Appendix H

WEST YOST ASSOCIATES
Consulting Engineers

TECHNICAL MEMORANDUM

DATE:	July 15, 2013	Project No.: 569-00-13-01
TO:	Robert Holbrook, P.E. First Solar, Inc.	
FROM:	Kenneth Loy, P.G. #7008	
SUBJECT:	Silver State Groundwater Impact Analysis	

PROFESSIONAL GEOLOGIST KENNETH L. LOY NO. 7008 EXP. 11/30/13 STATE OF CALIFORNIA

1.0 PROPOSED SILVER STATE SOLAR ELECTRIC PROJECT

The Silver State project is a proposed photovoltaic solar power project within the Mojave Desert region of Nevada (Figure 1). The project consists of two phases, one of which is already constructed and in operation. Figure 2 shows the water demand over the construction periods for both phases. Phase I, a 50-megawatt (MW) project known as Silver State North, was completed in Winter 2011 and is currently operating. Phase II, a 250-MW project known as Silver State South, is currently undergoing design for construction, and construction is expected to commence in Spring 2014. Phase II construction is expected to be completed by Winter 2016. The existing and proposed projects require groundwater for construction and/or operation. This technical memorandum (TM) provides an assessment of groundwater conditions in the vicinity of the Silver State project and documents the evaluation of the potential effects of the groundwater pumping on groundwater levels in neighboring wells and on mobilization of groundwater with high salinity. The potential effects of project pumping were evaluated using the United States Geological Survey (USGS) groundwater flow model, MODFLOW. The model is described in Section 4 of this TM.

The Silver State project currently has authorization through the Las Vegas Valley Water District (LVWWD) for up to 200 acre-feet per year (afy) of groundwater pumping to a maximum of 600 acre-feet (ac-ft). The full extent of future pumping described in this TM with regard to Phase II is not currently permitted, and applications to pump additional water necessary for this phase have not yet been filed with the Water Rights Section of the Nevada Division of Water Resources. Furthermore, pumping for Phase II will only commence consistent with permits granted in the future and Silver State's contractual agreement with LVVWD. LVVWD did not participate in the development of this TM or the underlying groundwater model and as such LVVWD makes no warranty as to the accuracy of the data and results contained herein.

Figure 3 shows the location of the existing Phase I Silver State North well, the locations of the possible alternative well sites within the Phase II proposed project area, and the locations of other existing supply wells near the Silver State project sites. The water supply requirement during the Phase I construction period was about 143 ac-ft. The water-supply requirement during the planned 3-year construction period for Phase II is estimated to be 800 ac-ft and will not exceed a worst-case scenario of 1,185 ac-ft. The water-supply requirement evaluated for the planned 30-year operational life of the Phase I and II facilities was 21 afy, based on the operational water provided under the LVVWD agreement; however, it is expected that the actual water use will be about 1 afy for each of the phases, for a total of 2 afy.

The following sections of this TM describe the regional hydrogeologic setting, groundwater conditions near the Silver State project sites, expected groundwater drawdowns due to project pumping, and the potential for mobilization of groundwater with high salinity. References cited in the text are provided at the end of the TM.

2.0 DESCRIPTION OF REGION SURROUNDING PROJECT SITE

2.1 Physiographic Setting

Ivanpah Valley is located on the California-Nevada border, about 40 miles southwest of Las Vegas (Figure 1). The valley covers about 560,000 acres, including 340,000 acres within California and 220,000 acres within Nevada, including Jean Lake Valley. The California part of Ivanpah Valley is referred to in this report as south Ivanpah Valley. The Nevada part of Ivanpah Valley and Jean Lake Valley are referred to as north Ivanpah Valley.

Ivanpah Valley is a topographically closed basin within which surface water drains to and evaporates on either the Ivanpah Lake or Roach Lake playas. The basin is a northward trending physiographic feature bordered by the Bird Spring Range on the north; the Sheep Mountains, Lucy Grey Range, and New York Mountains on the east; the Spring Mountains, Clark Mountain Range, and Ivanpah Mountains on the west; and by a low topographic divide between Ivanpah Valley and Shadow Valley. Topographic altitudes range from about 2,600 feet on the playas to about 7,200 feet within the eastern mountains and 8,500 feet within the western mountains.

2.2 Geologic Setting

The most complete geologic mapping of Ivanpah Valley and adjacent areas was done by Hewett (1956). That mapping includes consolidated rocks and unconsolidated deposits. The consolidated rocks include carbonate, intrusive, and extrusive rocks. The unconsolidated deposits are alluvial deposits. Figure 4 shows the surface exposures of the consolidated rocks and unconsolidated deposits. The unconsolidated deposits are underlain and bounded by the consolidated rocks. The consolidated rocks are underlain by a basement of silicate metamorphic rocks.

2.2.1 Consolidated Rocks

The consolidated rocks represent units ranging from pre-Cambrian to Tertiary age (Hewett, 1956; Plume, 1996; Harrill and Prudic, 1998). The carbonate rocks include limestone and dolomite of pre-Cambrian and Paleozoic age. They occur within the Spring Mountains, Bird Spring Range, and Sheep Mountains on the northwestern and northeastern boarders of Ivanpah Valley. The intrusive rocks are mostly granitic rocks of pre-Cambrian and Tertiary ages. They occur within the McCullough Range, New York Mountains, Clark Mountain Range, and Ivanpah Mountains on the southeastern and southwestern borders. The extrusive rocks are mostly basaltic rocks of Tertiary and Quaternary age. These rocks occur within the McCullough Range on the western border of Jean Lake Valley.

The hydraulic properties of the consolidated rocks vary greatly among the rock types (Plume, 1996; Harrill and Prudic, 1998). The carbonate rocks are most permeable at large length scales. While the carbonate-rock matrix is poorly permeable, fault-induced and fold-induced significant fracture permeability is sufficient. Correspondingly, groundwater underflow can occur through carbonate-rock mountain ranges where supporting hydraulic gradients exist. The granitic and basaltic rocks are poorly permeable at large scales. While those rocks are fractured, poor fracture connectivity and small apertures at depth limit the ability to transmit water. Correspondingly, no groundwater underflow occurs through the non-carbonate-rock mountain ranges, and those ranges act as barriers to underflow.

2.2.2 Unconsolidated Deposits

The unconsolidated deposits consist of alluvial and playa deposits of Pliocene to Holocene ages (Hewett, 1956; Plume, 1996). An older alluvium, which represents alluvial-fan deposits of Pliocene and early Pleistocene ages, is composed of gravel, sand, and silt with some boulders and clay. This unit underlies the valley-floor areas within both Ivanpah Valley and Jean Lake Valley. The older alluvium is generally below the regional groundwater table, and produces good yields to production wells. The younger alluvium, which represents alluvial-fan deposits of late Pleistocene and Holocene ages, is composed of gravel and sand with some silt and clay. The younger alluvium is generally above the regional groundwater table, and only perched groundwater occurs. The playa deposits, which represent pluvial deposits of Holocene age, are composed of fine sand, silt, and clay. The playa deposits are above the regional groundwater table, and only perched groundwater occurs.

2.2.3 Structural Features

Numerous faults exist within Ivanpah Valley and adjacent areas (Hewett, 1956). The faulting consists most prominently of thrusts, but notable normal faults also occur (Figure 4). Thrust faulting occurred episodically during the Mesozoic era, which resulted in deformation of the carbonate and pre-Cambrian granitic rocks. Significant normal faulting occurred starting in the Tertiary period, which has produced deformation in the basalts and Tertiary granitic rocks. Furthermore, the normal faulting produced the down-dropped structural basins that now are filled with the unconsolidated deposits.

Faults can impact groundwater flow. Thrusts within consolidated rocks tend to impede transverse groundwater flow. Normal faults in either consolidated rocks or unconsolidated deposits also tend to impede transverse groundwater flow. However, normal faults in consolidated rocks can act as conduits for longitudinal groundwater flow, even when they simultaneously act as impediments to transverse groundwater flow.

The principal thrusts within Ivanpah Valley are the Mesquite, Keystone, and Contact thrusts. The Mesquite Thrust brings older carbonate rocks over younger carbonate rocks within the Clark Mountain Range and Ivanpah Mountains. South of the Ivanpah fault, the thrust plane is nearly horizontal, is above the regional groundwater table, and can have no impact on regional groundwater flow. North of the Ivanpah fault, however, the thrust plane dips northwestward, intersects the regional groundwater table, and probably impedes groundwater underflow from Ivanpah Valley through the Clark Mountain Range into Mesquite Valley. The Keystone and Contact thrusts likewise bring older carbonate rocks over younger carbonate rocks. The thrust planes dip toward the west, intersect the regional groundwater table, and probably impede groundwater underflow from Ivanpah Valley through the Spring Mountains into Mesquite Valley.

The principal normal faults are Stateline, Ivanpah, Roach, and McCullough faults. The Stateline fault is downdropped on its southwest side, the Ivanpah fault is downdropped on its northeast side, and the McCullough fault is downdropped on its west side. These displacements produced a southeastward trending structural basin between the Ivanpah and Stateline faults, which deepens toward the southeast. The trough is filled with unconsolidated deposits that probably are at least several thousand feet in thickness (Langenheim, et. al, 2009). The Roach fault is downdropped on its west side. This displacement produced a northward trending structural basin beneath north Ivanpah Valley, which deepens eastward. The depth of the basin, and the corresponding thickness of the unconsolidated deposits, is less than south Ivanpah Valley but is probably several thousand feet (Langenheim, et. al, 2009).

2.3 Hydrologic Setting

Groundwater recharge occurs from precipitation on the mountains surrounding Ivanpah and Jean Lake valleys. While the valley-floor precipitation tends to be consumed entirely by evapotranspiration processes, the mountain precipitation produces runoff and deep infiltration. Runoff produces recharge by streambed infiltration, mostly on the alluvial fans that border the mountains. Deep infiltration produces recharge by groundwater flow through the mountain mass into the unconsolidated deposits. For the carbonate terrains, deep infiltration tends to be the dominant process, which coincides with the underdeveloped stream-channel networks within the carbonate terrains. For the granitic and basaltic terrains, streambed infiltration tends to be the dominant process, which coincides with the occurrence of dense stream-channel networks. These processes together produce recharge along the margins of the unconsolidated deposits.

The recharged groundwater flows northward because of geologic controls that prevent or impede westward or eastward groundwater flow. Granitic and basaltic rock within the McCullough Range and New York Mountains prevent groundwater flow between Ivanpah Valley and the adjacent Lanfair or Piute valleys. Granitic rocks occur within the Ivanpah Mountains and Clark Mountain Range between Ivanpah Valley and Shadow and Mesquite valleys. Westward dipping thrusts within the Clark Mountain Range and Spring Mountains impede groundwater flow between Ivanpah Valley and Mesquite Valley. However, the carbonate rocks within the Bird Spring Range and the northward trending structural texture allows groundwater flow between Ivanpah Valley and Las Vegas Valley. Concomitantly, the groundwater recharge within Ivanpah and Jean Lake valleys can flow only northward through the valleys into Las Vegas Valley.

3.0 GROUNDWATER CONDITIONS NEAR THE PROJECT SITE

3.1 Project Site Geologic Setting

The water supply for the project is proposed to be groundwater derived from the unconsolidated deposits that underlie the site. Information about these unconsolidated deposits was obtained from driller's logs obtained from the Nevada State Engineer. Table 1 provides the information compiled for each well. For a few wells, aquifer-test information was obtained and is listed in Table 1. Figures 5 through 7 show well depths, groundwater depths and sedimentary textures for each of the wells for which a log was available. The groundwater depth represents conditions when the well was constructed.

Table 1. Well with Lithologic Logs within Study Area												
Well ID	Nevada Log Number	Township Range Section	Quarter	Owner	Construction Date	Well Depth (feet)	Water Depth (feet)	Land Elevation (feet)	Water Elevation (feet)	Lithologic Type	Test Pumping Rate (gpm)	Specific Capacity (gam/ft)
1	690	S27/E59-8	NE NE	PRIMM, E J	09/27/48	600	85	2625	2540	M	100	
2	2861	S27/E59-16	NE NE	PRIMM INVESTMENT CO	01/05/55	555	105	2798	2693	M		
3	19773	S27/E59-9	NW NE	WHISKEY PETES HOTEL & CASINO	10/27/78	605	190	2679	2489	M	318	3.80
4	19774	S27/E59-9	SE NE	WHISKEY PETES HOTEL & CASINO	02/02/79	395	120	2714	2594	F		
5	28658	S27/E59-10	SW NE	WHISKEY PETES HOTEL & CASINO	05/06/87	560	312	2913	2604	C		
6	28659	S27/E59-10	SW NE	WHISKEY PETES HOTEL & CASINO	04/28/87	600	347	2913	2566	C	90	0.80
7	36704	S27/E59-8	SE SE	WHISKEY PETES HOTEL & CASINO	03/04/92	235	200	2674	2407	C	15	
8	36705	S27/E59-8	SE SE	WHISKEY PETES HOTEL & CASINO	03/04/92	250	195	2607	2412	M	15	
9	26706	S27/E59-9	SW NE	WHISKEY PETES HOTEL & CASINO	03/04/92	250	200	2769	2569	C	15	
10	36707	S27/E59-9	SW NE	WHISKEY PETES HOTEL & CASINO	03/04/92	160	135	2769	2634	C	15	
11	64308	S27/E59-5	NE NE	PRIMM INVESTMENT CO	06/11/54	672	100	2610	2510	M		
12	64311	S27/E59-8	NE NW	BARHAM, EARLE M	09/25/55	150	115	2617	2502	F		
13	64312	S27/E59-8	NW NE	DABAU, RAY & SWIFT, GEORGE	03/02/54	617	159	2672	2513	F		
14	64313	S27/E59-8	NW NE	TOWER CLUB CASINO	07/03/82	300	121	2672	2551	M		
15	72448	S27/E59-8	SE NW	PRIMADONNA RESORTS	08/10/98	935	110	2610	2500	M	145	
16	75640	S27/E59-8	SE NW	PRIMADONNA RESORTS	08/10/98	935	110	2610	2500	M	145	
17	77553	S27/E59-8	SW NE	PRIMADONNA RESORTS	12/09/99	240	155	2646	2491	C		
18	77554	S27/E59-8	SW NE	PRIMADONNA RESORTS	12/09/99	240	166	2646	2480	C		
19	77555	S27/E59-8	SW NE	PRIMADONNA RESORTS	12/09/99	120	80	2646	2566	C		
20	77556	S27/E59-8	SW SE	PRIMADONNA RESORTS	12/09/99	120	101	2653	2552	C		
21	86866	S27/E59-9	NW SE	GRAYCOR	07/31/02	138	160	2693	2533	F		
22	86867	S27/E59-9	NW SE	GRAYCOR	07/31/02	238	160	2693	2533	F		
23	86913	S27/E59-9	NW SE	GRAYCOR	08/08/02	232	187	2693	2506	M		

As indicated in Table 1 and on Figure 5, the wells with available logs range in depth from 120 to 935 feet. The land surface rises to the east in the vicinity of the proposed project, but the well depths shows no apparent relationship to the easterly rise in land surface elevations. As shown in Table 1 and on Figure 6, the depth to the groundwater ranges from 80 to 347 feet. Corresponding to the land-surface rise, the groundwater depth increases eastward from less than 200 feet to more than 300 feet. Based on this information, it is likely that the depth to groundwater in the vicinity of the proposed Silver State wells will be 100 feet to more than 300 feet, depending on well location.

Table 1 and Figure 7 shows the characteristic textures of the sediments penetrated by the respective wells in terms of three classifications: “F” for fine grained, “M” for medium gained, and “C” for course grained. The fine-grained texture is characterized by significant clay, sandy clay, and clayey sand horizons. The medium-grained texture is characterized by significant clayey sand and clayey gravel. The coarse-grained texture is characterized by significant sand and gravel horizons embedded within fine-grained and medium-grained horizons. Because drillers have their individual idiosyncrasies regarding lithologic reporting, the available logs are only an approximation of actual subsurface conditions. Considering the overall collection of logs, the subsurface in the vicinity of the proposed production wells most likely is composed of sediments of at least medium texture.

A medium texture would correspond to a hydraulic conductivity of about 2 feet per day (ft/d), which is toward the low range of hydraulic conductivities for unconsolidated deposits. The 2-ft/d hydraulic conductivity was derived from the reported specific capacities for wells 3 and 6 in Table 1, which have respective specific capacities of 3.8 and 0.8 gallons per minute per foot of drawdown. These specific capacities translate into respective transmissivities of 1,100 and 240 square feet per day (ft^2/d). These transmissivities correspond to hydraulic conductivities of 2.8 and 1.2 ft/d, based on respective screened intervals of 400 and 200 feet. The average hydraulic conductivity is 2 ft/d.

The average hydraulic conductivity of 2 ft/d represents the horizontal conductivity of the unconsolidated deposits. However, the vertical conductivity, specific storage, and specific yield of the deposits also are important hydraulic characteristics. The horizontal hydraulic conductivity represents the ability of the unconsolidated deposits to transmit groundwater horizontally. The vertical conductivity represents the ability to transmit groundwater vertically. The specific storage represents the ability of the deposits to release stored groundwater due to the elastic compaction of the deposits. Finally, the specific yield represents the ability of the deposits to release stored groundwater due to the decline of the groundwater. These hydraulic characteristics for the project site were estimated based on the texture of the unconsolidated deposits as represented by the lithologic logs. Correspondingly, the vertical hydraulic conductivity most likely is about one-tenth of the horizontal conductivity, or 0.2 ft/d. The specific storage is about 10^{-4} 1/ft. The specific yield is about 0.05.

4.0 POTENTIAL GROUNDWATER DRAWDOWNS DUE TO PROJECT PUMPING

For Phase I of the Silver State project, water demand during the 7-month construction period was approximately 143 ac-ft. Figure 2 shows the pumping information for Silver State North’s now completed construction period. Recorded pumping information was provided for the first four months of construction. The remaining construction pumping was estimated by First Solar.

The water-supply requirement for Phase II is anticipated to be 800 ac-ft and will not exceed a worst-case scenario of 1,185 ac-ft during the planned 3-year construction period. Three tiers of construction pumping were modeled for Phase II:

- Tier 1 with a total of 800 ac-ft (anticipated water use)
- Tier 2 with a total of 1,000 ac-ft (potential need)
- Tier 3 with a maximum of 1,185 ac-ft (worst-case scenario)

Figure 2 shows the planned monthly water use in ac-ft for the construction period under each of the tiers.

Temporary, lined, storage ponds will be constructed to meet peak water demands during construction of Phase II.

The water-supply requirement evaluated for the planned 30-year operational life of the Phase I and II facilities was 21 afy, based on the operational water provided under the Las Vegas Valley Water District agreement; however, it is expected that the actual water use will be about 1 afy for each of the phases, for a total of 2 afy. All of the water uses during operations will be indoors at the operations buildings. Permanent above-ground water-storage tanks will be used to meet peak demands during the operational life of the facilities.

Figure 3 shows the locations of the Silver State North production well, possible well sites for the Silver State South project, and the neighboring production wells owned and operated by others.

As shown on the figure, the Silver State South arrays are grouped into four areas, three of which are separated from the fourth by a floodway. Alternative Well #1 and Alternative Well #2 would be used for construction in the northern area. After construction is completed, Alternative Well #1 would continue to be used during operations. Alternative Wells #3 through #6 are located in the southern area. These wells would be used for construction in the southern area. It was assumed that the northern part of the array would be constructed first followed by the southern part of the array. Based on the relative sizes of the two array areas, it was assumed that the northern area would take 40 percent, or approximately 14 months, of the 3-year construction period to complete. It was assumed that construction of the southern area would take 60 percent, or approximately 22 months, of the 3-year construction period to complete (Figure 2).

There are four neighboring wells near the proposed projects for which potential impacts were evaluated (Figure 3):

- WP-1A
- WP-2
- WP-4
- #50808

Wells WP-1A, WP-2 and WP-4 are owned by the Nevada Energy Higgins power plant. In this report, WP-1A/2 is used to designate WP-1A and WP-2, which are located in close proximity to one another. Because changes in groundwater elevation vary with distance from the proposed project pumping, simulated drawdowns for the two wells are virtually identical, and the two wells were treated as a single entity. Well #50808 is owned by the Primm Casino.

The Phase I and II pumping has or will produce localized groundwater-level declines, mostly during construction when demands are highest. A groundwater-flow model was used to simulate those impacts at neighboring wells WP-1A/2, WP-4 and #50808.

4.1 NUMERICAL MODELING APPROACH

Simulations were conducted using MODFLOW (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996; and Harbaugh, et. al., 2000). MODFLOW is a widely used, thoroughly tested and well documented finite difference program developed by the USGS. MODFLOW implements an approximate finite difference solution to the groundwater flow equation and was implemented using the Groundwater Vistas interface.

Table 2 lists the parameters used in the simulations. The input parameters included horizontal hydraulic conductivity, vertical hydraulic conductivity, specific storage, specific yield, aquifer thickness, and well-screen depth intervals. The hydraulic parameters were estimated based on the information discussed in the preceding section describing the project site geologic setting.

Table 2. MODFLOW Model Parameters

Parameter	Value	Units
Horizontal hydraulic conductivity	2	feet per day
Vertical hydraulic conductivity	0.2	feet per day
Specific storage	0.0001	1/feet
Specific yield	0.05	unitless
Aquifer thickness	1,000	feet
Depth to screen top	400	feet
Depth to screen bottom	600	feet

Figure 8 shows the model grid, which covers the entire groundwater basin beneath north Ivanpah Valley. The model was constructed with grid spacing ranging from 375 feet in the area of interest to 2,250 feet in outer areas, and 20 layers. No flow boundary conditions were used to represent the bedrock and faults bounding north Ivanpah Valley. The model was run in transient mode, with 50 stress periods accommodating the pumping schedules of the existing Phase I well and the proposed Phase II wells.

Table 3 provides a summary of the six model scenarios evaluated. Figure 3 shows the locations of the wells evaluated in each of the scenarios.

Table 3. Summary of Groundwater Pumping Scenarios

Scenario	Hydrograph Figures	Phase	Period	Wells (Percentage of Pumping per Phase)						
				SSN I	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
1a, 1b, 1c	9, 10, 11	I	Construction	100%						
			Operations	100%						
		II	Construction, Northern Area		100%					
			Construction, Southern Area				100%			
			Operations		100%					
2a, 2b, 2c	12, 13, 14	I	Construction	100%						
			Operations	100%						
		II	Construction, Northern Area		50%	50%				
			Construction, Southern Area				25%	25%	25%	25%
			Operations	100%						

Percentages are based on the approximate size of the arrays to be constructed. The northern area of Phase II is about 40 percent of the total area and would take about 40 percent of the time to construct. The southern area of Phase II is about 60 percent of the total area and would take about 60 percent of the time to construct. For scenarios evaluating pumping from two or more wells in the north or south area during the Phase II construction period, the total pumping was evenly allocated to each well.

In Scenarios 1a, 1b, and 1c, it was assumed that three wells would be used during construction of the entire Silver State project. SSN Well 1 would be used for 100 percent of construction and operation of Phase I. Alternative Well #1 was simulated to be used to meet the demands for water during construction of the northern part of Phase II. The well would be pumped during the first 40 percent, or approximately first 14 months, of the construction period. After construction of the northern part of Phase II is complete until the end of the 30-year operational period, the well was assumed to meet the demand for indoor water use at the operations building. Alternative Well #3 was simulated to meet the demand during construction of the southern part of Phase II. Alternative Well #3 would be pumped during the last 60 percent, or approximately 22 months, of the construction period. Thereafter, the well would not be used.

Scenario 1a uses the water allocation described above, but uses the Tier 1, or 800 ac-ft, of total water pumping over the Phase II construction period. Scenario 1b uses the Tier 2, or 1,000 ac-ft, of total water pumping over the Phase II construction period. Scenario 1c uses the Tier 3, or 1,185 ac-ft, of total water pumping over the Phase II construction period.

In Scenarios 2a, 2b, and 2c, it was assumed that seven wells would be used to supply water during the construction of the project. SSN Well 1 would be used for 100 percent of construction and operation of Phase I. Alternative Well #1 and Alternative Well #2 were simulated to be used to meet the demands for water during the first 40 percent of the construction period, with production volumes split evenly between the two wells, for the northern area of Phase II. After completion of the first 40 percent of the construction period, Alternative Well #1 was simulated to meet the demand for indoor water use at the operations building until the end of the 30-year operational period for Phase II. Alternative Wells #3 through #6 were simulated to be used to meet the demands for water during the last 60 percent of the construction period, with production volumes split evenly between the four wells, for the southern area of Phase II. After completion of construction, Alternative Wells #3 through #6 would not be used.

Scenario 2a follows the above but uses the Tier 1, or 800 ac-ft, of total water pumping over the Phase II construction period. Scenario 2b uses the Tier 2, or 1,000 ac-ft, of total water pumping over the Phase II construction period. Scenario 2c uses the Tier 3, or 1,185 ac-ft, of total water pumping over the Phase II construction period.

4.2 NUMERICAL MODELING RESULTS

Figures 9, 10, and 11 display simulated hydrographs for neighboring wells WP-1A/2, WP-4 and #50808 for the pumping simulated under the three-well pumping Scenarios 1a, 1b, and 1c, respectively.

The figures display the simulated drawdown at the three neighboring wells caused by pumping for the two phases of the Silver State project. Table 4 lists the maximum drawdowns that were simulated for all three pumping Phase II pumping tiers (Scenarios 1a through 1c):

Table 4. MODFLOW Maximum Drawdowns from Scenarios 1a, 1b, and 1c

Scenario	Phase II Pumping Tier	Maximum Drawdown (feet) per Monitoring Well		
		WP-1A/2	WP-4	#50808
Scenario 1a	1 (800 ac-ft)	0.6	1.3	1.4
Scenario 1b	2 (1,000 ac-ft)	0.7	1.5	1.7
Scenario 1c	3 (1,185 ac-ft)	0.8	1.8	2.0

Simulated results for Scenarios 1a, 1b, and 1c show that the water levels in wells WP-4 and #50808 recovered after the construction period and generally stabilized at a drawdown of less than 0.9 feet during the 30-year operational period. The water level in well WP-1A/2 stabilized at a drawdown of less than 0.8 feet during the 30-year operational period.

Figures 12, 13, and 14 display simulated hydrographs for neighboring wells WP-1A/2, WP-4 and #50808 for the pumping simulated under the seven-well pumping Scenarios 2a, 2b, and 2c, respectively.

The figures display the simulated drawdown at the three neighboring wells caused by pumping for the entire two-phase Silver State project. Table 5 lists the maximum drawdowns that were simulated for all three pumping Phase II pumping tiers (Scenarios 2a through 2c):

Table 5. MODFLOW Maximum Drawdowns from Scenarios 2a, 2b, and 2c

Scenario	Phase II Pumping Tier	Maximum Drawdown (feet) per Monitoring Well		
		WP-1A/2	WP-4	#50808
Scenario 2a	1 (800 ac-ft)	0.6	0.9	1.0
Scenario 2b	2 (1,000 ac-ft)	0.7	1.1	1.3
Scenario 2c	3 (1,185 ac-ft)	0.8	1.3	1.5

Simulated results for Scenarios 2a, 2b, and 2c show that the water levels in wells WP-4 and #50808 recovered after the construction period and generally stabilized at a drawdown of less than 0.9 feet during the 30-year operational period. The water level in well WP-1A/2 also stabilized at a drawdown of less than 0.8 feet during the 30-year operational period.

Comparison of the two modeling scenarios (three wells versus seven wells) indicated a drawdown increase of approximately 0.6 feet or less in the two closest neighboring wells (#50808 and WP-4) would be expected if construction water demands were met using only three production wells (Scenario 1) instead of seven (Scenario 2). In both scenarios, drawdown stabilized to less than 0.9 feet during the 30-year operational period.

4.3 COMPARISON TO 2010 FIRST SOLAR SILVER STATE – GROUNDWATER AVAILABILITY ASSESSMENT

A groundwater availability assessment for a 400-MW Silver State project was prepared by West Yost Associates in 2010 (West Yost Associates, 2010). The 400-MW project previously assessed has 100 MW greater generating capacity than the projects (Phases I and II) evaluated in this report. The assessments differ in that the previous assessment evaluated a single phase of construction, and the current assessment evaluated two phases of construction (with the additional 100 MW third phase eliminated). Also, in the previous assessment, all pumping was from one well. In the current assessment pumping from multiple wells was assessed.

In this previous assessment, the construction period for the 400-MW project was modeled assuming 200 afy of groundwater pumping for construction over a four-year period. Groundwater needs for operations were modeled assuming a pumping rate of 20 afy for 50 years. Two alternative well locations, designated Location 1 and Location 2, were modeled. Location 1 was approximately 0.5 mile from the closest existing wells, WP-1A/2. Location 2 was approximately one mile from WP-1A/2. The maximum drawdowns simulated in the assessment were at WP-1A/2, because drawdown decreases with distance from pumping wells.

In the previous assessment pumping at Location 1 resulted in less than 2 feet of drawdown in WP-1A/2 after four years of construction, and Location 2 resulted in less than 1 foot of drawdown in WP-1A/2 after four years of construction. Both location alternatives resulted in less than half a foot of drawdown in WP-1A/2 after the modeled 50-year operational period.

Even though higher construction pumping rates were evaluated under the current analysis, the results were similar to the previous analysis because the pumping was distributed over more wells, which were generally located farther from existing wells than the proposed locations originally evaluated.

5.0 POTENTIAL GROUNDWATER QUALITY IMPACTS DUE TO PROJECT PUMPING

Groundwater-quality data for the project site were not available for this evaluation. However, water-quality data were available for the vicinity of the Primm Valley Golf Course, which is located on the west side of Ivanpah Valley about 8 miles southwest of the project. The general water-quality condition is that poor-quality groundwater occurs near the valley center, but groundwater-quality improves westward from the valley center. Near the valley center, dissolved solids are 1,000 mg/L and higher. Near the golf-course wells and westward, the dissolved solids are about 600 mg/L and lower. At both locations, dissolved solids tend to increase with depth. The groundwater-quality conditions near the project site may be similar. Dissolved solids are highest near the valley center, but they decrease eastward. Furthermore, dissolved solids may increase with depth.

Figure 15 shows the simulated drawdown contours and flow velocity vectors in cross section through Alternative Well #1 for Scenario 1c. The cross section represents conditions near the end of construction in the northern part of the array (approximately March 2015 on Figure 2). The figure demonstrates that project pumping has little effect on vertical flow velocities, and limited potential to mobilize high salinity groundwater from deeper parts of the groundwater basin. Also, the lateral extent of drawdown is limited, which reduces the potential for mobilization of any saline water underlying the central part of the groundwater basin.

6.0 CONCLUSIONS

The use of three production wells (one well for Phase I and two wells for Phase II as evaluated in Scenario 1) for the Silver State projects (i.e., the completed Phase I and future Phase II) result in negligible groundwater level impacts to neighboring wells. Future impacts can be further reduced by siting more pumping wells for the southern area of Phase II, as evaluated in Scenario 2, because the potentially affected neighboring wells are located closer to the southern area of the Phase II project. Distributing the pumping across multiple wells in the southern area of Phase II reduces the impacts to the neighboring wells. Additionally, using a smaller quantity of water during the Phase II construction period will reduce the impacts of pumping on neighboring wells, as shown by the results of the Tier 1 through 3 water use.

The project pumping has limited potential to mobilize saline groundwater by vertical flow from depth or by horizontal flow from the central part of the basin. This is because groundwater gradients induced by the pumping are very small except near the wells, even during the most intensive pumping intervals.

7.0 REFERENCES CITED

Harbaugh, A.W., and McDonald, M.G., 1996, User's documentation for MODFLOW-96, an update to the U.S. Geological Survey modular finite-difference ground-water flow model. Open-File Report 96-485. U.S. Geological Survey.

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.

Harrill, James R. and David E. Prudic, 1998, Aquifer systems in the Great Basin region of Nevada, Utah, and adjacent states – summary report: U. S. Geological Survey Professional Paper 1409-A.

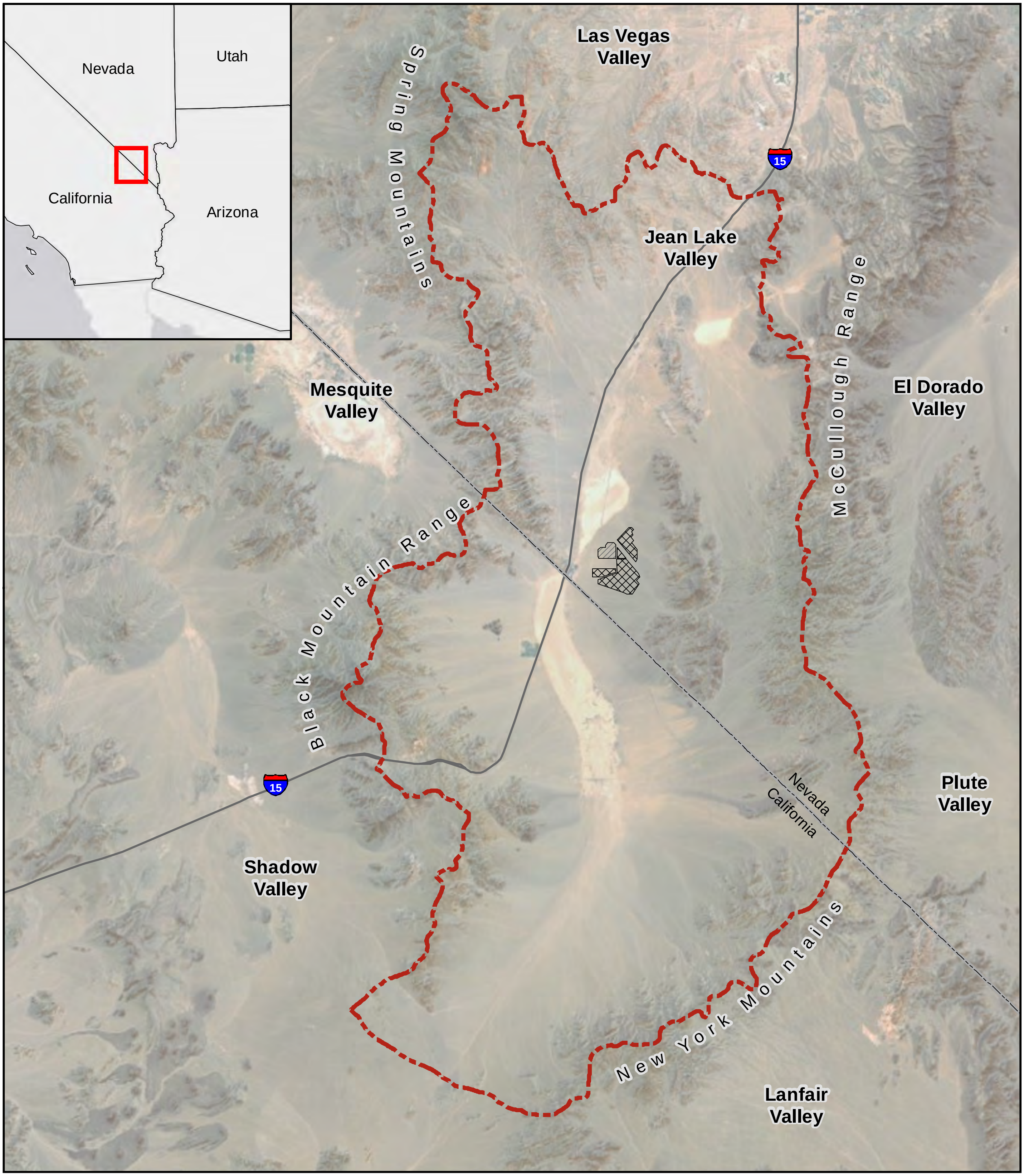
Hewett, D. F., 1956, Geology and mineral resources of the Ivanpah quadrangle California and Nevada: U. S. Geological Survey Professional Paper 275.

Langenheim, V.E., S. Biehler, R. Negrini, K. Mickus, D.M. Miller, and R.J. Miller, 2009, Gravity and Magnetic Investigations of the Mojave National Preserve and Adjacent Areas, California and Nevada, U. S. Geological Survey Open-File Report 2009-1117.

McDonald, M. G. and Harbaugh, A. W., 1988, A modular three-dimensional finite-difference ground-water flow model, Technical Report, U.S. Geological Survey, Reston, VA.

Plume, Russell W., 1996, Hydrogeologic framework of the Great Basin region of Nevada, Utah, and adjacent states: U. S. Geological Survey Professional Paper 1409-B.

West Yost Associates, 2010, First Solar Silver State – Groundwater Availability Technical Memorandum.



LEGEND

- PHASE I: Existing Silver State North Site
- PHASE II: Proposed Silver State South Site
- Ivanpah Valley

N

0 3.5 7
Miles

FIGURE 1

Silver State South, LLC
Groundwater Impact Analysis

LOCATION MAP

WEST YOST ASSOCIATES
Consulting Engineers

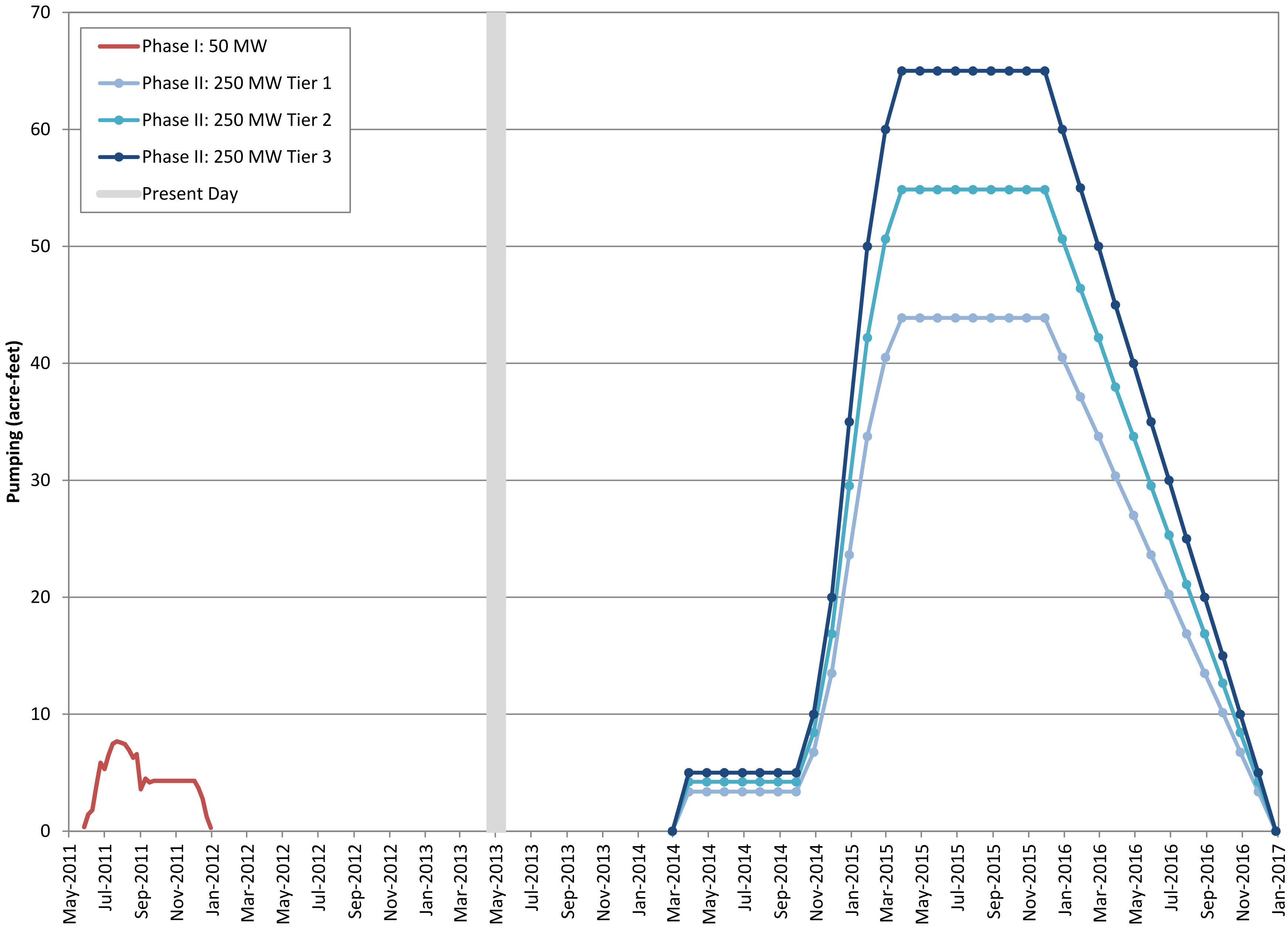


Figure 2

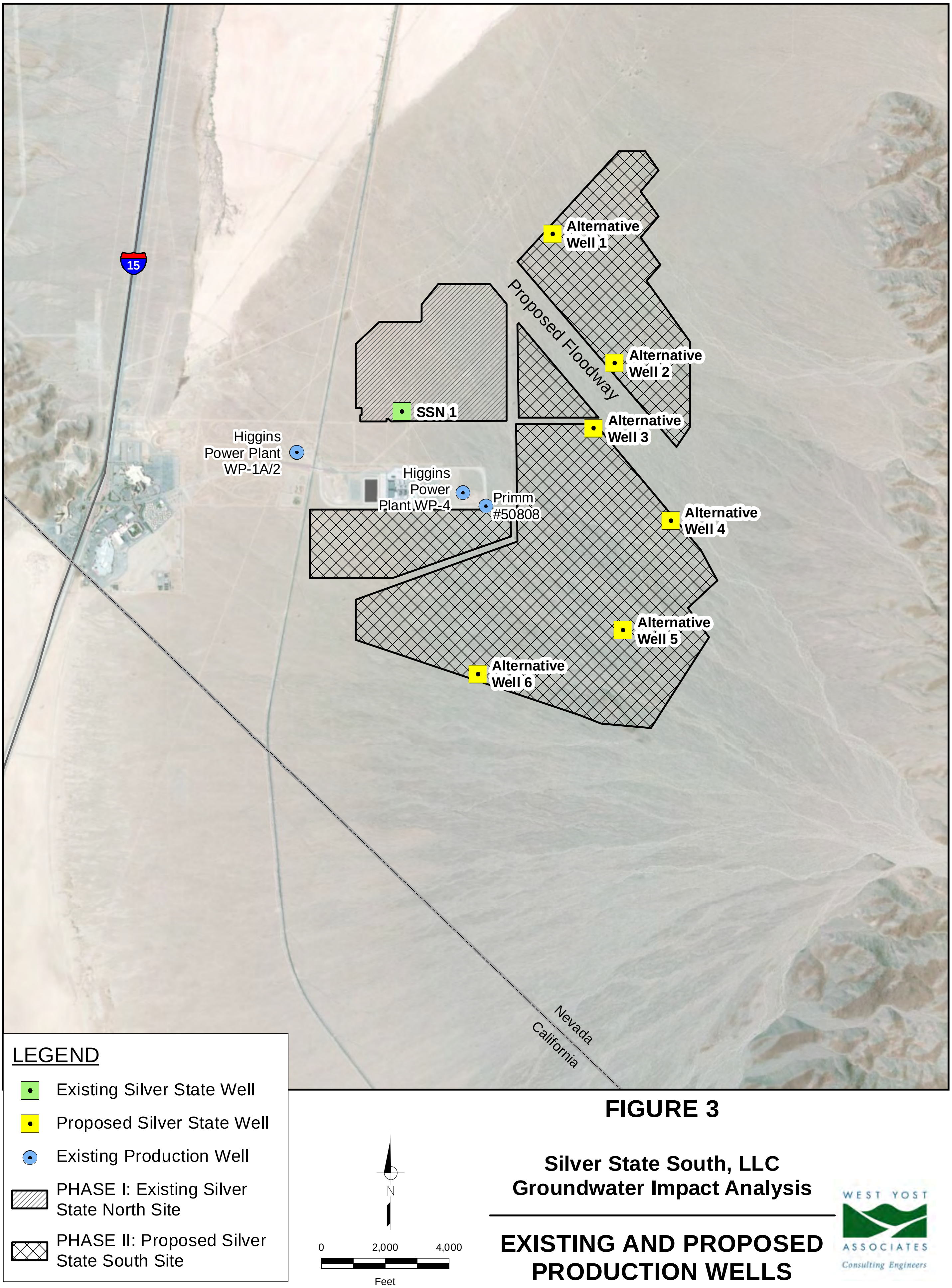
Silver State South, LLC

Groundwater Impact Analysis

WATER DEMAND DURING CONSTRUCTION

WEST YOST ASSOCIATES

Consulting Engineers



LEGEND

- Existing Silver State Well
- Proposed Silver State Well
- Existing Production Well
- PHASE I: Existing Silver State North Site
- PHASE II: Proposed Silver State South Site

FIGURE 3

Silver State South, LLC
Groundwater Impact Analysis

EXISTING AND PROPOSED PRODUCTION WELLS

WEST YOST ASSOCIATES
Consulting Engineers

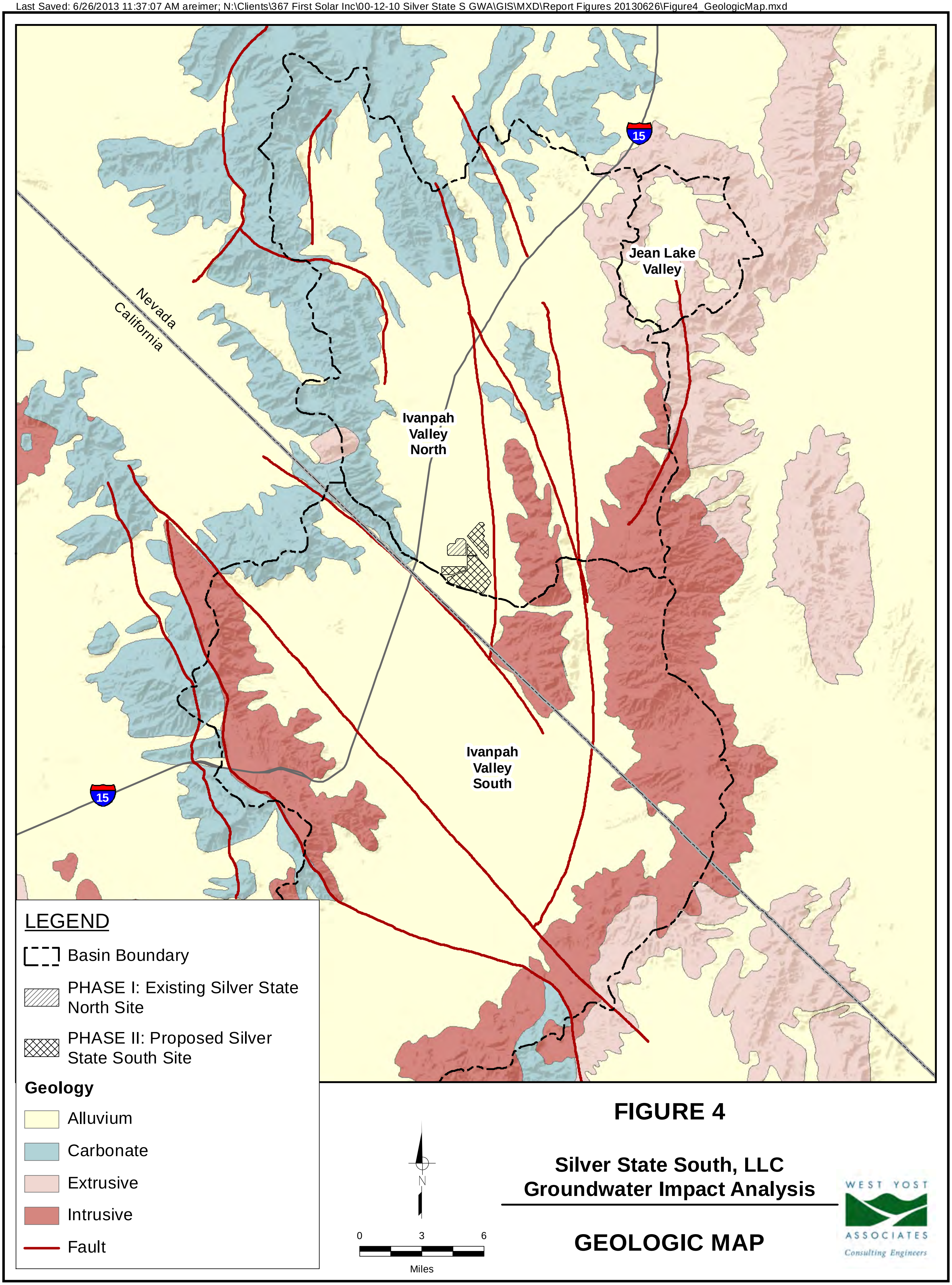


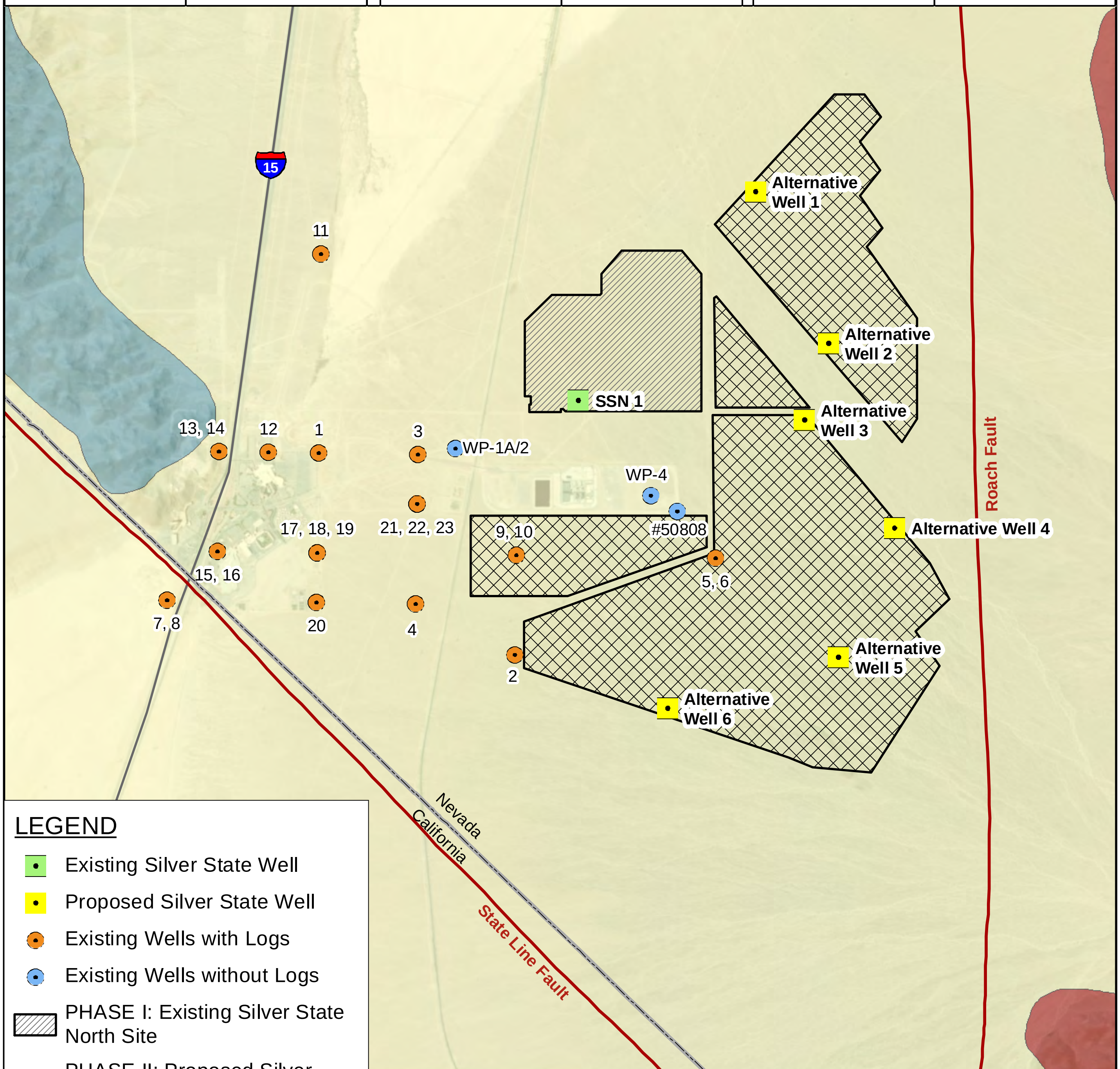
FIGURE 4

Silver State South, LLC
Groundwater Impact Analysis

GEOLOGIC MAP

WEST YOST ASSOCIATES
Consulting Engineers

Well ID	Well Depth (feet)	Well ID	Well Depth (feet)	Well ID	Well Depth (feet)
1	600	9	250	17	240
2	555	10	160	18	240
3	605	11	672	19	120
4	395	12	150	20	120
5	560	13	617	21	238
6	600	14	300	22	238
7	235	15	935	23	232
8	250	16	935	SSN 1	800



LEGEND

- Existing Silver State Well
- Proposed Silver State Well
- Existing Wells with Logs
- Existing Wells without Logs
- PHASE I: Existing Silver State North Site
- PHASE II: Proposed Silver State South Site

Geology

- Alluvium
- Carbonate
- Intrusive
- Fault

N

0 2,000 4,000

Feet

FIGURE 5

Silver State South, LLC
Groundwater Impact Analysis

WELL DEPTHS

WEST YOST ASSOCIATES
Consulting Engineers

Well ID	Depth to Water (feet)	Well ID	Depth to Water (feet)	Well ID	Depth to Water (feet)
1	85	9	200	17	155
2	105	10	135	18	166
3	190	11	100	19	80
4	120	12	115	20	101
5	312	13	159	21	160
6	347	14	121	22	160
7	200	15	110	23	187
8	195	16	110	SSN 1	224

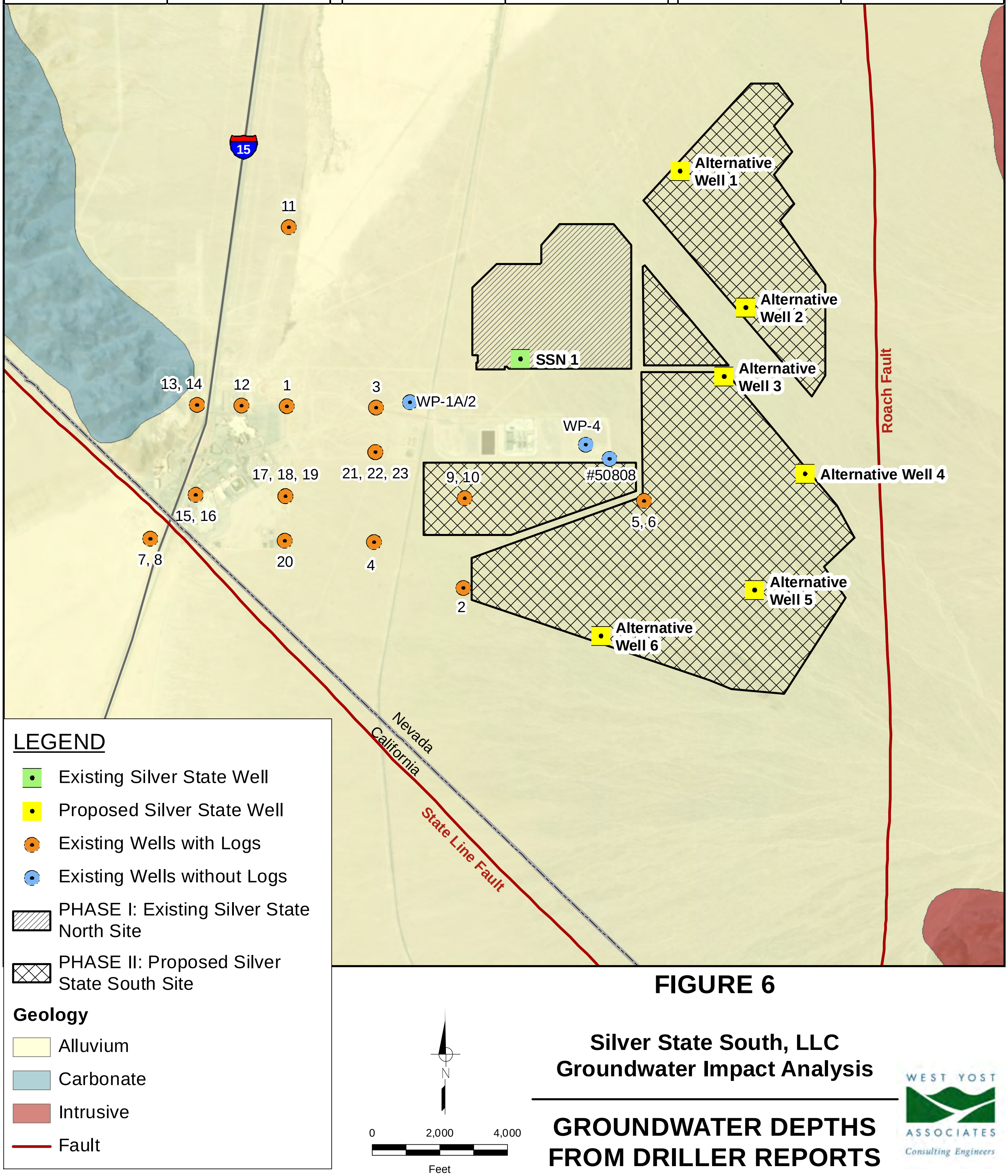


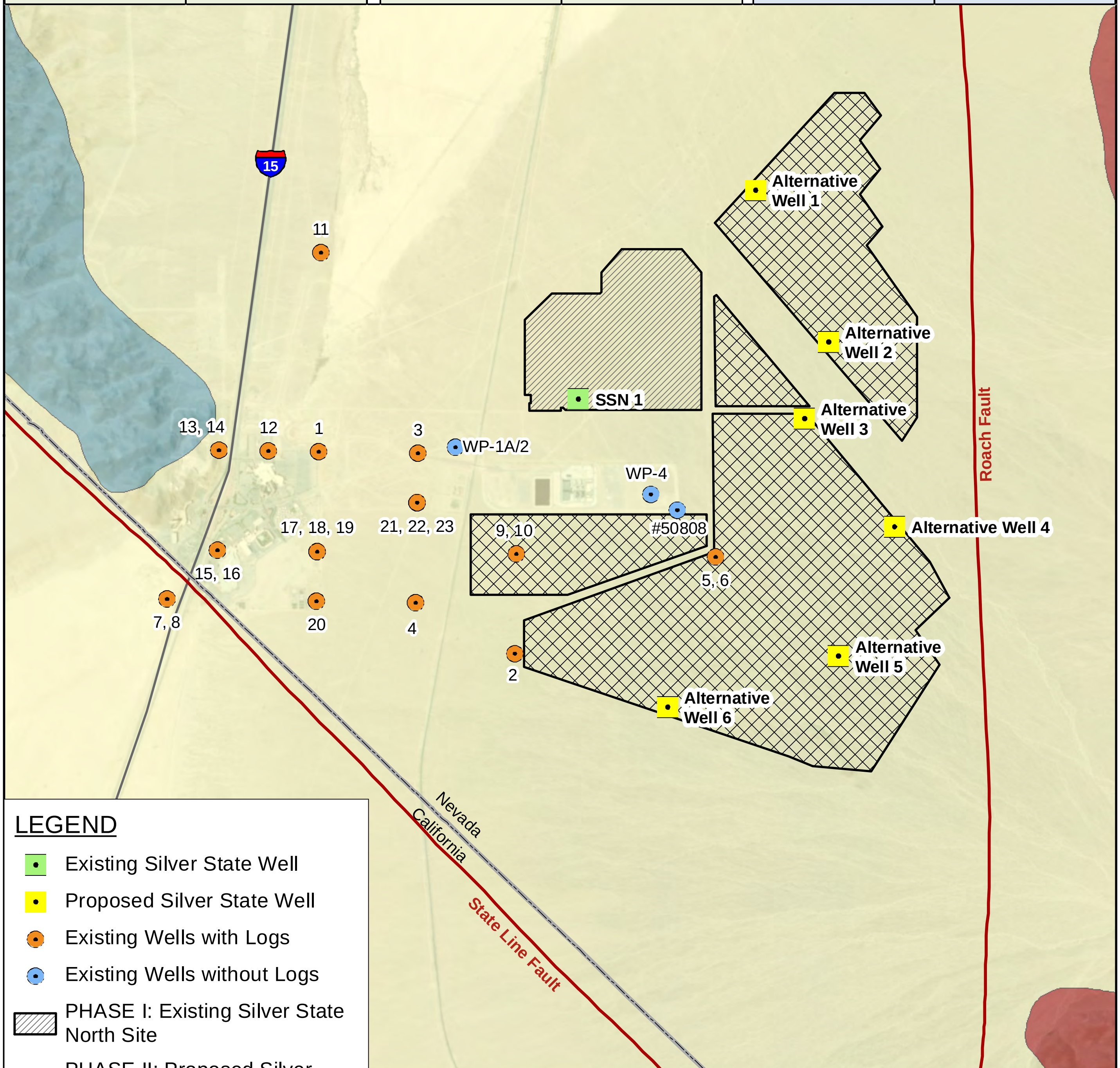
FIGURE 6

Silver State South, LLC
Groundwater Impact Analysis

GROUNDWATER DEPTHS FROM DRILLER REPORTS

WEST YOST ASSOCIATES
Consulting Engineers

Well ID	Texture	Well ID	Texture	Well ID	Texture
1	medium	9	coarse	17	coarse
2	medium	10	coarse	18	coarse
3	medium	11	medium	19	coarse
4	fine	12	fine	20	coarse
5	coarse	13	fine	21	fine
6	coarse	14	medium	22	fine
7	coarse	15	medium	23	medium
8	medium	16	medium	SSN 1	fine



LEGEND

- Existing Silver State Well
- Proposed Silver State Well
- Existing Wells with Logs
- Existing Wells without Logs
- PHASE I: Existing Silver State North Site
- PHASE II: Proposed Silver State South Site

Geology

- Alluvium
- Carbonate
- Intrusive
- Fault

N

0 2,000 4,000

Feet

FIGURE 7

Silver State South, LLC
Groundwater Impact Analysis

LITHOLOGIC TEXTURES AT EACH WELL

WEST YOST ASSOCIATES
Consulting Engineers

Last Saved: 6/26/2013 11:45:42 AM areimer; N:\Clients\367 First Solar Inc\00-12-10 Silver State S GWA\GIS\MXD\Report Figures 20130626\Figure8_ModelBoundary.mxd

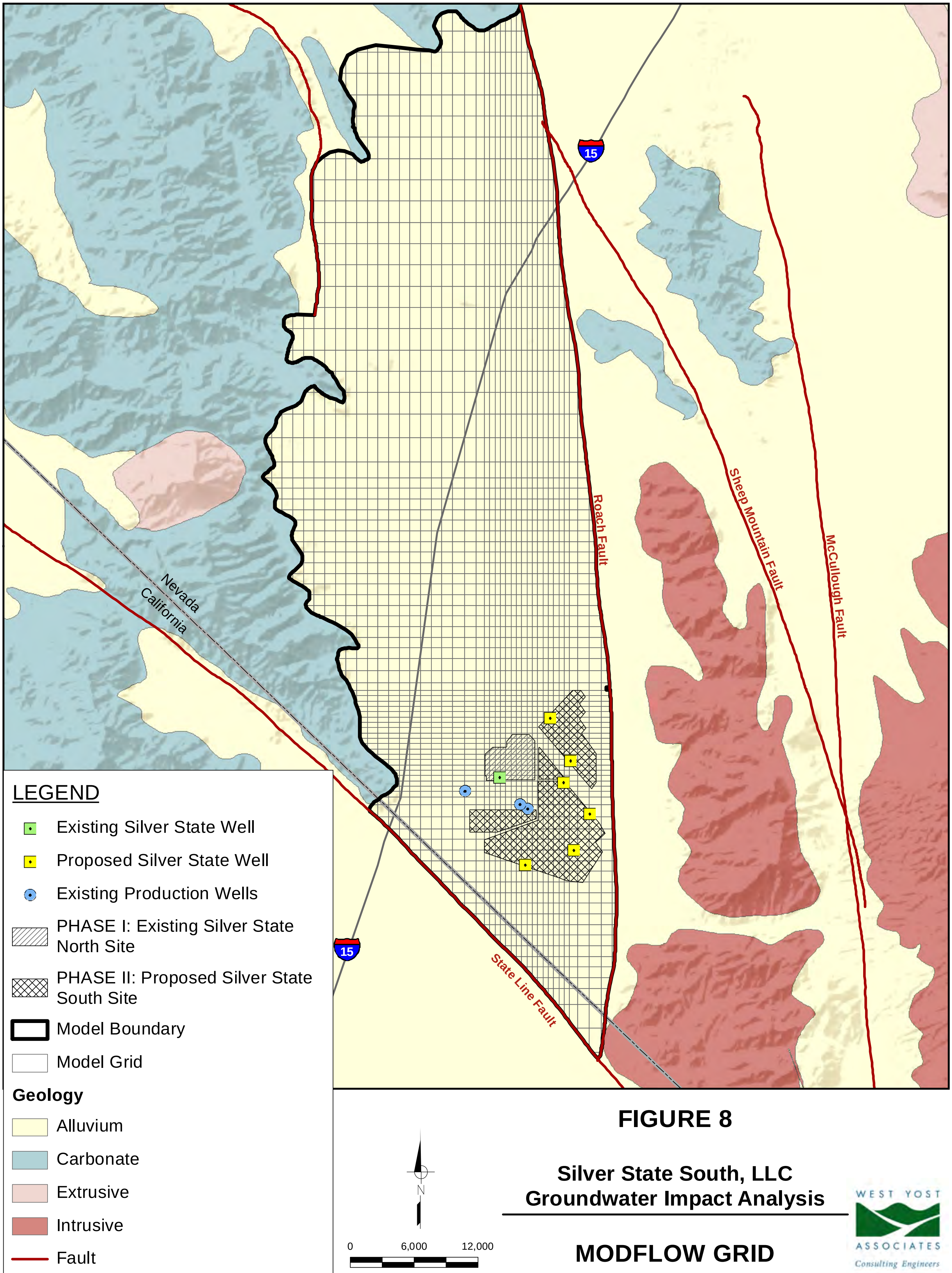


FIGURE 8

Silver State South, LLC
Groundwater Impact Analysis

MODFLOW GRID

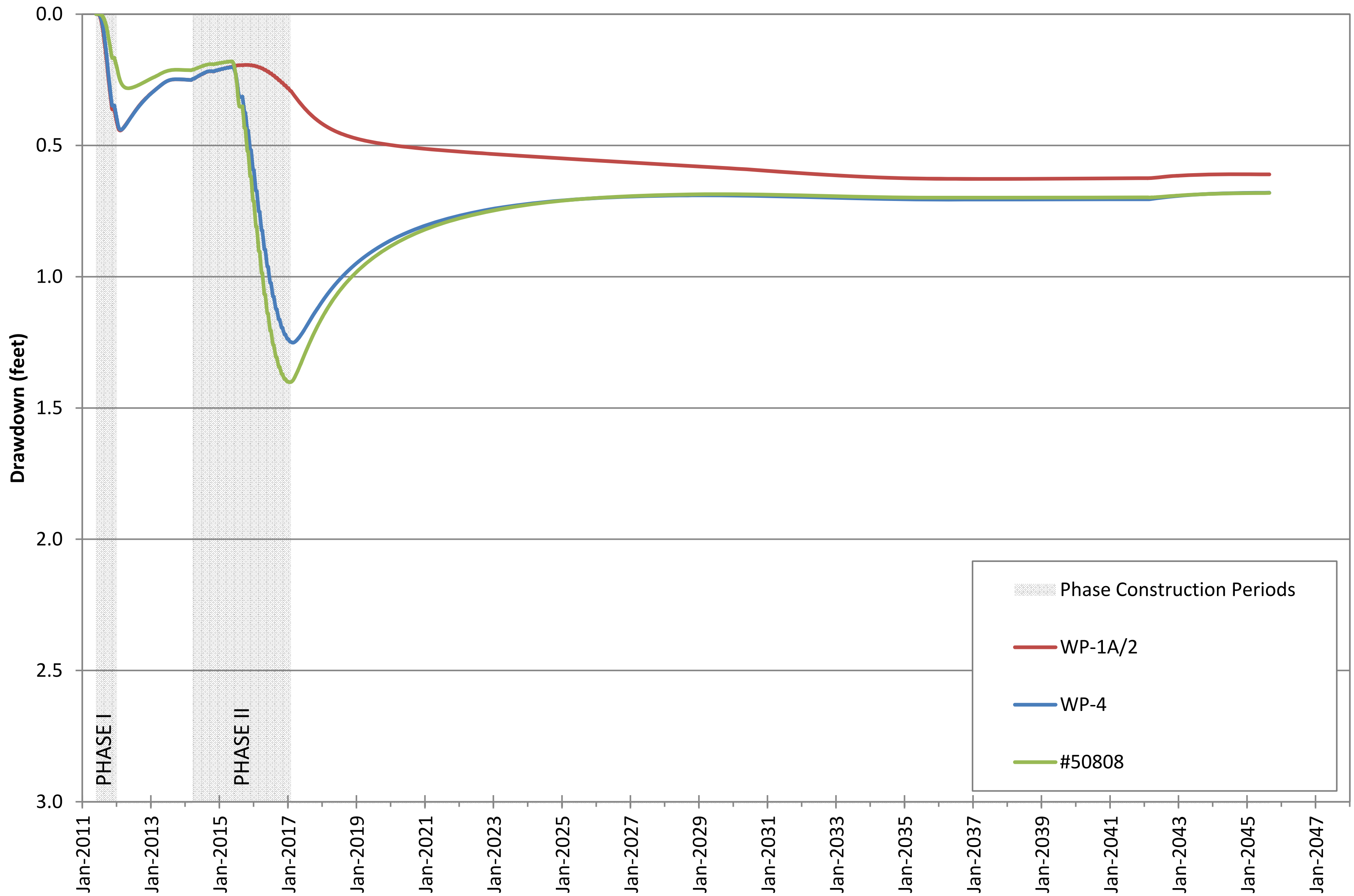


Figure 9

Silver State South, LLC

Groundwater Impact Analysis

SCENARIO 1a HYDROGRAPHS

800 AC-FT PHASE II PUMPING TIER

WEST YOST ASSOCIATES
Consulting Engineers

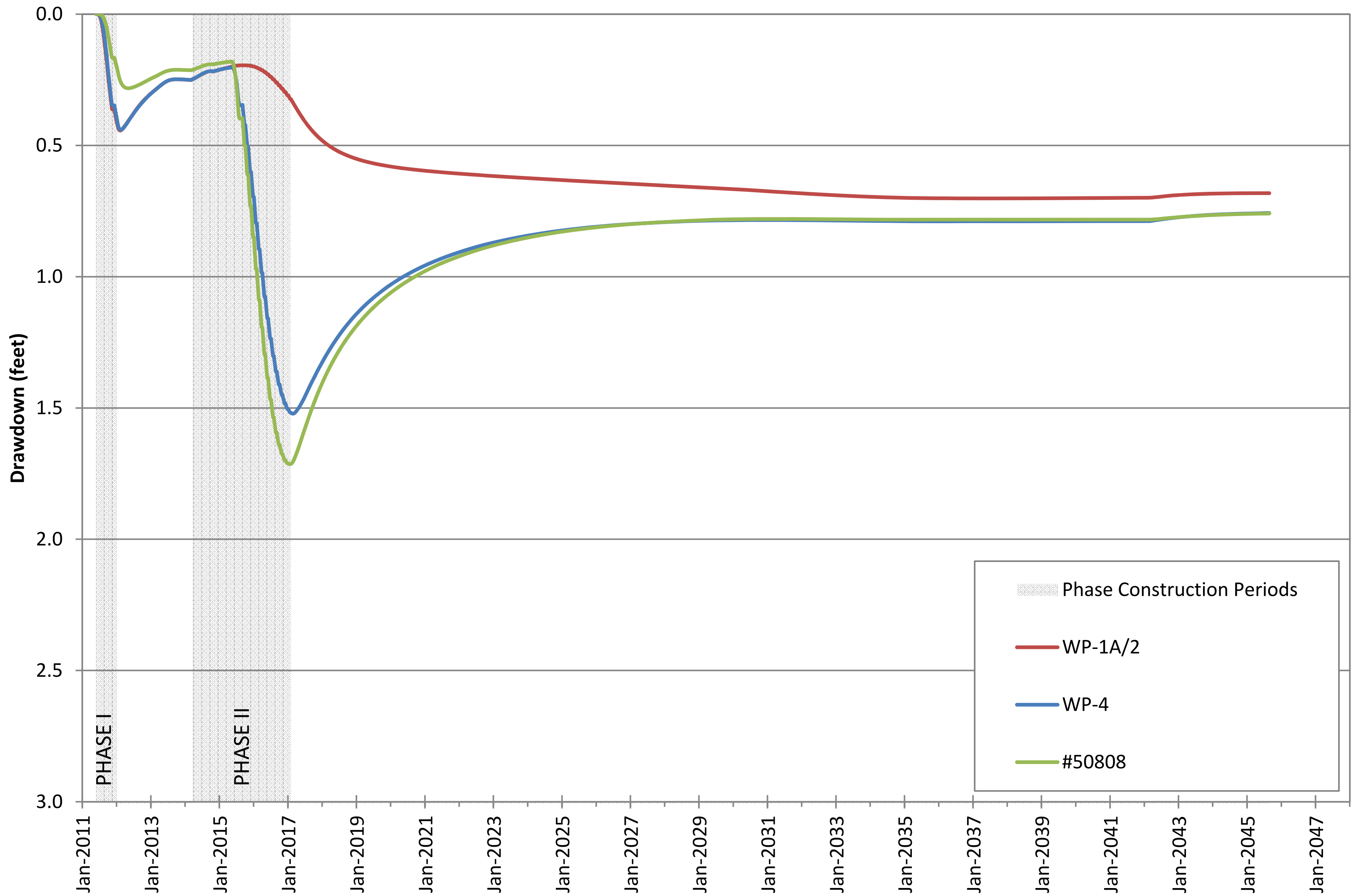


Figure 10

Silver State South, LLC
Groundwater Impact Analysis

SCENARIO 1b HYDROGRAPHS
1,000 AC-FT PHASE II PUMPING TIER

WEST YOST ASSOCIATES
Consulting Engineers

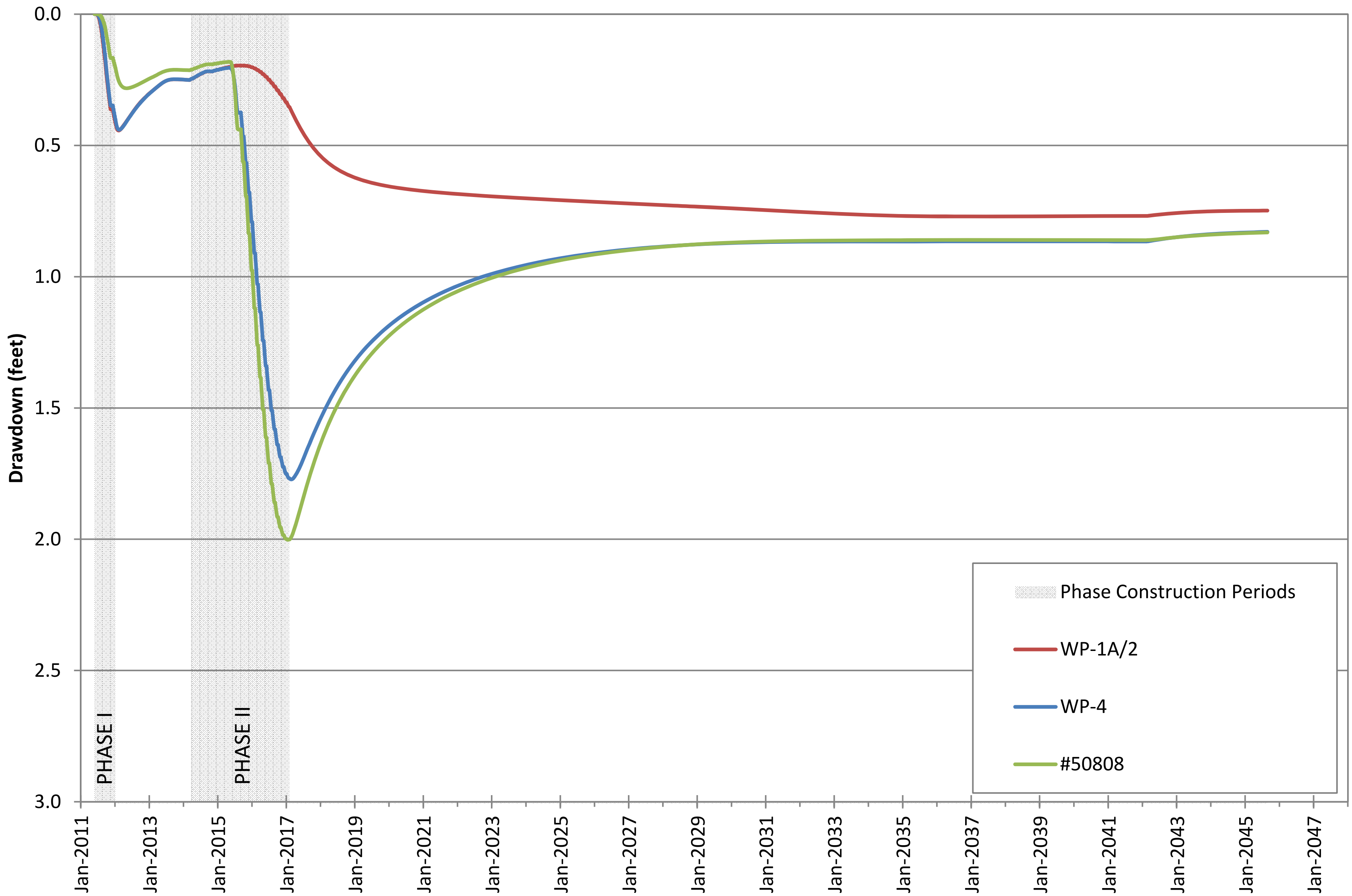


Figure 11

Silver State South, LLC
Groundwater Impact Analysis

SCENARIO 1c HYDROGRAPHS
1,185 AC-FT PHASE II PUMPING TIER

WEST YOST ASSOCIATES
Consulting Engineers

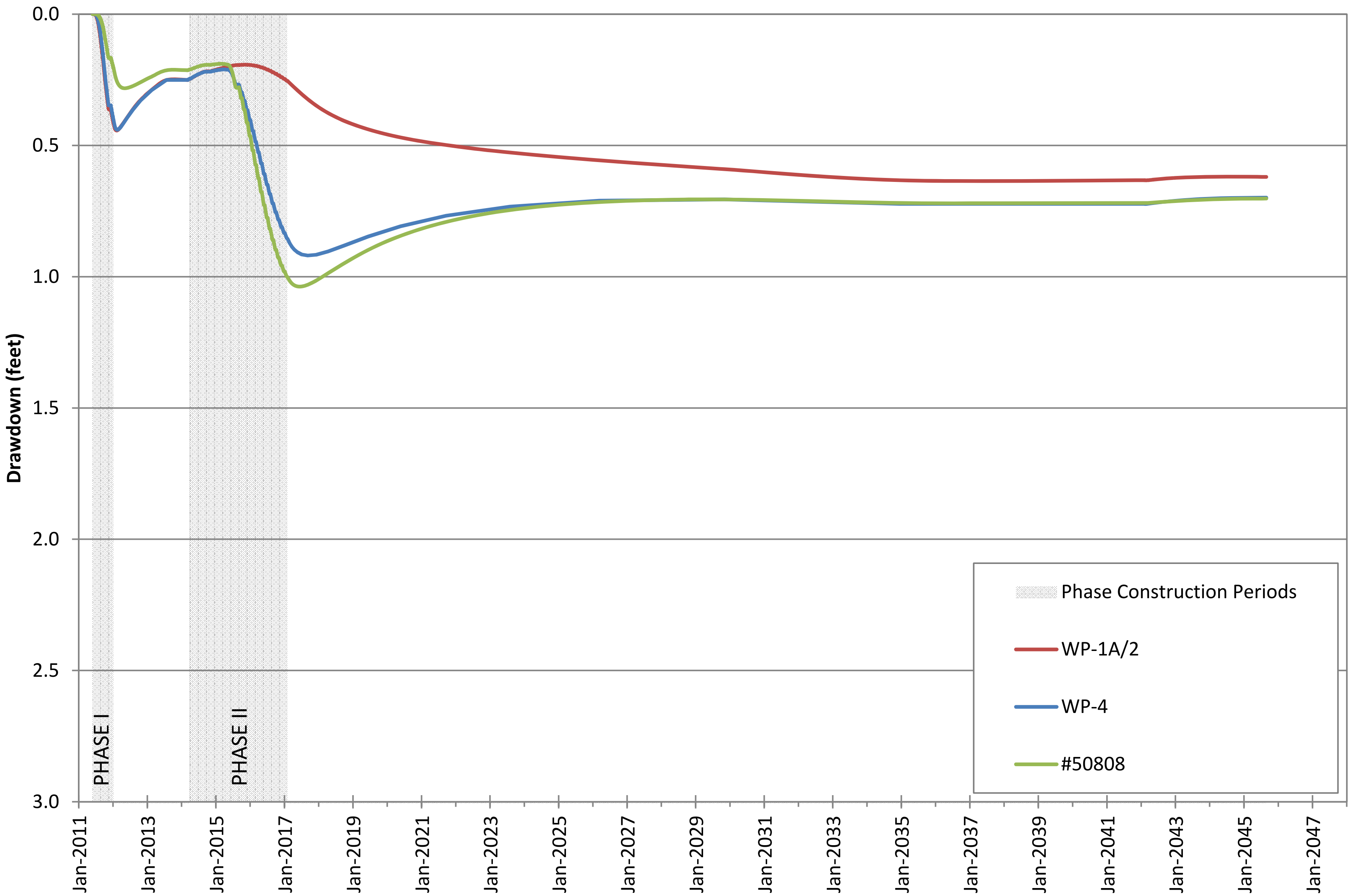


Figure 12

Silver State South, LLC
Groundwater Impact Analysis

SCENARIO 2a HYDROGRAPHS
800 AC-FT PHASE II PUMPING TIER

WEST YOST ASSOCIATES
Consulting Engineers

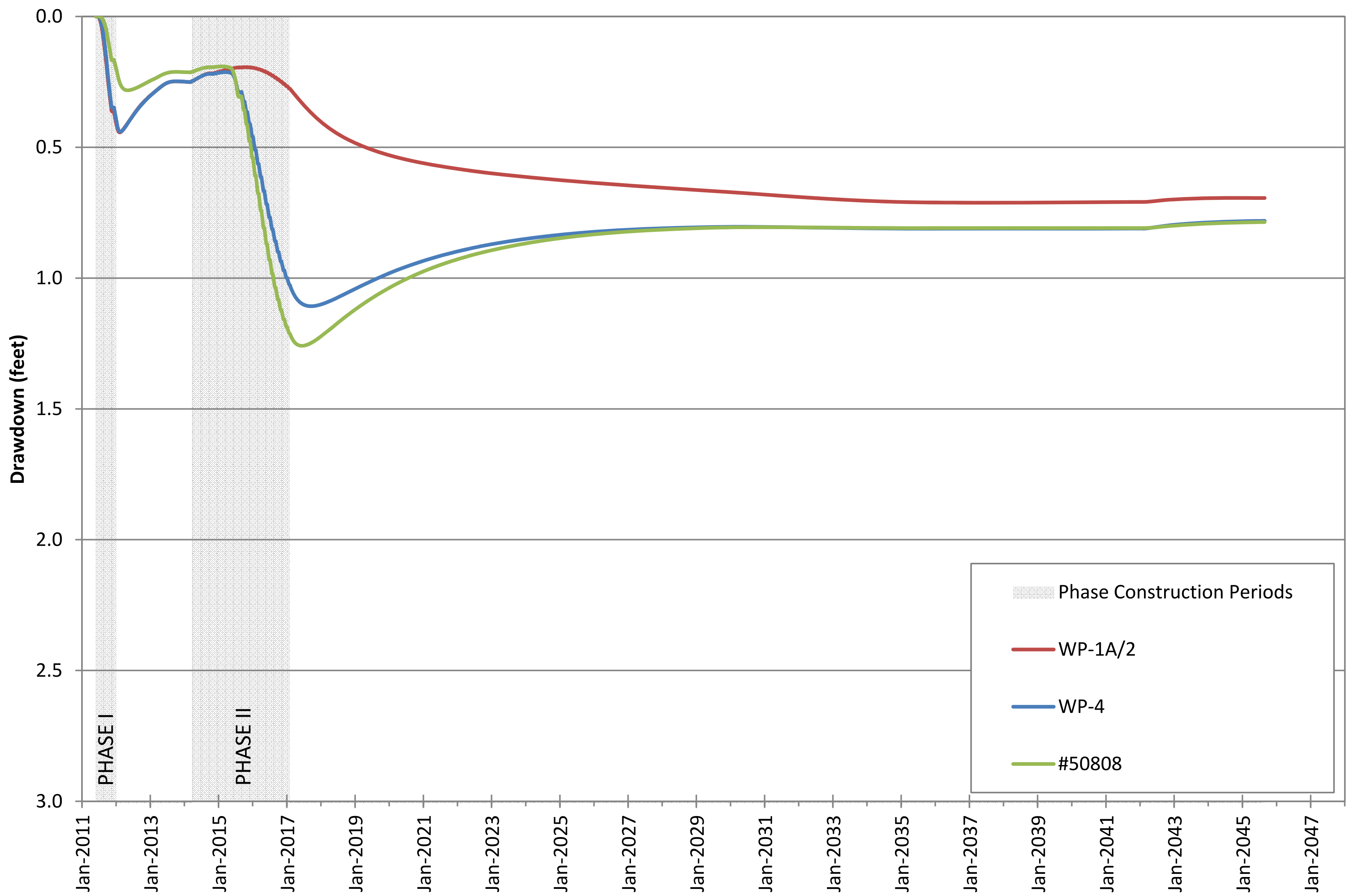


Figure 13

Silver State South, LLC
Groundwater Impact Analysis

SCENARIO 2b HYDROGRAPHS
1,000 AC-FT PHASE II PUMPING TIER

WEST YOST ASSOCIATES
Consulting Engineers

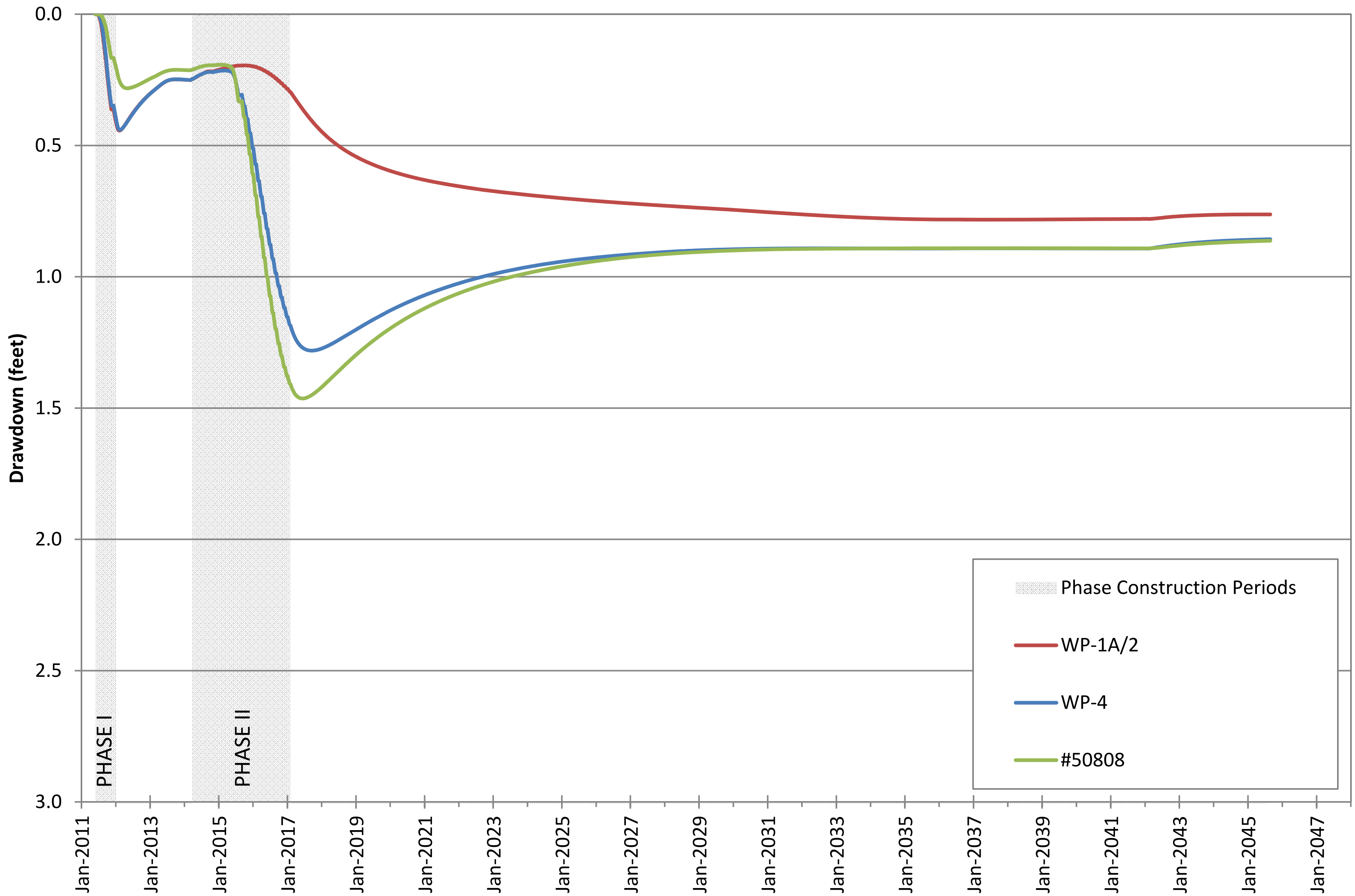


Figure 14

Silver State South, LLC
Groundwater Impact Analysis

SCENARIO 2c HYDROGRAPHS
1,185 AC-FT PHASE II PUMPING TIER

WEST YOST ASSOCIATES
Consulting Engineers

Cross-Section Along Column 70

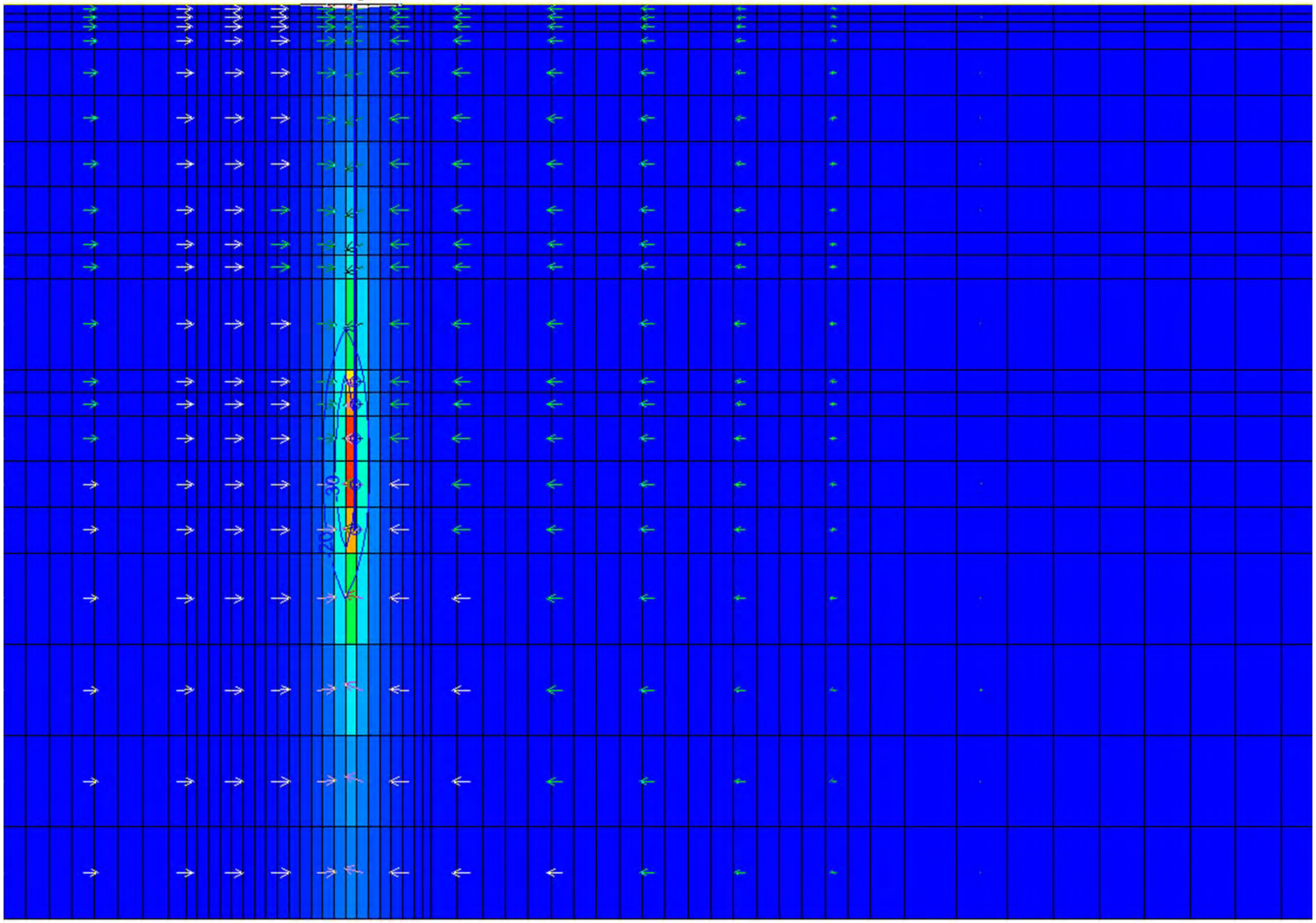


Figure 15

Silver State South, LLC

Groundwater Impact Analysis

SIMULATED INCREMENTAL CHANGE IN FLOW VELOCITY VECTORS DUE TO PUMPING IN A SINGLE WELL

WEST YOST ASSOCIATES
Consulting Engineers