TECHNICAL MEMORANDUM

To File TOWN OF SILVER CITY/RECHARGE July 16, 2010

From Dave M. Romero, P.H. and Casey W. Cook, P.E.

Subject GROUNDWATER RECHARGE ANALYSIS AND ESTIMATE OF RECHARGE OPTION COSTS

Summary and Introduction

The Town of Silver City (the Town) is considering groundwater recharge options at its municipal wellfields. In March of 2009, the Town retained Balleau Groundwater, Inc. (BGW) to evaluate the general hydrology of a prospective groundwater recharge program. The evaluation involves an overall assessment of the hydrologic system, which has been historically influenced by regional groundwater development, in conjunction with an assessment of how the system can be expected to change in the future with managed groundwater recharge. Water for use by the Town is supplied by Frank's wellfield (three wells in production), the Gabby Hayes well, the Anderson well and the Woodward wellfield (five wells in production) (Figure 1).

The Town is interested in initially recharging groundwater in the area of Frank's wellfield. General options under consideration include infiltration along natural intermittent channels and an injection well system. Recharge water is expected to come from the Gila River. The elevation change between the Gila River and the Town wellfields is approximately 1,700 feet. If it is feasible to use existing facilities for water conveyance, the existing pipeline that runs from Bill Evan's lake to Tyrone Mine is suitable for routing water part of the way to the Town wellfields. Additional pipeline would be necessary to route water from the existing pipeline to Frank's wellfield. A proposed route of new pipeline and an estimate of costs are included herein. A recharge project is considered hydrologically and economically feasible if permitting requirements are satisfied.

Purpose and Scope

This work is intended to enhance the understanding of the regional aquifer system with an emphasis on hydrologic effects caused by the Town wellfields, regional water use, and managed groundwater recharge. The area of interest is shown on Figure 1. We assess the hydrologic system and characterize the extent of groundwater captured by the Town wells. This technical memorandum describes our analysis, which is based on a water accounting model that integrates MODFLOW-2000 (Harbaugh and others, 2000) and Geographic Information System (ArcGIS, 2009) techniques with data and results from previous studies. The objectives of the assessment are to (1) characterize the region of groundwater captured by the Town wells, (2) assess hydrologic effects in terms of water levels and flow rates from managed groundwater recharge operations, and (3) propose preliminary sites and estimated costs for development of a groundwater recharge program.

Technical Approach

In coordination with the Town, BGW developed a model of the aquifer system in the region of the Mangas Trench (Trauger, 1972, p. 22) that accounts for the water in the area influenced by Town wellfields and for regional water use of others. The boundary of the model is the area of interest shown on Figure 1. The New Mexico Office of the State Engineer (OSE) has developed two earlier versions of groundwater flow models in generally the same area; Hathaway (1986) and Johnson (2000) each developed two-dimensional models to assess hydrologic effects from proposed transfers of groundwater rights. The new model builds on the previous work. We developed a three-dimensional model to account for both shallow and deep recharge operations within the aquifer system. The model provides a mathematical simulation method for examining the change in aquifer conditions resulting from historical groundwater development and for calculating the projected effects of proposed future water-management actions in the basin. The model is based on the U.S. Geological Survey (USGS) MODFLOW 2000 program (Harbaugh and others, 2000). Wellfield capture areas are estimated with an advective particle tracking approach (Pollock, 1994). The model was calibrated to approximately match pre-development water levels and estimated flow conditions, and 62 years of historical groundwater development from 1946 to 2008. Pre-development water-level

statistics and historical water-level hydrographs for the Town wells are included in Appendix A. The model remains under progressive improvement; however, it is in a form suitable for the analysis described herein.

The term “zone of contribution” (Alley, 2003) is standard terminology by the U.S. Geological Survey for the three-dimensional volumetric part of an aquifer through which groundwater is displaced into the well in a certain time period. We apply this term herein also to the aquifer volume through which water is displaced by injection water.

Hydrogeologic Setting

Geology in the area has been reported by others (Paige, 1916; Koopman and others, 1969; Trauger, 1972; Cunningham, 1974; Hedlund, 1978a; Hedlund, 1978b; 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 dominant geologic feature in the area of interest is a northwest-trending structure 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 Town wells yield water ranging from 230 to 950 gallons per minute (gpm) with transmissivity (in the screen zone) ranging from about 850 to 2600 feet squared per day (ft^2/d) (BGW, 2006, Table 1).

The continental divide runs through the area of interest and is the topographic divide between the Gila and Mimbres basins. Northwest of the continental divide is the Gila Basin. The principal drainage of the Gila Basin is Mangas Creek, which is intermittent along most of its course until it becomes perennial at Mangas Spring located about 12 miles from the continental divide, or four miles away from the Gila River. Surface-water flow measurements on Mangas Creek below the spring indicate that the creek gains flow along the perennial segment below

the spring.[1] Southeast of the continental divide, the principal drainage in the Mimbres Basin is San Vicente Arroyo, which is intermittent through most of the area of interest.

Others have estimated the quantity of groundwater flow through the Mangas Trench region. Based on the transmissivity of wells in the Warmsprings, Faywood and Whitewater areas and on regional aquifer head gradients, Trauger (1972, p.64) estimates the amount of groundwater moving southeast into the Deming Basin from the San Vicente watershed to be 10,800 acre feet per year (AFY); an independent estimate by Hawley and others (2000, p. 39) is 10,000 AFY. Northwest in the Gila Basin along Mangas Creek near Mangas Spring, Trauger (1972, p. 64) estimates 3,000 to 4,000 AFY moving through the basin fill until it eventually discharges to the Gila River. The OSE model (Johnson, 2000) of groundwater flow through the Mangas Trench derives quantities that are comparable to the aforementioned estimates of Trauger (1972) and Hawley and others (2000); about 9,800 AFY of groundwater flow to the Mimbres Basin and 6,100 AFY discharging to Mangas Spring and the Gila River. These reports provide a basis for a corresponding groundwater recharge rate on the order of 15,000 to 20,000 AFY in the region of the Mangas Trench with about 60 percent flowing toward the Mimbres Basin and 40 percent flowing toward the Gila Basin.

Hydrogeologic Model

We compiled data (Trauger, 1972; Cunningham, 1974; Hedlund, 1978a; Hedlund, 1978b; Hawley and others, 2000) to provide a basis for the construction of a three-dimensional hydrogeologic unit solids model (Figure 3). The solids model provides a framework for specifying hydrologic parameter zones within the water-accounting model and provides a basis for using the Hydrogeologic Unit Flow (HUF) package that works with MODFLOW-2000 (Anderman and Hill, 2003). The HUF package provides flexibility in the water accounting model in that as new information provides improved or alternative hydrogeologic interpretations, they can be readily incorporated into the simulated aquifer framework.

[1] Trauger (1972, p.47) reports that flow below the spring increases with an average flow of about 1.6 cubic feet per second (1,200 acre feet per year) ¼-mile below the spring and an average flow of 1.8 cubic feet per second (1,300 acre feet per year) about ¾-mile further downstream.

The model simulates hydrologic features on an average annual basis that define the interaction of the local aquifer system: regional aquifer subsurface flow, natural recharge, stream channels, and riparian evapotranspiration (ET). The model-derived water flow budget is illustrated on Figure 4; it represents natural conditions of the 1940s prior to significant development of groundwater. The modeled budget of water flow results in 19,400 AFY of recharge that leaves the model as 8,400 AFY southeast to the Mimbres Basin, 7,000 AFY northwest including Mangas Creek (4,600 AFY) and the Gila River (2,400 AFY) and 4,000 AFY to model-wide ET, which is consumed predominantly along riparian vegetation at Mangas Creek and in some riparian areas along San Vicente Arroyo within the Town. The results are compatible with other estimates described above. The modeled predevelopment water-levels are shown on Figure 5. The predevelopment hydrologic setting serves as an initial condition for the model scenarios.

Model Scenarios

The model scenarios are intended to examine how the regional geohydrology influences water-level changes as groundwater has been developed historically and as it may be developed and managed in the future. Results include estimates of groundwater capture zones, or the zone of contribution, for the Town wells during the historical period from 1946 to 2008 and during a 102-year extended period from 1946 to 2048. We simulate four model scenarios: (1) a historical simulation from 1946 to 2008, (2) a future 40-year baseline simulation, (3) the future baseline with injection wells to provide managed recharge, and (4) the future baseline with infiltration to provide managed recharge. Scenarios (3) and (4) assume that managed recharge water is available at a continuous rate of 1.0 cubic foot per second (cfs) throughout the year, or about 725 AFY. In the case of Scenario 3, we assess how managed groundwater recharge influences the wellfield capture zones. The scenarios are described below.

<u>Scenario 1: Historical Simulation</u>

The historical simulation requires specifying groundwater diversions model-wide. For the Town well diversions, we specified pumping based on meter records on file with the Town

and as described in BGW (2006, Figure 11). The Town has a wastewater treatment plant (WWTP) that discharges water to San Vicente arroyo in the Mimbres Basin. We estimate that the WWTP provides about 1,000 AFY of recharge to groundwater in the Mimbres Basin (BGW, 2006, Figure 12). We added the Town WWTP return flow to the historical simulation to account for return flow to the Mimbres Basin aquifer. Regional groundwater diversions for water users other than the Town are based on withdrawal data compiled in the OSE model of the Mangas Trench (Johnson, 2002) that has been updated by the OSE to include regional groundwater pumping data on file at the OSE District III office in Deming, New Mexico. The updated model does not include individual domestic well use. We compiled information on domestic wells[2] and added it to the model herein so that regional domestic well water use would be accounted for.

The modeled water-level condition at the end of the historical period is shown on Figure 6. The change in water levels over the 62-year period from 1946 to 2008 is shown on Figure 7. The largest degree of water-level change (decline) occurs at the Town well field and at Tyrone mine. Also apparent on Figure 7 is water-level rise associated with return flow from the Town WWTP. Figure 8 shows the historical extent of groundwater zone of contribution by the Town wellfield since the 1940's; the green streaks represent the distances over which groundwater has been displaced into and captured by individual Town wells since they began pumping. Historical wellfield capture areas are within a few miles of the Town's wells.

Scenario 2: Future 40-Year Baseline Simulation

The baseline simulation runs 40 years into the future from 2008 to 2048. Groundwater use by the Town is assumed to grow at a rate of 0.5 percent per year. Regional groundwater diversions for water users other than the Town are assumed to remain constant. The future 40-year water-level condition resulting from assumed levels of groundwater use is shown on Figure 9. Figure 10 shows the extent of groundwater captured over the 102-year period from 1946 to 2048, which is somewhat greater than the historical extent depicted on Figure 8. The baseline simulation serves to provide a condition upon which the two future groundwater recharge scenarios (injection and infiltration) can be superimposed.

[2] New Mexico Office of the State Engineer Water Administration Technical Engineering Resource System database: data accessed May, 2009.

Scenario 3: Future 40-Year Recharge Scenario with Injection Wells

The projected 40-year recharge scenario with injection wells is the same as the baseline scenario except for including injection of 1.0 cfs equally split in two wells. The injection wells are assumed to be 1,000 feet deep and to have completions compatible with Frank's wells 5, 6 and 7 (BGW, 2006, Table 1 and Figure 6). Figure 11 shows the water-level build-up associated with 1.0 cfs (725 AFY) injected into the Gila Group aquifer for 40 years. The build-up of water levels is relative to the 40-year baseline condition shown on Figure 9. Figure 11 also shows the extent to which injection water travels over the 40-year period.

The model provides a means to assess how the injected water affects the 102-year capture zone depicted on Figure 10. For the spatial layout of the recharge operation simulated in Scenario 3, Figure 12 shows the wellfield capture zone with managed recharge. The format on Figure 12 is analogous to Figure 10 so the two figures display the difference that the managed recharge has on the wellfield capture zone. The difference is that there is an area where the wellfield capture zone is displaced toward the injection wells by the managed recharge. In the 40-year simulation depicted herein, the municipal wells do not capture any of the recharge water; however, the shape of the shifted capture zone toward the injection wells suggests that, eventually, some of the recharge water may be captured by the Town wells. That result is dependent on the magnitude of future water use, the magnitude of injected water, the location of injected water relative to existing municipal wells and local features of the hydrogeologic system.

Scenario 4: Future 40-Year Recharge Scenario with Infiltration

The projected 40-year recharge scenario assumes recharge water is infiltrated into the ground along an existing arroyo south of Frank's wellfield. The recharge rate is constant at 1.0 cfs of water for 365.25 days per year, or 725 AFY for 40 years. As with Scenario 3, the analysis is the same as the baseline (Scenario 2) with the exception of infiltration recharge water. Figure 13 shows the build-up of water levels relative to the 40-year baseline condition on Figure 9; the extent to which infiltrated water travels is also shown.

Comment on Model Results

Model Scenario 3 indicates that mixing of recharge water with Gila Group aquifer water is a factor to be considered in planning (i.e. the wellfield may eventually produce water that is a mixture of Gila Group aquifer water with managed recharge water). The timing and degree of capture (of injected water) depends on the amount and location of recharge and on the magnitude of wellfield pumping. Actual recharge operations can be planned to avoid or to create mixing of recharge water with Gila Group aquifer water in municipal wells. The degree to which mixing occurs is a factor to consider; however, unless a reason to do so becomes apparent, an allowance for eventual mixing should be planned.

The results of Scenarios 3 and 4 indicate that there is notable difference between the extent of water travelled and the extent of water-level build-up (Figure 11 and Figure 13). The area of water-level build-up reaches substantially farther away from the recharge water source than the distance that recharge water travels in 40 years.

The structural layout of the aquifer system in the area of the Town wellfields is characterized by a system of faults (Figure 2). Model representation of the Pipeline Draw and Treasure Mountain faults as general features that impede groundwater flow is found to improve the overall simulation of local water-level trends (BGW, 2010). Improved simulation of water-level trends provides a basis for modeling the faults as features with less permeability than the regional aquifer system; however, the specific influence that the fault network has on the hydrologic system is not completely understood. The analysis approach herein involves a regional model that cannot represent all the local details of the hydrologic system. The model is capable of generally matching water-level trends observed in the area of the Town wellfield, so we consider it to be a tool that reasonably quantifies the magnitude of water-level changes associated with well diversions and groundwater recharge operations, and that estimates contributing areas of the Town wellfields and recharge operations.

In regard to estimating groundwater zone of contribution for the Town wells, the Gabby Hayes well warrants additional discussion. The Gabby Hayes well is completed in the Gila

Group aquifer and in a deeper volcanic sequence of beds of sand, pumice, cinders and basalt of Tertiary age (Jenkins and Prentice, 1982; Trauger and Lavery, 1976); the well is described to produce most of its water from the deeper volcanic beds beneath the Gila Group aquifer. The other Town wells (Frank's and Woodward wellfields and the Anderson well) are completed in the Gila Group aquifer. The specific capacity of the Gabby Hayes well is five to ten times greater than the typical specific capacity of the other Town wells (BGW, 2006, Table 1), suggesting the volcanic beds in the area of the Gabby Hayes well produce greater quantities of water than what is typically observed from the the regional Gila Group aquifer. To account for this, we developed a higher permeability zone representative of the volcanic beds during model calibration. The zone extends a few miles west of the Gabby Hayes well; however, the direction in which the simulated zone extends is not specifically defined by the model calibration (i.e. the zone could have been extended toward the east to achieve a similar calibration of water levels at the well). This point is of interest because the modeled groundwater capture zone for the Gabby Hayes well is sensitive to the direction that the higher permeability zone extends from the location of the well. For that reason, if the results herein are used for delineating wellhead protection areas, then we recommend that the groundwater capture area for Gabby Hayes well be expanded beyond the extent depicted on Figure 10. Expanding the capture area is to account for the uncertain extent of the high permeability volcanic beds that appear to provide the principal source water to the well. An example expanded capture area for the Gabby Hayes well is shown on Figure 14. For planning purposes and for the reason described above, we recommend that the capture area for Gabby Hayes well be expanded to include a similarly shaped area that extends a few miles east of Highway 90. We do not consider this approach necessary, if wellhead protection areas are delineated for the other Town wells, as they are completed in the Gila Group aquifer and the model does not represent the Gila Group aquifer system with any localized zones that significantly influence the estimated groundwater capture areas.

Example Recharge Projects and Estimated Costs

If the Town plans to move forward with groundwater recharge operations, there are a number of factors to consider that are beyond the scope of this document. This document is not intended to address all project aspects; however, for planning purposes, we have compiled

information regarding two example groundwater recharge options that involve new infrastructure to convey water to Frank's wellfield, including a general estimate of project costs. Prior to moving forward with an actual groundwater recharge program, a detailed assessment of infrastructure development and analysis of more specific costs would be required.

In this section, we provide two examples of full-scale, operating projects the Town might undertake for aquifer recharge. Example recharge sites near Frank's wellfield are shown on Figure 15. Options for recharge by injection and by infiltration are described, including general infrastructure requirements and estimated costs. Both injection and infiltration recharge options require the construction of a new pipeline to deliver water to the recharge site. Existing infrastructure that delivers Gila River water from Bill Evans Lake to Tyrone Mine may be available for use by the Town to deliver water part way to recharge sites. New infrastructure will be needed to convey water the rest of the way, to treat water and provide for direct injection, and to control and monitor recharging water. The following sections describe existing and new infrastructure needed, estimated costs, and foreseeable permitting requirements. Table 1 outlines estimated costs for injection and infiltration projects.

Existing and Required New Infrastructure

The Southwestern New Mexico Regional Water Plan (DBS&A, 2005 p. 8-103) describes existing diversion and conveyance facilities from the Gila River to Tyrone Mine operated for mine-water purposes. The diversion location and the conveyance alignment are shown in Figure 15. Diversions up to 40 cfs are made from the Gila River and pumped to Bill Evans Lake, which has 2,100 AF storage capacity. Water is conveyed from the lake to the mine by two pumping stations through 22 miles of 27-inch diameter pipe at rates up to 21 cfs. Part of the existing infrastructure may be available for use by the Town for recharge operations.

Conveying water to prospective recharge sites requires a new pumping station and new pipeline. Figure 15 shows one possible tie-in point and alignment for new pipeline to convey water from the existing pipe to the recharge sites. About eight miles of new pipeline is needed for either recharge option. From the Gila River to the recharge sites, the elevation change is 1,690 feet, of which about 1,000 feet is along the new pipeline. We estimate that a 400-

horsepower pump station is needed to convey one cfs (about 500 gpm) from the tie-in with existing pipe eight miles and 1,000 vertical feet to the recharge site, assuming new pipe is eight-inch diameter. Capital cost of the pump and pipeline is estimated at about $4.2 million (Table 1), which is necessary for both recharge options (injection and infiltration). A description of the basis for estimated costs is appended to this technical memorandum (Appendix B).

Managed Injection of Recharge Water

The injection project involves directly recharging water to the regional aquifer by gravity feed through one or several wells. A proposed site is shown on Figure 15. Gila River surface water to be used for injection is expected to require treatment, which would happen at an on-site facility prior to injection. Treatment involving filtration and disinfection is necessary to protect the aquifer and prevent well-screen fouling. In the example project herein, two injection wells are proposed to be constructed in the area of Frank's Wellfield at depths of 600 and 1,100 feet (Figures 16 and 17) corresponding to shallow and deep completions in Town wells at Frank's wellfield. The injection wells would be equipped with a drop pipe and orifice to prevent cascading water, and valves and gages to monitor and control pipeline pressure and injection rates. A separate nested observation well with piezometers screened at the injection zones is recommended to monitor shallow and deep aquifer conditions (Figure 18). Injection wells and observation piezometers would be instrumented with pressure transducers to measure and record water levels.

Table 1 summarizes estimated capital and annual costs for the example injection project. Annual costs include pumping and treating water, and rehabilitating wells to remove scale and restore capacity. The annualized cost of the example injection project, including pipeline and a pumping station, is estimated at about $1.1 million per year and the unit cost at $1,400 per AF.

Managed Infiltration of Recharge Water

We propose to use in-channel infiltration at local arroyos near the Town's wellfield for managed recharge. Two arroyo locations are shown in Figure 19; anywhere along the arroyo lengths indicated is prospective for infiltration. The feasibility of recharging water in arroyos has been demonstrated by Hernandez and others (1984, p.70), who report that discharge from a 1982 three-day pumping test of Frank's Well 7 was routed to one such arroyo (Figure 19). The resulting flow of 1.35 cfs infiltrated into the arroyo bed over a distance of less than 2,000 feet, or an infiltration rate of over three cfs per mile. In a separate project, the Town is presently monitoring recharge of wastewater effluent discharged to San Vicente Arroyo (BGW, 2009). In that area, effluent from a WWTP that began discharging in 1979 infiltrates into the arroyo bed at a rate of approximately three cfs per mile.

For the example project, untreated water from the new pipeline would be discharged into one or two natural drainage areas near Frank's Wellfield. As with the injection approach, a new pump and pipeline are necessary to convey water to the recharge site. The pipeline outlet would be equipped with valves and totalizing flow meters to control and monitor discharge rates. Discharge to the arroyo at one cfs is expected to flow about 2,000 feet before fully infiltrating. No preparation of the arroyo bed prior to beginning operations is necessary, but periodic treatment or tilling of the bed may be needed to remove algae or other clogging materials. An instrument nest (Figure 20) would be installed in each recharge drainage to monitor percolation of water through the vadose zone. A second nest may be installed above the wetted reach to monitor background conditions. A series of temperature and moisture-content sensors in each nest will track percolation of water from the surface down to the regional water table. A 450-foot deep monitor well screened across the water table and instrumented with a pressure transducer would monitor water-table conditions.

Estimated costs for the example infiltration recharge project are summarized in Table 1 and detailed in Appendix B. The annualized cost is estimated at about $0.8 million per year, including pipeline and a pumping station, and the unit cost at about $1,000 per AF.

The annualized costs for larger recharge quantities involving, for example, two cfs would be higher than the smaller example projects at $1.8 and $1.2 million per year for injection and infiltration, but unit costs would be lower at $1,100 and $700 per acre foot.

Administrative Permitting

We understand the source of recharge water for the Town may be Gila River water leased from the mine. A water-transfer application to the OSE is needed to change the place and purpose of use of mine water to recharge water. The application will need to be advertised and may be protested. A protested application with an administrative hearing may take two to three years for a decision, with uncertain outcome; however, an application for groundwater recharge may be less controversial than others which are sometimes protested based on water-level drawdown effects from groundwater depletion. OSE permits are not required for drilling instrument nests if the borehole does not intersect a water-bearing unit, but monitor wells and injection wells will require drilling permits.

A NMED groundwater discharge permit is not expected to be required for the infiltration approach, but likely will be needed for injection. Federal NPDES requirements, which control point discharge to surface water bodies, may or may not come into play with infiltration. With either recharge approach, we recommend the Town first submit a Notice of Intent to NMED that describes the program, the water source and recharge method and location, monitoring program and water quality sampling results. On that basis NMED will advise whether and what water-quality permitting is required.

There is a Ground Water Storage and Recovery Act (the Act) (NMSA 1978, 72-5A-1) and Regulation 19.25.8 NMAC (the Regulation) that governs the general process and procedures involved for projects authorized under the Act. The Act allows for governmental entities to store surplus supplies of water underground and to withdraw the recoverable amount at a later date for use. The Regulation describes a water storage account with a limit on the amount of water that can be administratively recovered for later use (19.25.8.31 NMAC). The Regulation requires a pre-application meeting with representatives of the State Engineer to, among other requirements, discuss the proposed method to calculate the amount of

recoverable water in storage. If the Town plans to apply for a permit authorized under the Act, we recommend coordinating with the OSE to determine a technically suitable calculation method to quantify the amount of stored water that can be administratively accounted for. If the Town plans to recharge groundwater without an administrative account of the recoverable quantity, then the recharge still has the benefit of raising groundwater levels and enhancing aquifer storage life.

Recommended Pilot Program

Although the three-day aquifer test in 1982 at Frank's Well 7 provided information on local infiltration rates, it would be prudent to conduct a pilot test for a longer period of time to confirm conditions suitable for the full scale project. We recommend the Town undertake a short-term recharge pilot project that would involve pumping one or more of the Town's supply wells and conveying water to an arroyo at a reasonably constant rate for several months. The program would demonstrate technical and hydrologic feasibility of recharging water through arroyos prior to moving forward with the $4.2 million cost of installing the infrastructure to import water from the Gila River. The rate and duration may depend on available well capacity and Town water-service demands, but a minimum of 0.5 cfs (220 gpm) for three to five months is recommended. The test could be conducted through the fall, winter or spring months when municipal demand is lowest. We recommend at least one subsurface instrument nest installed along the wetted reach to track recharge progress.

If possible, water from the wells could be routed through the Town's existing water supply line to a tee fitting that directs water to the head of the recharge reach. A few hundred feet of temporary PVC may be needed to convey water to the site, which can be buried in a shallow trench for security and to prevent freezing. The pipe would include a pressure gage, rate control valve and totalizing meter to track and control discharge. The cost of buying and installing equipment for the example setup would be about $10,000 to $20,000 for the outlet pipe and valves and about $40,000 for an instrument nest, or a total of up to $60,000.

Administrative and permitting issues for a short pilot test with State agencies are uncertain, but may be relatively simple. Water for the project would come from the Town's

OSE-permitted quantities and wells, and would be used within the Town's permitted place of use. The Town may want to confirm with their water attorney whether use of the water for recharge is within permitted purposes of use. A Notice of Intent to OSE for the project will be needed. The Town should also plan to submit a Notice of Intent to NMED, but we understand a groundwater discharge permit usually is not required for temporarily discharging potable groundwater from a municipal well directly to the ground surface.

Conclusions

1. The hydrogeologic model provides a suitable tool for assessing the hydrologic effects of groundwater development and management in the region of the Mangas Trench. The model is capable of simulating hydrologic conditions observed in the field and it may be used to understand the performance of the hydrologic system and to assist with future planning of local regional water use and management alternatives.

2. Historical groundwater pumping has resulted in water-level declines at the Town of Silver City wells. The extent of groundwater displaced into the Town wells is within a few miles of the wellfields.

3. Managed recharge options available to the Town of Silver City include direct injection to the aquifer with wells and infiltration along natural channels. Managed recharge in the wellfield area would reduce the amount of future drawdown that otherwise would occur and it is expected to provide a means to replenish aquifer storage historically consumed.

4. Long-term injection operations at the locations described herein may eventually result in the Town wells capturing recharge water. The timing and degree of capture depends on the amount and locations of recharge and on the magnitude of wellfield pumping. Actual recharge operations can be developed and managed to either avoid or create mixing of recharge water with Gila Group aquifer water. Unless a reason to design and manage an actual recharge operation to prevent mixing of recharge water with Gila Group aquifer water becomes apparent, an allowance for some mixing should be planned for.

5. Assuming existing infrastructure is available for conveying water, we estimate a recharge project involving infiltration of 800 acre feet per year of Gila River water would have an annual cost of about $0.8 million per year, or a unit cost of $1,000 per acre foot. The same amount of recharge water with direct injection into the aquifer (injection wells) costs more, or about $1.1 million per year with a unit cost of $1,400 per acre foot. A recharge project with more water than 800 acre feet per year has higher annualized costs, but lower unit costs in terms of cost per acre foot.

6. A pilot program to confirm infiltration performance in existing intermittent channels near Frank's wellfield would cost about $60,000 to set up. The test should run for a few months.

Recommendation

1. If the Town of Silver City decides to move forward with recharge operations, undertake a pilot program involving several months of routing well water to a local intermittent channel to demonstrate hydrologic feasibility of infiltration recharge. Install a vadose zone temperature and moisture-content instrument nest to track recharge progress. Findings will assist with decisions on moving forward.

Attachments: Table 1
Figures (20)

References

Alley, W.M., 2003, Office of Ground Water Technical Memorandum No. 2003.02: Terminology Used in Studies of the Source Water to Wells Under Steady-State Conditions, Distribution: All WRD Employees, Technical Memorandum dated May 28, 2003, from William M. Alley, Chief, Office of Ground Water.

Anderman, E.R. and Hill, M.C., 2003, MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model—Three Additions to the Hydrogeologic-Unit Flow (HUF) Package: Alternative Storage for the Uppermost Active Cells (SYTP Parameter Type), Flows in Hydrogeologic Units, and the Hydraulic-Conductivity Depth-Dependence (KDEP) Capability: U.S. Geological Survey Open-File Report 03-347.

ARC GIS, 2009, Geographical Information System: ESRI, http://www.esri.com/software/arcgis/arcinfo/index.html.

Balleau Groundwater, Inc., 2010, Hydrologic Assessment of Water-Level Rise Beneath Southwest New Mexico Solid Waste Authority Landfill: Unpublished Consultant Report to Town of Silver City, Technical Memorandum dated July 14, 2010.

Balleau Groundwater, Inc., 2009, Installation of Monitoring System for Tracking Subsurface Thermal Water Movement: Unpublished Consultant Report to Town of Silver City, New Mexico, Technical Memorandum dated May 1, 2009.

Balleau Groundwater, Inc., 2006, Supplement on Water Use and Wellfield Service-a 40-Year Water Plan for the Town of Silver City, New Mexico: Unpublished Consultant Report to Town of Silver City, New Mexico.

Cunningham, J.E., 1974, Geologic Map and Sections of Silver City Quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources.

Daniel B. Stephens & Associates, Inc., 2005, Southwest New Mexico Regional Water Plan Volume 1: Report Text, Appendix A.

Hanson, R.T., McLean, J.S. and Miller, R.S., 1994, Hydrogeologic Framework and Preliminary Simulation of Ground-Water Flow in the Mimbres Basin, Southwestern New Mexico: U.S. Geological Survey Water-Resources Investigations Report 94-4011.

Harbaugh, A.W., Banta, E.R., Hill, M.C. and McDonald, M.G., 2000, MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model—User Guide to Modularization Concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92.

Hathaway, D.L., 1986, Hydrogeologic Evaluation of Proposed Transfer of Water from the Gila River to Tyrone by the Phelps Dodge Corporation: New Mexico Office of the State Engineer.

Hawley, J.W., Hibbs, B.J., Kennedy, J.F., Creel, B.J., Remmenga, M.D., Johnson, M., Lee, M.M. and Dinterman, Phil, 2000, Trans-International Boundary Aquifers in Southwestern New Mexico.

Hedlund, D.C., 1978a, Geologic Map of the Wind Mountain Quadrangle, Grant County, New Mexico: U.S. Geological Survey, Map MF-1031.

Hedlund, D.C., 1978b, Geologic Map of the White Signal Quadrangle, Grant County, New Mexico: U.S. Geological Survey, Map MF-1041.

Hernandez, J.W., Hines, W.G. and Trauger, F.D., 1984, Evaluation of a Municipal Water Supply for the Silver City Area Using Ground Water Recharge of Water from Conner Reservoir on the Gila River: Report prepared for Town of Silver City and New Mexico Interstate Stream Commission, dated August 1984.

Jenkins, D.N. and Prentice, J.K., 1982, Theory for Aquifer Test Analysis in Fractured Rocks Under Linear (Nonradial) Flow Conditions: Ground Water – January-February 1982, Vol. 20, No. 1.

Johnson, M.S., 2000, Hydrologic Evaluation of Application GSF-1745 into GSF-1014 for Permit to Change Location of Well and Place or Purpose of Use in the Gila-San Francisco

Underground Water Basin Grant County, New Mexico: New Mexico Office of the State Engineer Hydrology Report 00-3.

Johnson, M.S., February 6, 2002 Technical Memorandum "Modifications to the OSE Silver City Ground-Water Flow Model": New Mexico Office of the State Engineer.

Koopman, F.C., Trauger, F.D and Basler, J.A., 1969, Water Resources Appraisal of the Silver City Area New Mexico: New Mexico Office of the State Engineer Technical Report 36.

Paige, S., 1916, Description of the Silver City Quadrangle, New Mexico: U.S. Geological Survey Atlas, Folio 1999, 19 pp.

Pollock, D.W., 1994, User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S. Geological Survey Finite-Difference Ground-Water Flow Model: U.S. Geological Survey Open-File Report 94-464.

Trauger, F.D. and Lavery, N.G., 1976, Geohydrology of the Upper Pipeline Draw Area, Grant County, New Mexico: Consultant Report to Exxon Minerals, USA, Houston, Texas.

Trauger, F.D., 1972, Water Resources and General Geology of Grant County, New Mexico: New Mexico State Bureau of Mines and Mineral Resources Hydrologic Report 2.

TABLE 1. ESTIMATED CAPITAL AND ANNUAL COSTS
FOR EXAMPLE INJECTION AND FOR INFILTRATION PROJECTS

Element	Cost per unit	Unit	No. of Units	Totals
Injection				
Capital Costs				
Pumping station	-	-	-	$210,000
Pipeline	$500,000	mi	8	$4,000,000
Treatment Plant	$1,200	AF	800	$960,000
1100-ft injection well	$250	ft	1100	$275,000
600-ft injection well	$250	ft	600	$150,000
Well appurtenances	$50,000	each	2	$100,000
Observation well	$150	ft	1100	$165,000
			Total	$5,860,000
			Ten Percent Annualized[1]	$586,000
O&M Costs				
Pumping water	$460	AF	800	$370,000
Water Treatment	$150	AF	800	$120,000
Well rehabilitation	$15,000	each	2	$30,000
			Total	$520,000
			Total Annual Cost for Water Injection	$1,106,000
			Unit Cost ($/AF)[2]	$1,400
Infiltration				
Capital Costs				
Pumping station	-	-	-	$210,000
Pipeline	$500,000	mi	8	$4,000,000
Monitor Well	$100	ft	450	$45,000
Instrumentation nests	$42,500	nest	2	$85,000
			Total	$4,340,000
			Ten Percent Annualized[1]	$434,000
O&M Costs				
Pumping water	$460	AF	800	$368,000
Arroyo bed rehabilitation	$5,000	acre	2	$10,000
			Total	$378,000
			Total Annual Cost for Water Infiltration	$812,000
			Unit Cost ($/AF)[2]	$1,000

[1]Equivalent to annual payments for 20 years at 8 percent interest.

[2]Rounded to nearest $100

Bill Evans Lake
Mangas Springs
Pinos Atos
Town of Silver City
Arenas Valley
180
Santa Clara
Bayard
Mangas Valley
Frank's
PROPOSED RECHARGE SITES
Woodward
Tyrone
Gabby Hayes
Hurley
LITTLE BURRO MOUNTAINS
BURRO MOUNTAINS
Anderson
Tyrone Mine
90
Area of Interest (Model Boundary)

0 5 Miles

Map Projection: New Mexico West, NAD83.

N
W E
S

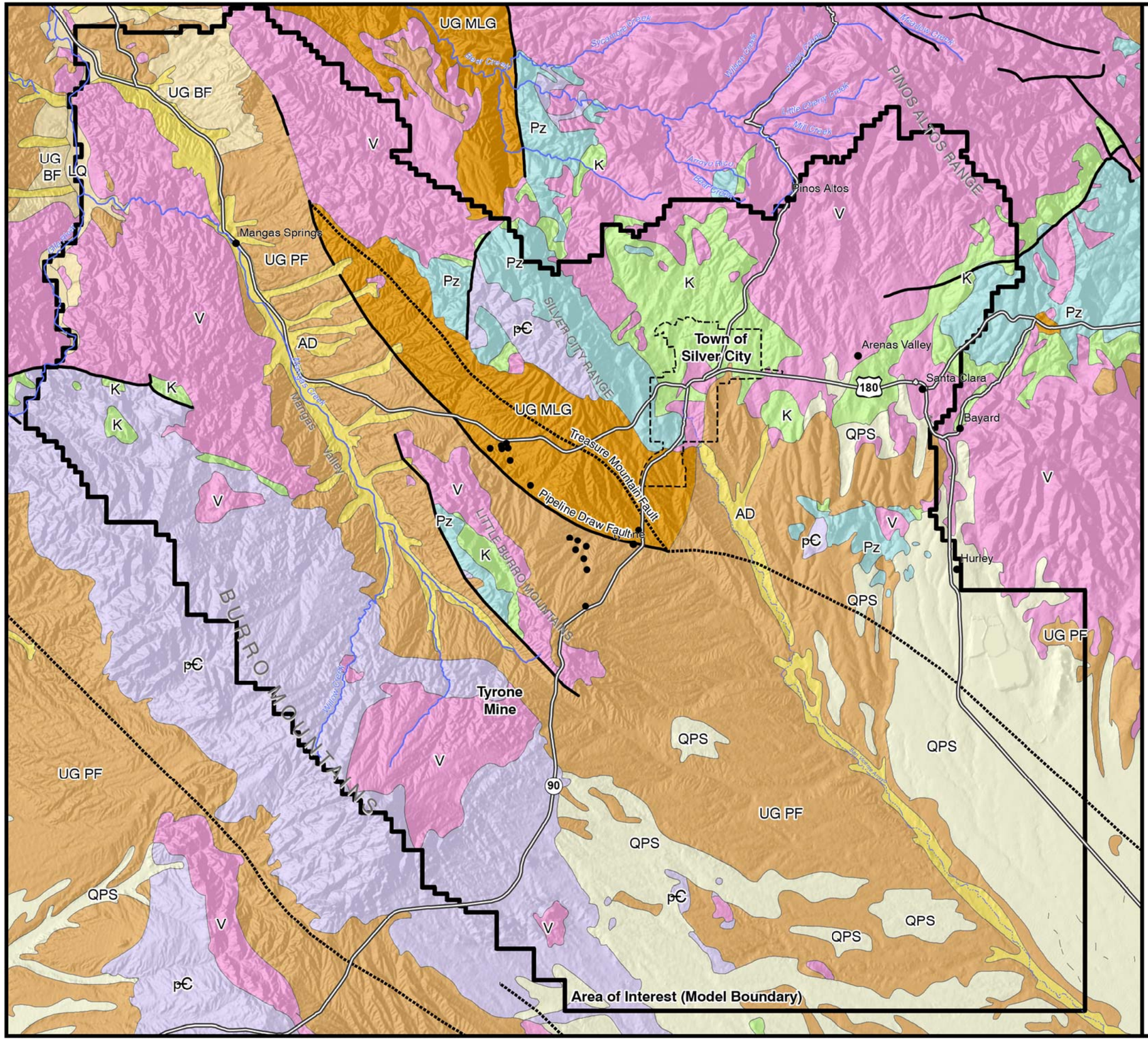
TOWN OF SILVER CITY / GROUNDWATER RECHARGE

LOCALITY AND AREA OF INTEREST

DATE: 7/14/2010	**FIGURE 1**
PRODUCED BY: SES	
CHECKED BY: DR	
FILE NAME: Fig1.MXD	

BGW

BALLEAU GROUNDWATER, INC.



EXPLANATION

TERTIARY
- PALEOGENE
- NEOGENE

QUARTERNARY

- AD Alluvial deposits of major ephemeral streams
- LQ Late Quaternary fluvial hydrostratigraphic units
- QPS Quaternary piedmont slope hydrostratigraphic units
- UG BF Upper Gila Group hydrostratigraphic units - Basin-floor facies
- UG PF Upper Gila Group hydrostratigraphic units - Piedmont facies
- UG MLG Middle/Lower Gila Group hydrostratigraphic units - Middle and Lower Gila
- K Cretaceous rocks
- Pz Paleozoic rocks
- pC Pre-Cambrian
- V Volcanics (Quarternary and Tertiary)
- 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 West, NAD83.

N W E S

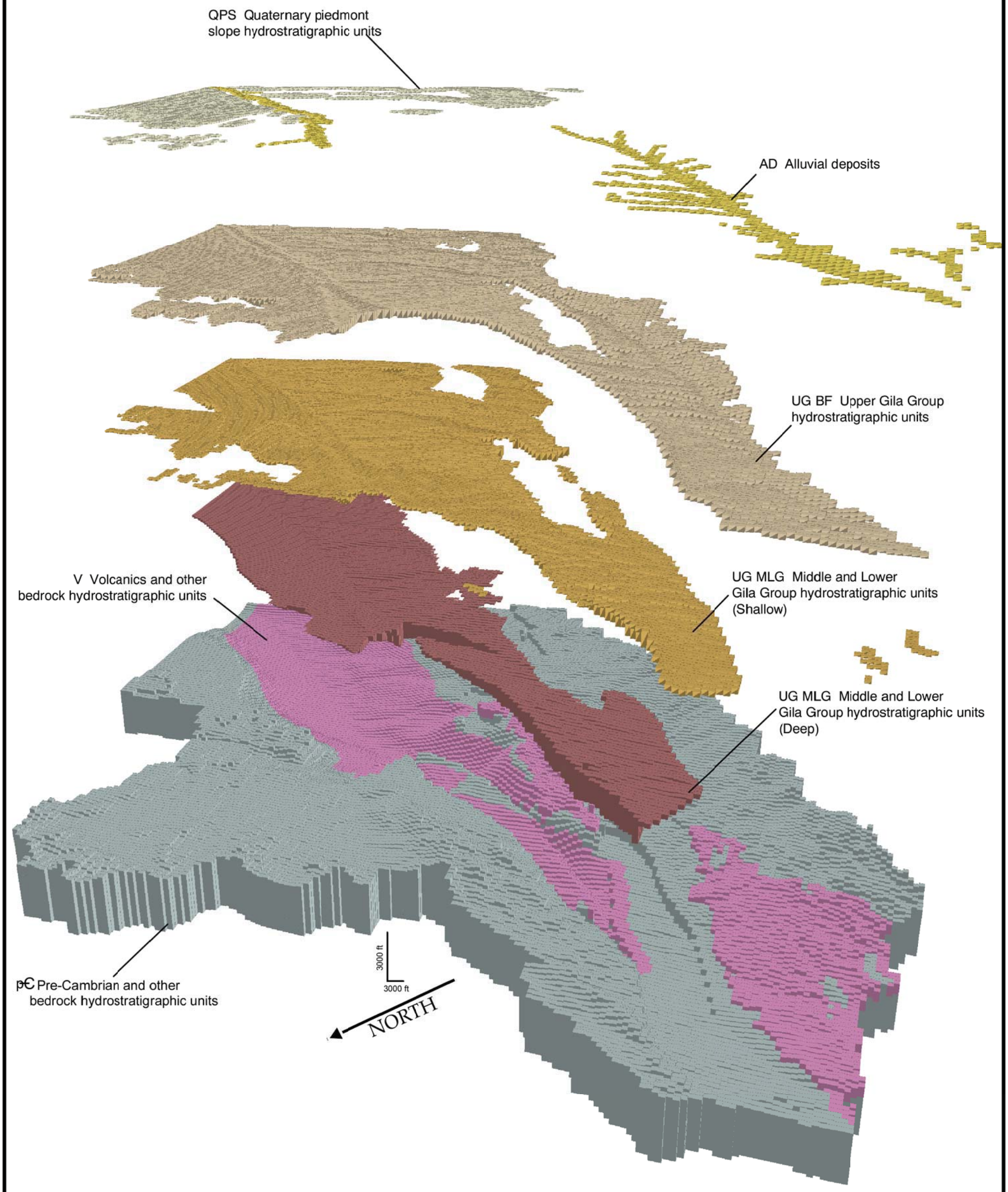
TOWN OF SILVER CITY / GROUNDWATER RECHARGE

GEOLOGY OF SILVER CITY AREA

DATE: 7/14/2010
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIG2.MXD

FIGURE 2

BALLEAU GROUNDWATER, INC.



TOWN OF SILVER CITY / GROUNDWATER RECHARGE

THREE-DIMENSIONAL MODEL STRUCTURE

DATE:	7/14/2010
PRODUCED BY:	SES
CHECKED BY:	DR
FILE NAME:	FIG3.MXD

FIGURE 3

BALLEAU GROUNDWATER, INC.

Mangas Creek
4,600 AFY

Gila River
2,400 AFY

ET
4,000 AFY

Recharge
19,400 AFY

Subsurface
Flow Out
8,400 AFY

Mangas Springs
Pinos Atos
Town of
Silver City
Arenas Valley
Santa Clara
Bayard
Hurley
Frank's
Woodward
Tyrone
Gabby
Hayes
Anderson
Tyrone
Mine
Mangas Valley
LITTLE BURRO MOUNTAINS
BURRO MOUNTAINS
180
90

Area of Interest (Model Boundary)

0 5 Miles

Map Projection: New Mexico West, NAD83.

N
W E
S

TOWN OF SILVER CITY /
GROUNDWATER RECHARGE

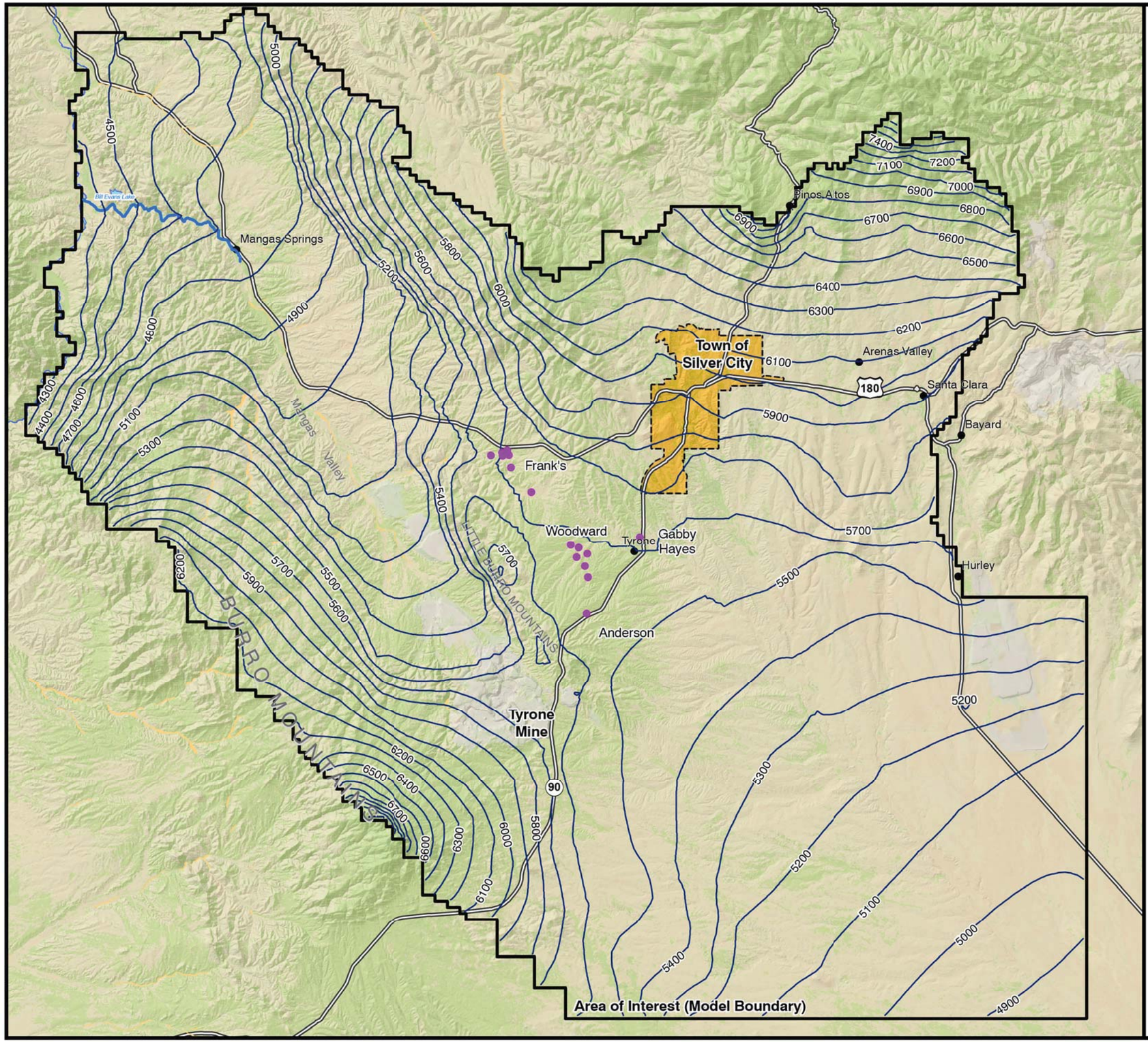
**PRE-DEVELOPMENT
GROUNDWATER FLOW BUDGET**

DATE:	7/14/2010
PRODUCED BY:	SES
CHECKED BY:	DR
FILE NAME:	FIG4.MXD

FIGURE 4

BGW

BALLEAU GROUNDWATER, INC.



EXPLANATION

5500 WATER-TABLE CONTOUR (FT)

0 5 Miles

Map Projection: New Mexico West, NAD83.

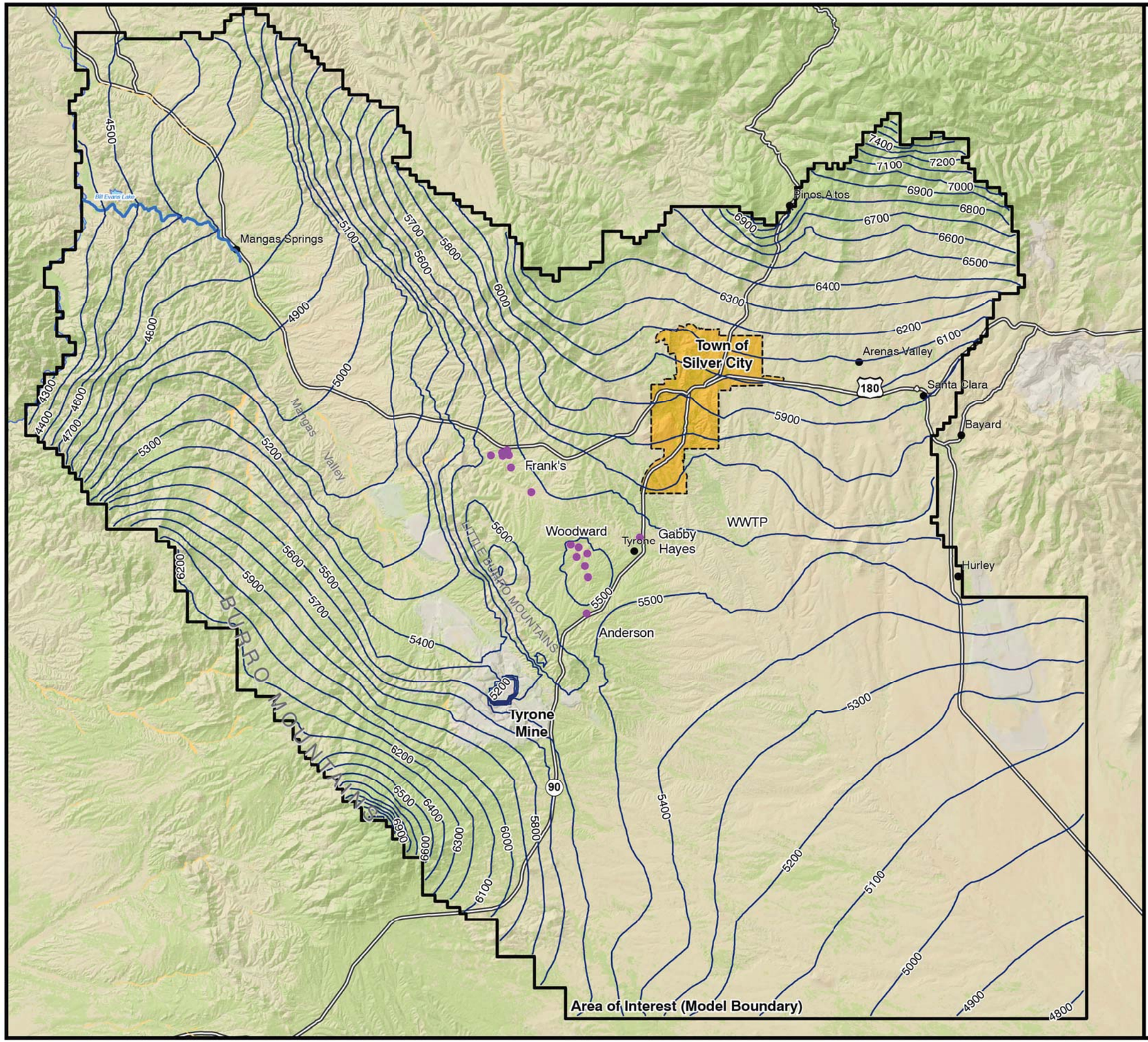
N
W E
S

TOWN OF SILVER CITY / GROUNDWATER RECHARGE

SIMULATED PRE-DEVELOPMENT WATER-LEVEL MAP

DATE: 7/14/2010	**FIGURE 5**
PRODUCED BY: SES	
CHECKED BY: DR	
FILE NAME: FIG5.MXD	

BALLEAU GROUNDWATER, INC.



EXPLANATION

5500 WATER-TABLE CONTOUR (FT)

0 5 Miles

Map Projection: New Mexico West, NAD83.

N
W E
S

TOWN OF SILVER CITY / GROUNDWATER RECHARGE

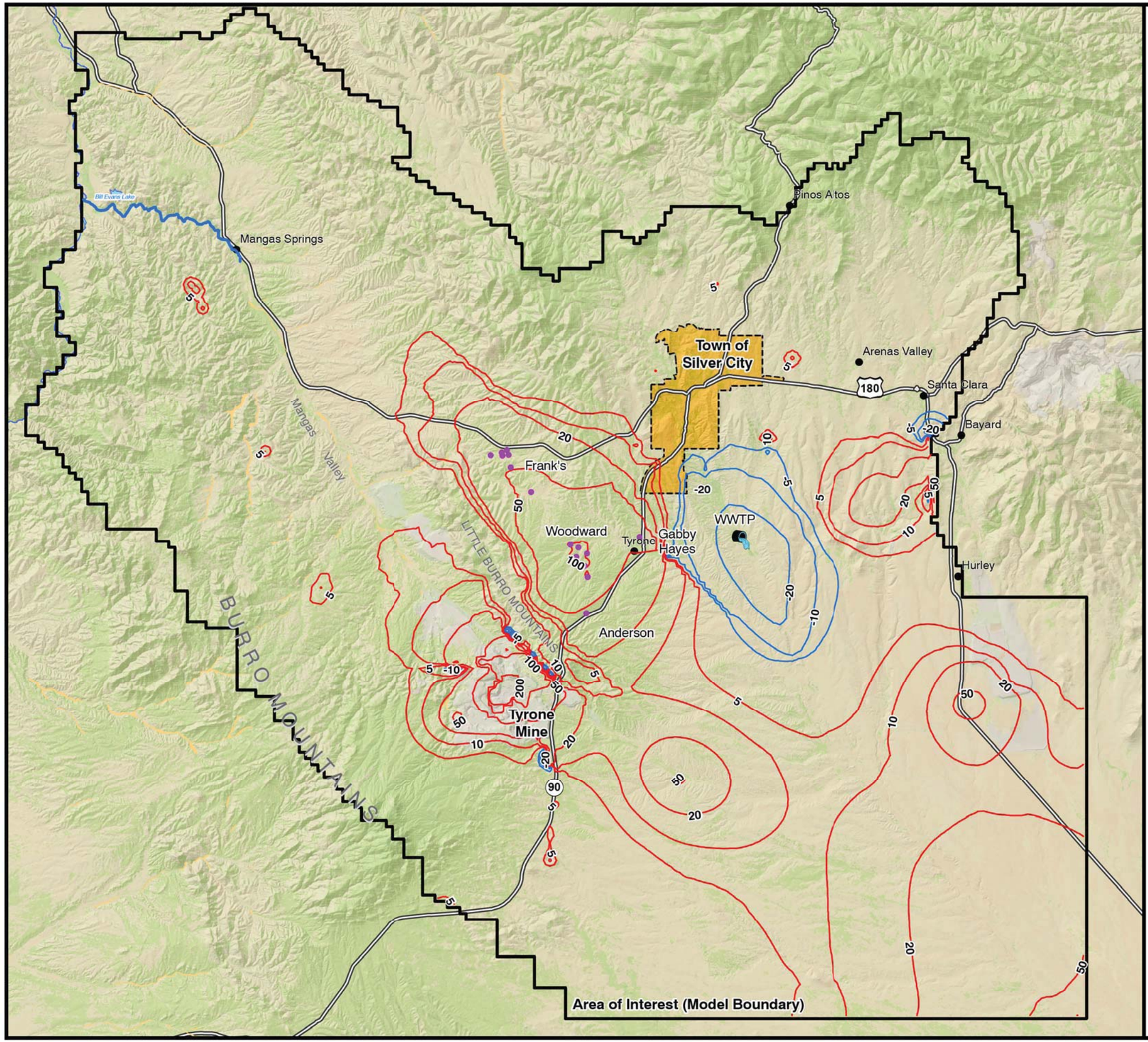
SIMULATED YEAR 2008 WATER-LEVEL MAP

DATE: 7/14/2010
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIG6.MXD

FIGURE 6

BGW

BALLEAU GROUNDWATER, INC.



EXPLANATION

20 WATER-TABLE BUILD-UP (FT)

20 WATER-TABLE DRAWDOWN (FT)

0 5 Miles

Map Projection: New Mexico West, NAD83.

N
W E
S

TOWN OF SILVER CITY / GROUNDWATER RECHARGE

SIMULATED HISTORICAL WATER-LEVEL CHANGE

DATE: 7/14/2010	
PRODUCED BY: SES	**FIGURE 7**
CHECKED BY: DR	
FILE NAME: FIG7.MXD	

BGW

BALLEAU GROUNDWATER, INC.

Town of Silver City

Frank's

Capture Zones

Woodward

Gabby Hayes

Tyrone

Anderson

Tyrone Mine

Mangas Valley

LITTLE BURRO MOUNTAINS

180

90

EXPLANATION

5500 WATER-TABLE CONTOUR (FT)

EXTENT OF GROUNDWATER CAPTURED BY WELL

0 5 Miles

Map Projection: New Mexico West, NAD83.

N W E S

TOWN OF SILVER CITY / GROUNDWATER RECHARGE

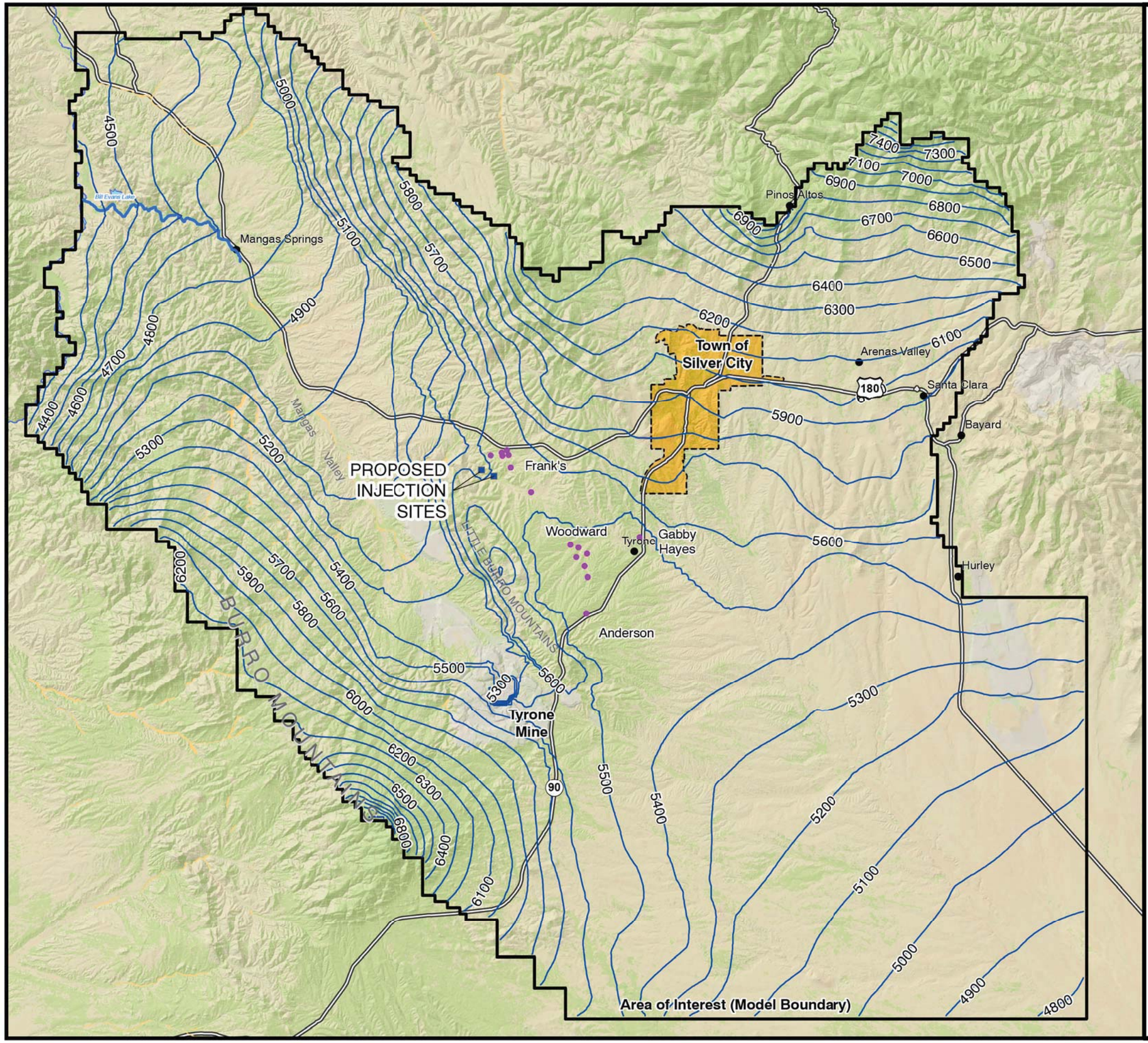
SIMULATED EXTENT OF GROUNDWATER CAPTURED BY TOWN WELLFIELD FROM 1946 TO 2008

DATE: 7/14/2010
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIG8.MXD

FIGURE 8

BGW

BALLEAU GROUNDWATER, INC.



EXPLANATION

5500 WATER-TABLE CONTOUR (FT)

0 5 Miles

Map Projection: New Mexico West, NAD83.

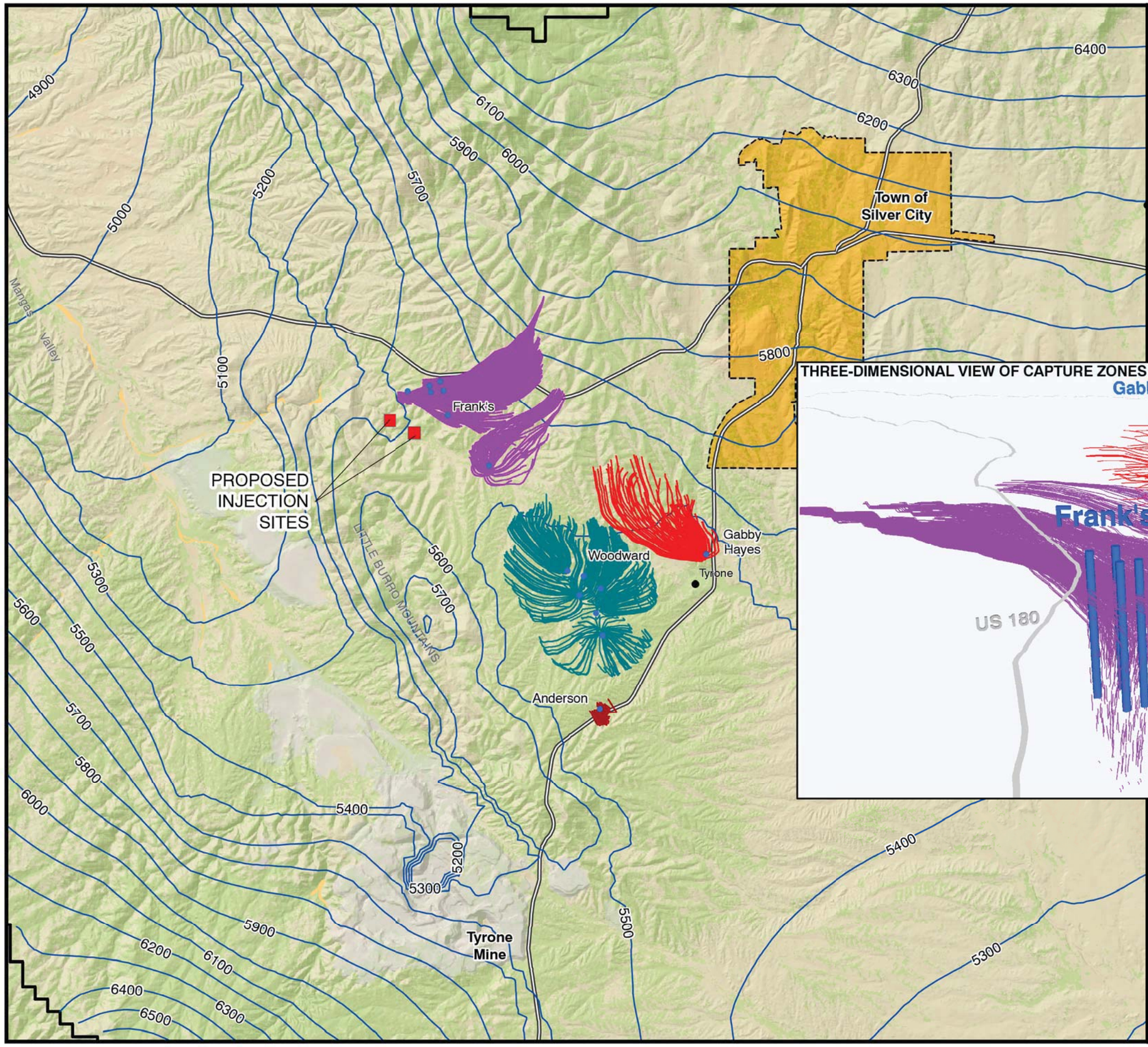
N W E S

TOWN OF SILVER CITY / GROUNDWATER RECHARGE

40-YEAR FUTURE BASELINE WATER-LEVEL CONDITION

DATE: 7/14/2010	**FIGURE 9**
PRODUCED BY: SES	
CHECKED BY: DR	
FILE NAME: FIG9.MXD	

BALLEAU GROUNDWATER, INC.



EXPLANATION

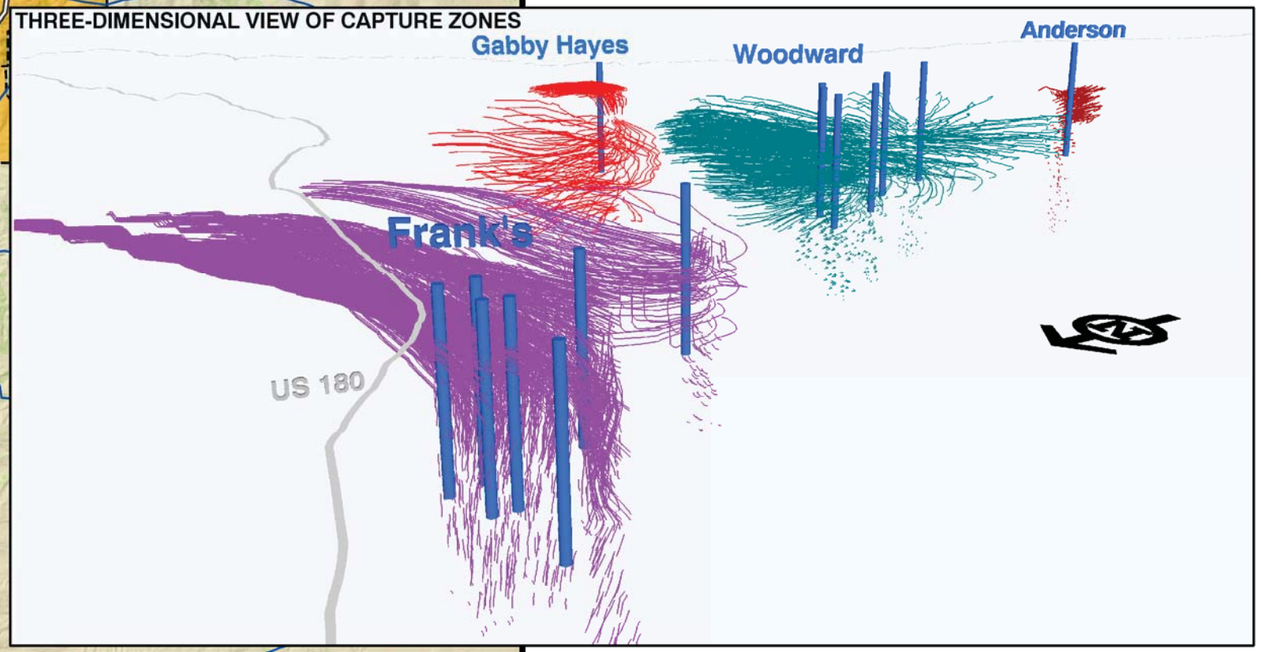
5200 — WATER-TABLE CONTOUR (FT)

EXTENT OF GROUNDWATER CAPTURED BY WELL (Color Indicates Wellfield)

0 — 5 Miles

Map Projection: New Mexico West, NAD83.

THREE-DIMENSIONAL VIEW OF CAPTURE ZONES



N
W E
S

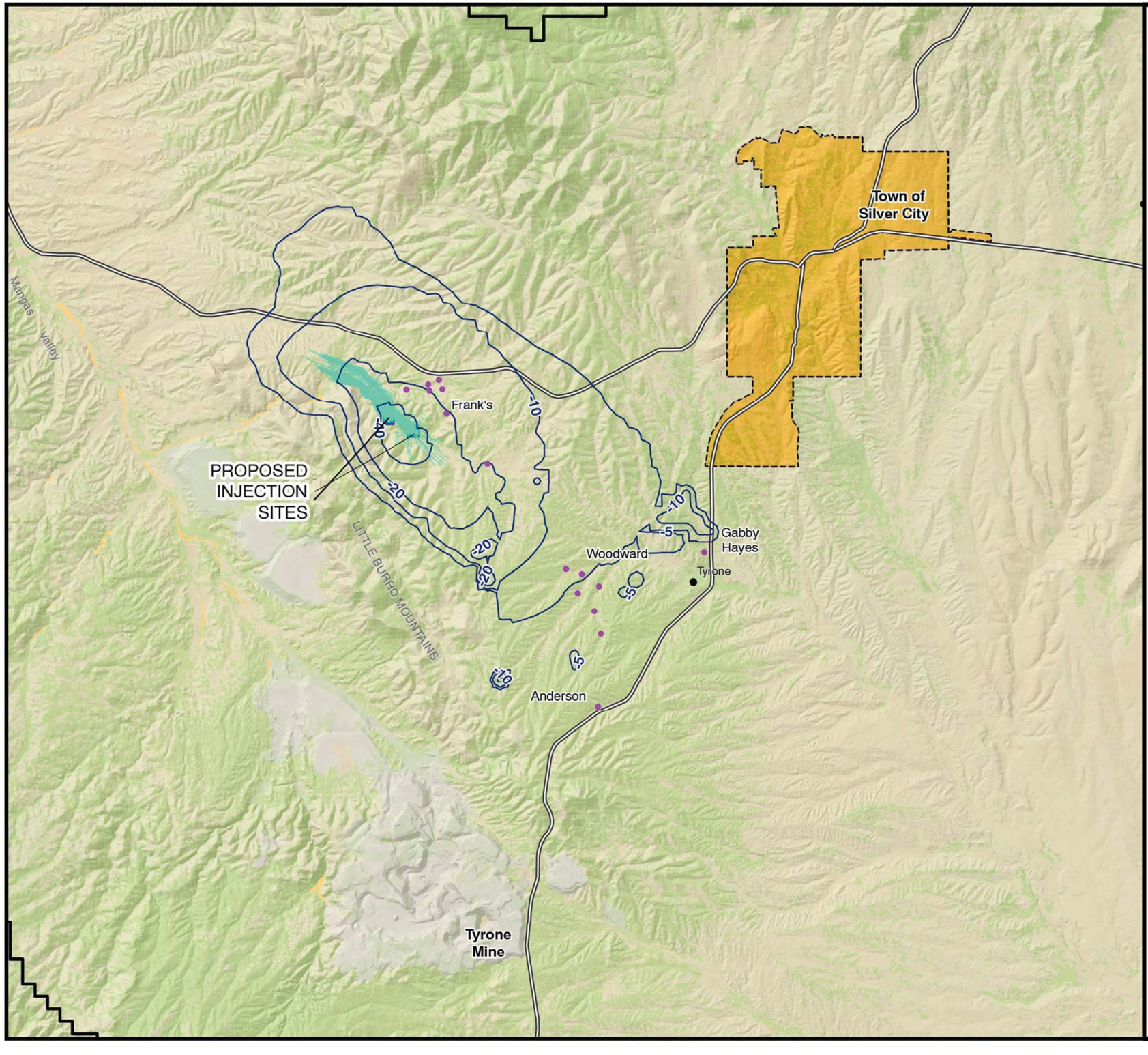
TOWN OF SILVER CITY / WATER USE

EXTENT OF GROUNDWATER CAPTURED BY TOWN WELLFIELD FROM 1946 TO 2048 (BASELINE)

DATE: 7/13/2010	**FIGURE 10**
PRODUCED BY: SFS	
CHECKED BY: DR	
FILE NAME: FIG10NEW.MXD	

BGW

BALLEAU GROUNDWATER, INC.



EXPLANATION

5 — 40-YEAR WATER-TABLE BUILD-UP CONTOUR (FT) FROM 1.0 CFS INJECTION

EXTENT TRAVELED BY RECHARGE WATER

0 — 5 Miles

Map Projection: New Mexico West, NAD83.

N
W E
S

TOWN OF SILVER CITY / WATER USE

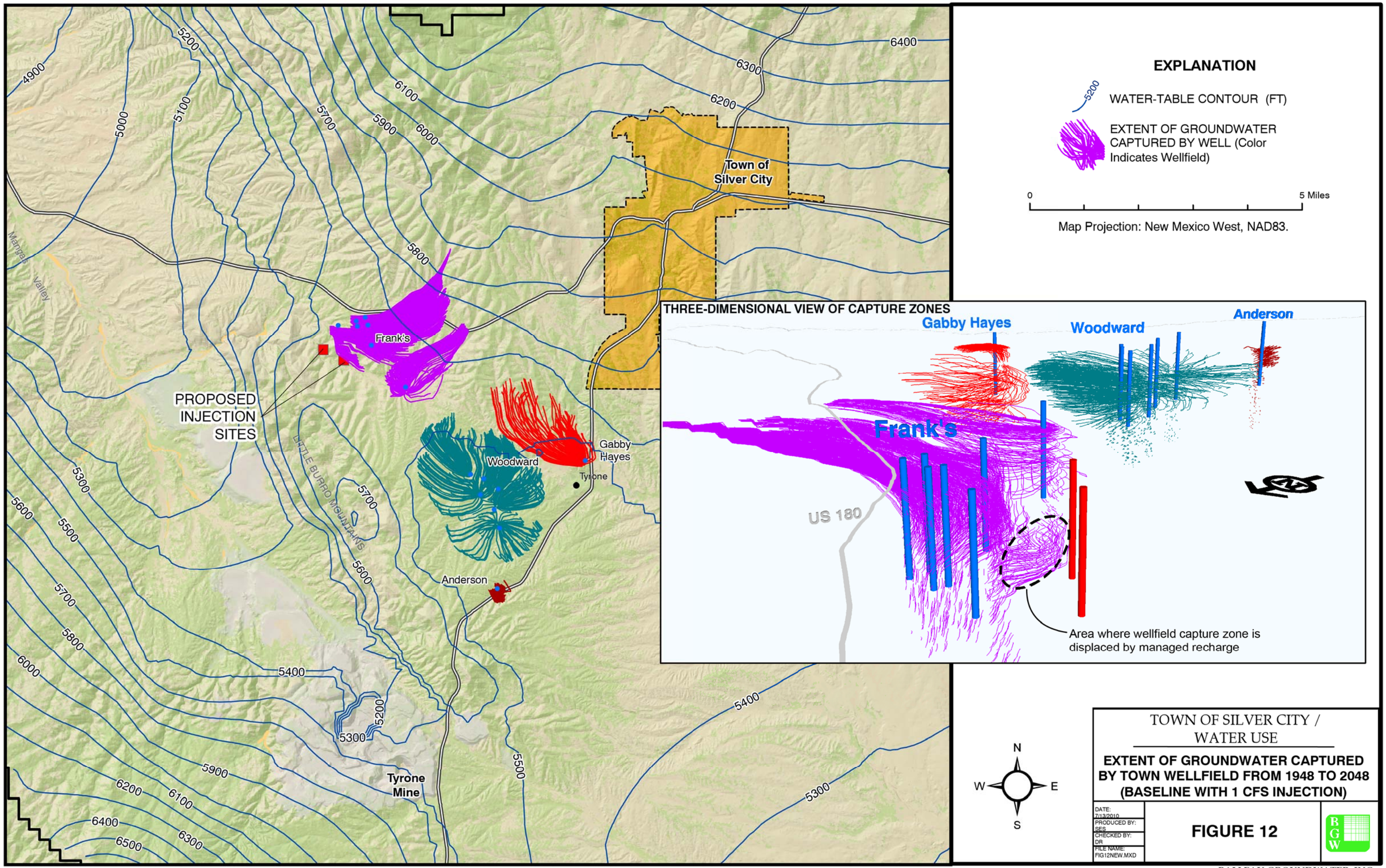
40-YEAR WATER-LEVEL BUILD-UP AND EXTENT OF INJECTION WATER

DATE:	7/14/2010
PRODUCED BY:	SES
CHECKED BY:	DR
FILE NAME:	FIG11NEW.MXD

FIGURE 11

BGW

BALLEAU GROUNDWATER, INC.



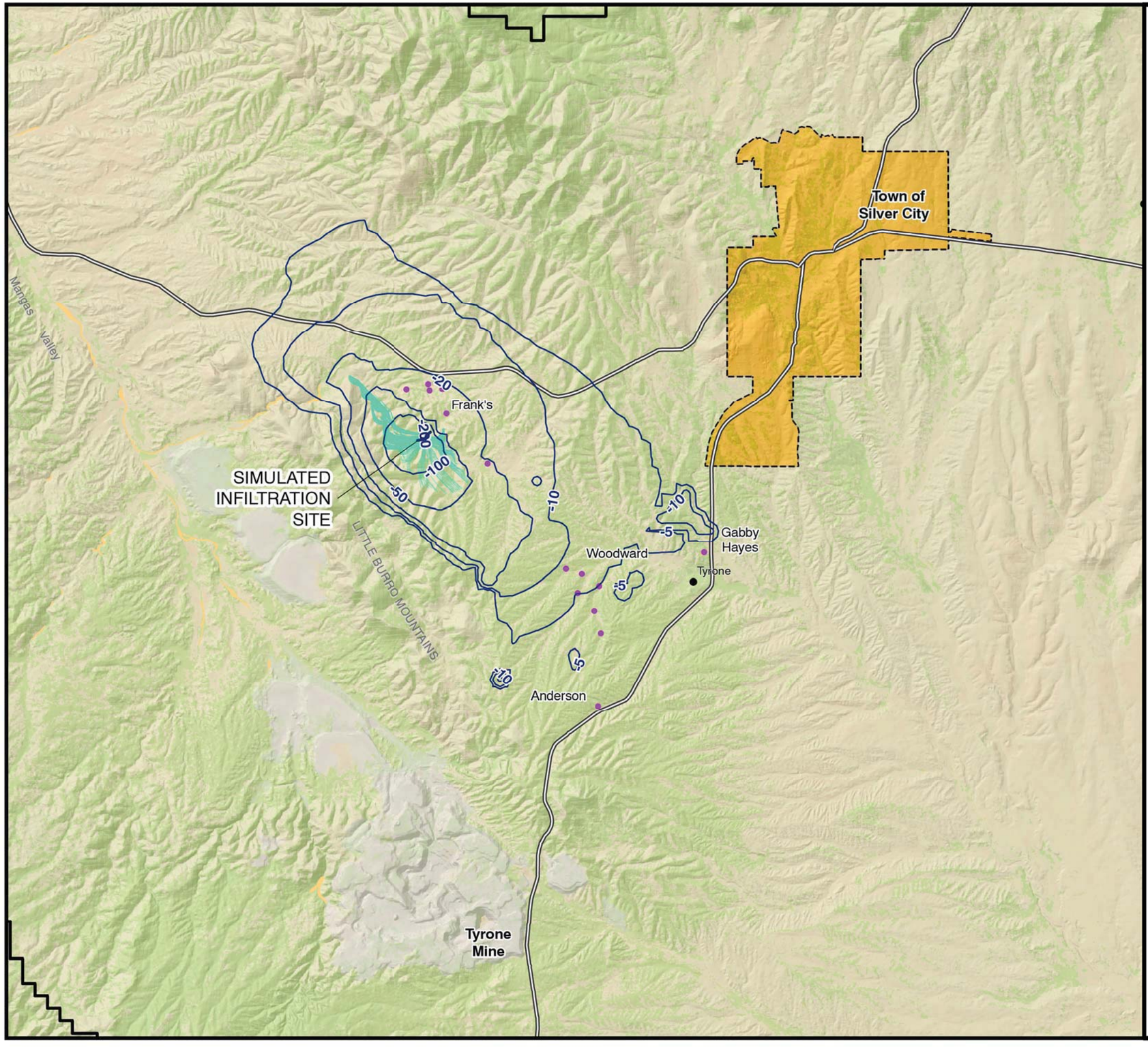
TOWN OF SILVER CITY / WATER USE

EXTENT OF GROUNDWATER CAPTURED BY TOWN WELLFIELD FROM 1948 TO 2048 (BASELINE WITH 1 CFS INJECTION)

DATE: 7/13/2010
PRODUCED BY: SES
CHECKED BY: DR
FILE NAME: FIG12NEW.MXD

FIGURE 12

BALLEAU GROUNDWATER, INC.



EXPLANATION

-50 40-YEAR WATER-TABLE BUILD-UP CONTOUR (FT) FROM 1.0 CFS INFILTRATION

EXTENT TRAVELED BY RECHARGE WATER

0 5 Miles

Map Projection: New Mexico West, NAD83.

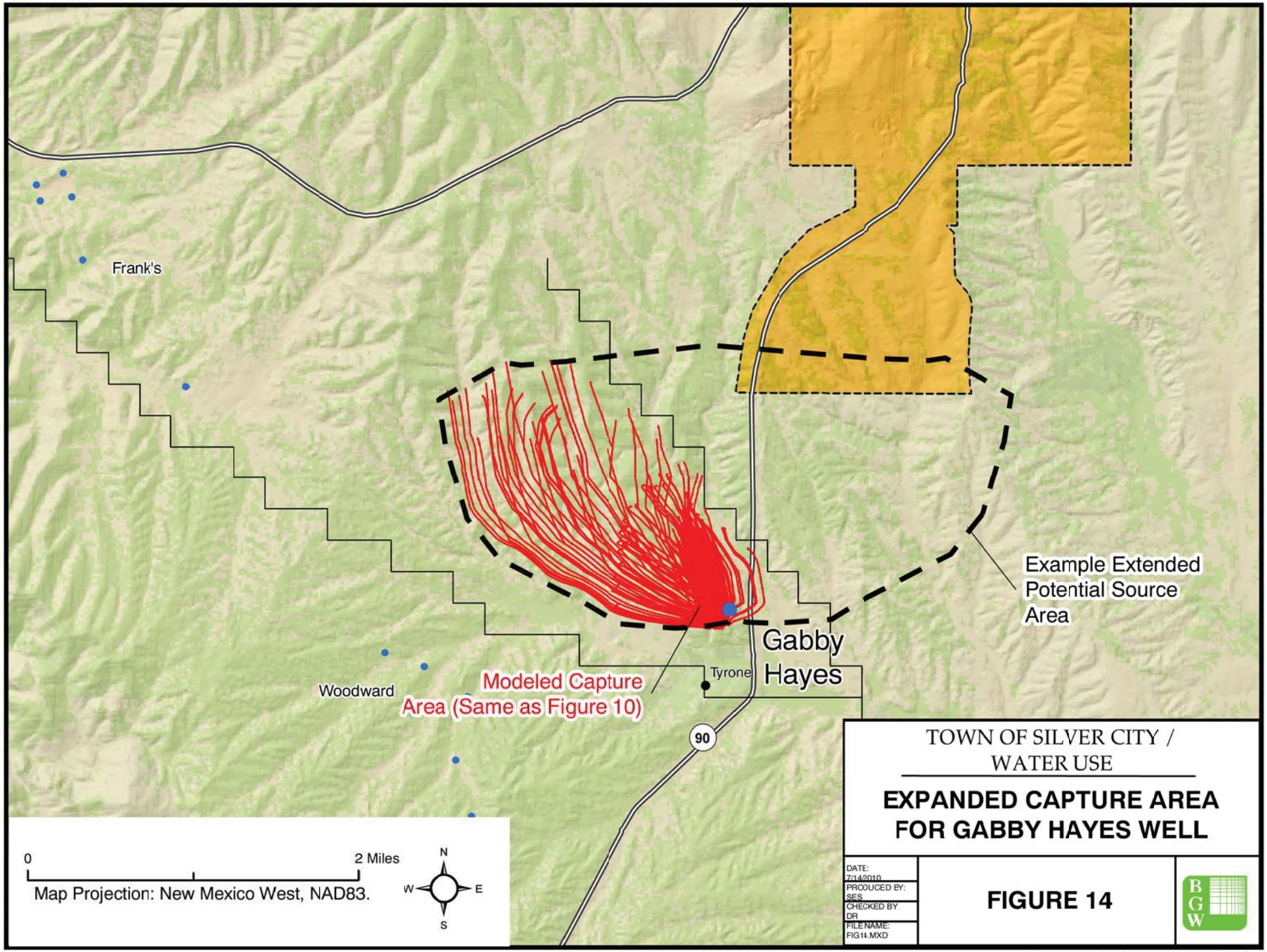
N
W E
S

TOWN OF SILVER CITY / WATER USE

40-YEAR WATER-LEVEL BUILD-UP AND EXTENT OF INFILTRATED WATER

DATE: 7/14/2010	
PRODUCED BY: SES	**FIGURE 13**
CHECKED BY: DR	
FILE NAME: FIG13.MXD	

BALLEAU GROUNDWATER, INC.



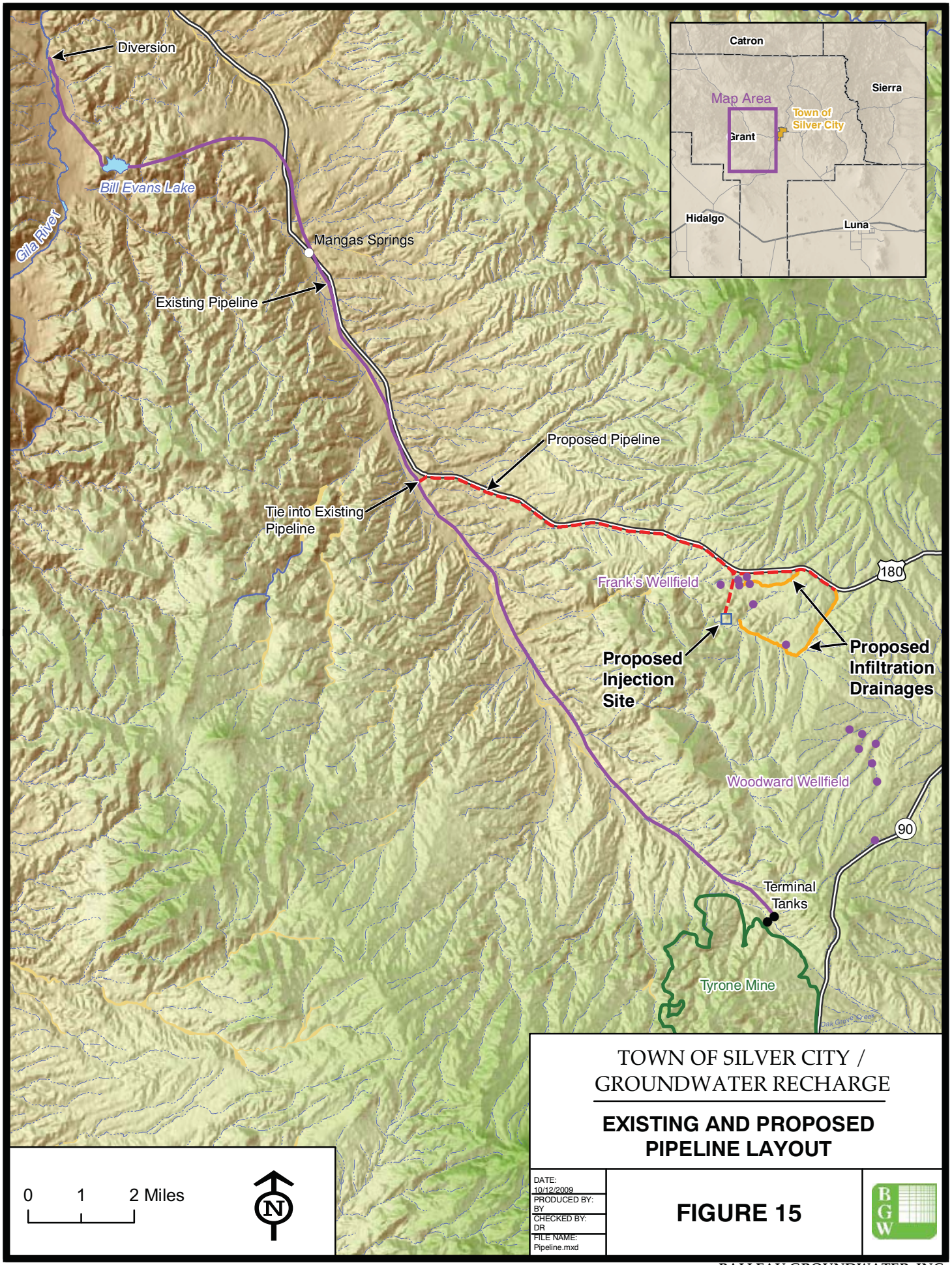
TOWN OF SILVER CITY / WATER USE

EXPANDED CAPTURE AREA FOR GABBY HAYES WELL

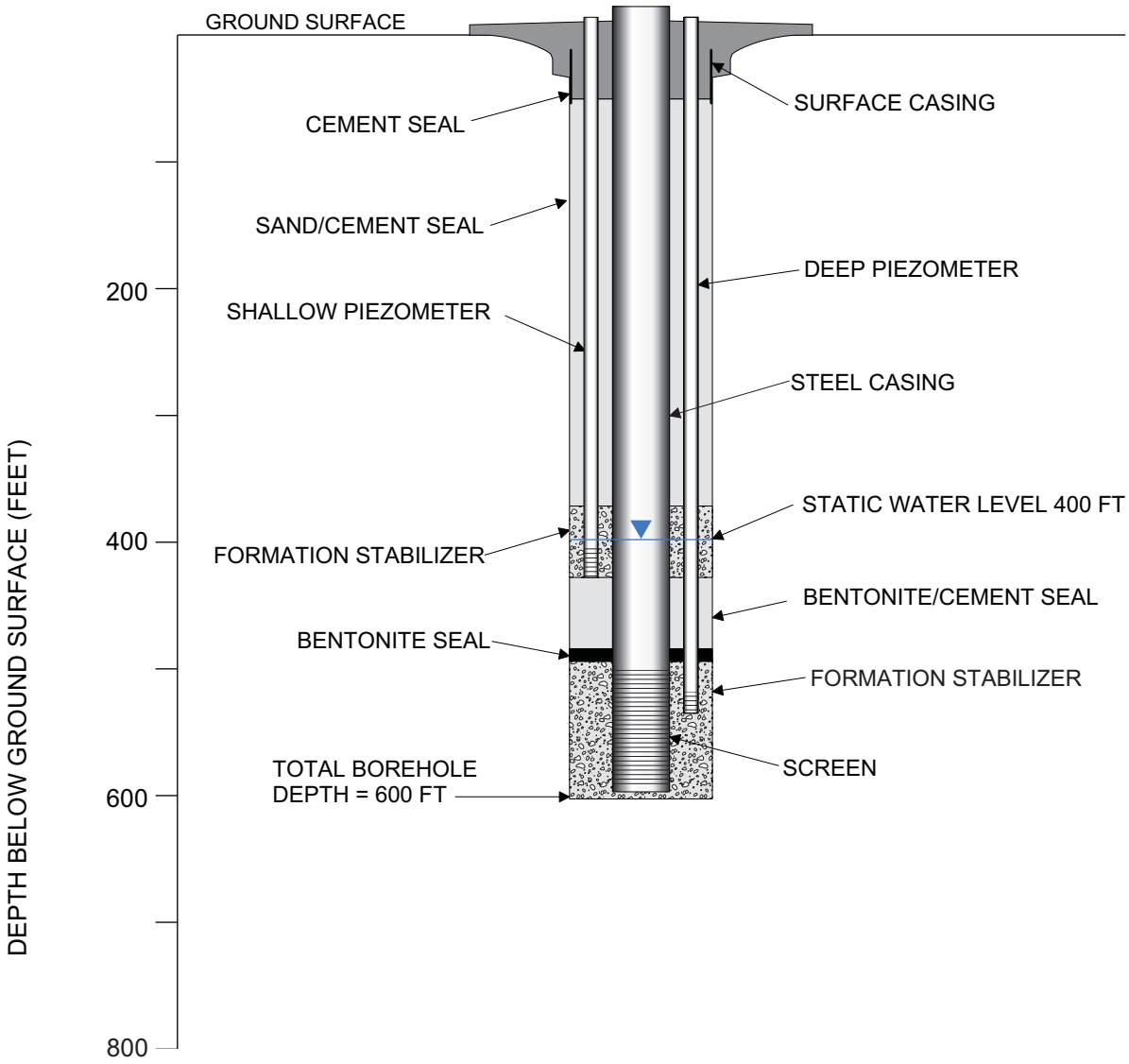
DATE: 7/14/2010	**FIGURE 14**
PRODUCED BY: SES	
CHECKED BY: DR	
FILE NAME: FIG14.MXD	

BGW

BALLEAU GROUNDWATER, INC.



BALLEAU GROUNDWATER, INC.

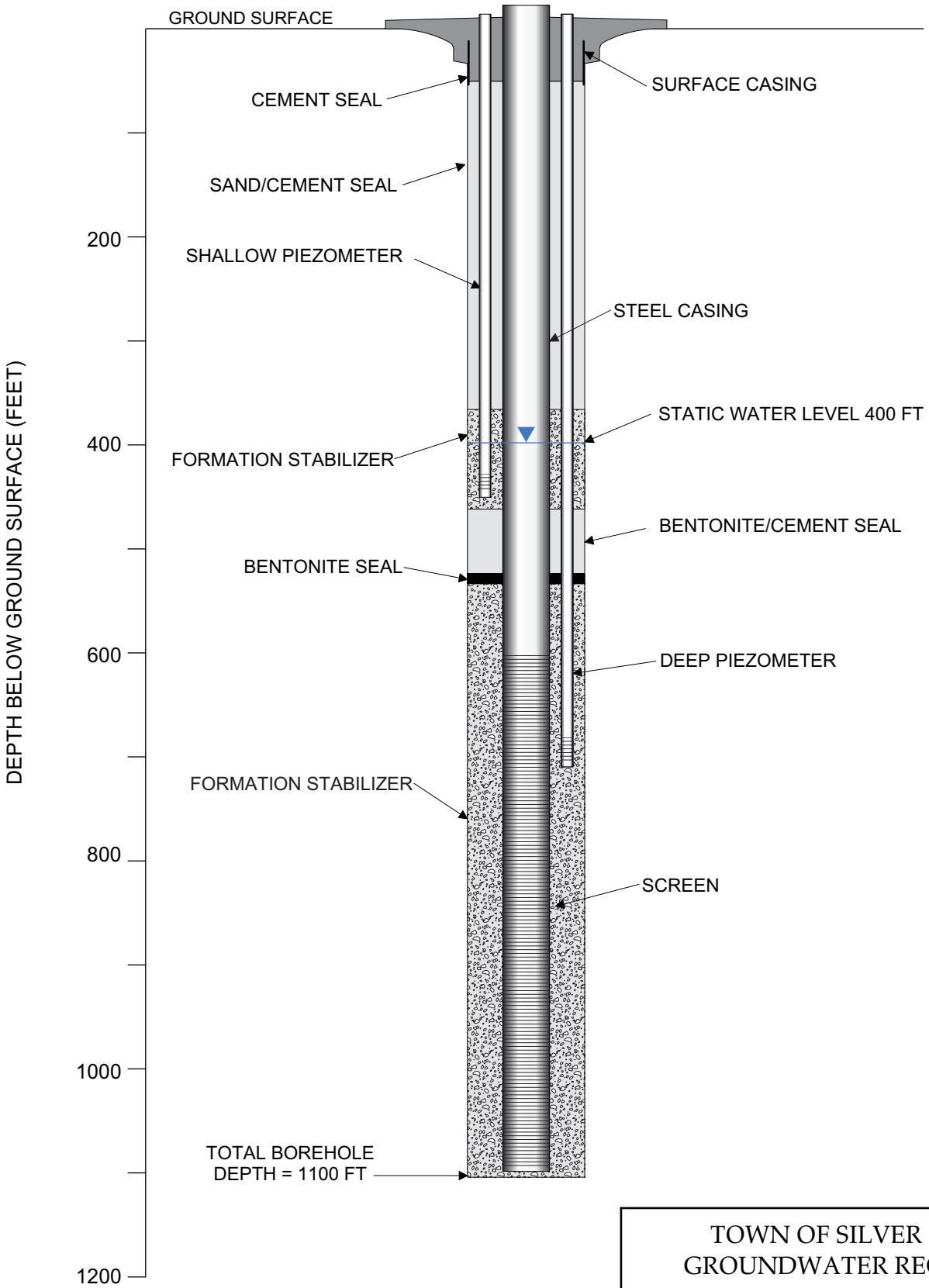


TOWN OF SILVER CITY / GROUNDWATER RECHARGE

EXAMPLE SHALLOW INJECTION WELL

Date: 10/14/2009	**FIGURE 16**
Produced By: BY	
Checked By: CC	
Filename: injwell_plan600.dsf	

BALLEAU GROUNDWATER, INC.

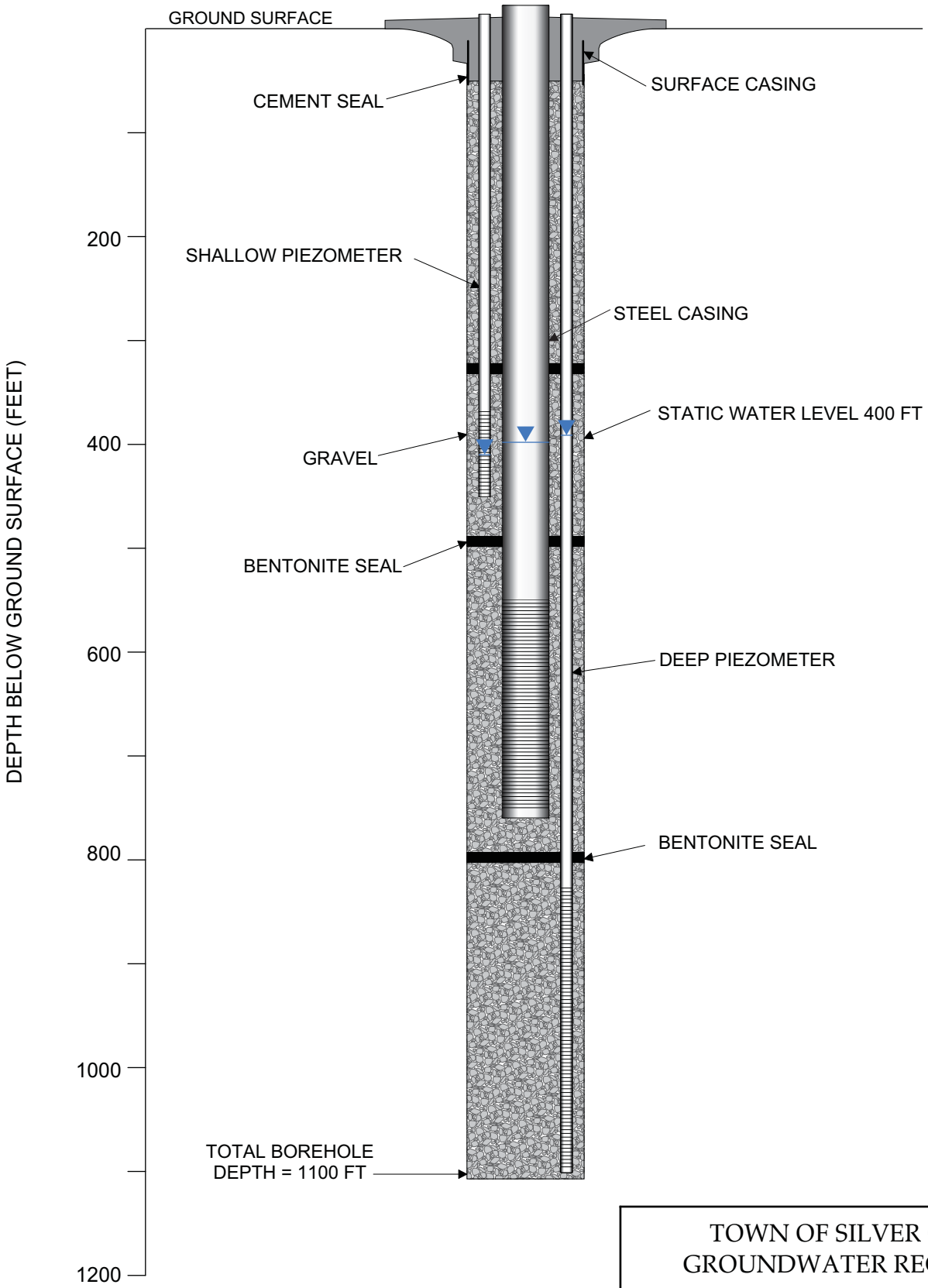


TOWN OF SILVER CITY / GROUNDWATER RECHARGE

EXAMPLE DEEP INJECTION WELL

Date: 10/14/2009	**FIGURE 17**
Produced By: BY	
Checked By: CC	
Filename: injwell_plan2.dsf	

BALLEAU GROUNDWATER, INC.

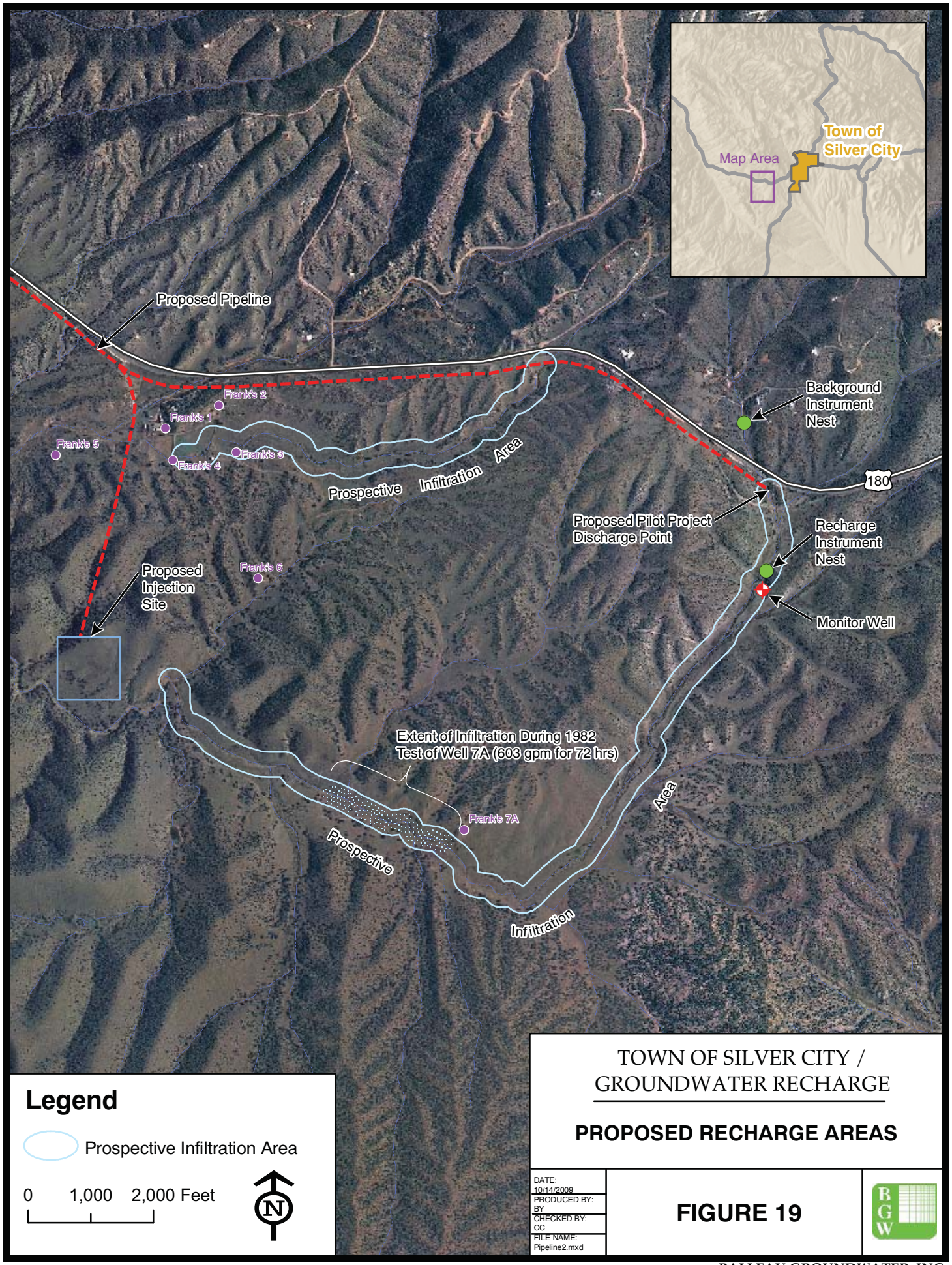


TOWN OF SILVER CITY / GROUNDWATER RECHARGE

EXAMPLE OBSERVATION WELL

Date: 10/14/2009	**FIGURE 18**
Produced By: BY	
Checked By: CC	
Filename: obswell_plan2.dsf	

BALLEAU GROUNDWATER, INC.



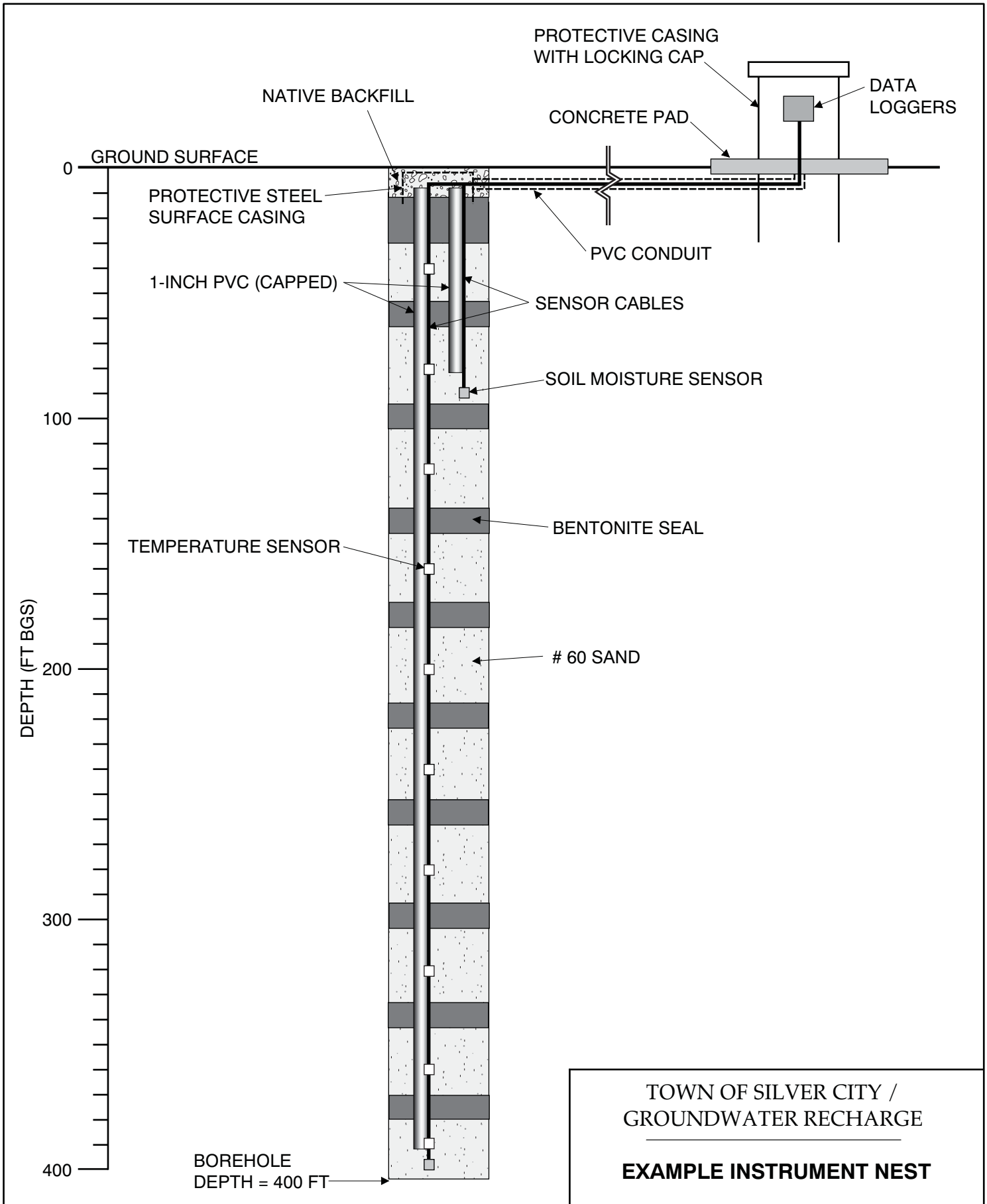
TOWN OF SILVER CITY / GROUNDWATER RECHARGE

PROPOSED RECHARGE AREAS

DATE: 10/14/2009	**FIGURE 19**
PRODUCED BY: BY	
CHECKED BY: CC	
FILE NAME: Pipeline2.mxd	

BGW

BALLEAU GROUNDWATER, INC.



TOWN OF SILVER CITY / GROUNDWATER RECHARGE

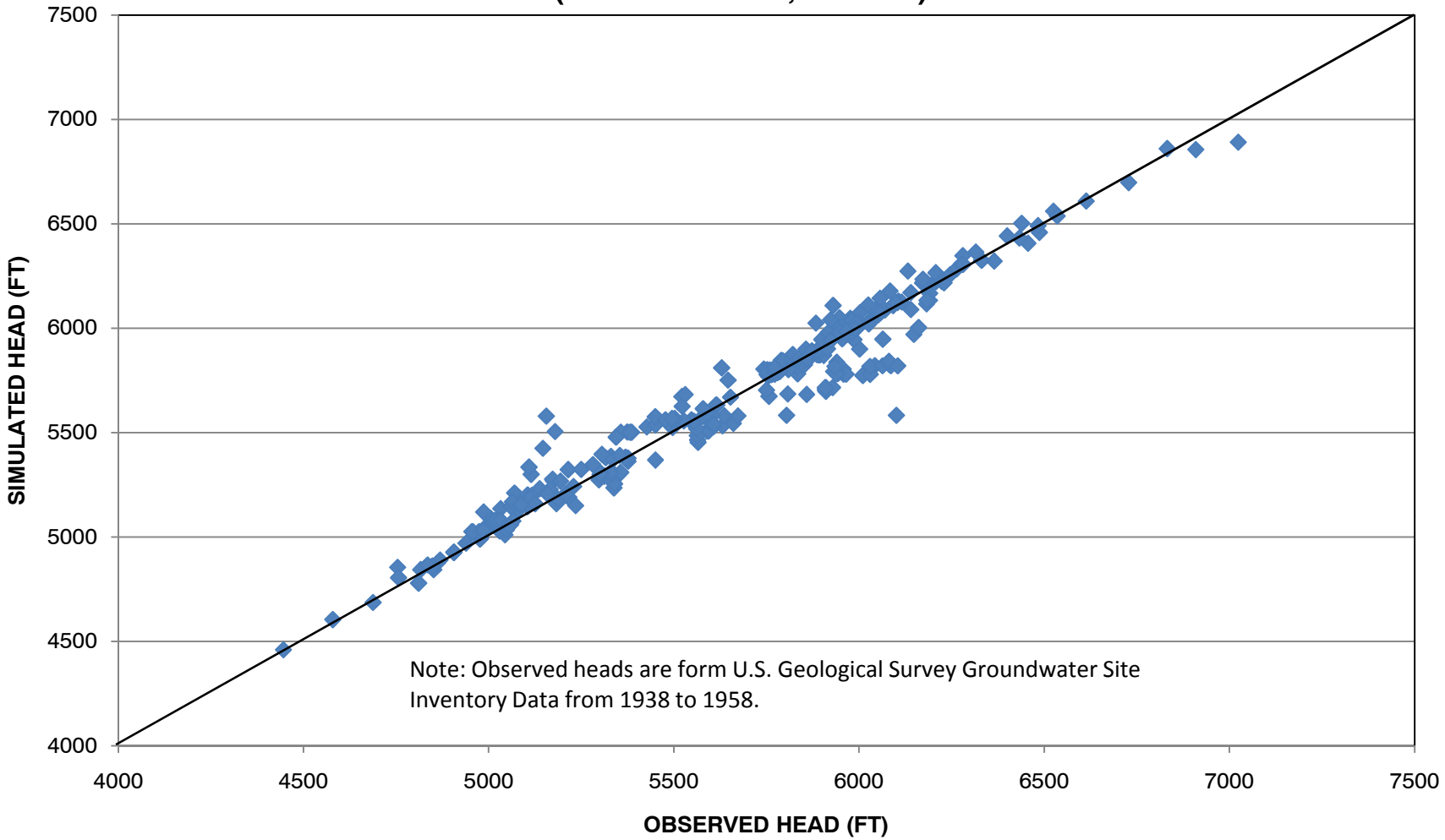
EXAMPLE INSTRUMENT NEST

Date: 2/2/09	**FIGURE 20**
Produced By: BY	
Checked By: DR	
Filename: IN-A As-Built.dsf	

BALLEAU GROUNDWATER, INC.

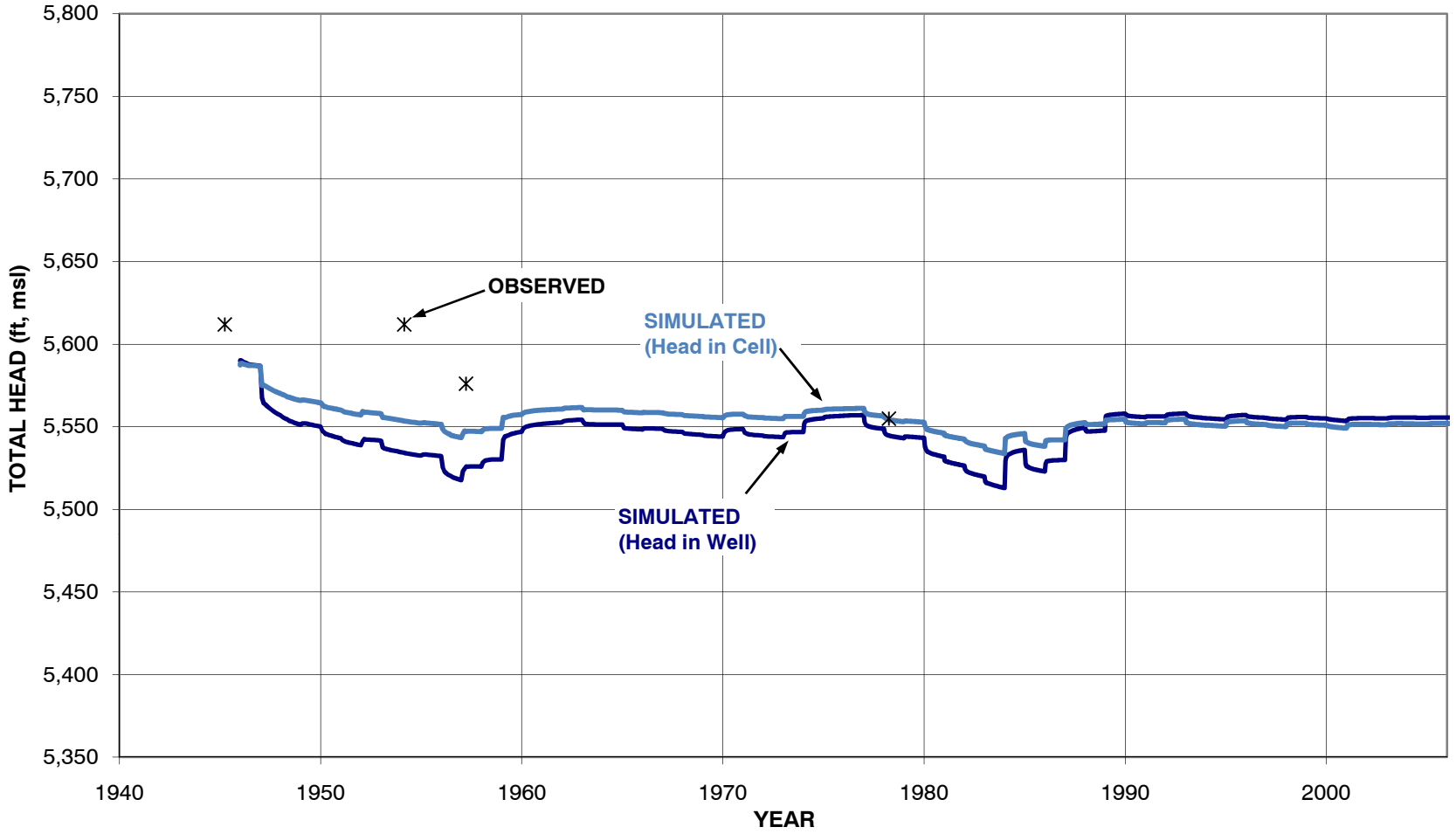
APPENDIX A

FIGURE A-1
CORRELATION OF OBSERVED AND SIMULATED HEADS
(RMS =104 feet, R^2=0.96)



XPLOTpmodel.xlsb
SES
7/15/2010

FIGURE A-2
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 1



AppAhgr.xlsb
SES
7/15/2010

FIGURE A-3
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 2

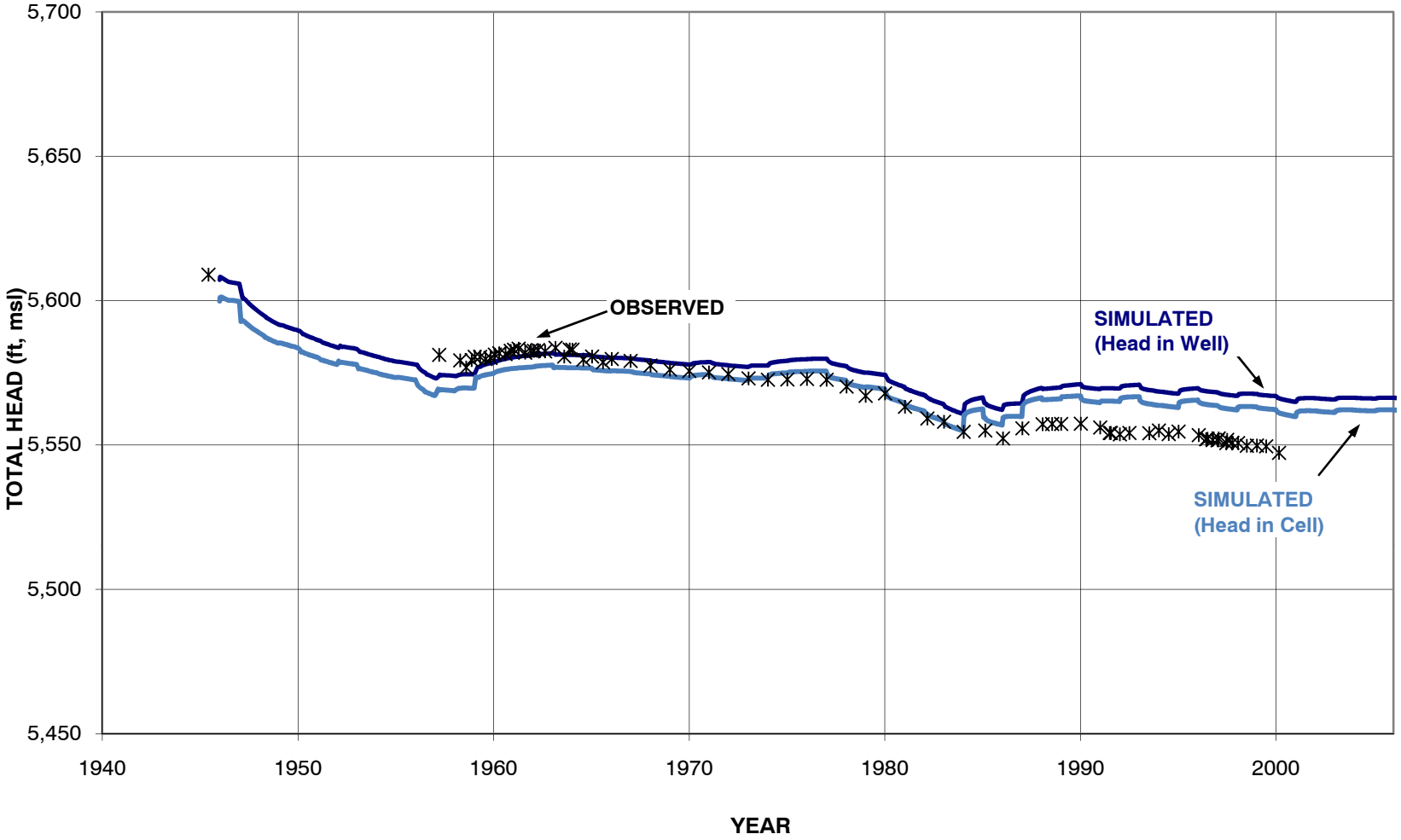
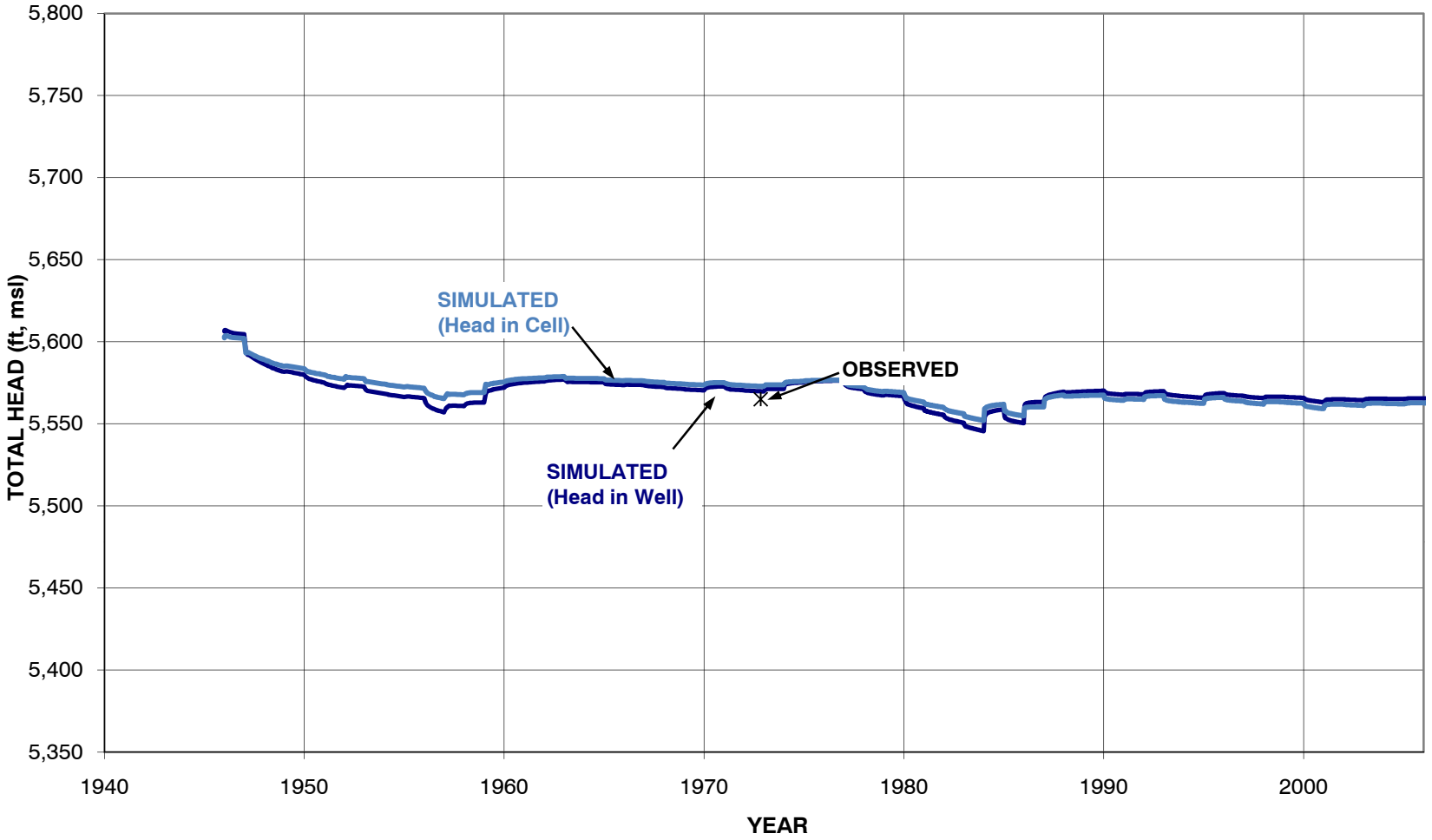
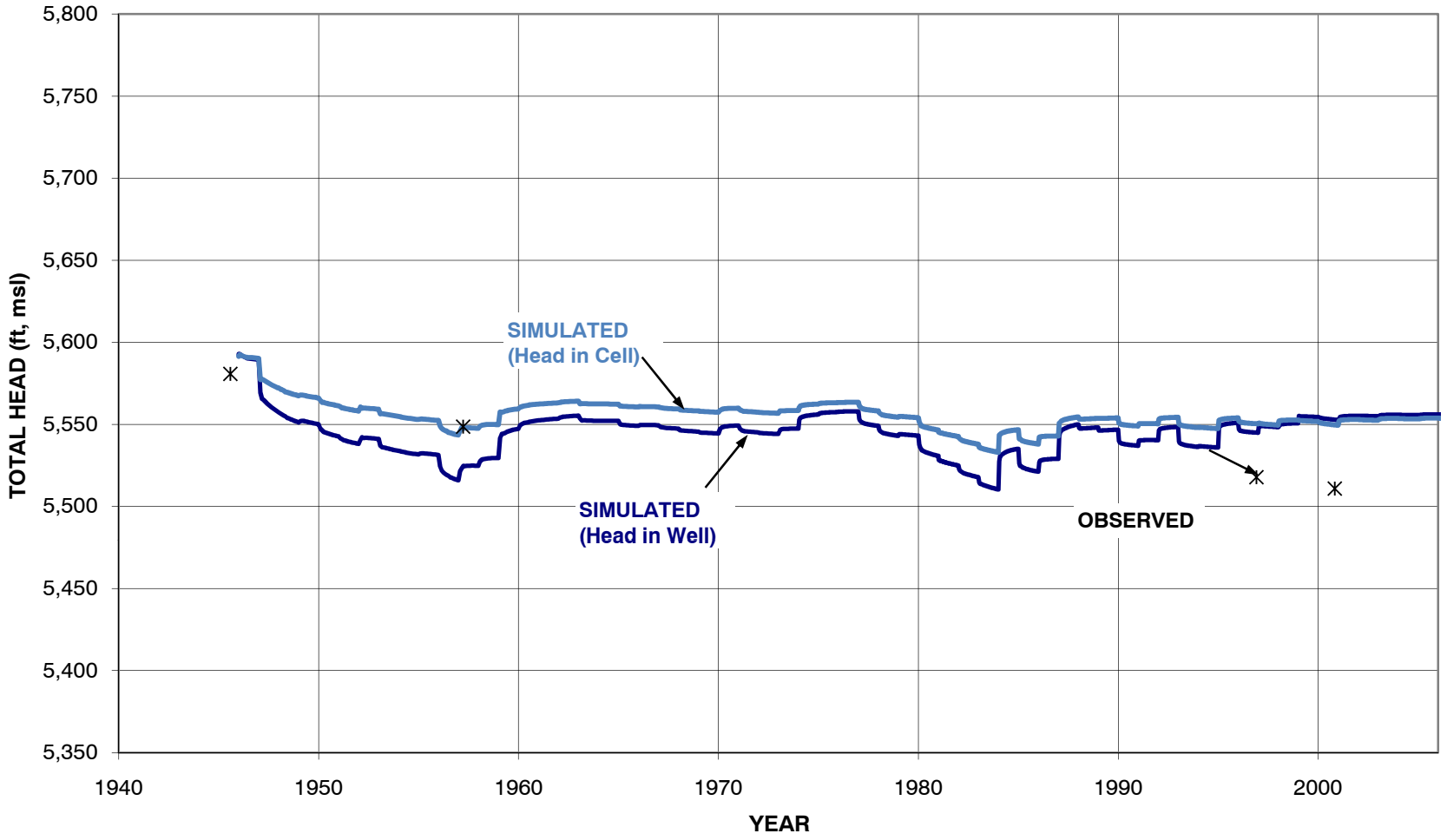


FIGURE A-4
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 3



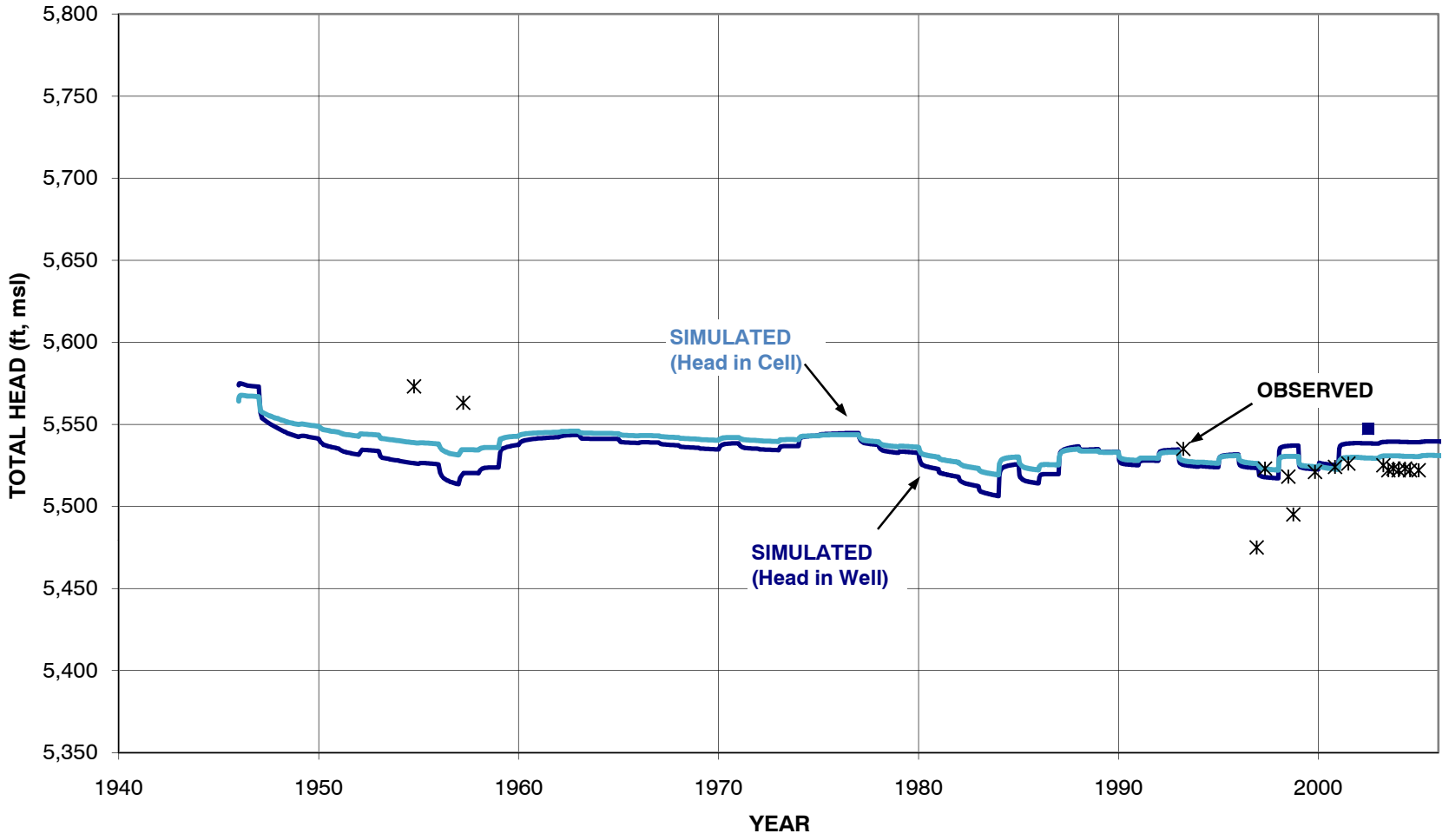
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-5
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 4



AppAhgr.xlsb
SES
7/15/2010

FIGURE A-6
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 5



AppAhgr.xlsb
SES
7/15/2010

FIGURE A-7
OBSERVED AND SIMULATED WATER LEVELS FRANK'S 6

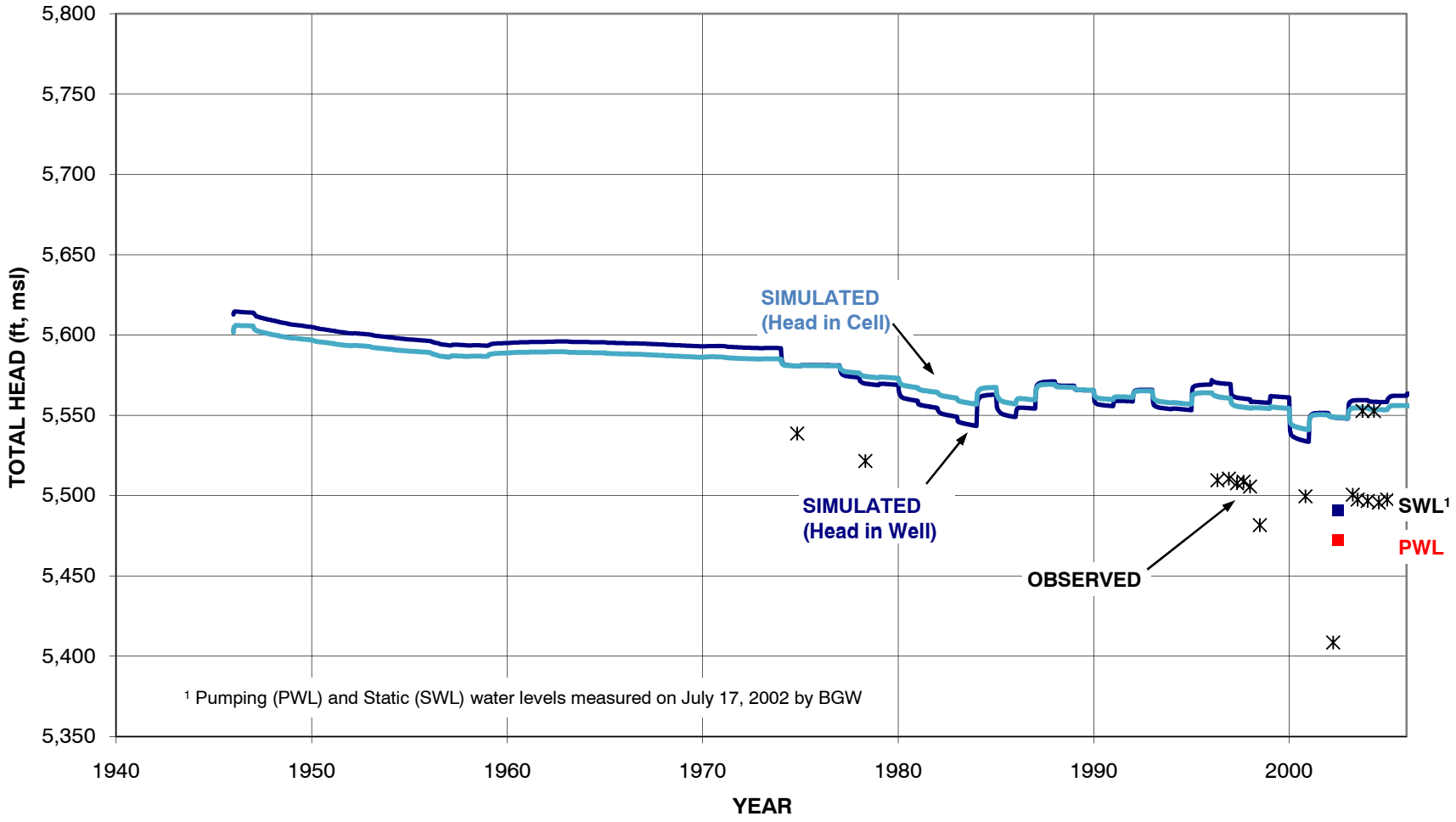
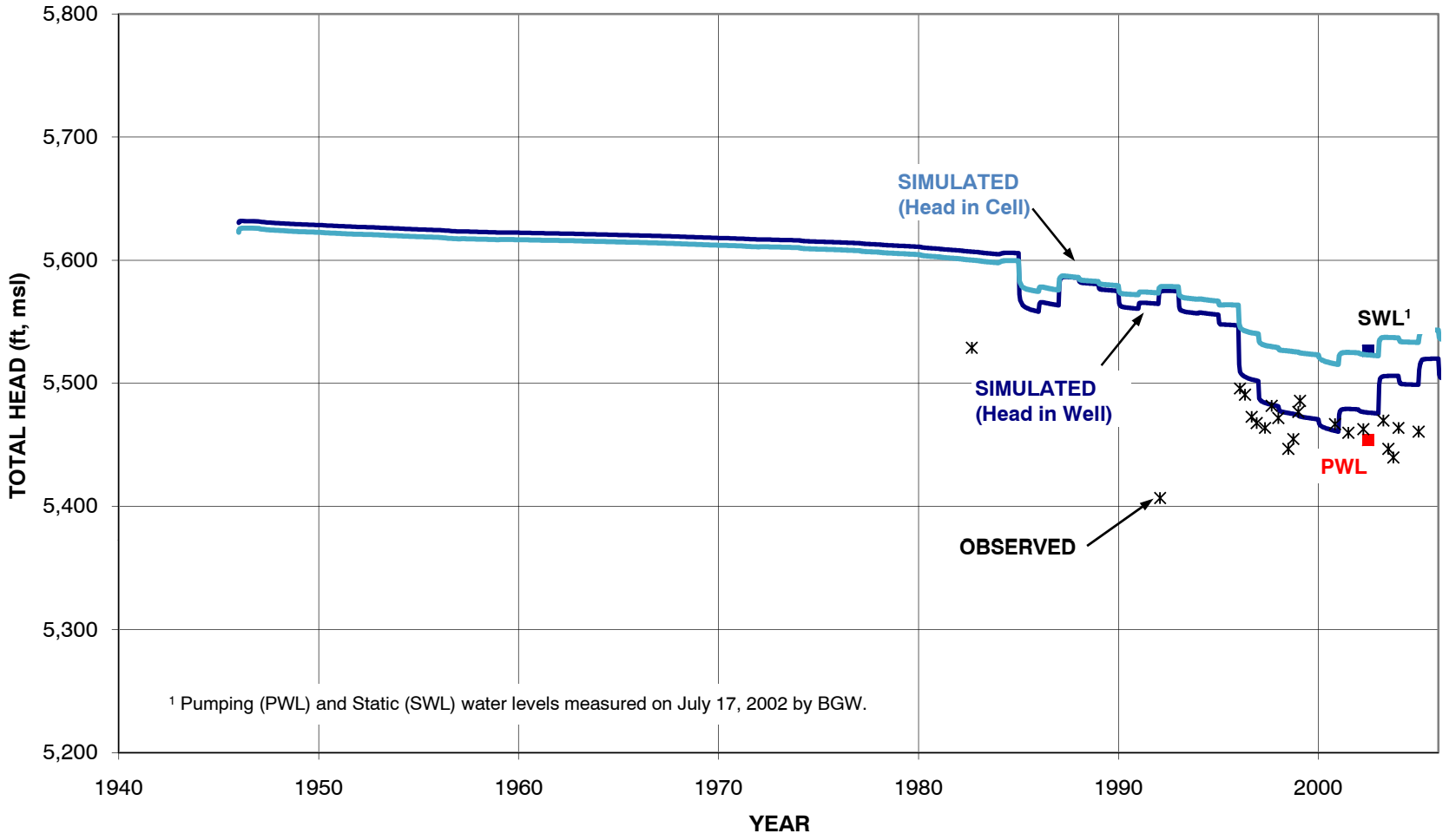
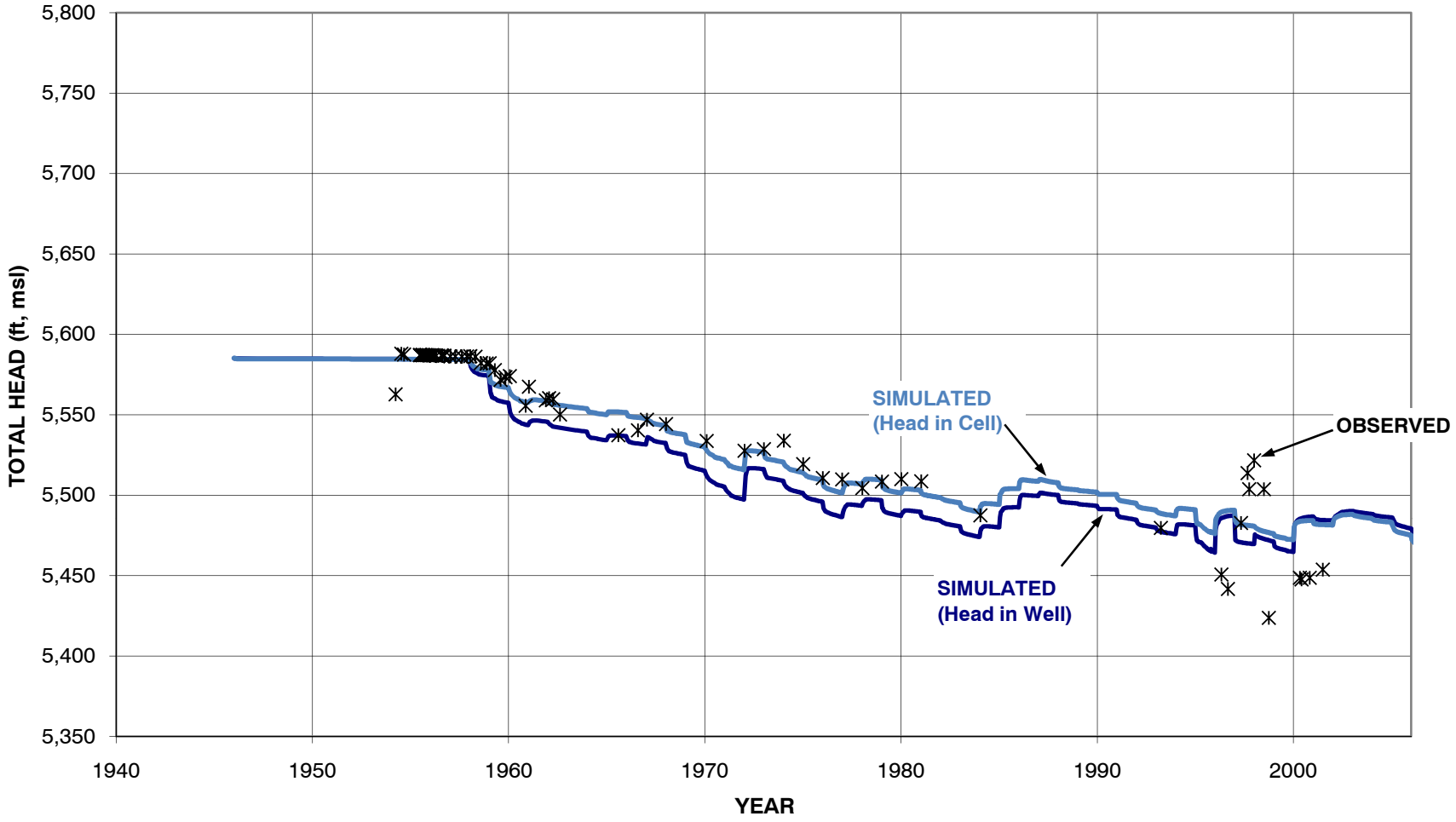


FIGURE A-8
OBSERVED AND SIMULATED WATER LEVELS AT FRANK'S 7A



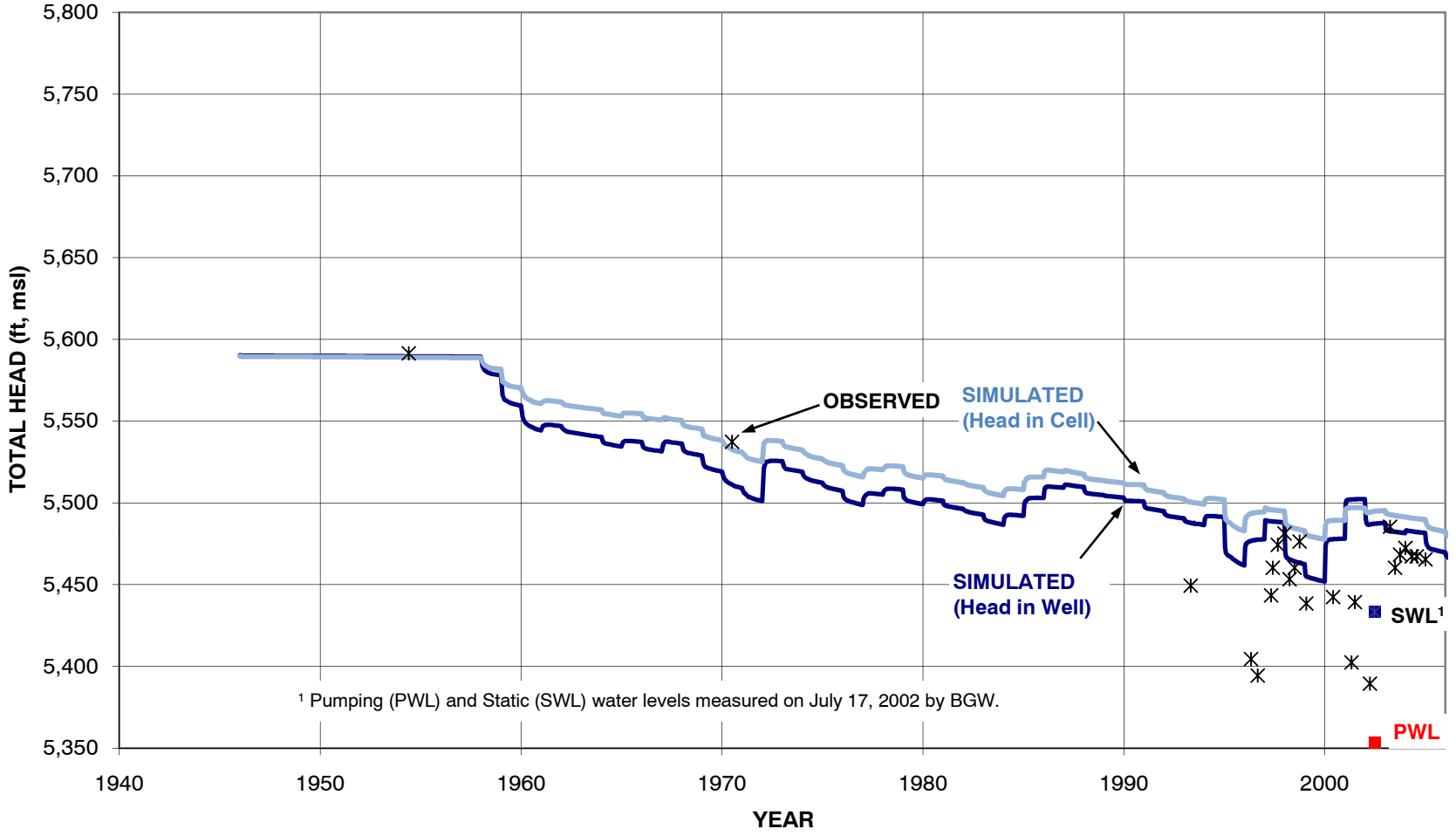
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-9
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 1



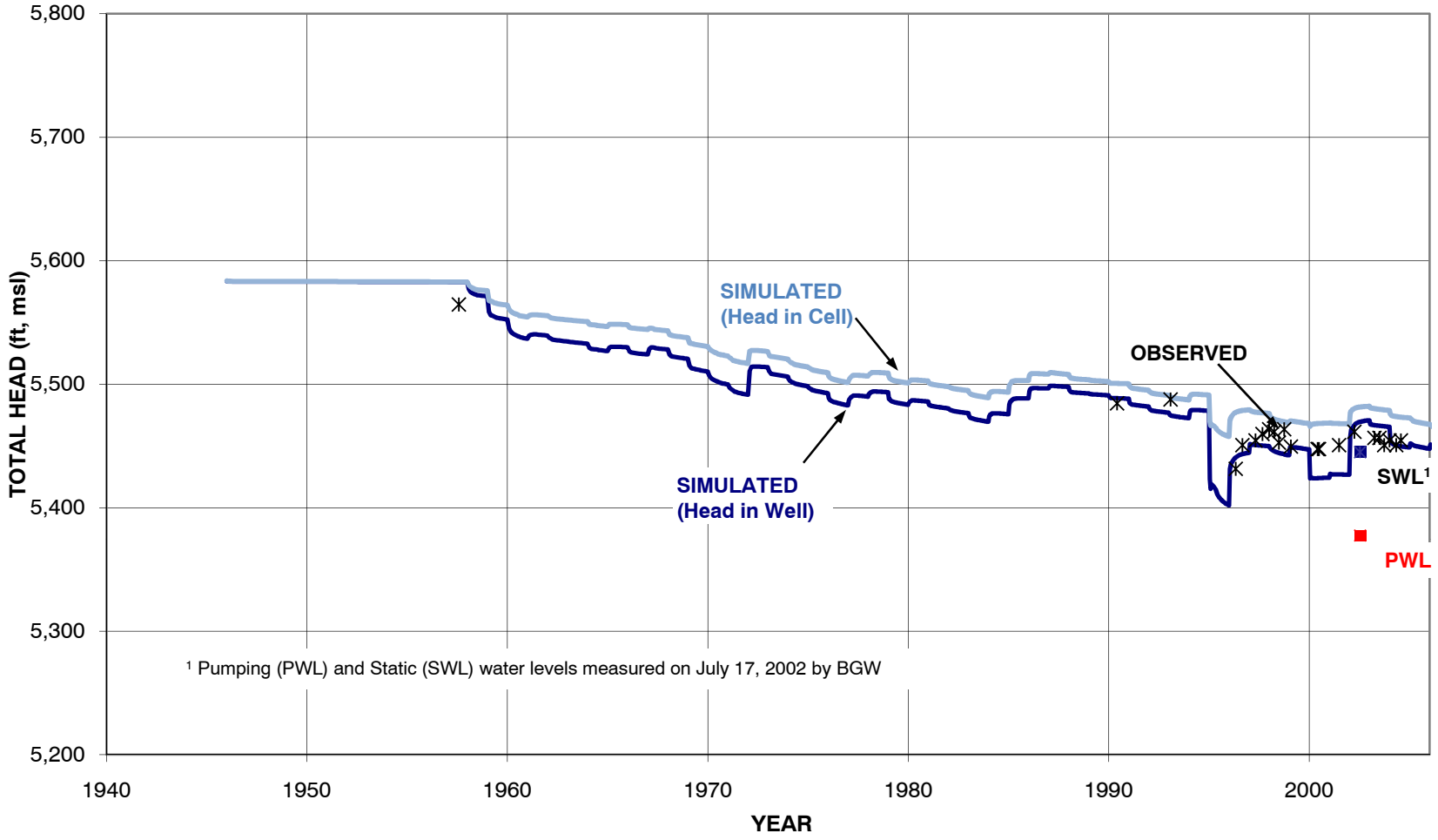
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-10
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 2



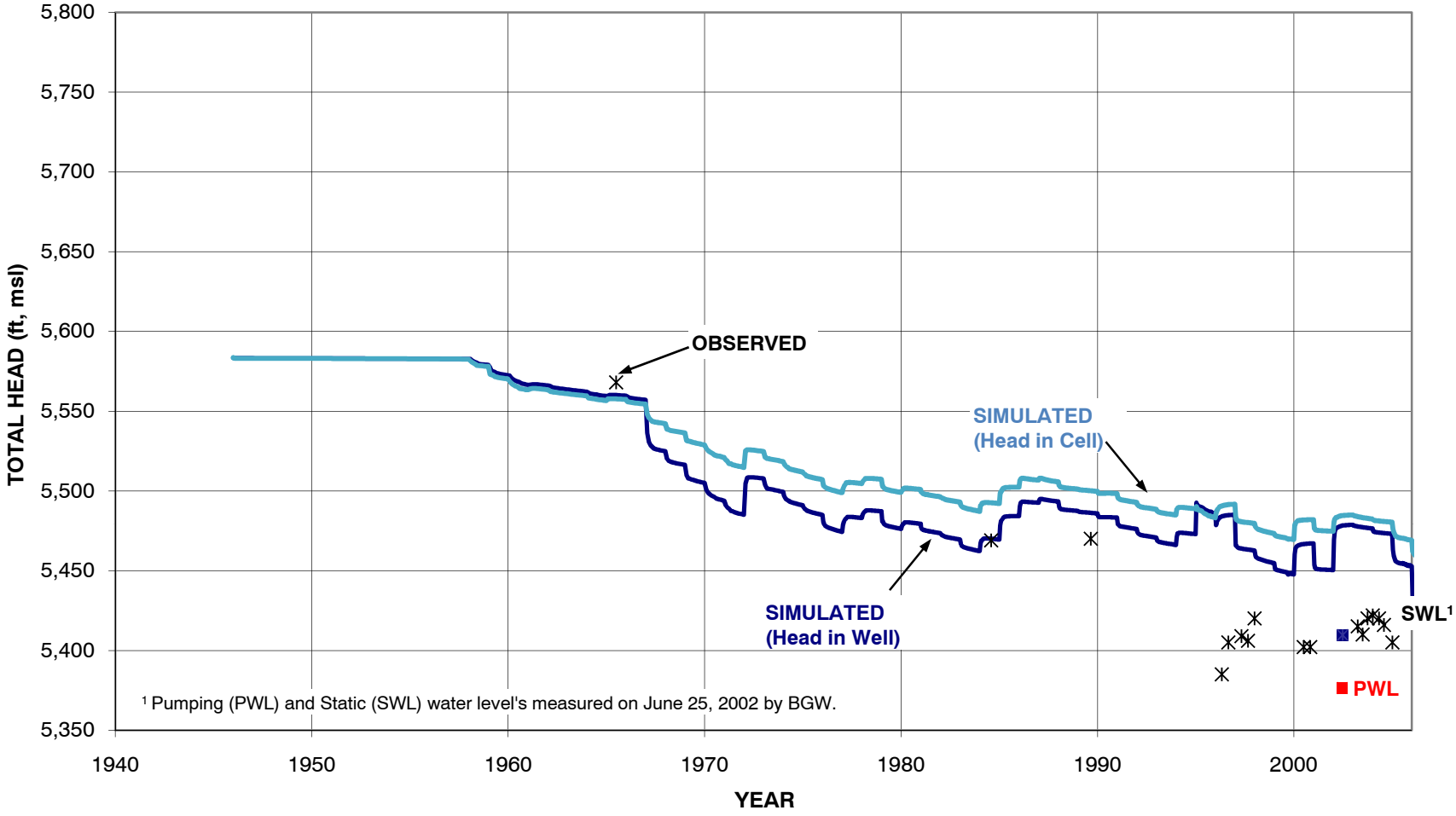
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-11
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 3



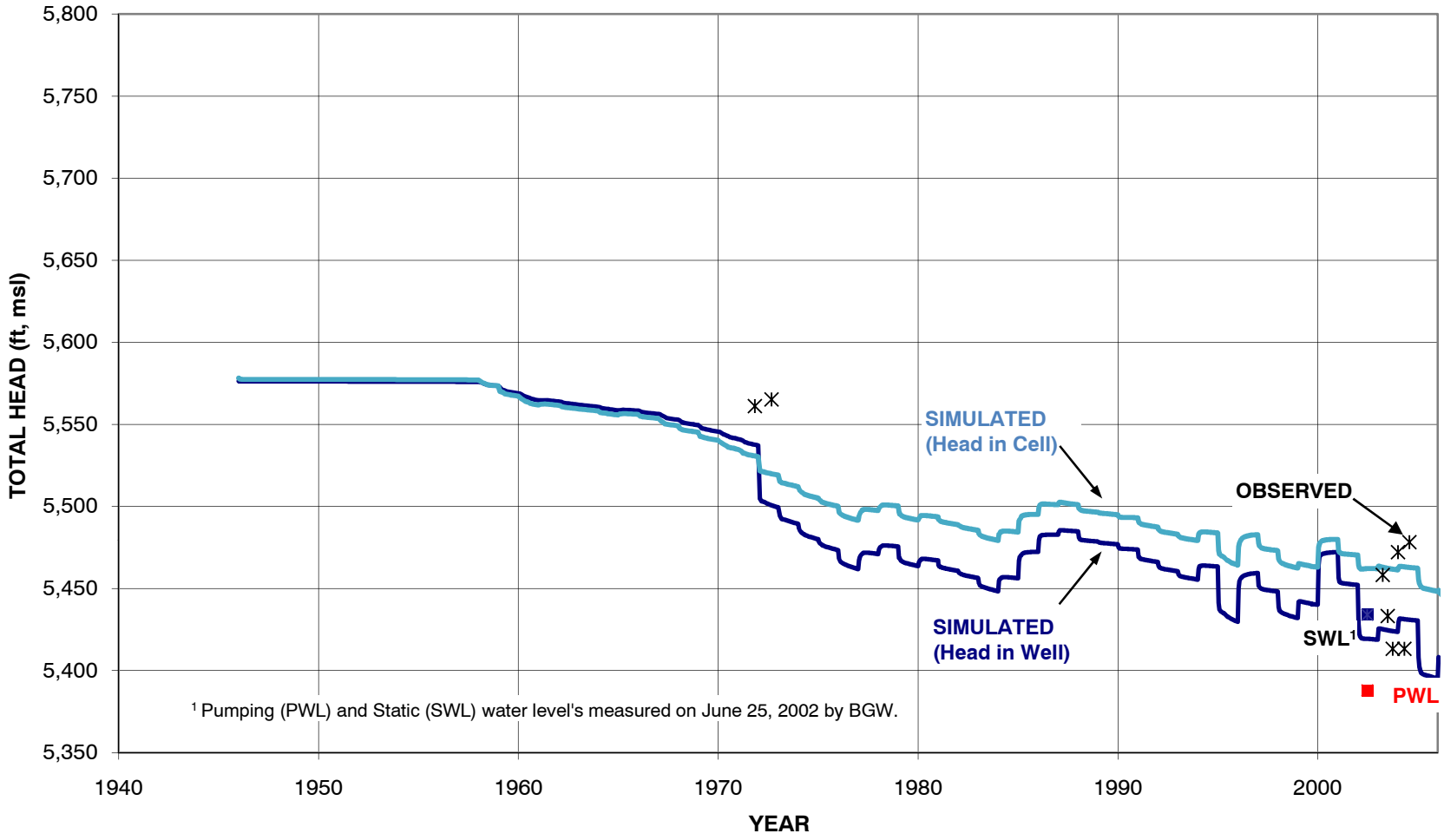
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-12
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 4



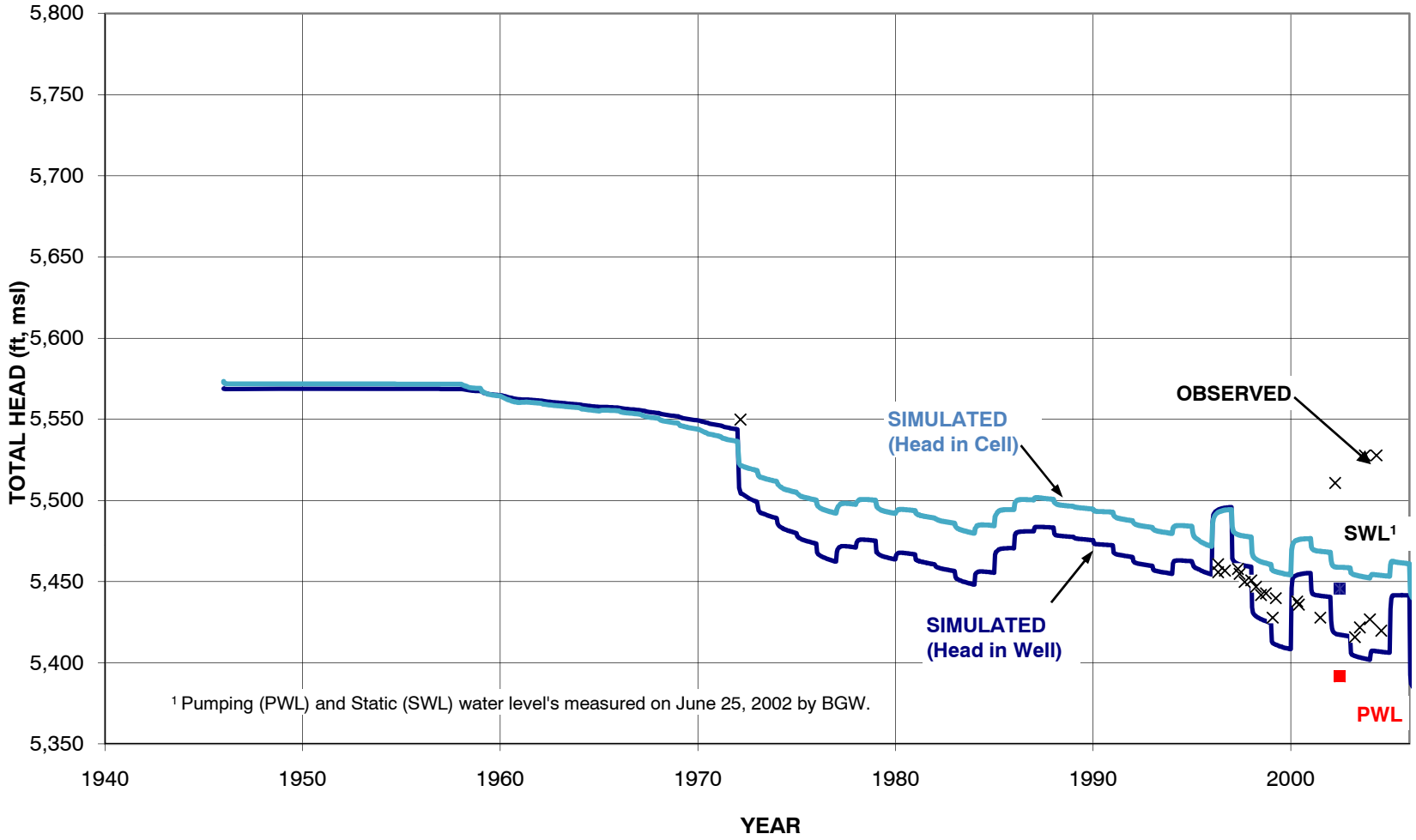
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-13
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 5



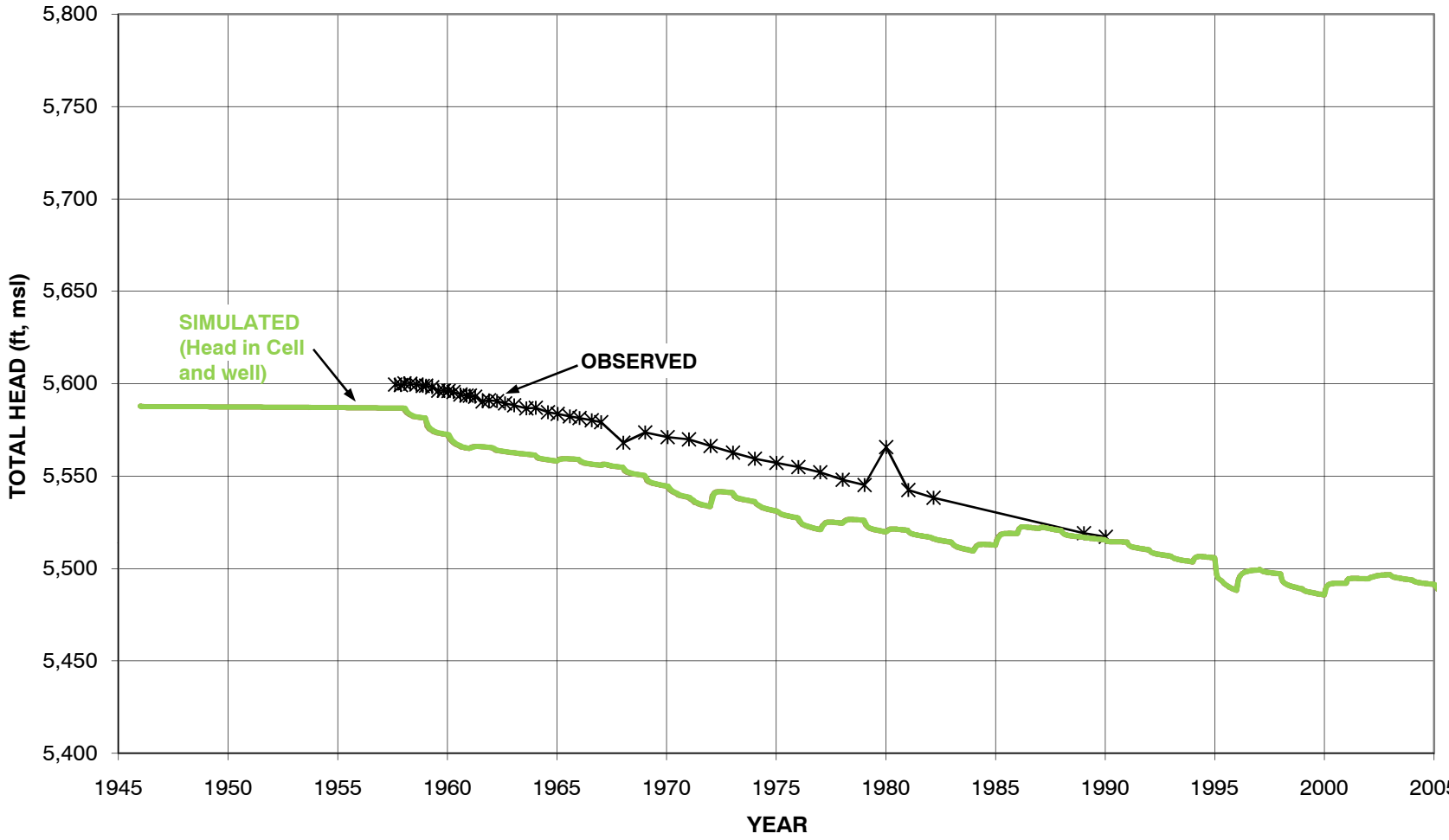
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-14
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD 6



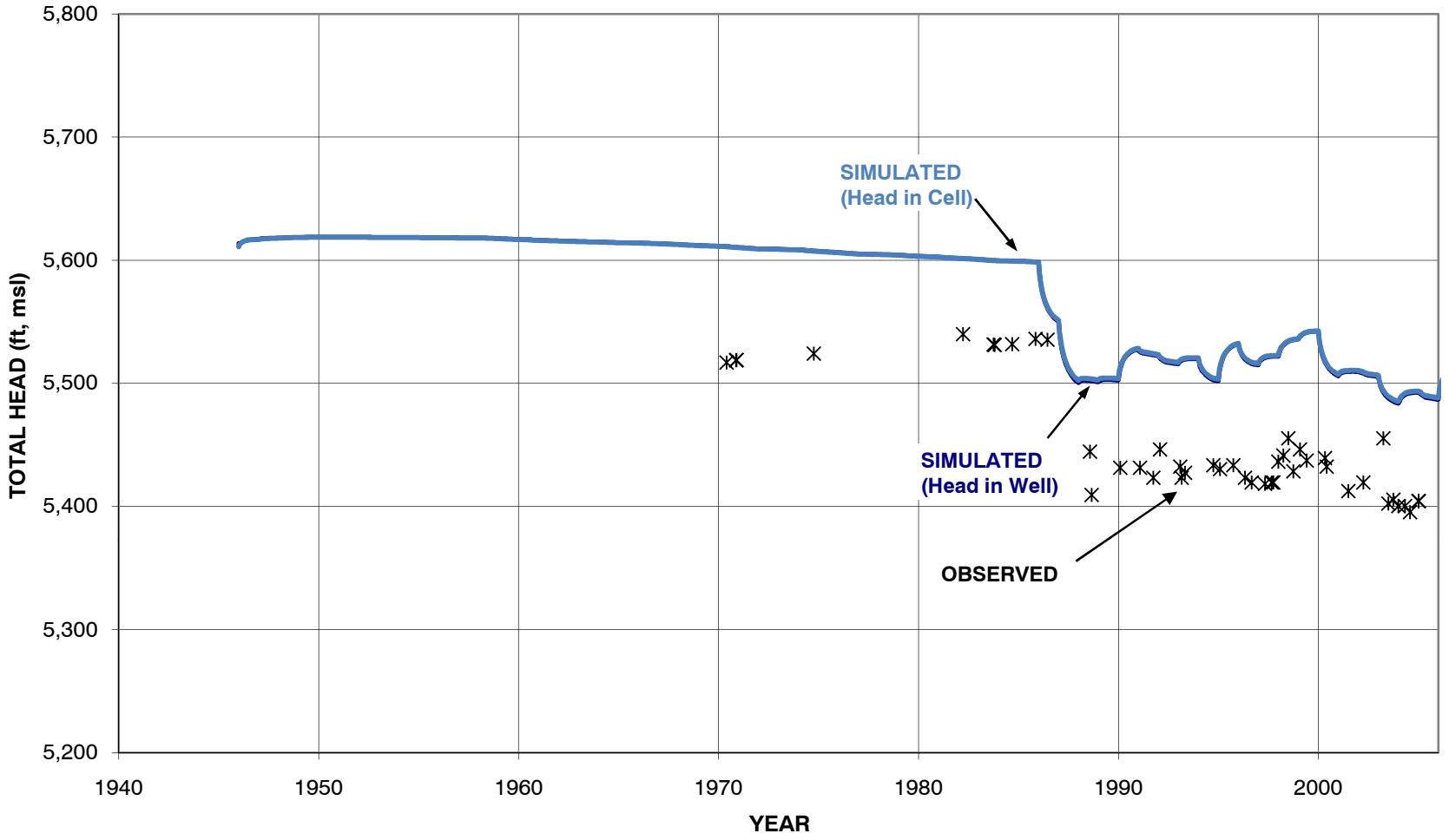
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-15
OBSERVED AND SIMULATED WATER LEVELS AT WOODWARD WELLFIELD



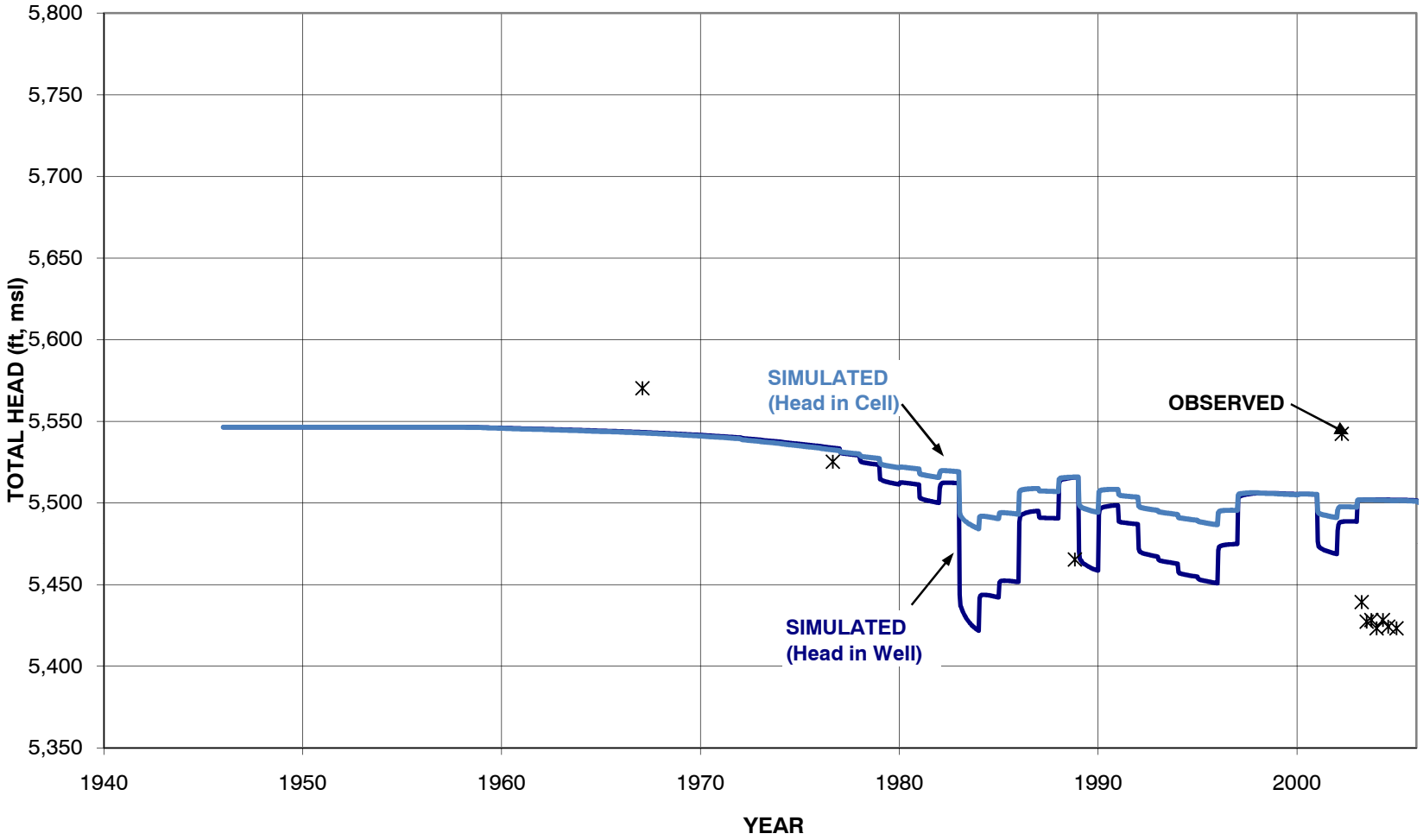
AppAhgr.xlsb
SES
7/15/2010

FIGURE A-16
OBSERVED AND SIMULATED WATER LEVELS AT GABBY HAYES WELL



AppAhgr.xlsb
SES
7/15/2010

FIGURE A-17
OBSERVED AND SIMULATED WATER LEVELS AT ANDERSON WELL



APPENDIX B

APPENDIX B

This Appendix describes the basis for estimated costs for example recharge projects in Technical Memorandum Table 1. Table B-1 summarizes the factors used to estimate costs for each approach.

Capital costs for recharge with the example injection approach involves a pumping station and pipeline, a water treatment plant, injection wells and appurtenances, and an observation well. Operation and maintenance costs are expected to include water pumping, water treatment and well rehabilitation.

An eight-inch diameter pipeline is assumed to cost $0.5 million per mile, including construction, material and acquiring rights' of way. We estimate an eight-mile pipeline would cost $4 million. For comparison, a recent feasibility study[1] for a pipeline from the Estancia Basin to City of Santa Fe estimated pipeline construction at $0.45 million (rural) to $0.8 million (urban) per mile for 24-inch pipe.

The cost of a pumping station depends on the size pump required. We estimate a 400-horsepower pump is needed to lift 500 gallons per minute through eight miles of pipe with 1,000 feet of elevation change, including about 200 feet of friction head loss. The estimate incorporates a combined pump and motor efficiency of 50 percent.

The cost of the pump station is based on a formula for a variable speed turbine pump in Wilbert and others (undated);

$$85{,}000\ (HP/100)^{0.65}$$

[1] Ryan, M., CDM, 2004, Letter to R. Carpenter, Water Resources Project Coordinator, City of Santa Fe: Estancia Basin Supply Project Feasibility Study Draft Report.

Based on the formula, a 400-horsepower pump would cost $210,000. The annual power cost to pump the water from the Gila River to the recharge site through existing and new pipeline, based on the foregoing factors and electricity rate of $0.1065/kWh[2], is $460 per acre foot or $370,000/year for the example 800 acre feet per year (AFY).

We anticipate that water for recharge through injection wells will require treatment to protect the target aquifer and to minimize screen clogging. Treatment methods are expected to be similar to conventional treatment of surface water for drinking purposes, specifically removal of suspended solids and disinfection. Environmental Protection Agency (EPA) (1979, Table 185) provides an estimated cost for a small-scale conventional treatment plant. Converting the EPA total estimated capital cost to a unit cost per AFY capacity and accounting for three percent inflation since 1979, we estimate constructing a treatment facility will cost $1,200 per AFY capacity. A plant capable of treating 800 AFY will cost about $960,000. The annual cost of operating the treatment plant is adapted from EPA (1979) Table 186, and adjusted for inflation. The resulting unit cost ($150 per acre foot treated) implies $120,000 per year to treat 800 acre feet.

Injection well drilling costs are adapted from recent drillers' estimates of similarly-constructed wells (12-inch casing with two nested piezometers) at $250 per foot. The example deep and shallow injection wells (1100 and 600 feet deep) are estimated to cost $275,000 and $150,000.

The example observation well has nested completions matching shallow and deep injection zones to monitor aquifer conditions during testing and operation. From recent drillers' estimates, we expect such a well to cost $150 per foot, or $165,000 for an 1100-foot well.

Well appurtenances including drop pipe, orifice, valves and gages for controlling and monitoring injection water flow and pressure are estimated to cost $50,000 for each well.

[2] Public Service Company of New Mexico TNMP Services, 2009, Services Rate Schedule, Second Revised Rate No. 12 Canceling First Rate No. 12. Schedule MPS Municipal Power Service.

GROUNDWATER RECHARGE

Injection wells will likely require rehabilitation each year, involving scale removal (acidation and brushing), disinfection and redevelopment. The cost of rehabilitating one well is estimated at $15,000 each time based on past drillers' estimates for similar work.

The infiltration method of recharge also will require a pump and pipeline to convey water to the recharge site with the same expected upfront costs. However, water treatment prior to recharge is not needed, as any suspended solids and bacteria will be filtered by travel through the vadose zone. Other expected costs are associated with constructing and installing subsurface instrumentation nests and wells for monitoring. These costs, and annual costs for pumping and arroyo bed rehabilitation, are described below.

The cost of instrumenting the vadose zone below the recharge basin is estimated from similar equipment installed for the Town in San Vicente Arroyo below the treatment plant. A nest up to 400 feet deep with ten to 12 sets of soil moisture and temperature probes and associated loggers will cost $4,500 for equipment and $38,000 for installation with a drill rig, or $42,500 for each nest.

A water table monitor well is expected to cost $100 per foot to drill and construct, or $45,000 for a 450-foot well.

Arroyo bed rehabilitation may be needed each year to remove clogging from sediments and algae. Based on a factor of $\$3/yd^3$ for dirt work, treatment of each acre to one-foot depth is estimated at $5,000, or $10,000 per year for a two-acre area along the recharge reach.

Attachment: Table B-1

TABLE B-1. FACTORS FOR ESTIMATING RECHARGE PROJECT COSTS

Factor	Injection	Infiltration
Rate (gpm)	500	500
Annual Volume (AF)	800	800
Existing Pipeline Distance (miles)	12	12
New Pipeline Distance (miles)	8	8
New Pipeline Elevation Change (ft)	1000	1000
Total Pipeline Elevation Change (ft)	1690	1690
Pipe Diameter (in)	8	8
Pump-Motor Combined Efficiency	50%	50%
Cost of Electricity ($/kWh)	0.1065	0.1065
Water Treatment Required	Filter/disinfect	None