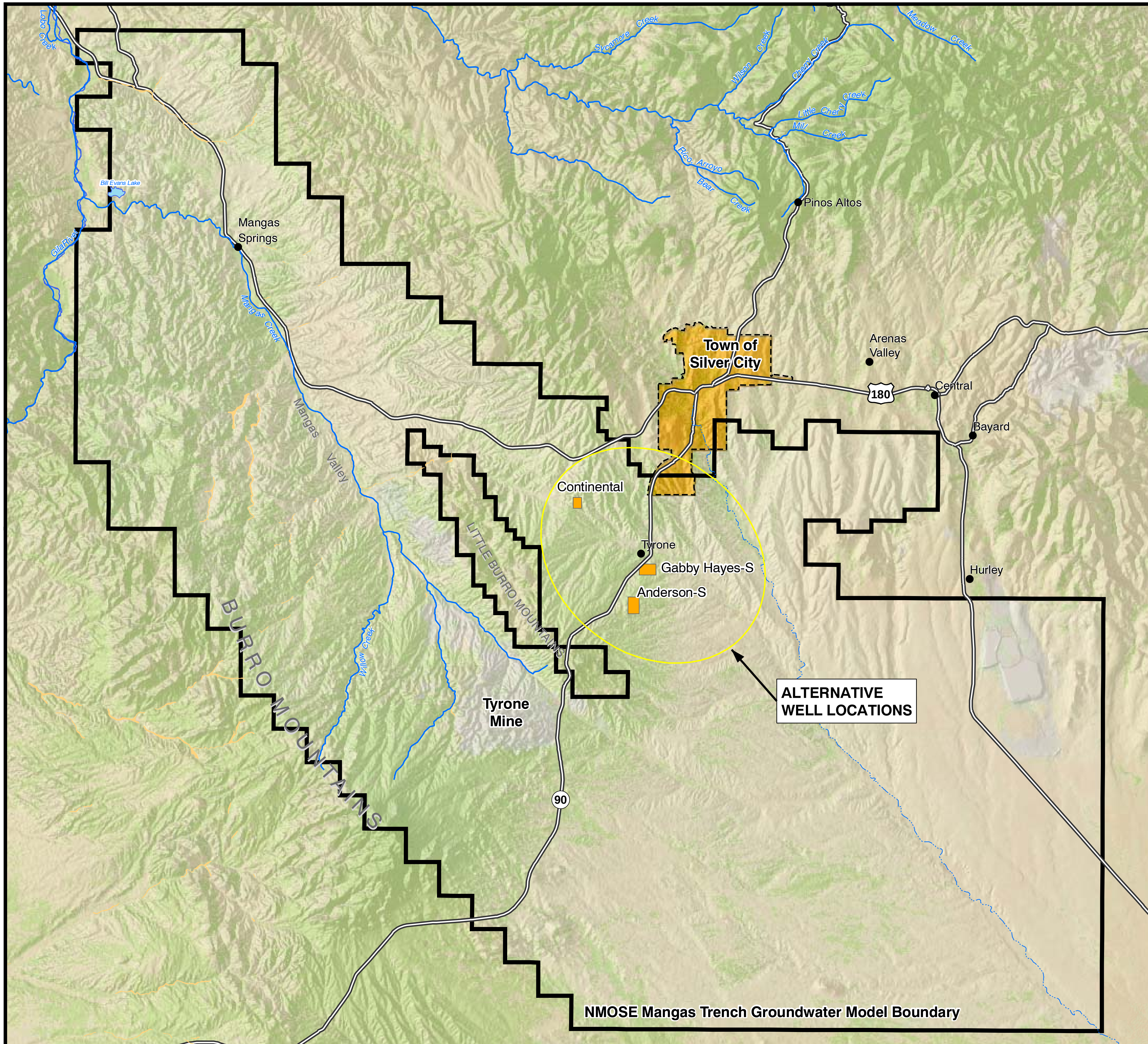
TOWN OF SILVER CITY / WATER USE

FUTURE 40-YEAR AQUIFER IMPACT FROM ALL WATER USES

DATE: 1/30/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE20.MXD

FIGURE 20

BALLEAU GROUNDWATER, INC.



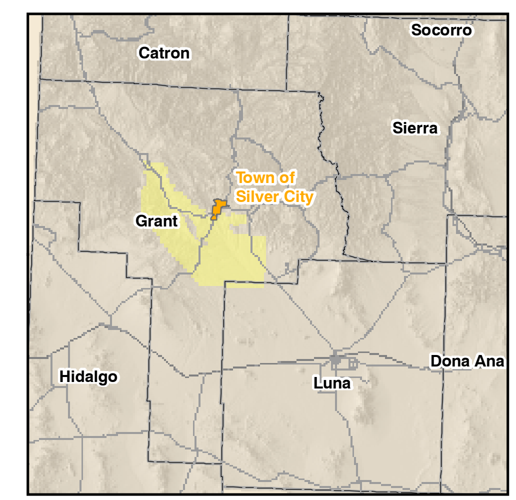
EXPLANATION

100 DRAWDOWN (FT)

Anderson-S = Well Name
SIMULATED TOWN OF SILVER CITY ALTERNATIVE WELL LOCATIONS

0 — 5 Miles

Map Projection: New Mexico West, NAD83.



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W E
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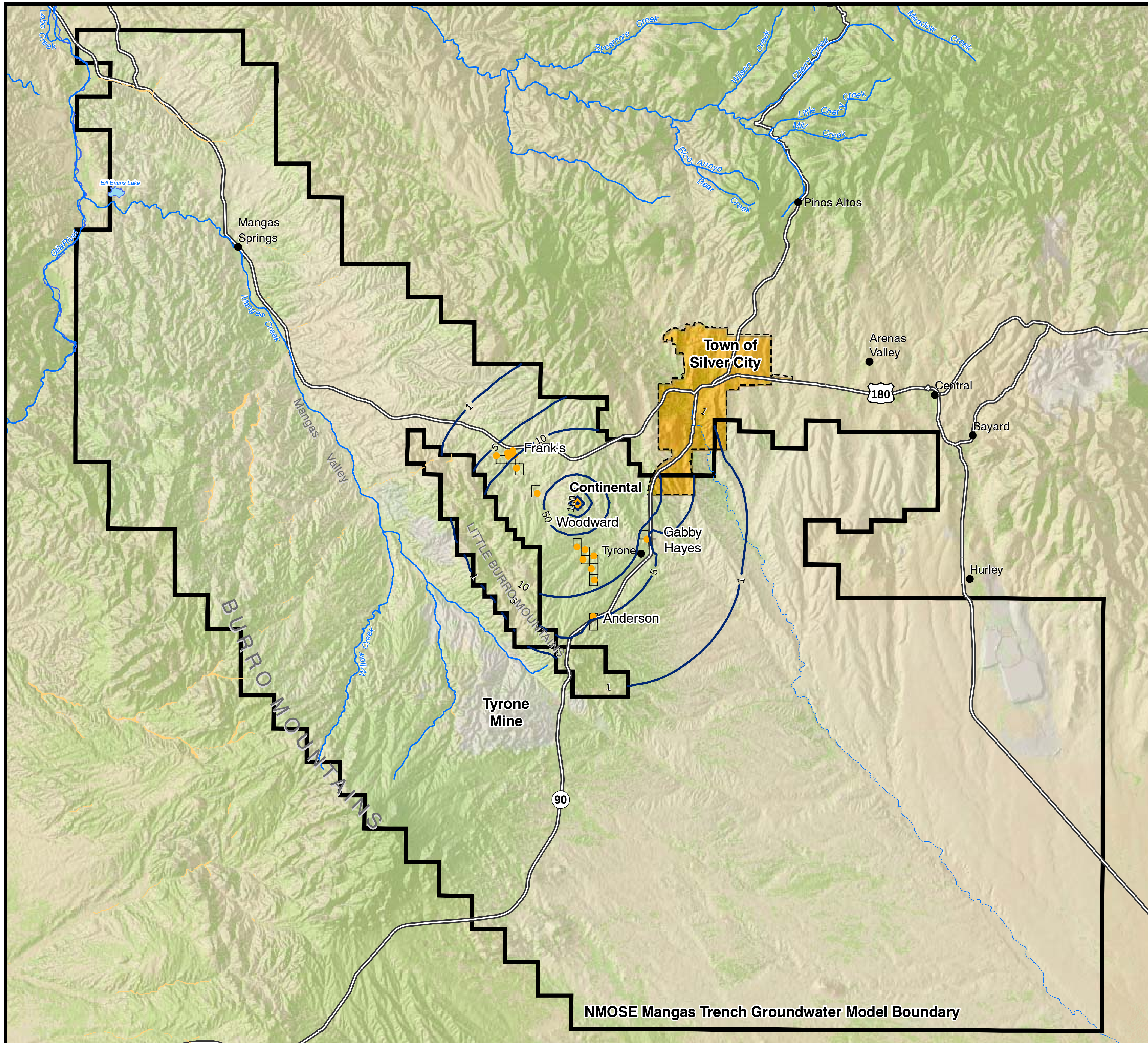
TOWN OF SILVER CITY / WATER USE

ALTERNATIVE WELL LOCATIONS

DATE: 2/2/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE21.MXD

FIGURE 21

BALLEAU GROUNDWATER, INC.



EXPLANATION

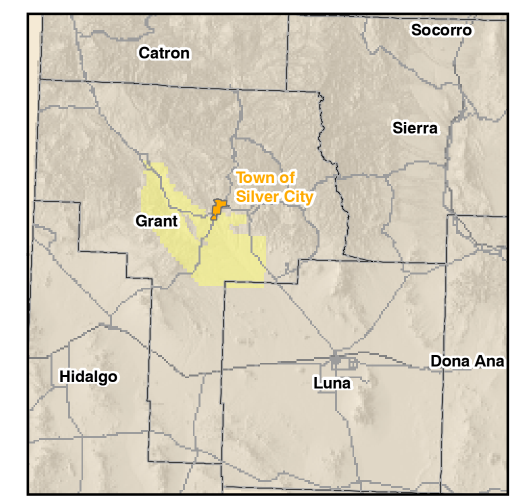
DRAWDOWN (FT)

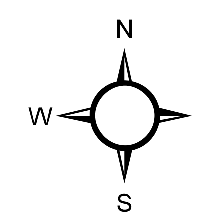
Continental = Proposed Well Name
SIMULATED TOWN OF SILVER CITY NEW WELL LOCATION

Frank's = Well or Wellfield Name
SIMULATED TOWN OF SILVER CITY WELL LOCATIONS -- BGW GPS location data.

0 5 Miles

Map Projection: New Mexico West, NAD83.





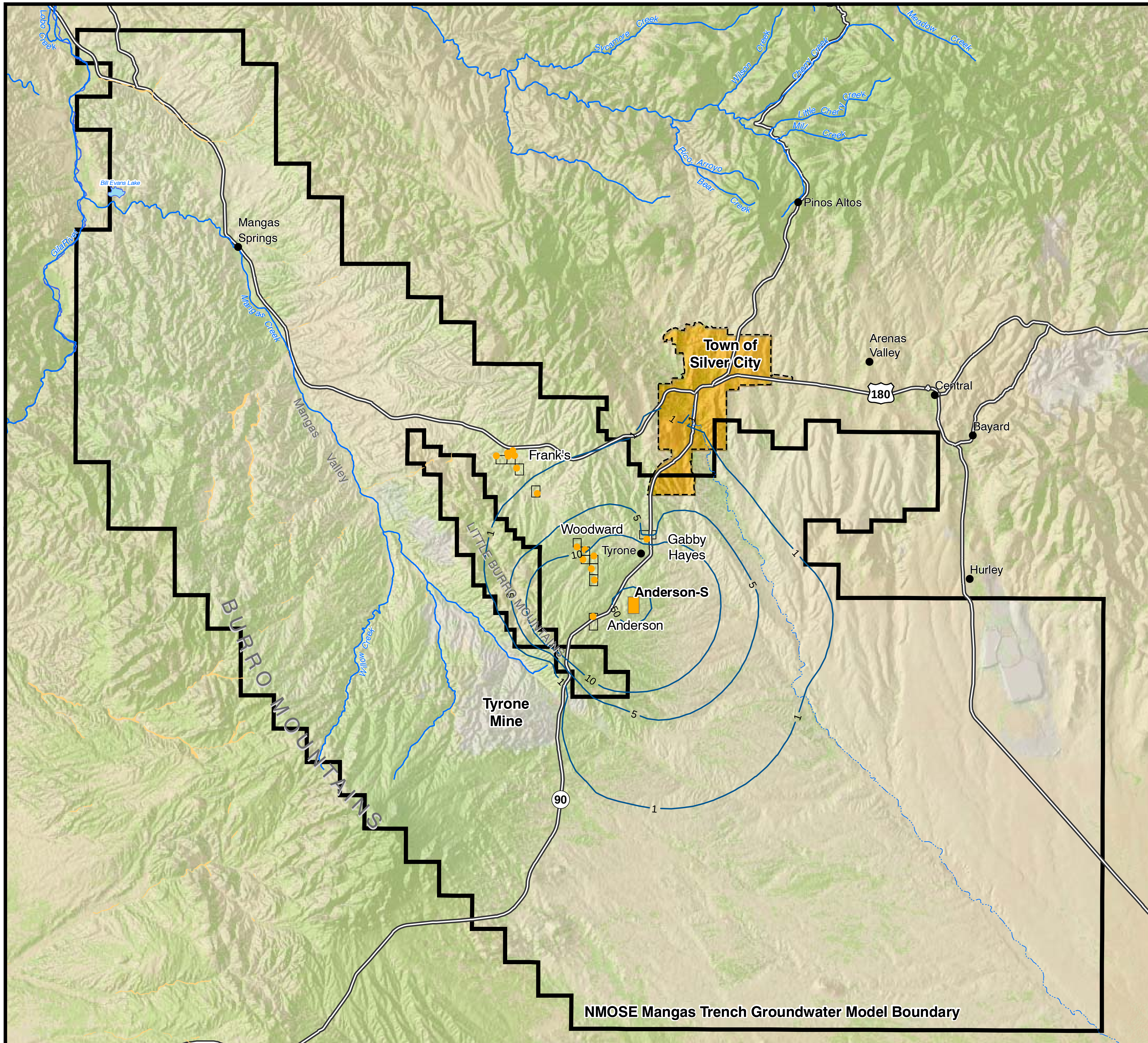
TOWN OF SILVER CITY / WATER USE

FUTURE 40-YEAR AQUIFER IMPACT FROM NEW CONTINENTAL WELL

DATE: 1/30/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE22.MXD

FIGURE 22

BALLEAU GROUNDWATER, INC.



EXPLANATION

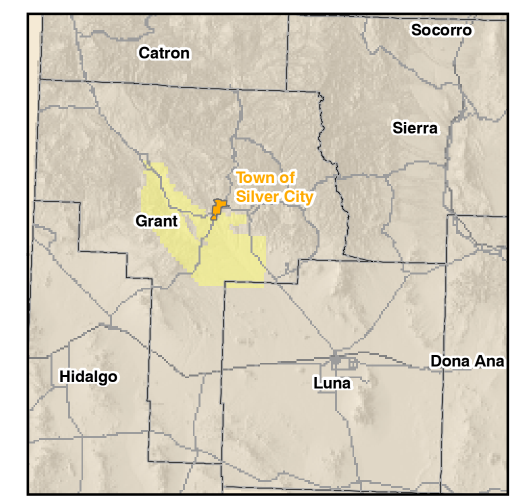
100 DRAWDOWN (FT)

Anderson = Proposed Well Name
SIMULATED TOWN OF SILVER CITY REPLACEMENT WELL LOCATION

Frank's = Well or Wellfield Name
SIMULATED TOWN OF SILVER CITY WELL LOCATIONS -- BGW GPS location data.

0 5 Miles

Map Projection: New Mexico West, NAD83.



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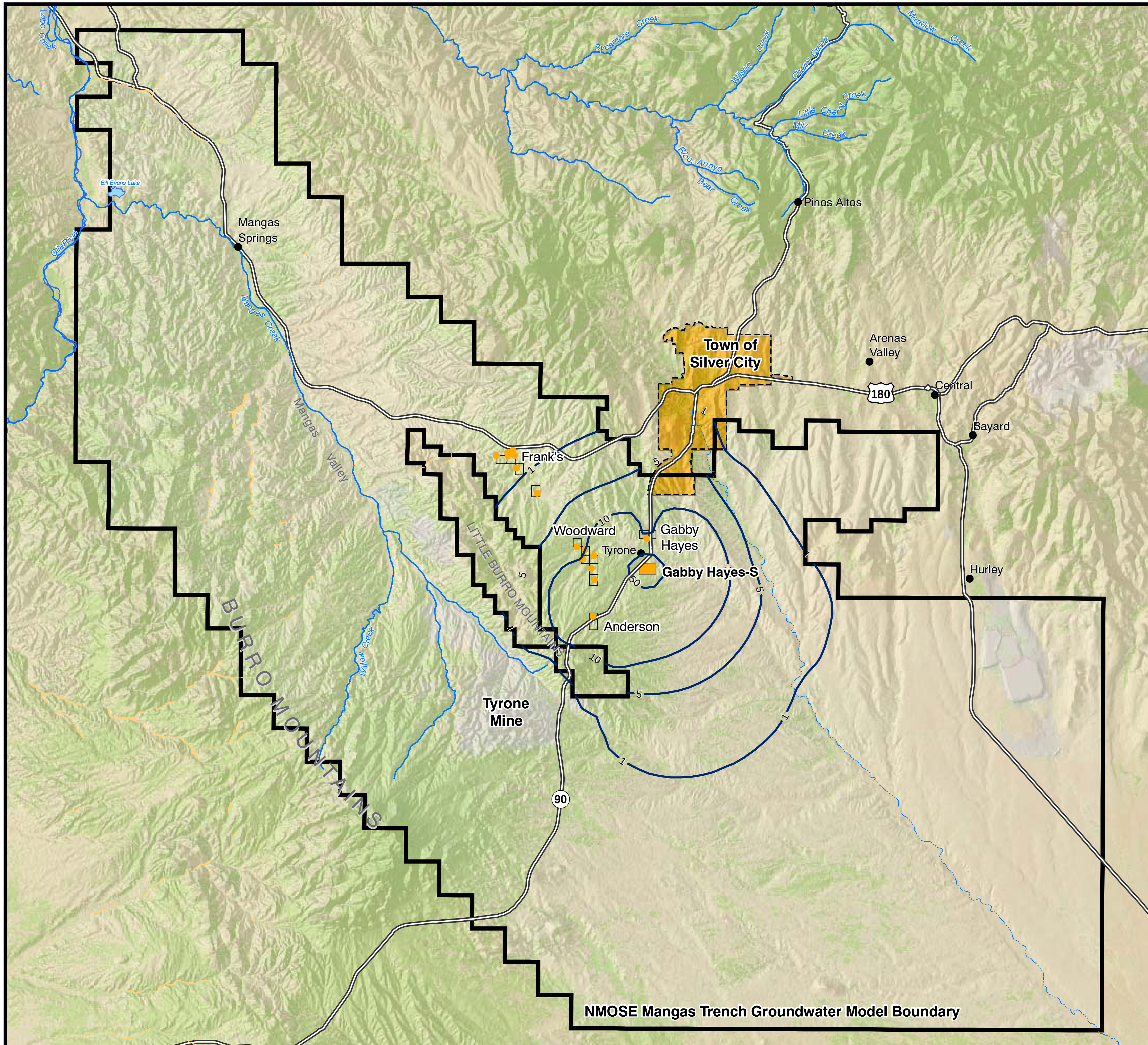
TOWN OF SILVER CITY / WATER USE

FUTURE 40-YEAR AQUIFER IMPACT FROM REPLACEMENT ANDERSON WELL

DATE: 1/30/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE23.MXD

FIGURE 23

BALLEAU GROUNDWATER, INC.



EXPLANATION

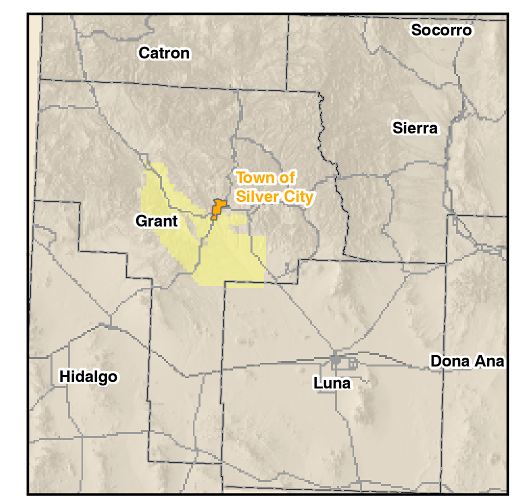
DRAWDOWN (FT)

Gabby Hayes-S = Proposed Well Name
SIMULATED TOWN OF SILVER CITY REPLACEMENT WELL LOCATION

Frank's = Well or Wellfield Name
SIMULATED TOWN OF SILVER CITY WELL LOCATIONS -- BGW GPS location data.

0 5 Miles

Map Projection: New Mexico West, NAD83.



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W E
S

TOWN OF SILVER CITY /
WATER USE

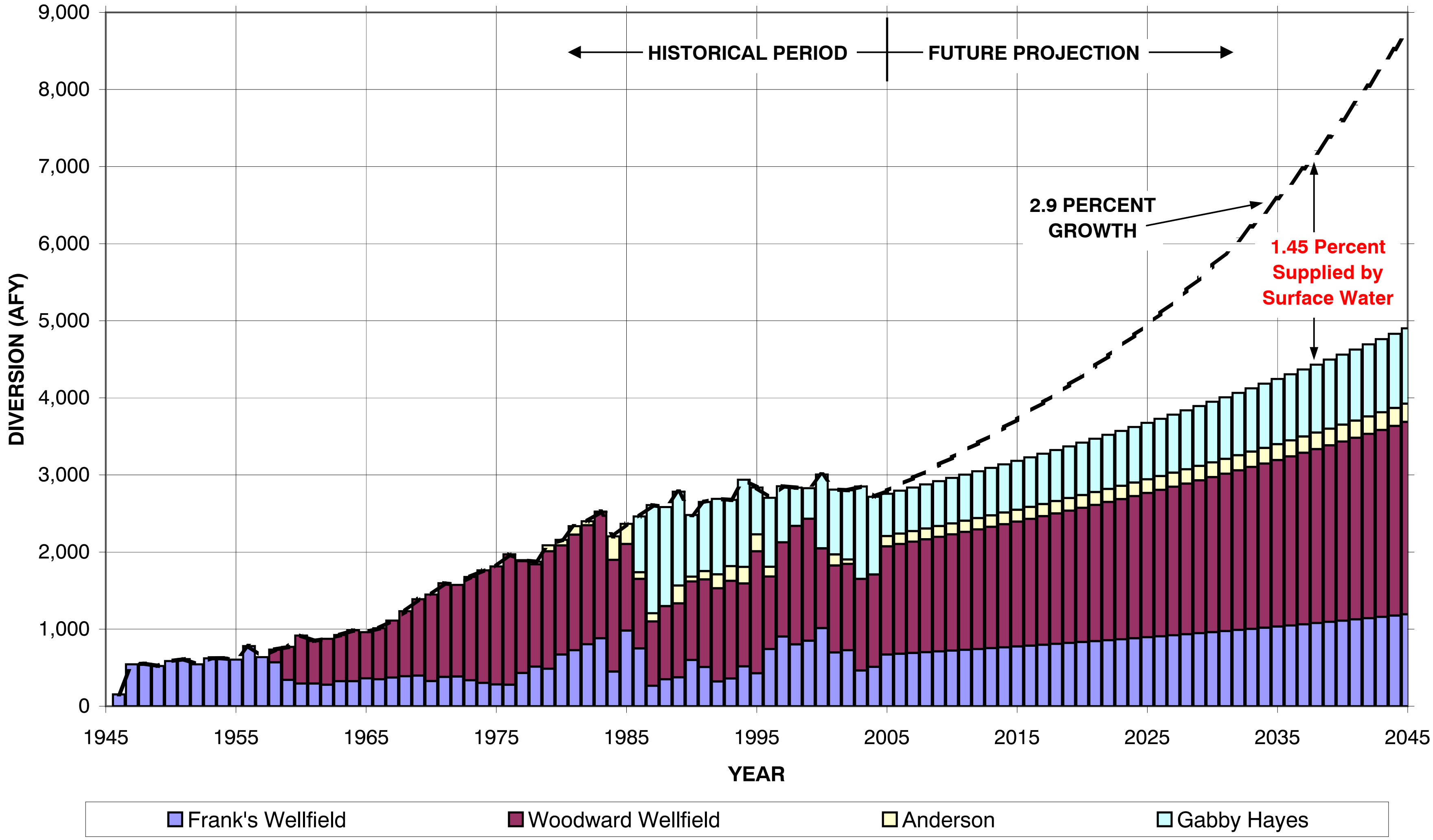
FUTURE 40-YEAR AQUIFER IMPACT FROM REPLACEMENT GABBY HAYES WELL

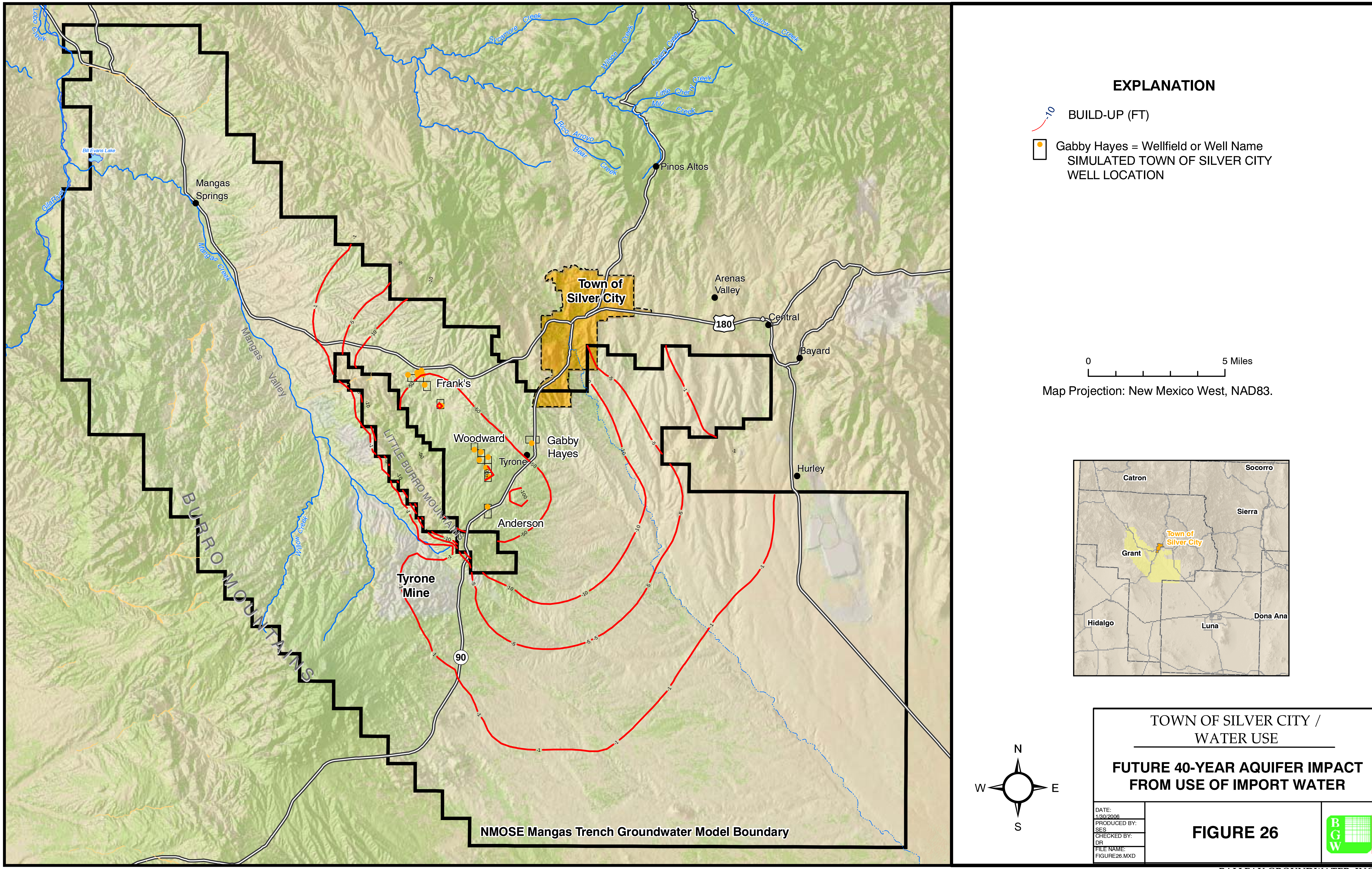
DATE: 1/30/2006
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIGURE24.MXD

FIGURE 24

BALLEAU GROUNDWATER, INC.

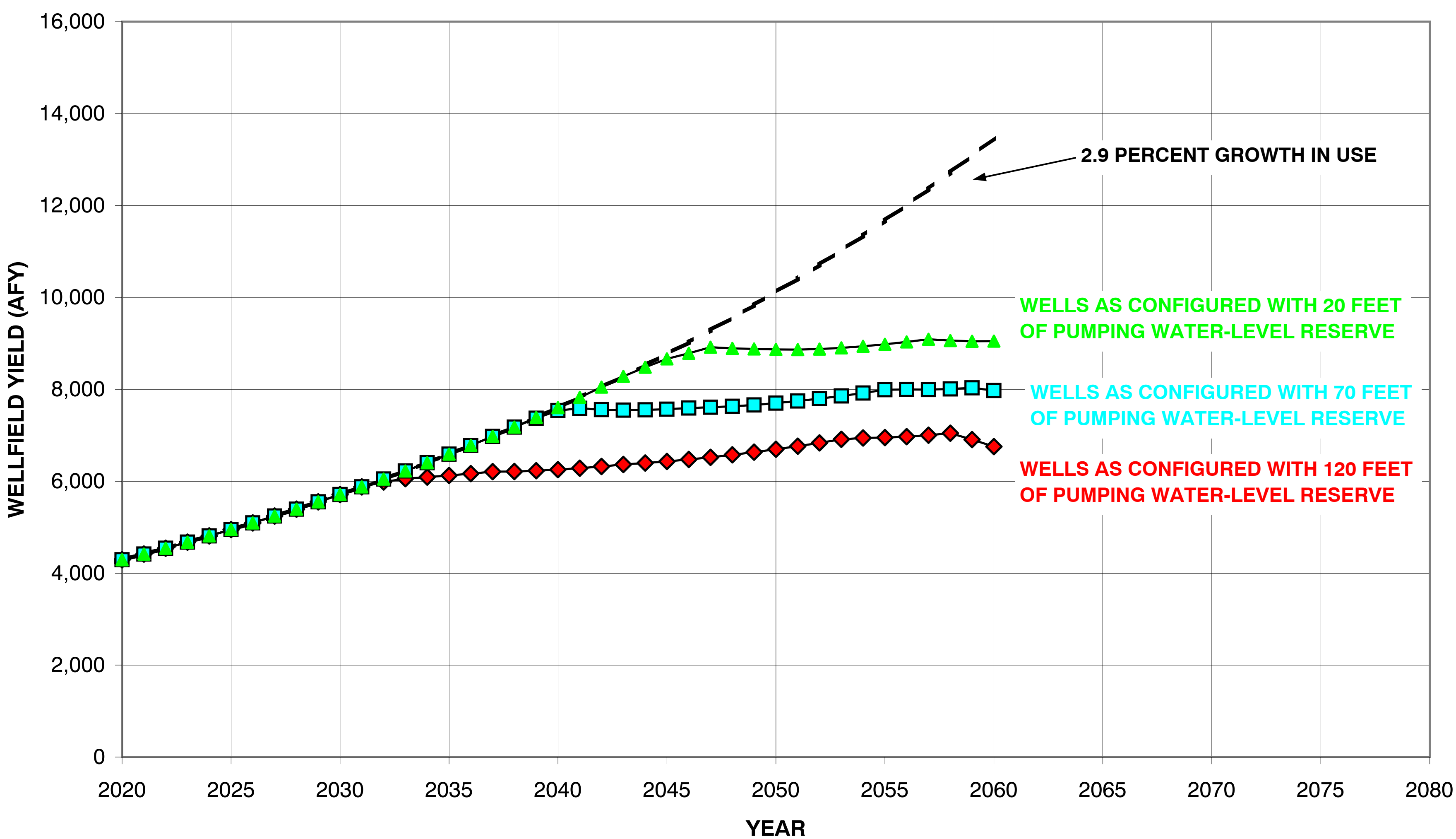
FIGURE 25
YIELD FROM EXISTING WELLS COMBINED WITH USE OF IMPORTED WATER

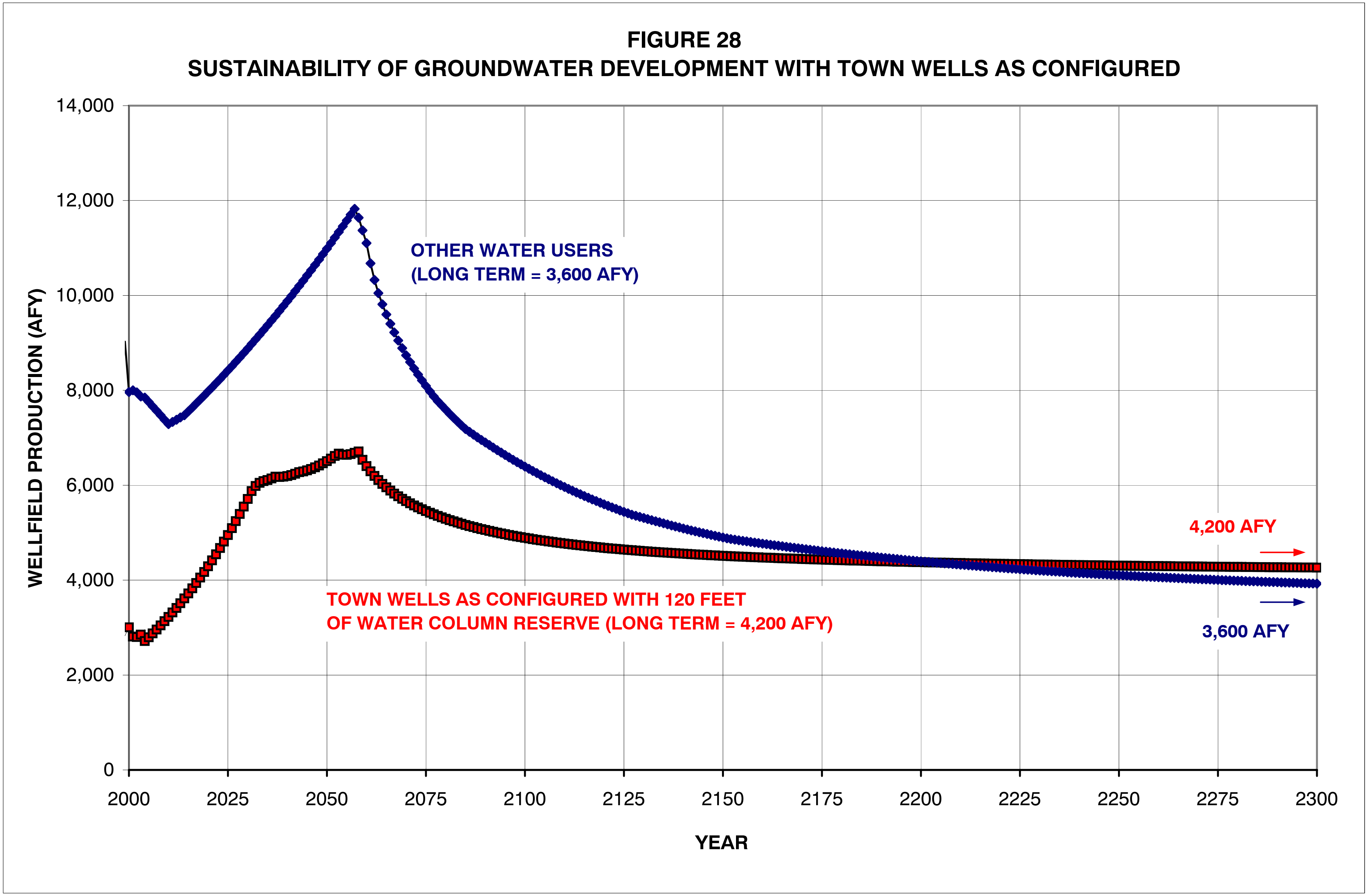




BALLEAU GROUNDWATER, INC.

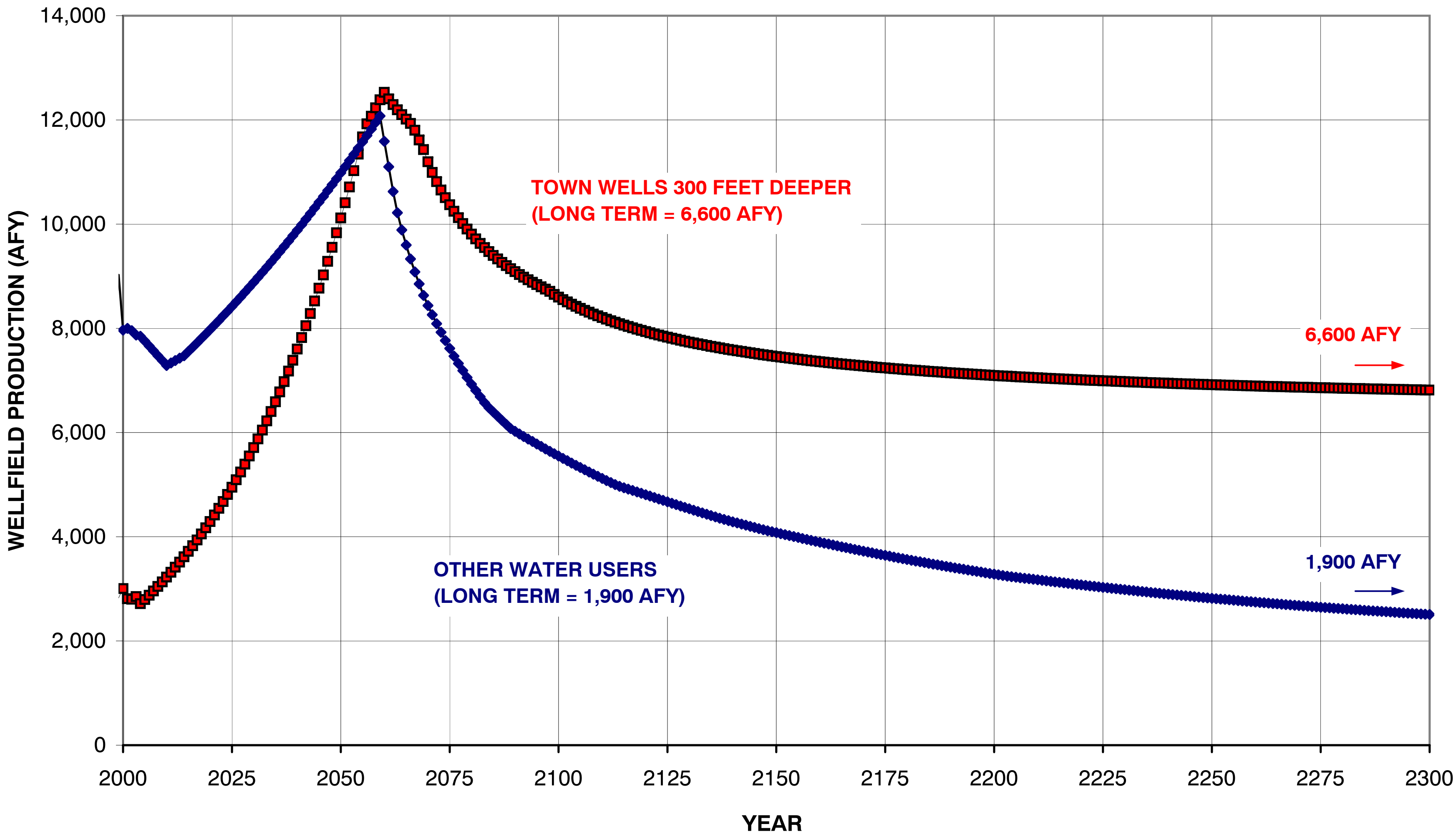
FIGURE 27
SENSITIVITY OF TOWN WELLFIELD YIELD TO DEPTH OF PUMP SETTING





SusYield2059Budget.xls
DMR
2/3/2006

FIGURE 29
SUSTAINABILITY OF GROUNDWATER DEVELOPMENT WITH TOWN WELLS DEEPENED

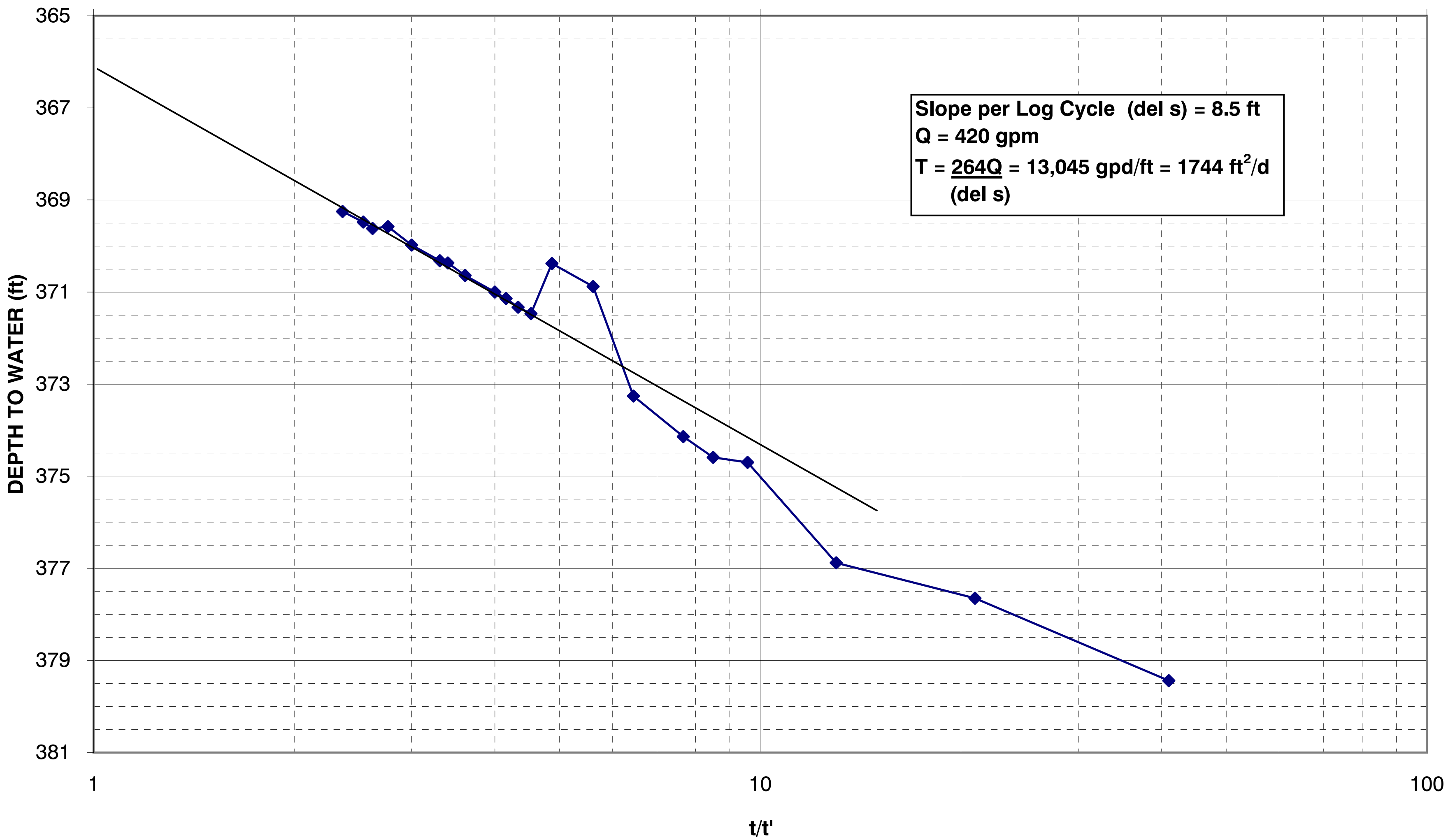


SusYield2_2060Budget.xls
DMR
2/3/2006

APPENDIX A

RECOVERY DATA COLLECTED DURING SUMMER 2002
FIELD SURVEY OF TOWN WELLS

FIGURE A1
PLOT OF RESIDUAL DRAWDOWN AT FRANK'S 6



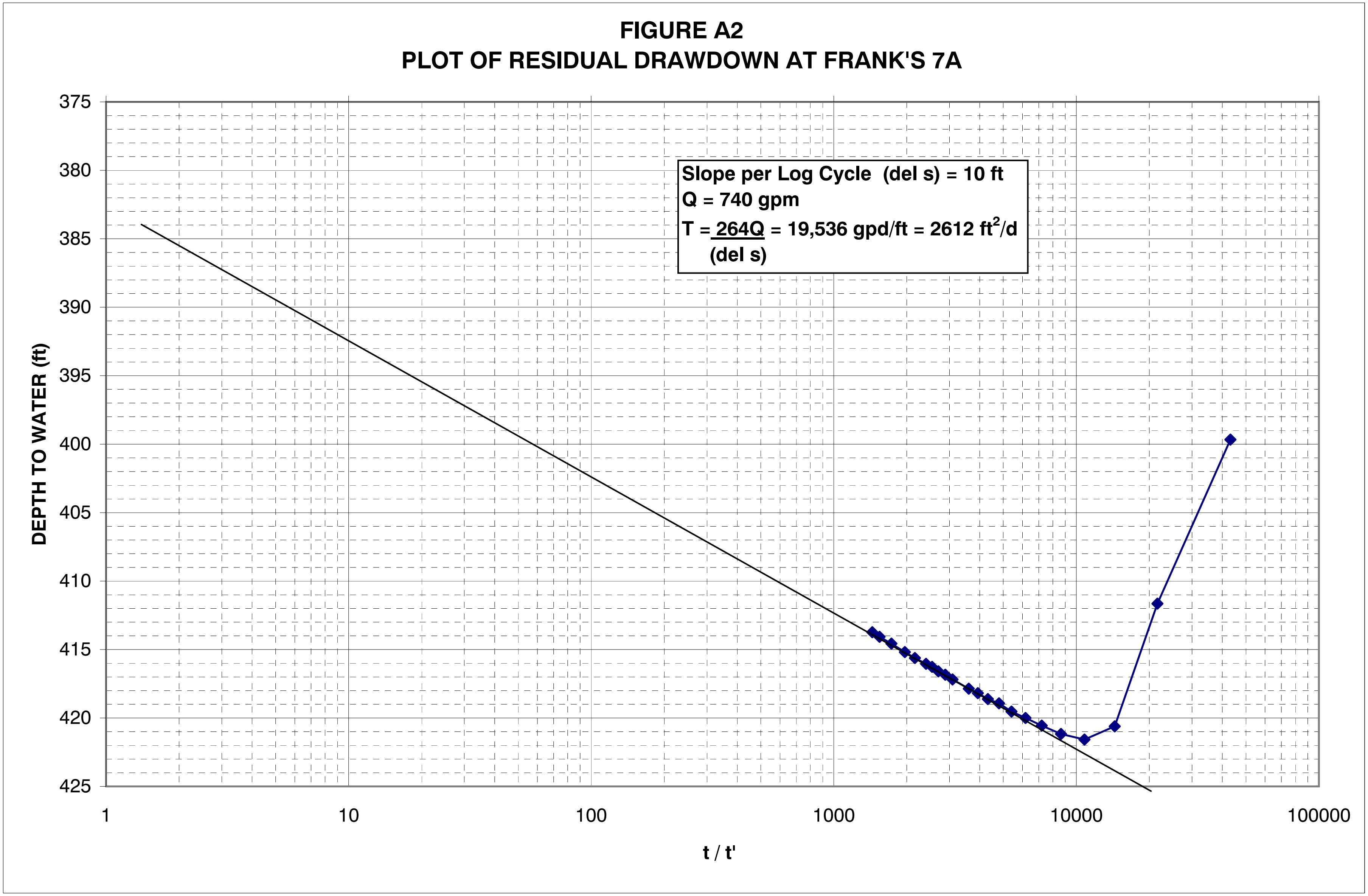


FIGURE A2
PLOT OF RESIDUAL DRAWDOWN AT FRANK'S 7A
Slope per Log Cycle (del s) = 10 ft
Q = 740 gpm
T = 264Q = 19,536 gpd/ft = 2612 ft2/d
(del s)
DEPTH TO WATER (ft)
375
380
385
390
395
400
405
410
415
420
425
1
10
100
1000
10000
100000
t / t'

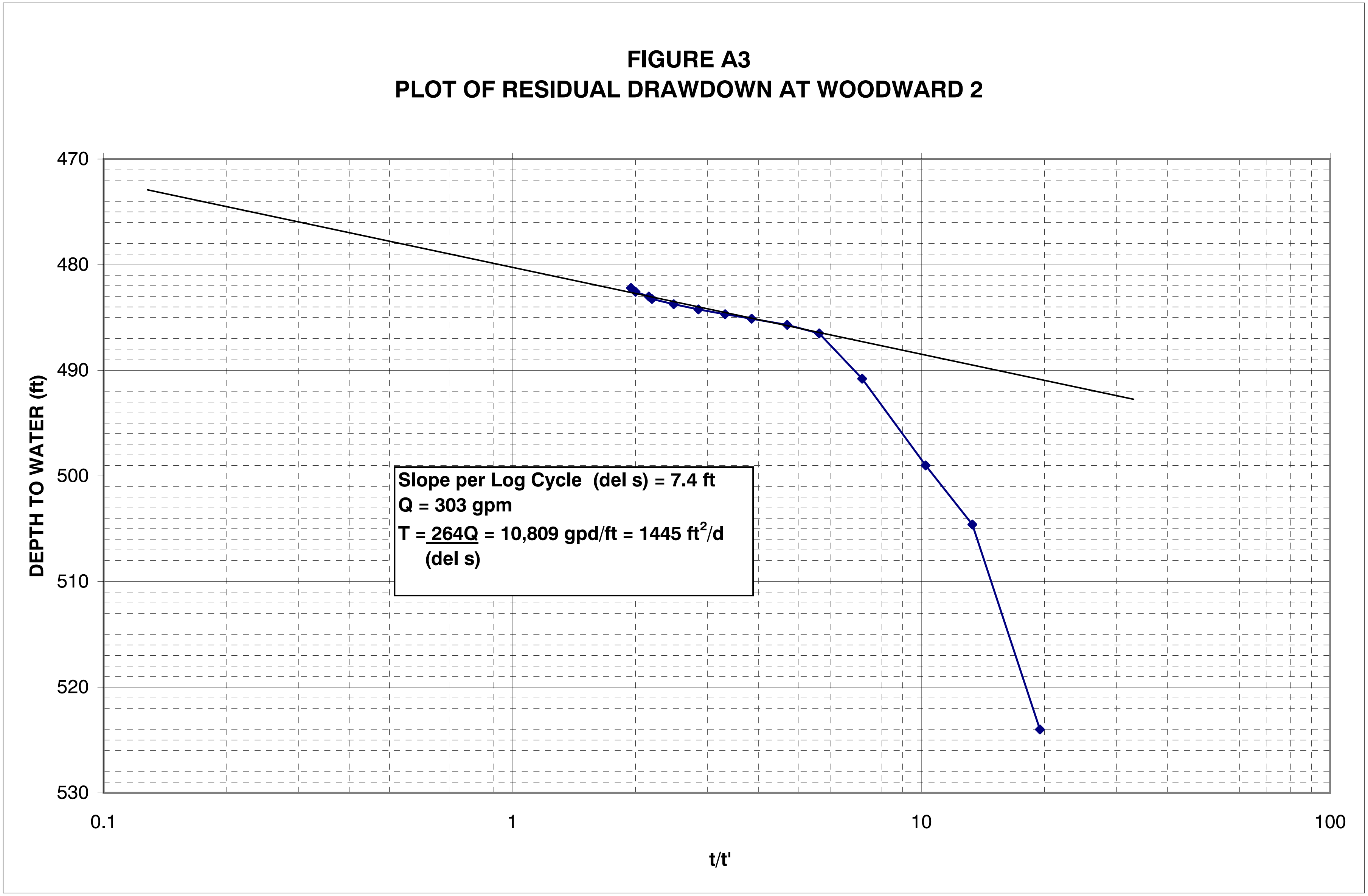


FIGURE A3
PLOT OF RESIDUAL DRAWDOWN AT WOODWARD 2
DEPTH TO WATER (ft)
470
480
490
500
510
520
530
0.1
1
10
100
t/t'
Slope per Log Cycle (del s) = 7.4 ft
Q = 303 gpm
T = 264Q = 10,809 gpd/ft = 1445 ft2/d
(del s)

FIGURE A4
PLOT OF RESIDUAL DRAWDOWN AT WOODWARD 4

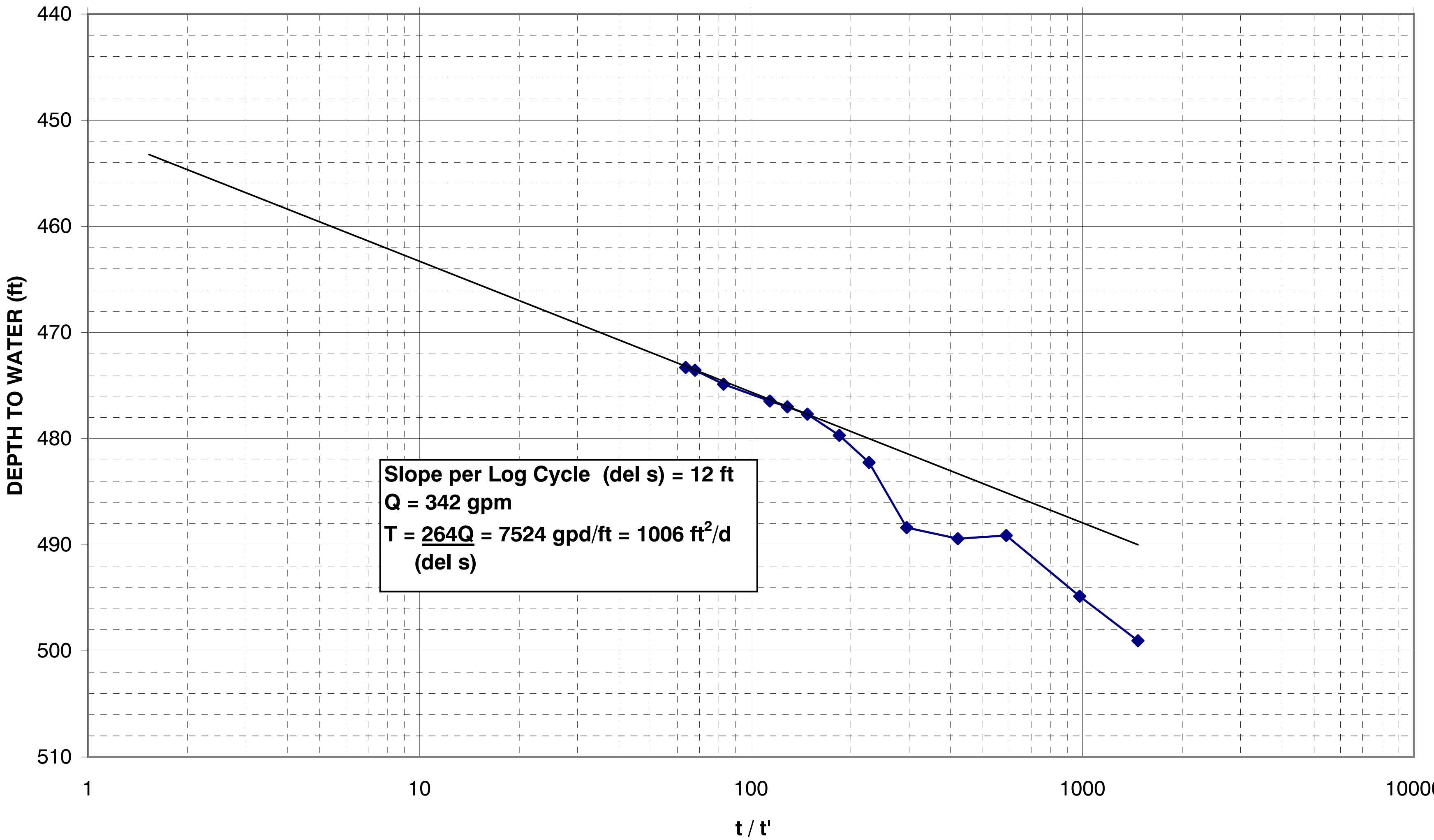


FIGURE A5
PLOT OF RESIDUAL DRAWDOWN AT WOODWARD 6

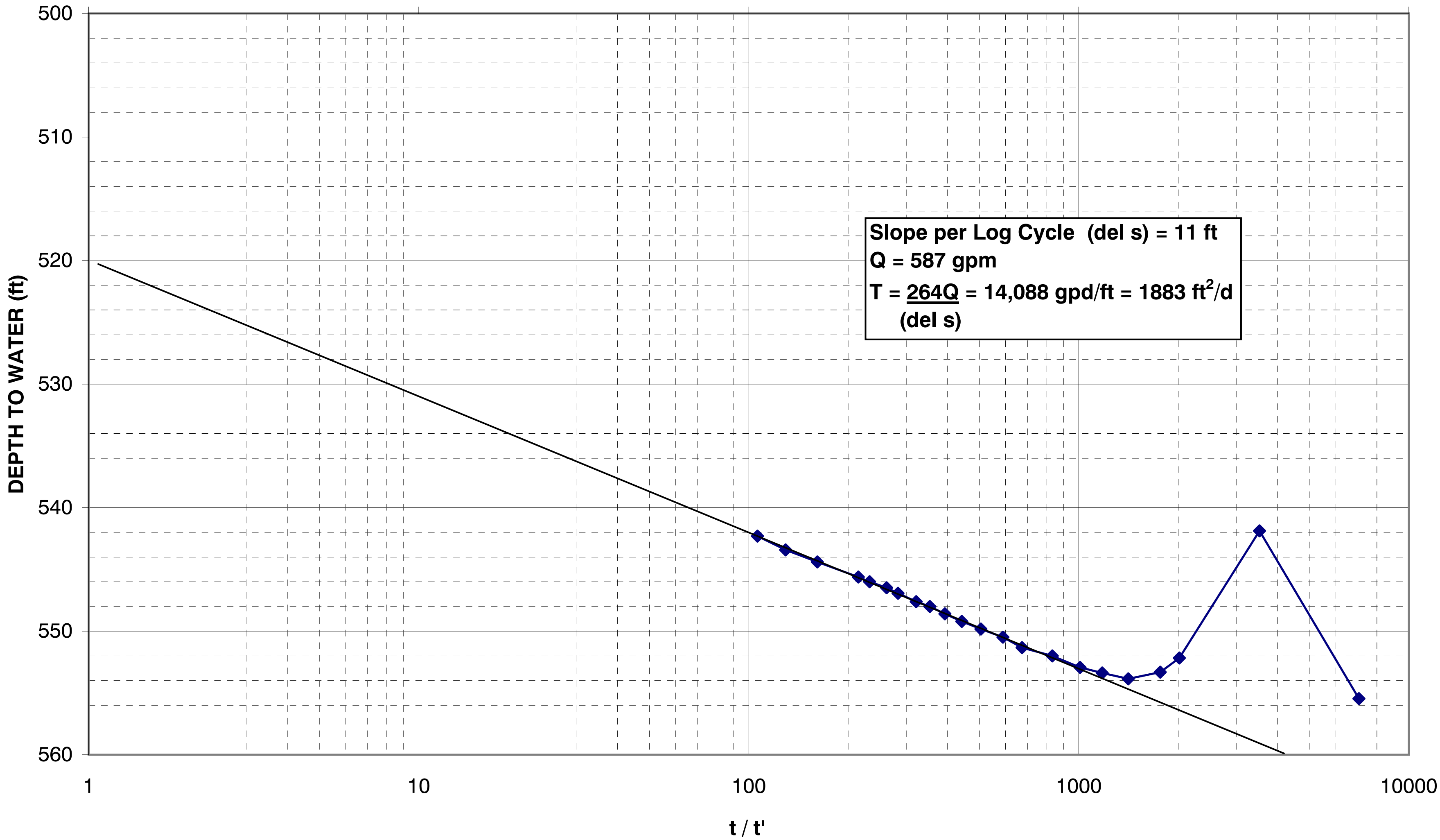
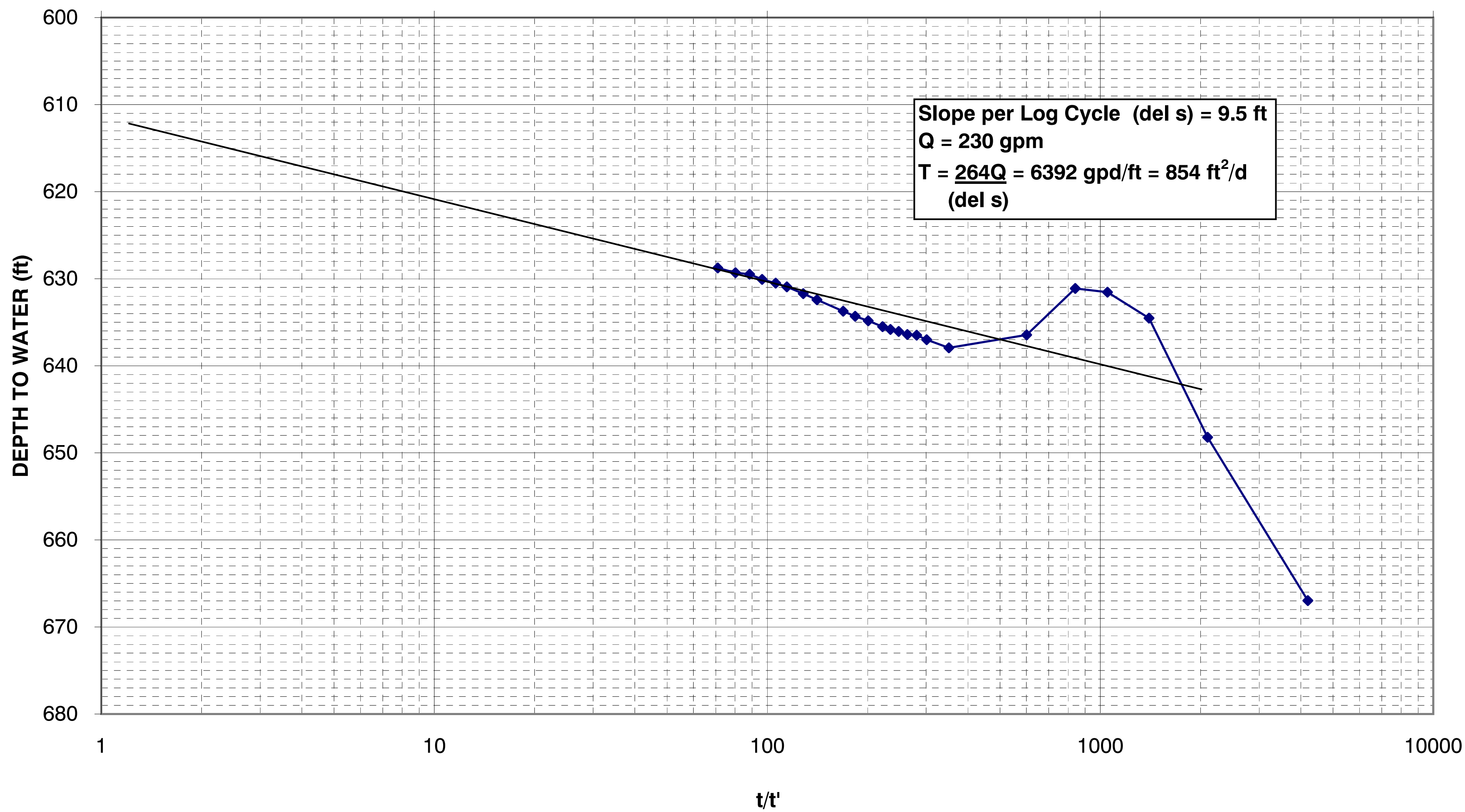


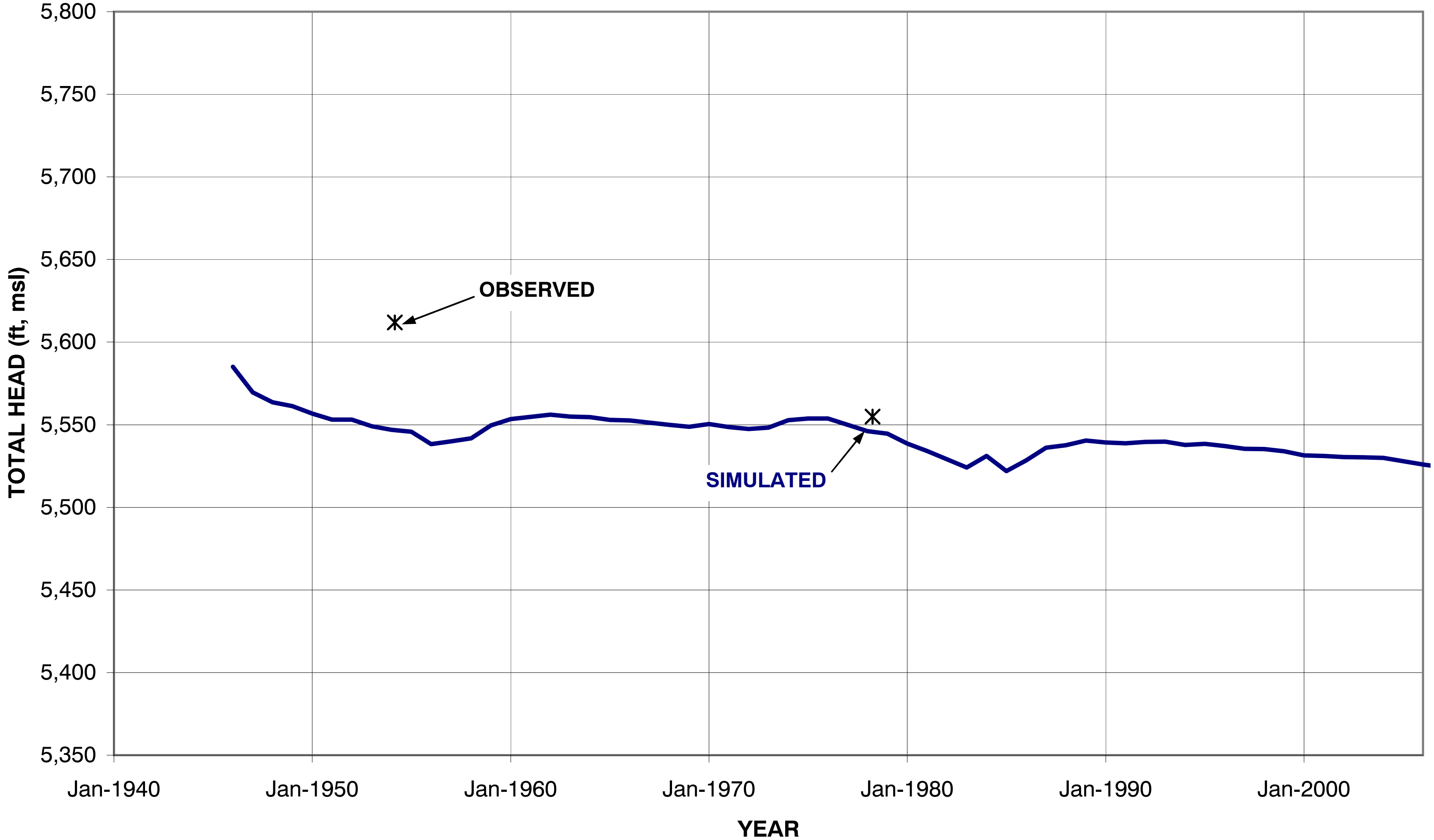
FIGURE A6
PLOT OF RESIDUAL DRAWDOWN AT ANDERSON WELL

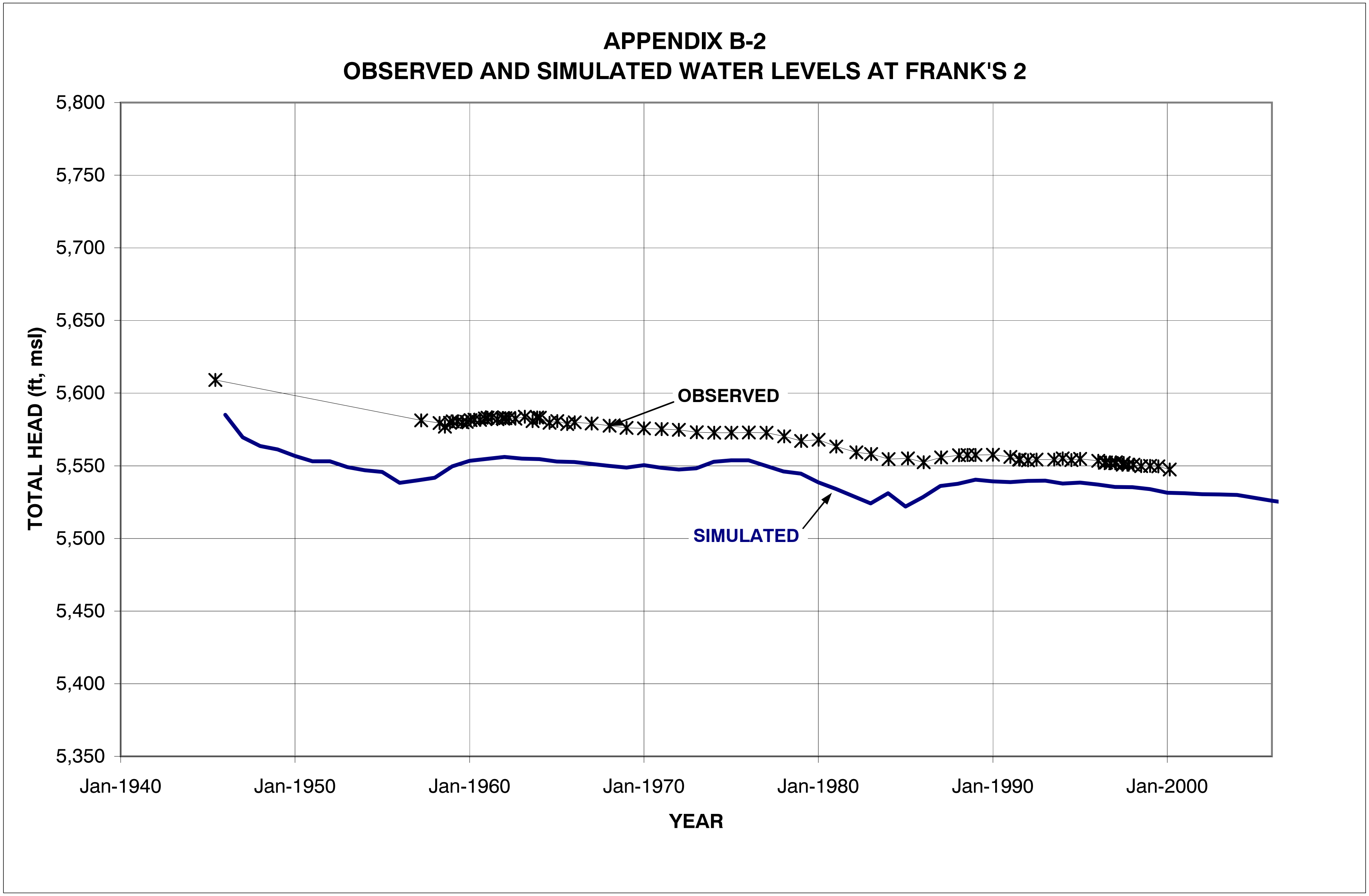


APPENDIX B

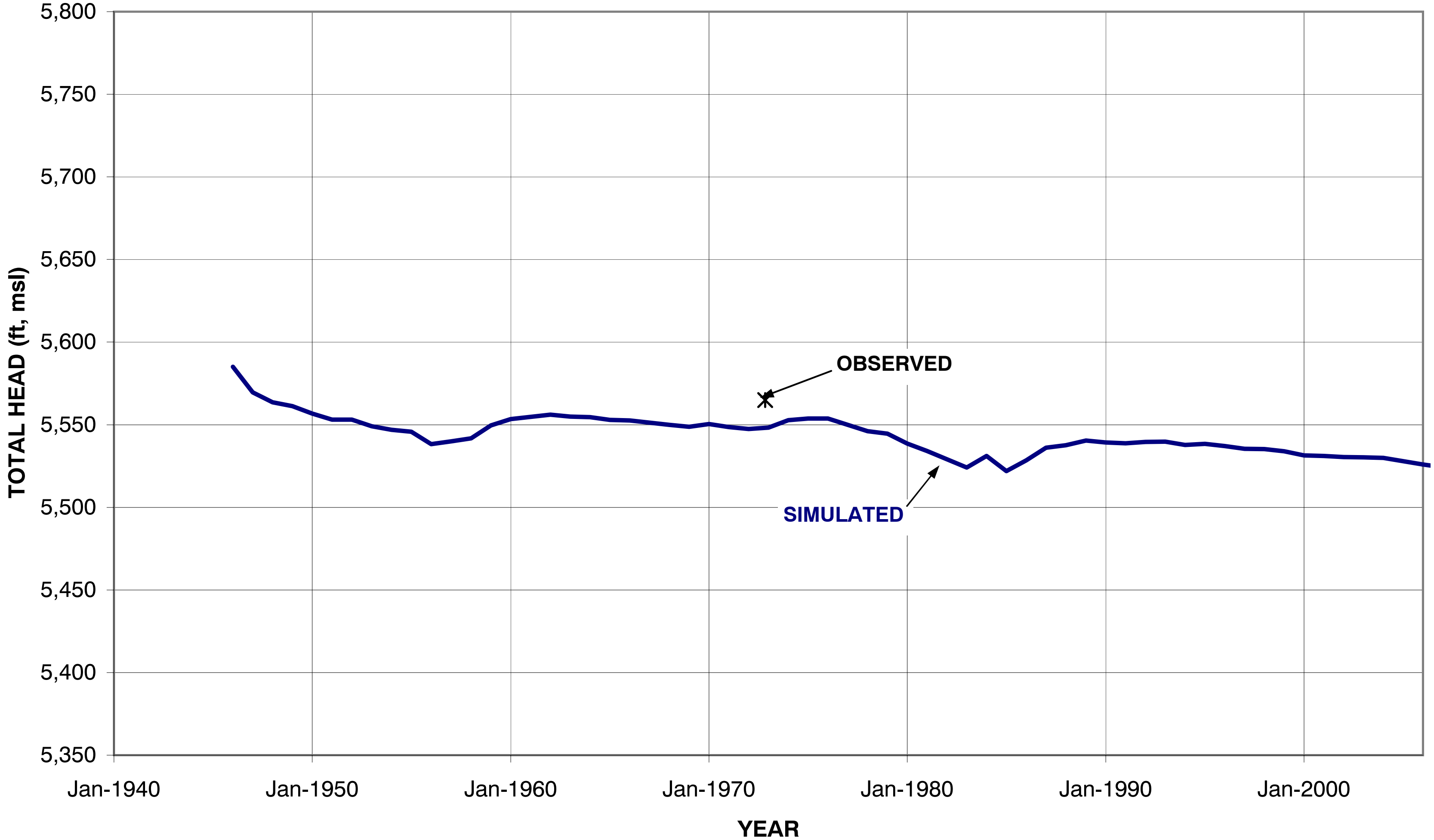
OSE MODEL HYDROGRAPHS OF WATER LEVELS
IN WELLS OPERATED BY TOWN OF SILVER CITY

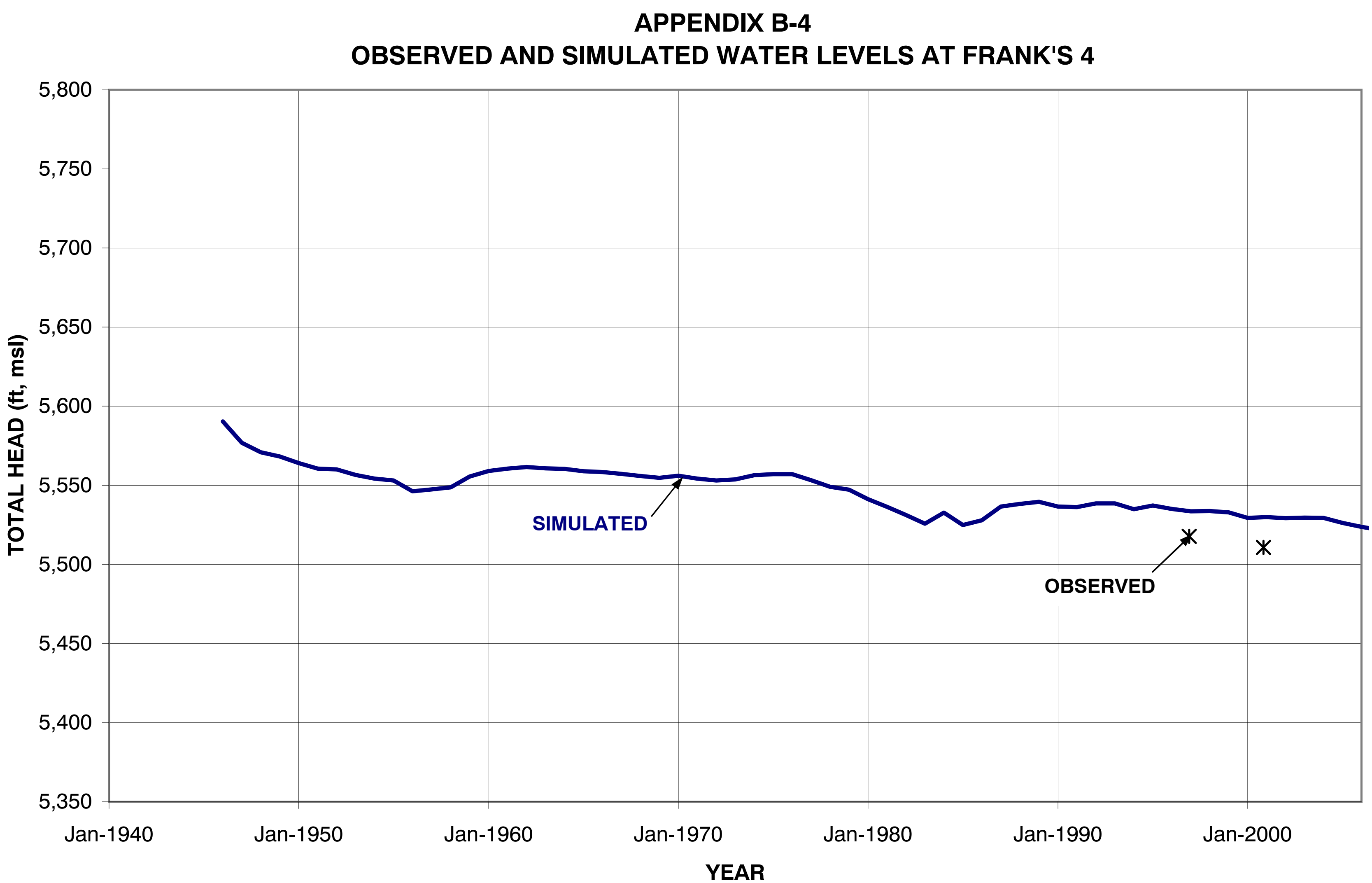
APPENDIX B-1
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 1

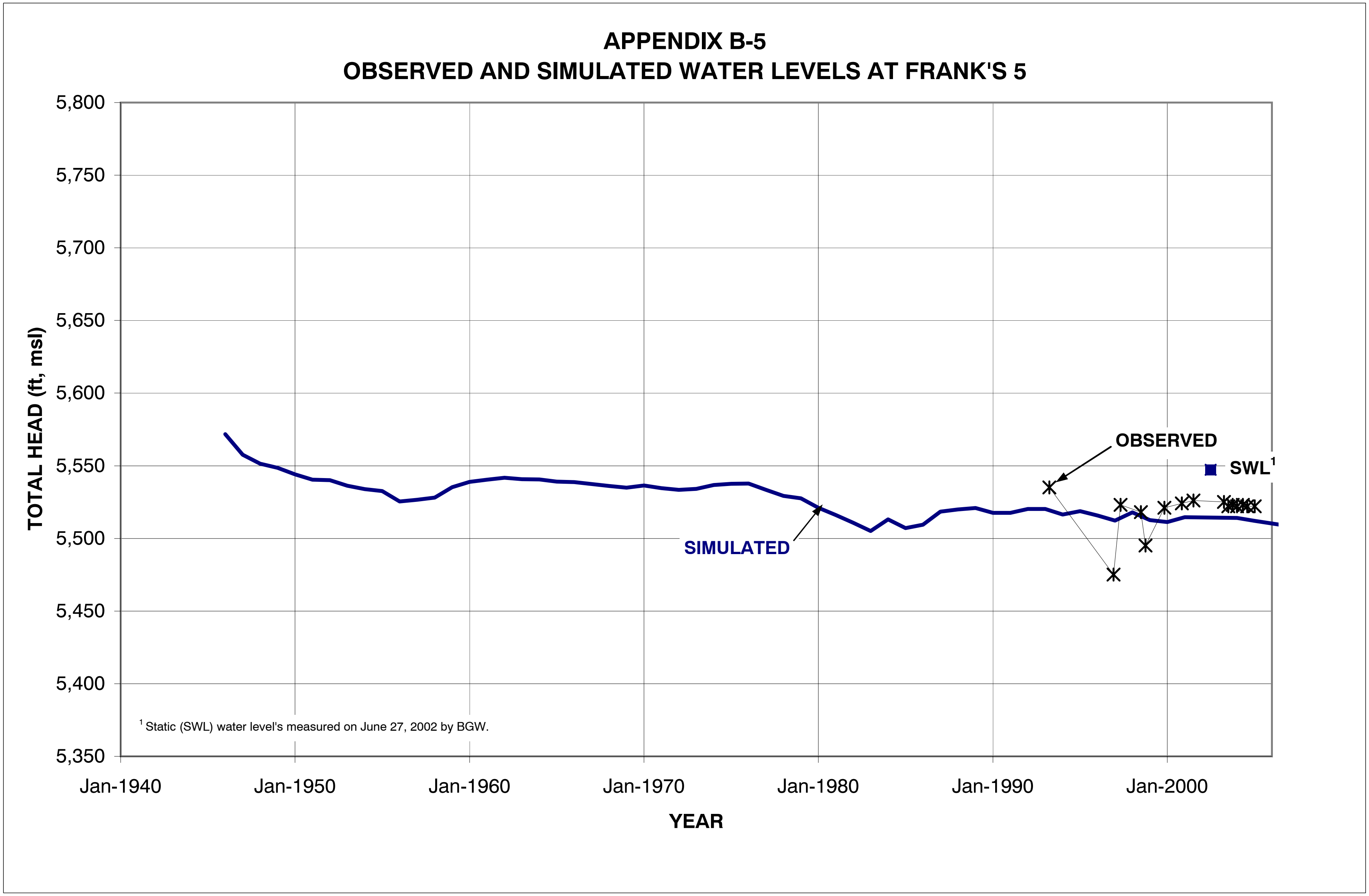


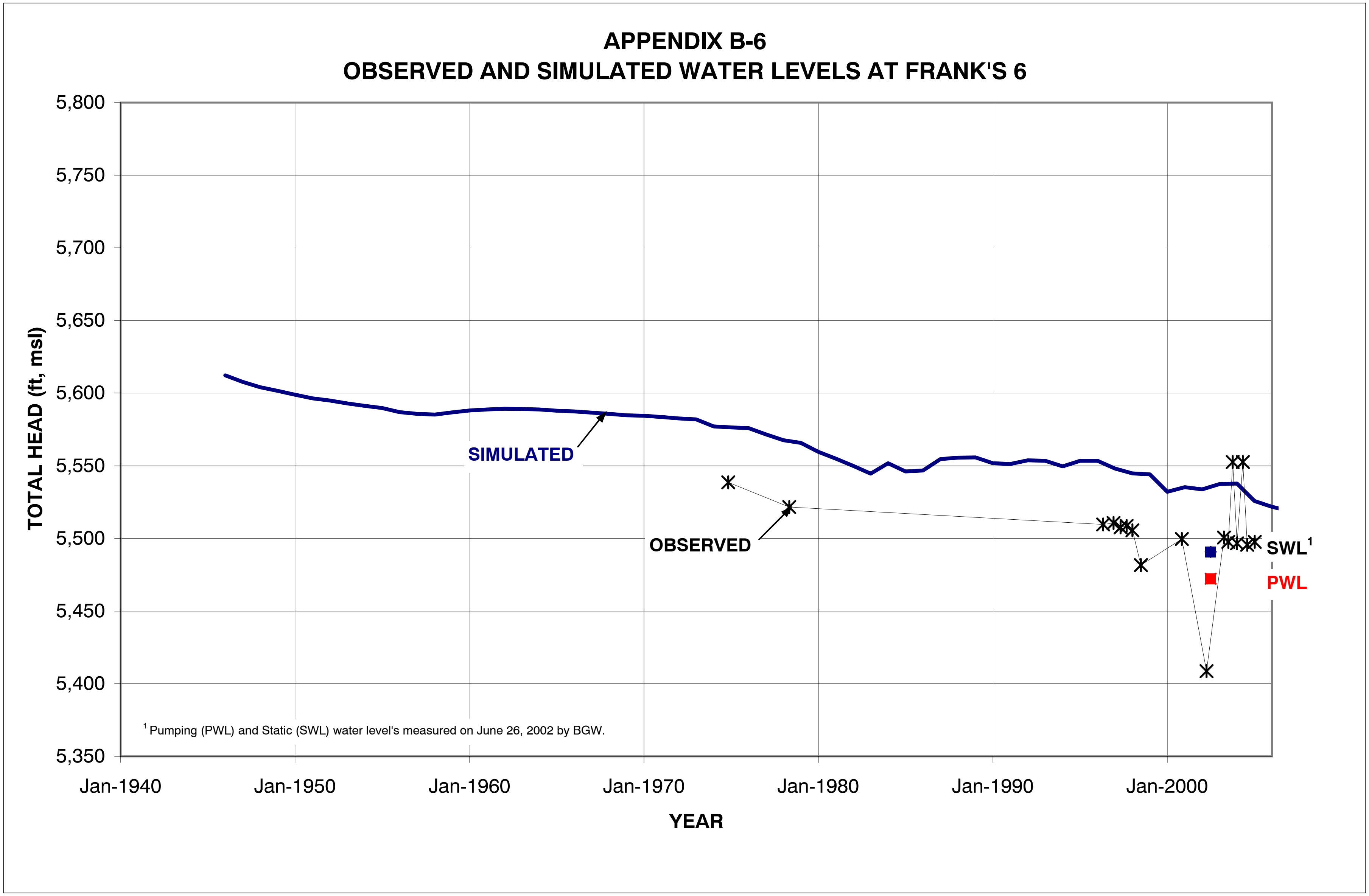

APPENDIX B-2
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 2
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
OBSERVED
SIMULATED
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR

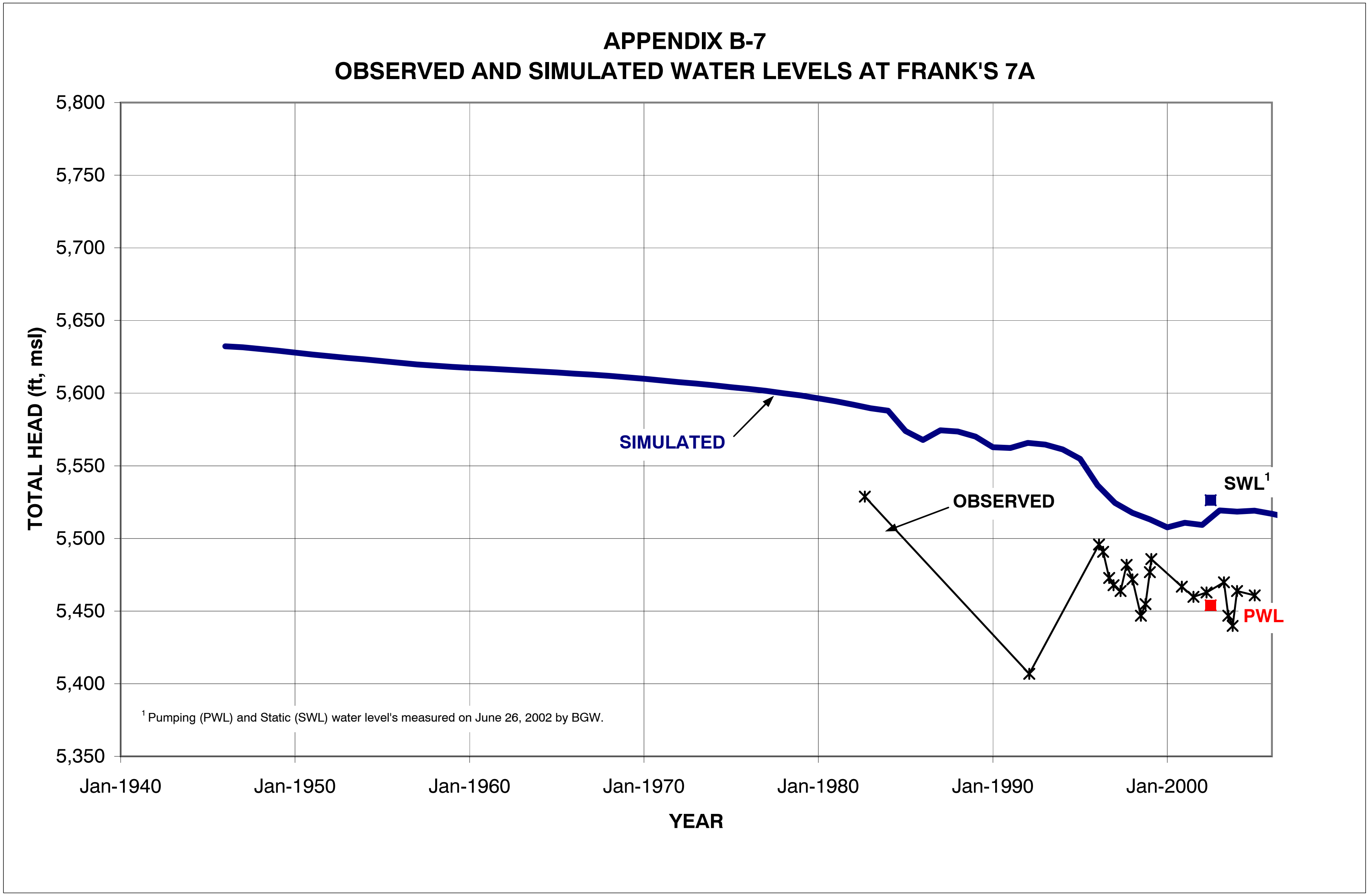
APPENDIX B-3
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 3

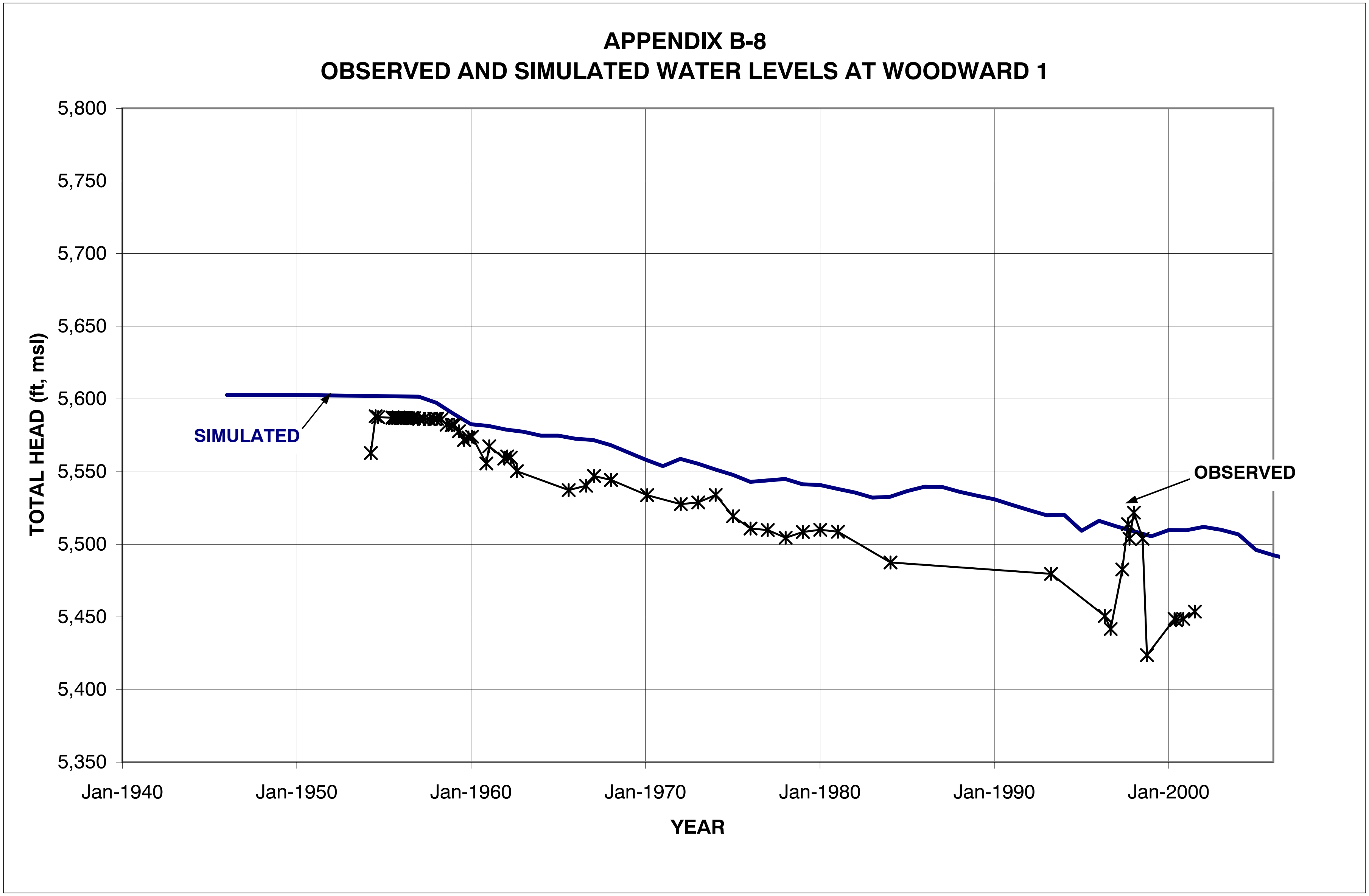


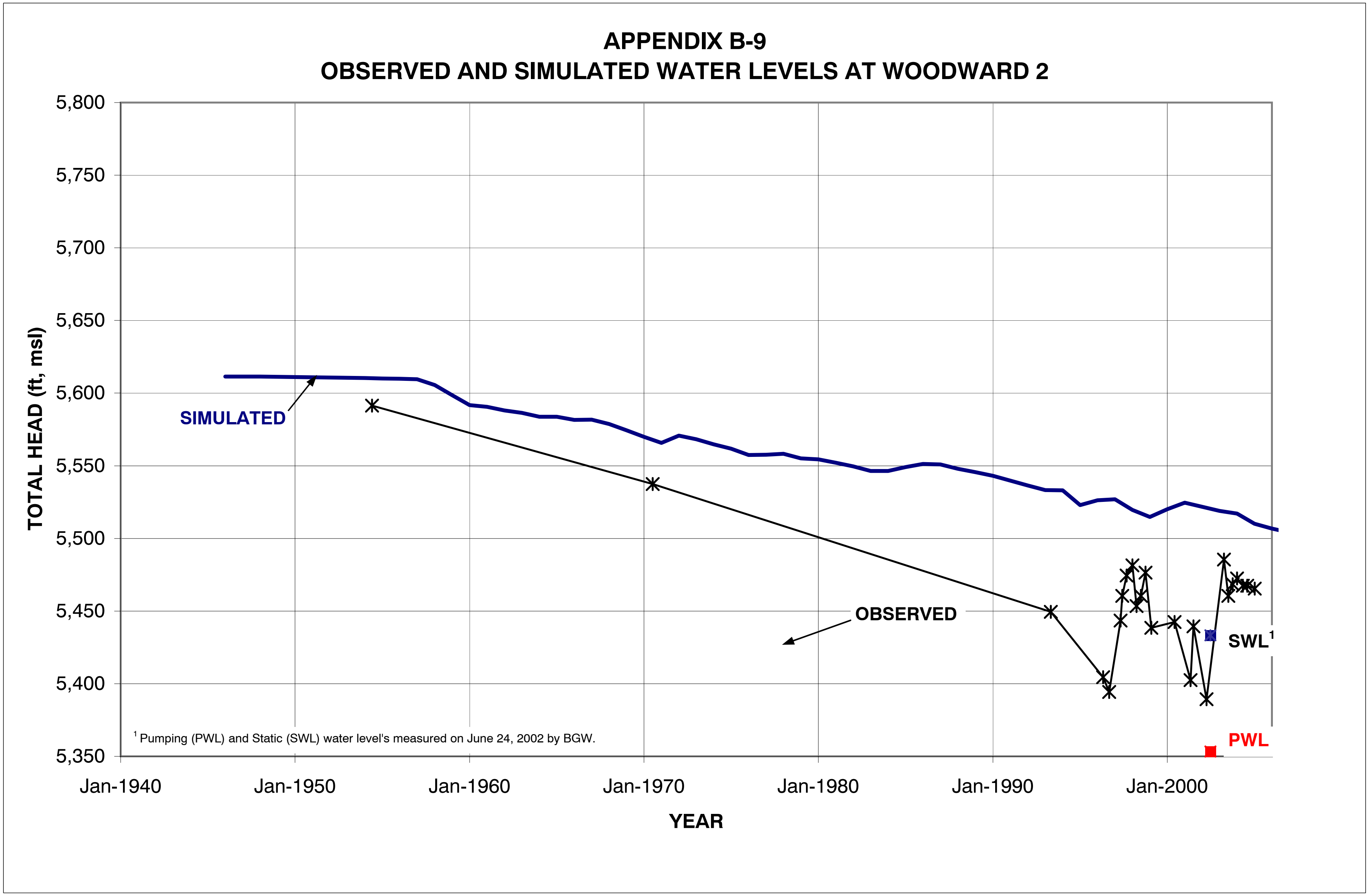

APPENDIX B-4
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 4
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
SIMULATED
OBSERVED
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR

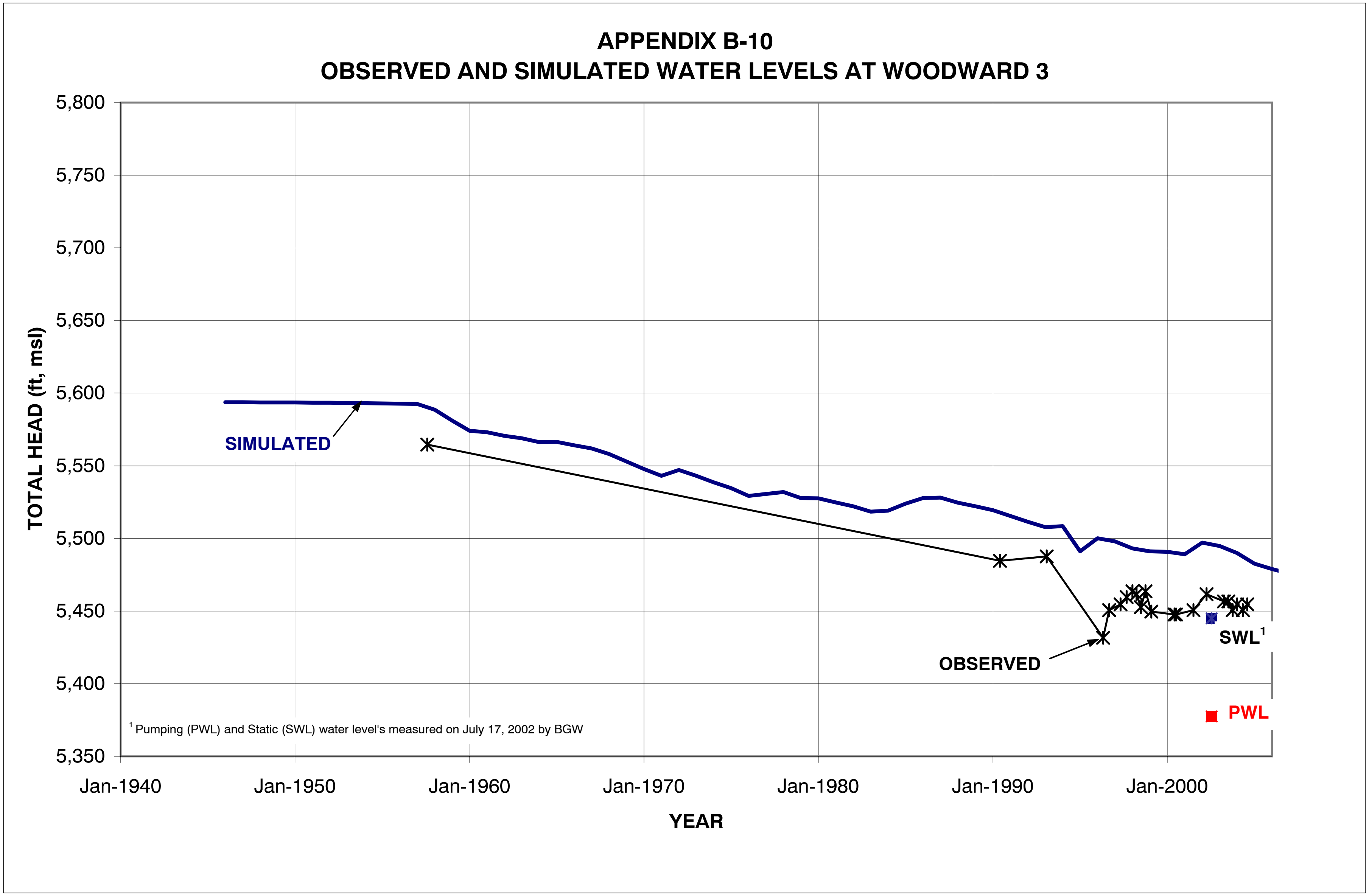

APPENDIX B-5
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 5
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR
OBSERVED
SWL[1]
SIMULATED
[1] Static (SWL) water level's measured on June 27, 2002 by BGW.


APPENDIX B-6
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 6
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
SIMULATED
OBSERVED
SWL[1]
PWL
[1] Pumping (PWL) and Static (SWL) water level's measured on June 26, 2002 by BGW.
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR

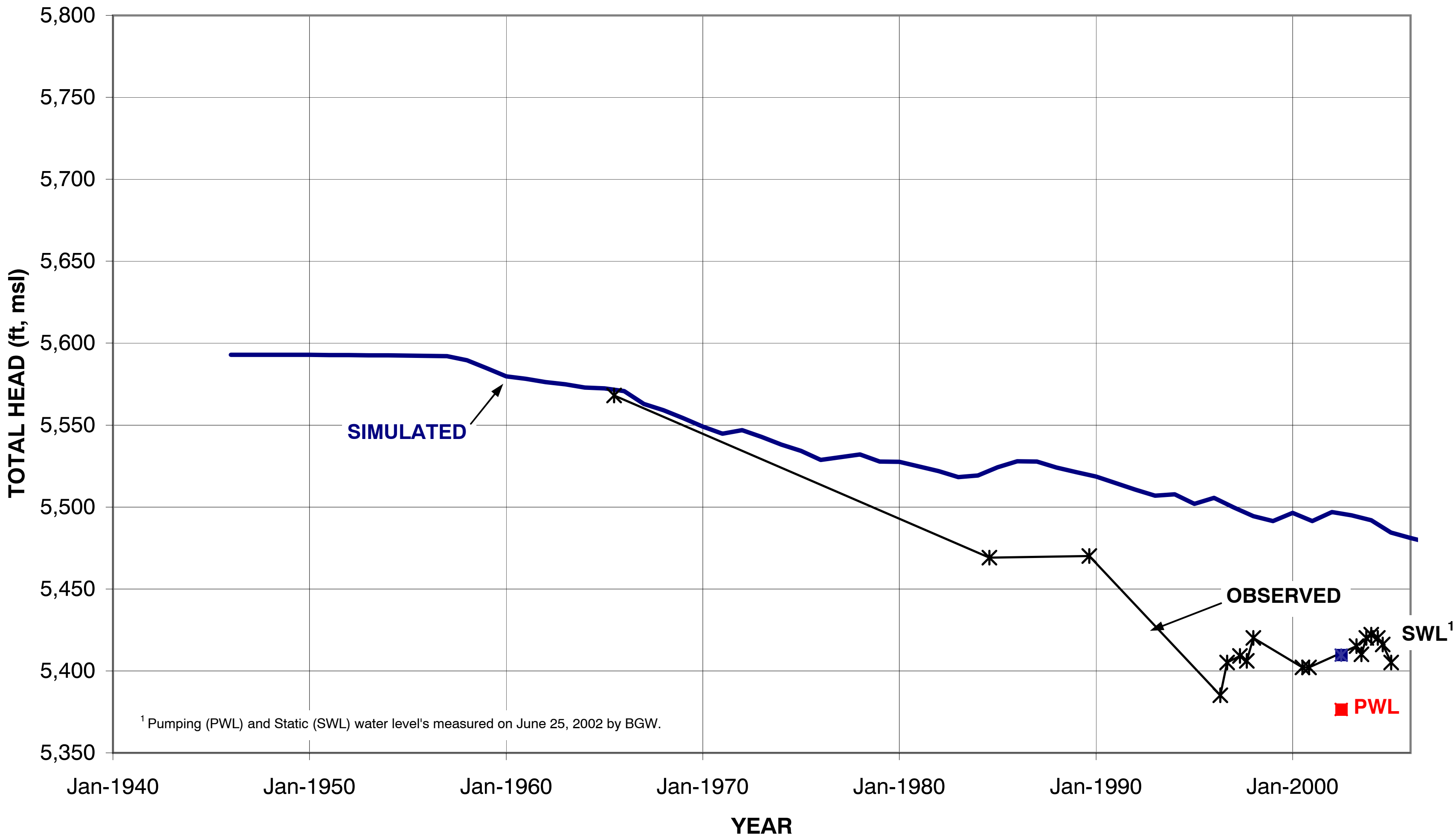

APPENDIX B-7
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 7A
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
SIMULATED
OBSERVED
SWL[1]
PWL
[1] Pumping (PWL) and Static (SWL) water level's measured on June 26, 2002 by BGW.
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR


APPENDIX B-8
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 1
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
SIMULATED
OBSERVED
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR


APPENDIX B-9
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 2
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR
SIMULATED
OBSERVED
SWL1
PWL
1 Pumping (PWL) and Static (SWL) water level's measured on June 24, 2002 by BGW.

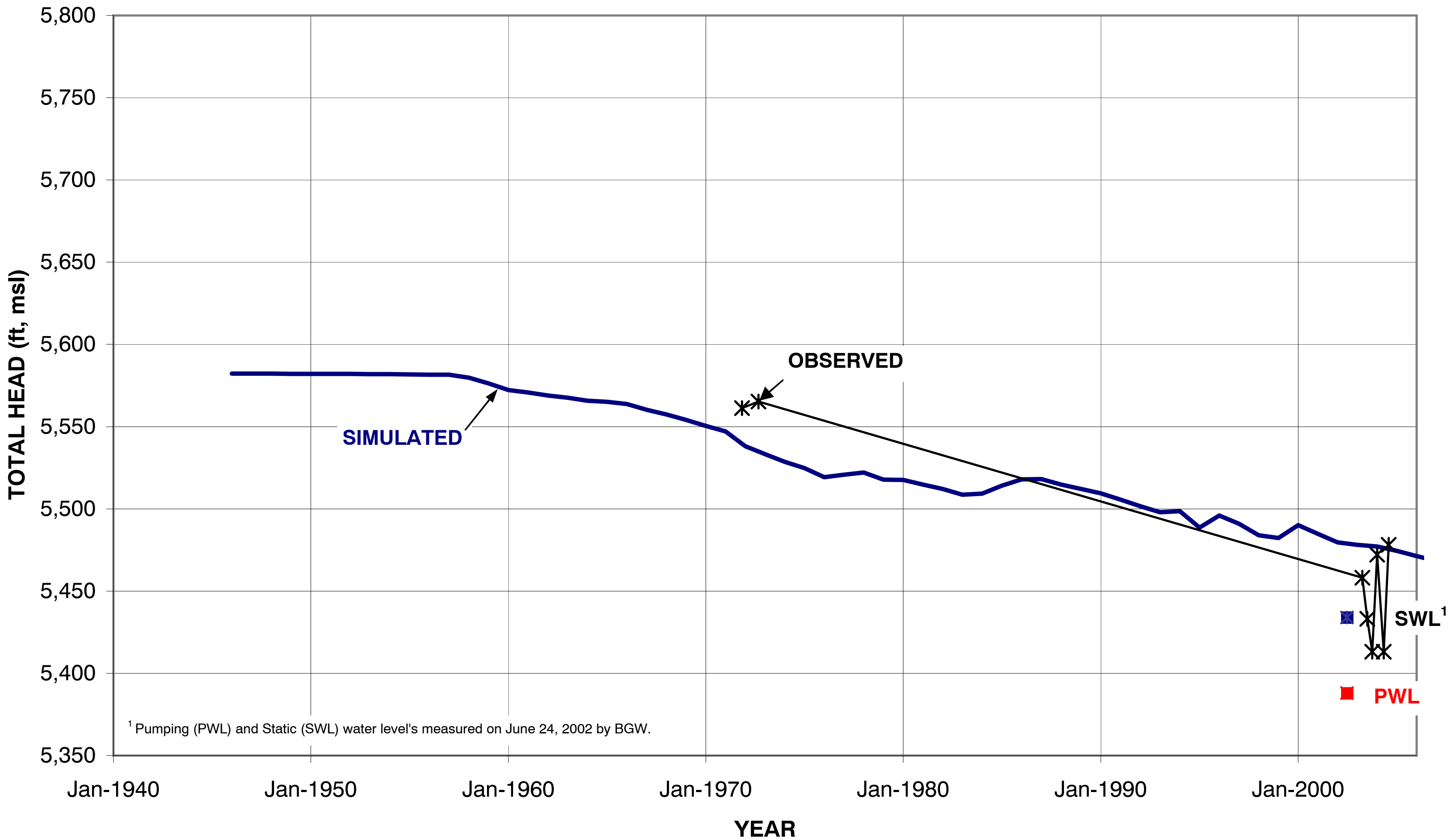

APPENDIX B-10
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 3
TOTAL HEAD (ft, msl)
5,800
5,750
5,700
5,650
5,600
5,550
5,500
5,450
5,400
5,350
SIMULATED
OBSERVED
SWL[1]
PWL
[1] Pumping (PWL) and Static (SWL) water level's measured on July 17, 2002 by BGW
Jan-1940
Jan-1950
Jan-1960
Jan-1970
Jan-1980
Jan-1990
Jan-2000
YEAR

APPENDIX B-11
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 4

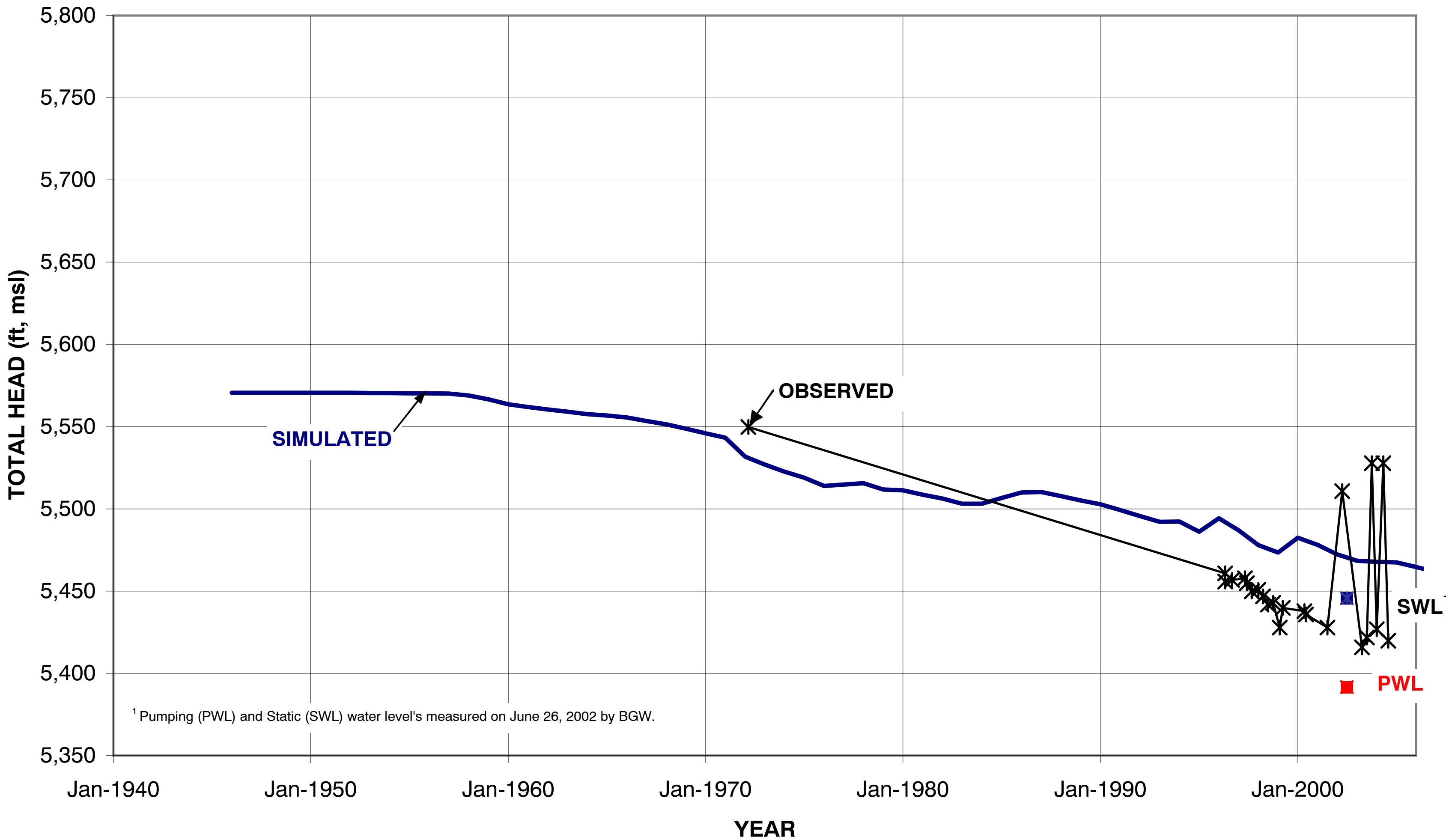


[1] Pumping (PWL) and Static (SWL) water level's measured on June 25, 2002 by BGW.

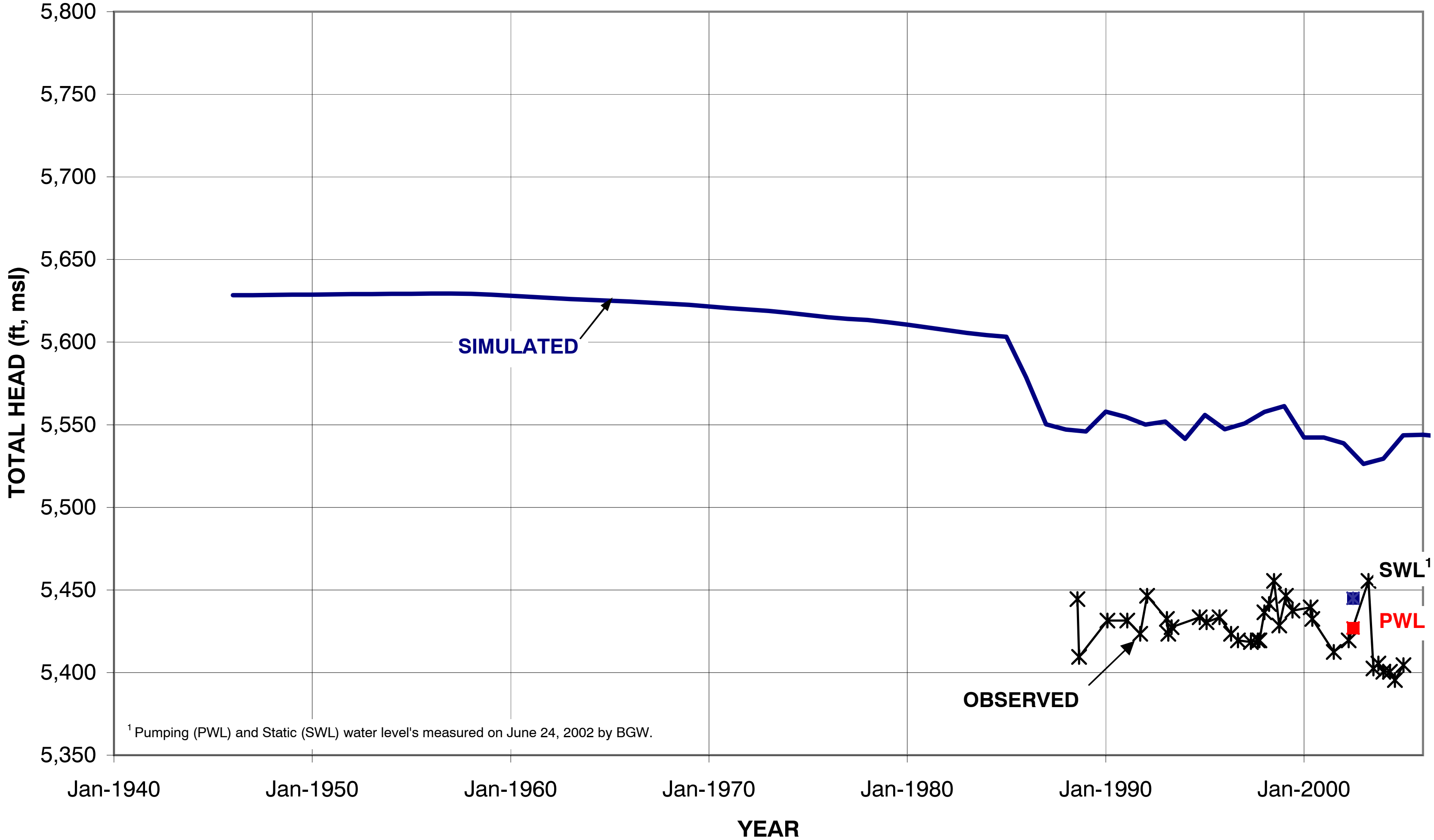
APPENDIX B-12
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 5



APPENDIX B-13
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 6

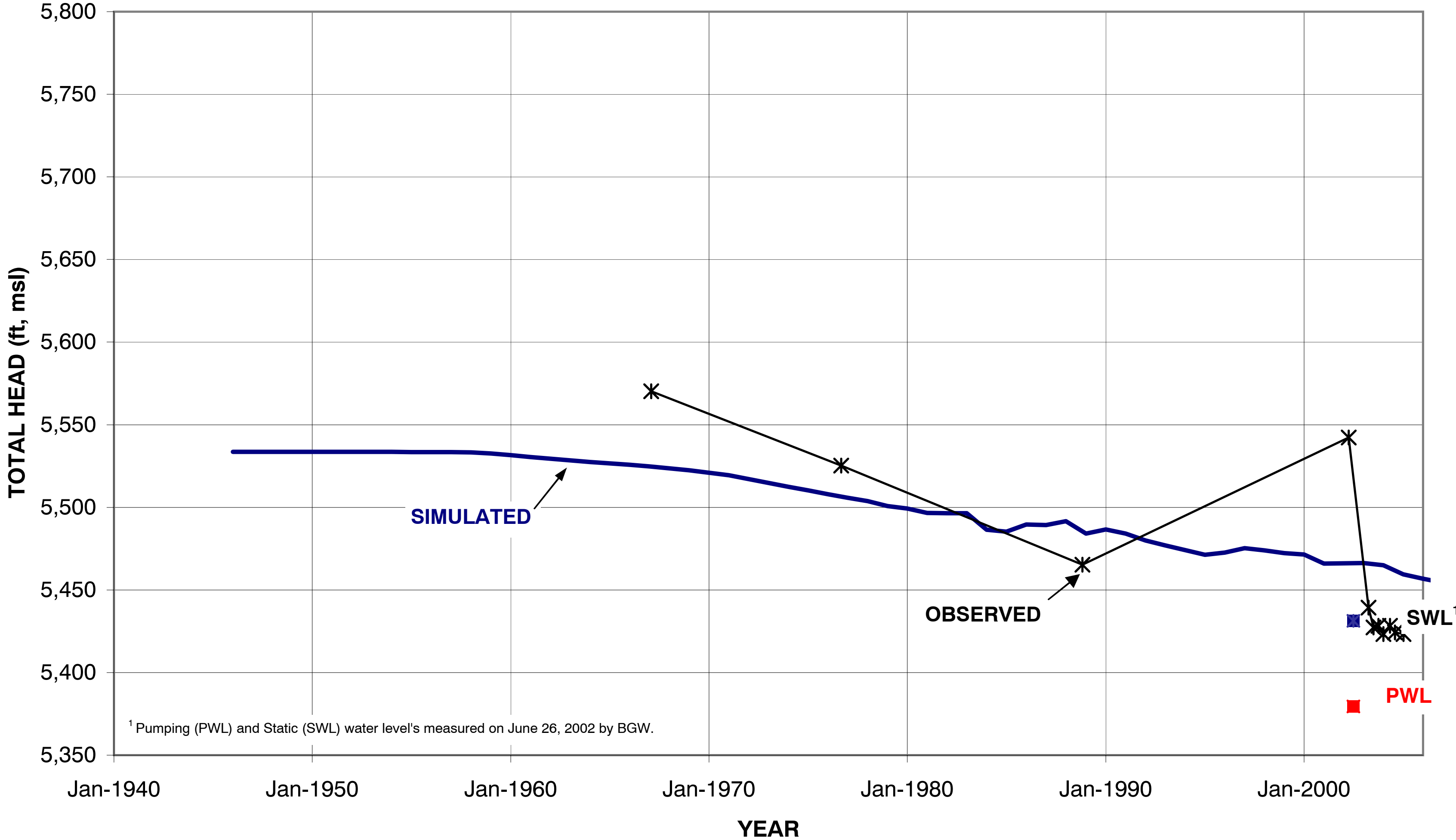


APPENDIX B-14
OBSERVED AND SIMULATED WATER LEVELS AT GABBY HAYES WELL



[1] Pumping (PWL) and Static (SWL) water level's measured on June 24, 2002 by BGW.

APPENDIX B-15
OBSERVED AND SIMULATED WATER LEVELS AT ANDERSON WELL



APPENDIX C

PHASE 1 – WELL-SITE IDENTIFICATION
GEOHYDROLOGY PROPOSAL
FOR THE TOWN OF SILVER CITY

Geohydrology Associates, Inc.

APR 02 1997
ENGINEERS INC

March 29, 1997

Mr. Joseph Gendron
Engineers, Inc.
P. O. Box 5080
Silver City, New Mexico 88062

RE: PHASE 1.--WELL-SITE IDENTIFICATION
GEOHYDROLOGY PROPOSAL FOR THE TOWN OF SILVER CITY

Dear Mr. Gendron:

Geohydrology Associates, Incorporated has completed the well-siting study for the town of Silver City, New Mexico. We evaluated the two different well sites as requested and present our findings below. Comments on a third site are included. The constraints imposed limiting the choices of sites to certain boundaries and administrative blocks greatly reduces the choices of optimum well sites. The following discussion considers these constraints.

<u>Gabby Hayes Well</u>
Records available for the Gabby Hayes Well (Sec. 28, T18S, R18W) indicate the diameter of the casing was reduced from 12 to 8-inch from a depth of 440 feet to the total completed depth of 700 feet and suggest the aquifer was not fully penetrated. Drilling apparently was stopped when the drill was still in cindery volcanic material.

Drilling records, pumping-test records, and records of water-level declines indicate that the aquifer was originally and remains confined. Eventually, through continued use, water-table conditions will be established.

Without knowing the lateral and vertical extent of the aquifer, we cannot be sure that a new well adjacent to the present well will guarantee appreciably greater yields than those currently reported. However, we do believe the aquifer is appreciably thicker.

Full penetration of the aquifer, installation of larger-diameter casing and high-yield pump will allow full development of the aquifer potential. Thereafter, annual declines should be less than present drawdown. This would in effect extend the useful life of the aquifer many years.

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Albuquerque, New Mexico 87107

We recommend a replacement well be drilled to a depth that fully penetrates the aquifer or to a depth of at least 900 feet. The replacement well should be drilled at a distance of no more than 500 to 600 feet northeast or northwest of the present well. Our first choice would be on the small topographic ridge or "nose" to the northeast; thus away from the fault that defines the Pipe Line Draw, and almost certainly acts an a hydrologic boundary.

The well should be completed with a casing screened in the production zone and of such diameter as to allow installation of a pump adequate to produce the allotted water right when installed at near the total depth.

If a borehole drilled near the present Gabby Hayes Well proves unsatisfactory, an alternative site in Section 33 in the same administrative block should be considered. A location in the northwest quadrant of the section would tap the upper part of the Gila Conglomerate but be far enough from the Woodward-field Wells that interference would not be a problem.

<u>Anderson Well</u>
The Anderson Well reportedly is inefficient and of low capacity. It could be relocated within its administrative block to assure a much larger yield. A location in the northeast quadrant of Sec. 5, T19S, R14W would keep it at a reasonable distance from an alternative Gabby Hayes replacement well in Sec. 33, T18S, R14W.

The area proposed for the replacement Anderson Well and the alternative site of the Gabby Hayes Well will permit development of large-capacity wells (1000 to 1500 gpm).

<u>Gila Basin Well</u>
The selection of a site in the Gila-San Francisco Basin presents a different problem. From the configuration of the water table (see Fig. 3, Hydrologic Report No. 2), we conclude that a new well in the Gila-San Francisco Basin should be located somewhere along or close to a line connecting the Franks Ranch Well No. 7 and Woodward-field Well No. 2. A well along this line must ultimately affect water levels in both the Franks No. 7 and the Woodward No. 2 Wells. Minimal effects in both wells would result from a well located in the southeast quarter of Sec. 24, T18S, R19W, halfway between Wells 7 and 2.

The well must be located west of the section line between Sec. 24, T18S, R15W, and Sec. 19, T18S, R14W. To equalize well interference effects between Woodward No. 2 and Franks No. 7, the new Gila Basin Well should be located at a point equidistant from the Franks and Woodward Wells. Placing the well appreciably closer to one or the other of the wells will result in disproportionate interference effects.

The Woodward and the Franks Well fields are completed in gravel-fill of Quaternary Age deposited in a southeast trending structural trough. The new Gila Basin Well can be expected to produce a quantity of water similar to the existing wells in the adjacent well fields and from similar materials at comparable depths. As in the case of the Gabby Hayes replacement well, we recommend strongly that the well be drilled to fully penetrate the aquifer. Drilling should not be halted provided the formation being penetrated can be identified as the so-called "upper part of the Gila".

If you should have any questions or need further information, please do not hesitate to contact me at my home at 505-299-3712 or our offices at 505-884-0580.

Sincerely,
GEOHYDROLOGY ASSOCIATES, INC.

Frederick D. Trauger

Frederick D. Trauger
Geohydrologist

FDT/kc