HYDROGEOLOGY OF SPRING VALLEY AND SURROUNDING AREAS

PART B: GROUNDWATER MODEL OF SNAKE AND SPRING VALLEYS, AND SURROUNDING AREAS

Presented to the Office of the Nevada State Engineer

On behalf of Great Basin Water Network and the Confederated Tribes of the Goshute Indians

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Introduction

This report documents the implementation of the conceptual model of groundwater flow in Spring and Snake Valley into a numerical groundwater model. The conceptual model was completed as Myers (2011a). Throughout this report, Myers (2011a) is referred to as Part A.

The conceptual model (Part A) describes the flow directions and rates within and into and from Spring, Tippett, and Snake Valley, Nevada and Utah. The conceptual model accurately represents the flow into, from, and within the model domain (Part A). The general hydrogeologic formations, faults, recharge rates by subbasin, evapotranspiration (ET) rates and locations, flow directions, and interbasin flow estimates are accurate at a basin and subbasin scale. It includes accurate descriptions of the flow at major springs. However, the conceptual model contains significant uncertainties.

The biggest uncertainty comes in the estimate of spring flow and groundwater ET (GWET). For example, GWET is often calculated as the difference between ET rates and annual precipitation at a point; in large phreatophyte areas with low ET, such as much of Snake Valley, an error of half an inch in the annual precipitation estimate can be thousands of acre-feet of difference in the GWET estimate. Adding to this the uncertainty in estimating the area of phreatophyte type, and the estimated GWET from a basin is very uncertain. In Snake Valley, holding all else equal, a decrease in GWET just increases the amount of water discharging to the Great Salt Lake basin (to the northeast of Snake Valley). In Spring Valley, the difference would be the amount discharging from springs to playas or to Tippett or Snake Valley as interbasin flow. Another example is the difference in springs and GWET discharge. Most springs in these valleys support large phreatophyte communities, but are areas of with high water tables. It is very difficult to discern whether the ET from a wetland is from a spring or directly from groundwater. For the purpose of large-scale modeling, it is not relevant.

The purpose of the model is to predict future conditions due to pumping large quantities of water from various parts of the valleys. These predictions rely on a conceptual models and parameterization of numerical models without ever having stressed the aquifers, especially in Spring Valley, at rates remotely similar to the proposed pumping.

Predictions completed with any numerical model of this area provide good estimates of the level of magnitude of impacts to be expected. The model is far more than an interpretative model (Hill and Tiedeman, 2007), but the predictions should be considered accurate, not precise. Accurate because the processes affecting the considered estimates are accurate but not precise because of the uncertainties outlined above.

Part A presents the conceptual model including water balance implemented in this numerical model. It also includes descriptions of the formation properties, including conductivity and thickness.

Previous Groundwater Models of the Study Area

Durbin (2006) prepared a groundwater model of Spring Valley and surrounding valleys and presented it at the first hearing on Southern Nevada Water Authority's (SNWA) Spring Valley water right applications. It was completed using the finite element code FEMFLOW3D for which Durbin had been an original author. The model input was based on recharge estimates using the Maxey-Eakin method and discharge estimates from the original reconnaissance reports for the valleys. Calibration for hydraulic properties used geostatistical methods of spatial correlation to constrain the values, but included in the data base values from outside the study area. The data however is site specific, resulting from pump and aquifer tests which are essentially "at a point" when compared to the size of an aquifer element being modeled. The conceptual model for valley fill resulting from these assumptions requires that fill be considered identical among valleys. This point I disagree with regarding Spring and Snake Valley because Spring is a closed-system with frequent (on a geologic time scale) pluvial events and Snake Valley is much more fluvial with much rarer pluvial events (on the scale of Lake Bonneville ponding into Snake Valley). Durbin also assumed vertical anisotropy equals 50 for the valley fill and 10 for bedrock; for bedrock, Durbin also found a horizontal, north to west, anisotropy equal to 10. Durbin estimated that 10,000 af/y flows from Snake into Tule Valley and another 10,000 af/y to the Great Salt Lake Basin. The model report does not provide unweighted residual statistics or calibrated storage coefficients.

Halford and Plume (2011) developed a model for Spring and Snake Valley to estimate the effects of pumping SNWA's Snake Valley applications the Great Basin National Park. The model used the Regional Aquifer System Analysis (RASA) model developed by Prudic et al (1995) as a base, similar to that done by Myers (2007). They decreased the cell size near the area of interest and added two layers to improve the definition of the water table. Using observations within the valleys of interest and up-to-date parameter estimation techniques they updated the parameters.

Myers (2006) developed a groundwater model for just the Spring Valley portion of this model domain. That model suffered by treating the valley as the essentially closed system (Part A) that most studies had treated the valley as prior to BARCAS (Welch et al, 2008). Flow to Snake Valley was allowed through a boundary representing the Limestone Hills. The second limitation was of using Maxey-Eakin recharge equaling about 75,000 af/ but with most of the water put into the aquifers based on the Maxey-Eakin distribution. This inaccurately distributes recharge around the domain (Stone et al, 2001). However, the largest drawback to the model was that the entire SNWA proposal of 92,000 af/y was drawn from a closed domain so that long-term equilibrium was almost impossible to reach. The model developed herein started with Myers (2006) as a base but has improved all of the aspects of that model which could have been considered inaccuracies.

Model development

I utilized the U.S. Geological Survey (USGS) finite difference groundwater modeling code MODFLOW-2000 (Harbaugh et al, 2000) for this project. I also utilized the drain return package (Environmental Systems Inc, 2007). This code has a long track record of use in the industry, having first been written during the 1980s (McDonald and Harbaugh, 1988). The Nevada State Engineer also has required its use due to its credibility and free public availability from the USGS.

Model Philosophy

The model developed herein was developed following many of the precepts outlined as "Guidelines for Effective Modeling" as discussed by Hill and Tiedeman (2007) and Hill et al (2000). This modeler pays particular attention to the first guideline, that of applying the principle of parsimony. Specifically, the modeler should start off with basic geologic blueprint of the study area and add complexity only as necessary to explain the observed hydrology. Geologic mapping gives the allusion of precision but there is no reason to incorporate such detail because of uncertainty. Table 1 lists the guidelines and discusses how and if they are used in the model development presented herein.

Table 1: Guidelines for effective modeling (Hill and Tiedeman, 2007), and this models utilization of them.

Guideline	Discussion
1: Apply the principle of parsimony	"Start simple and add complexity as warranted by the hydrology and hydrogeology, the inability of the model to reproduce observations, and the complexity that can be supported by the available observations." See text.
2: Use a broad range of system information to constrain the problem	Spatial and temporal structure has been identified using the hydrogeologic conceptual model described in Part A. Initial parameters were as broad as possible. Features were added only when necessary to cause the simulation to emulate observations. Primarily this was subdividing parameter zones, adding and altering fault boundaries, and adding interbasin flow boundaries. Geographic Information Systems were used extensively to describe precipitation and geologic patterns to estimate recharge.
3. Maintain a well-posed, comprehensive regression problem.	When developing parameter zones, it was desirable to only create zones for which the model would be sensitive – that is zones which affect the model results (affect the calibration statistics). This was not possible in all areas, especially the mountains, where there are few observations. In this case, the parameters were set based of subjective judgment.
4. Include many kinds of data as observations	Only head observations were used in the regression. The model was constrained, made unique, by targeting the water balance in whole and in specific reaches, meaning springs and interbasin flow.
5. Use prior information carefully	All parameters were initially set based on previous observations. During calibration, they were also constrained by observed parameter ranges from the literature. However, these ranges were

	not very constraining because most ranged as much as seven orders of magnitude.
6. Assign weights that reflect errors.	All head observations were weighted at 1. Rather than weighting perched wells lowly, they were ignored in this model because they are simply not part of the conceptual model of the regional aquifer.
7. Encourage convergence by making the model more accurate and evaluating the observations	At no stage in this model was convergence ever a problem.
8. Consider alternative models	The model was developed based on the conceptual model in Part A. At numerous points throughout the model development, this conceptual model was changed by fine-tuning the description at various springs, streams, faults, and interbasin flow points.
9. Evaluate model fit	The final model has the best fit statistics found for any conceptual model.
10. Evaluate optimized parameter values.	Individual parameter values were tested for sensitivity to optimize their value.
11. Identify new data to improve simulate processes, features, and properties.	New wells were added several times, as they were drilled by SNWA, UGS, and USGS. Additionally, I performed synoptic surveys on two streams and used such data from Elliot et al (2006). Additionally, spring data at Stateline Springs and the secondary recharge below several springs was estimated and modeled.
12. Identify new data to improve predictions	New transient simulations from Halford and Plume (2011) were used for transient calibration. Additionally, specific storage information from the USGS and UGS were used.
13. Evaluate prediction uncertainty and accuracy using deterministic methods	Prediction uncertainty will be discussed in part C, the estimates of the impacts of SNWA's proposed pumping. The uncertainty will be assessed by bracketing the specific storage values.
14. Quantify prediction uncertainty using statistical methods.	

Model Structure

Preserving the goal of parsimonious modeling, the grid size, layers, and layer thicknesses were set to accurately simulate horizontal and vertical groundwater movement through the model domain. I discretized the model more finely near areas of pumping and groundwater/surface water interaction. Layer thicknesses were set to simulate GWET and water table changes accurately and as precisely as possible; deeper layer thicknesses are larger because knowledge of the geology is less precise and because the simulation of pumping from a well with large screen lengths is less sensitive to layer thickness. More and thinner layers do not necessarily improve the model especially if the hydrologic data is sparse (Anderson, 1998).

The general grid cell size was one-mile square, but was decreased telescopically to one-quarter mile square near SNWA's proposed wells (Figure 1). This discretization was extended into the Snake Range to improve simulation in that area. To compensate for the increased computational time, the cell size of the far eastern, southern, and northern portions of the domain was set larger, up to four-miles square.

The model has seven layers, with total thickness based on the thickness of the deeper formations. The bottom elevation for each layer was set according to stratigraphy and topography, with particular attention in the valley fill to Watt and Ponce (2007) and Mankinen et al (2006). The top elevation of layer 1 was set based on DEM models (30 m where available, 10 m where 30 m not available). Most wells were located in basin fill and therefore the thickness of layers 1 and 2 were based on the basin fill wells (Figure 2, Part A).

The hydrogeology in the mountains is much more complicated due to the prevalence of fractured carbonate and volcanic rock, clastic aquitards, and impermeable intrusive rock. The carbonate outcrops in the mountains would be the tops of aquifer formations that have both unconfined and confined zones.

For model top elevations 6580 ft amsl and below, the layer 1 is 80 ft thick; for top elevations above 6580 ft amsl, the bottom is set at 6500 ft amsl, so the thickness ranges up to more than 6000 feet. The elevation 6500 ft amsl was chosen because it is approximately the elevation at the top of the alluvial fans, particularly near Baker. Although this renders some mountain block cells very thick, the cells near important springs are much less thick; for example the top elevation at the cell containing the Rowland Creek spring is 6585 and the bottom elevation is 6500 ft amsl. Because all formations above 6500 ft amsl are in layer 1, the mountain block aquifers are unconfined. Specific yield could be set a little lower than usual to reflect the combined aquifer types. Layer 2 is set simply to be 120 ft thick.

Layers 3 and 4 are 200 and 400 ft, respectively, to facilitate the modeling of existing wells in the 200 to 800 ft deep range. Layer 5 is expected to be the deepest SNWA pumping layer, and extends to 2000 feet below ground surface so it is 1200 feet thick.

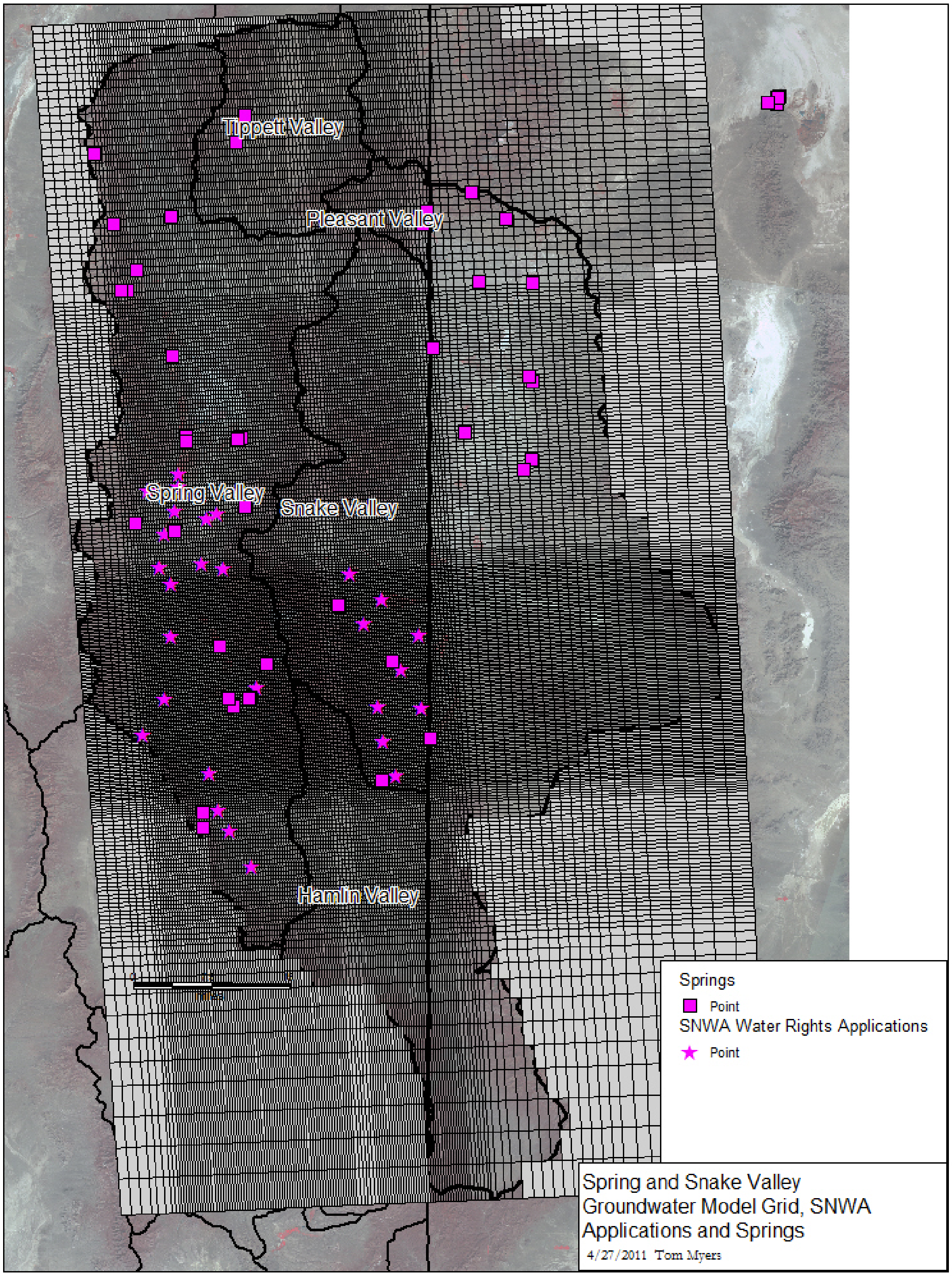

Figure 1: Grid Layout of Spring and Snake Valley Groundwater Model. Also shows major springs and locations of SNWA applications.

Layer 6 does not have a constant thickness because it was based on the published maximum fill thickness (Mankinen et al, 2006; Ponce and Watt, 2007). Initially, the depth to basement was interpreted from Welch et al (2008) using three bottom elevations: 500, -5000, and -10,000 ft amsl. Bottom elevation for layer 6 for the cells for which 500 ft amsl was too low was set so that the layer 6 thickness was 2500 feet, or the layer bottom elevation equals the layer 5 bottom elevation minus 2500 ft. The deepest layer 6 bottom elevations occurred in areas where the depth plunged steeply so that substantial drops in layer 6 bottom elevation from cell to cell did occur. The center of the areas with 500, -5000, or -10,000 ft amsl elevations were allowed to be flat but the cells in the concentric circles were roughly interpolated to intermediate thicknesses. Figure 2 shows that much of layer 6 is less than 2600 feet thick, but that it also is as much as 14,000 ft thick.

Layering within a geologic parameter zone allows the simulation of vertical flow and gradients, but using increasing the layers beyond the amount of data available for calibration is not justified. There are from one to six basin fill layers, depending on total basin fill depth, which allows the model to simulate vertical movement in the basin fill. Bedrock zones, carbonate, volcanic, or intrusive rocks, bound the basin fill. There are up to six layers within a given formation, depending on its thickness. Flow between fill and bedrock depends on the difference in conductivity parameters unless there is a fault between formations. Increased complexity in the model's vertical flow capability is not justified if the vertical gradient cannot be adequately calibrated.

Hydraulic Conductivity

Hydraulic conductivity was set according to parameter zones, which correspond to hydrogeologic formations (Figure 9, Table 1, Part A). Initially, model calibration was attempted with just 11 zones, but a need to divide the zones for different conductivity value became immediately apparent. Also, some basin fill and carbonate zones were subdivided into zones for each layer based on expected decreasing conductivity with depth. Table 2 shows the initial and final conductivity v values by parameter zone. Final conductivity was determined with steady state calibration, as described below. The initial zones were 1 through 11 and the added zones are as shown in Table 2, based on the general hydrogeologic zone. Figures 3 through 9 show the final conductivity zones for layers 1 through 7.

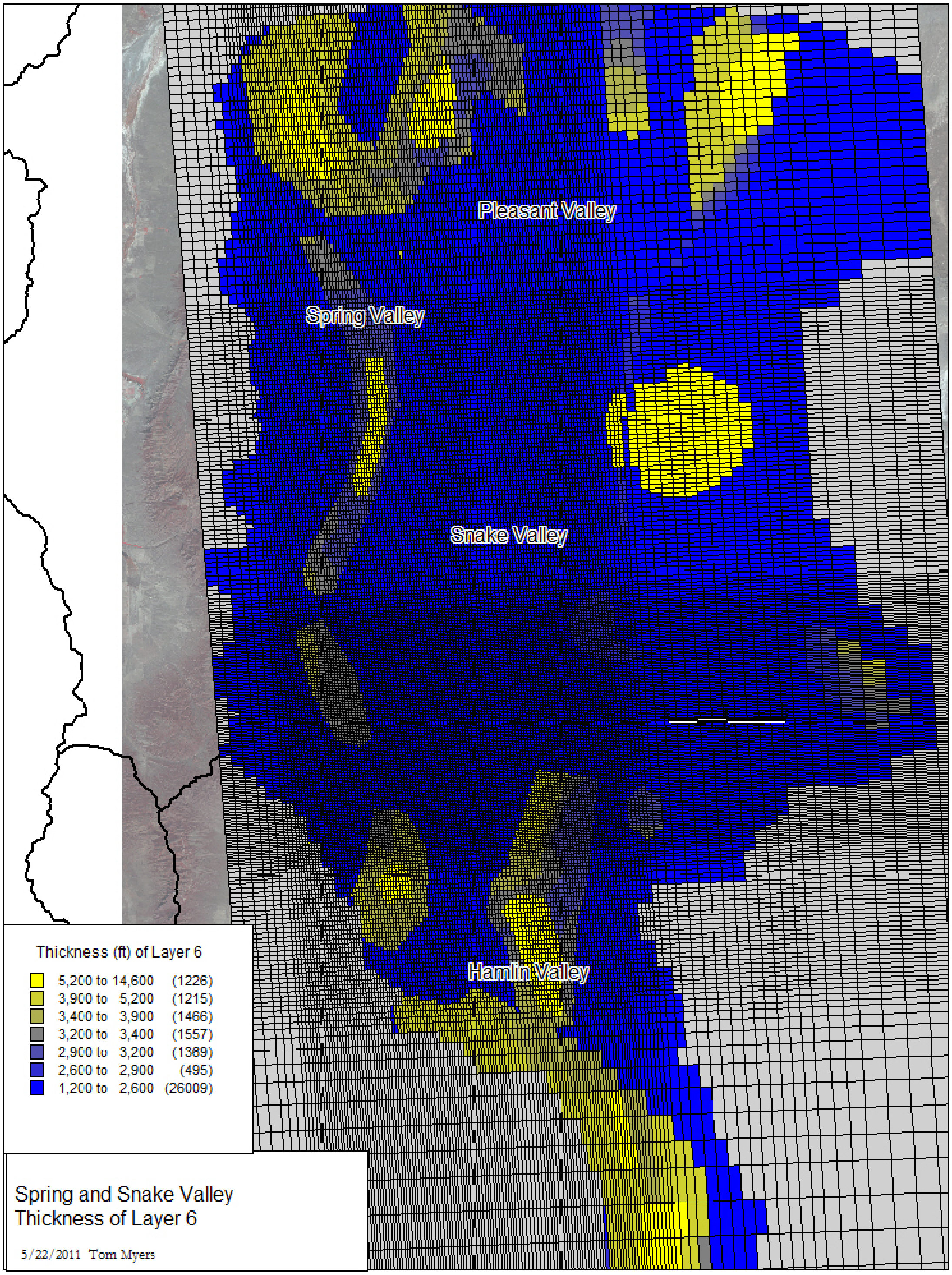

Figure 2: Spring and Snake Valley Groundwater Model, thickness of layer 6 in feet.

Table 2: Calibrated conductivity (ft/d) by parameter zone.

		Initial Conductivity (ft/d)		Calibrated Conductivity (ft/d)		
Parameter Zone	General Hydrogeologic Zone	Kh	Kv	Kx	Ky	Kz
1	FYSU	19		1.22	1.22	0.1
2	CYSU	10		1.16	1.16	0.02
20	CYSU			19.8	19.8	2
21	CYSU			34.7	34.7	1
22	CYSU			0.501	0.501	0.25
23	CYSU			1.2	1.2	0.01
24	CYSU			0.5	0.5	0.15
25	CYSU			0.03	0.03	0.003
26	CYSU			0.745	0.48	0.004
27	CYSU			0.2	0.2	0.02
28	CYSU			0.767	0.767	0.4
29	CYSU			0.492	0.492	0.002
30	CYSU			0.053	0.053	0.02
31	CYSU			0.173	0.173	0.02
32	CYSU			20	20	1
33	CYSU			10.1	10.1	1
34	CYSU			2.65	2.65	0.2
35	CYSU			51.4	51.4	3
36	CYSU			0.222	0.222	0.02
37	CYSU			0.769	0.769	0.2
3	OSU	.4	.04	0.183	0.183	0.01
4	VFU	2.0	.2	2.13	2.13	1.5
40	VFU			0.457	0.457	1
41	VFU			0.108	0.108	0.004
5	VTU	37	3.7	0.08	0.08	0.008
6	MSU	.004	.0004	0.004	0.004	0.0004
7	UCU	3	.3	0.0301	0.0301	0.3
71	UCU			0.269	0.269	0.02
72	UCU			4.89	4.89	0.02
8	USCU	.1	.01	0.1	0.1	0.01
9	LCU	4	.4	0.397	0.397	0.05

91	LCU			0.129	0.129	0.0005
92	LCU			0.02	0.02	0.0002
93	LCU			0.04	12	0.08
94	LCU			0.0965	0.0965	0.02
95	LCU			0.018	0.018	0.03
96	LCU			0.424	0.424	0.05
97	LCU			0.75	25	0.015
98	LCU			5	5	0.5
99	LCU			0.12	12	0.018
10	LCSU	.0000003	.00000003	0.00522	0.00522	0.004
100	LCSU			40	40	10
101	LCSU			0.001	0.001	0.001
11	IU	.01	.01	0.00203	0.00203	0.0008
111	IU			0.001	0.001	0.001

Faults

Faults were included in the model according their state geology mapping location (Part A). Faults can both impede and enhance groundwater flow. In MODFLOW, they are considered a horizontal flow barrier (HFB), although the term barrier is too strong. Faults are calibrated with a conductance which controls the flow between two cells separated by a HFB. Conductance was a calibration term with the value being decreased or increased to either increase or decrease the head drop across a HFB, respectively.

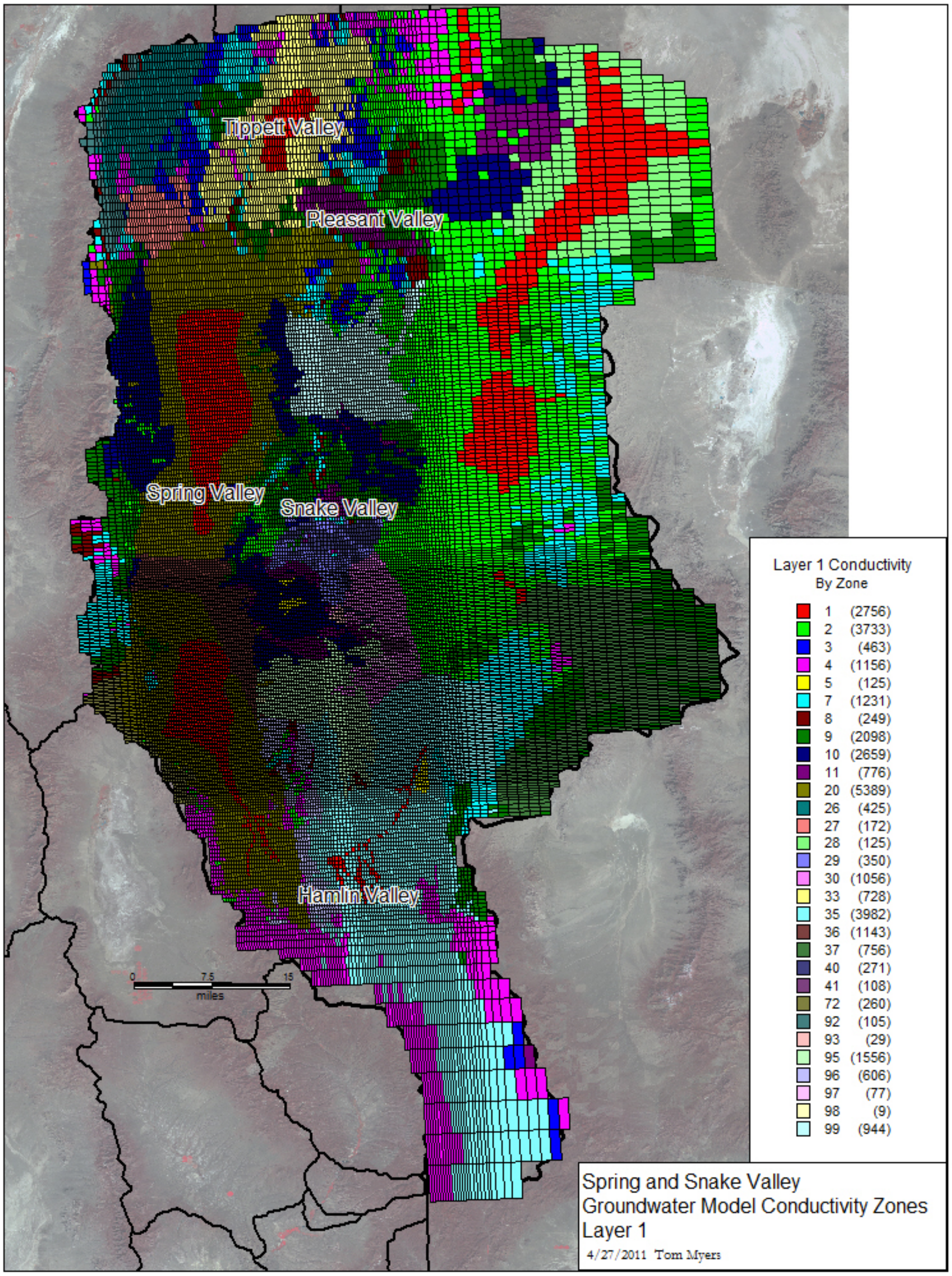

Figure 3: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 1.

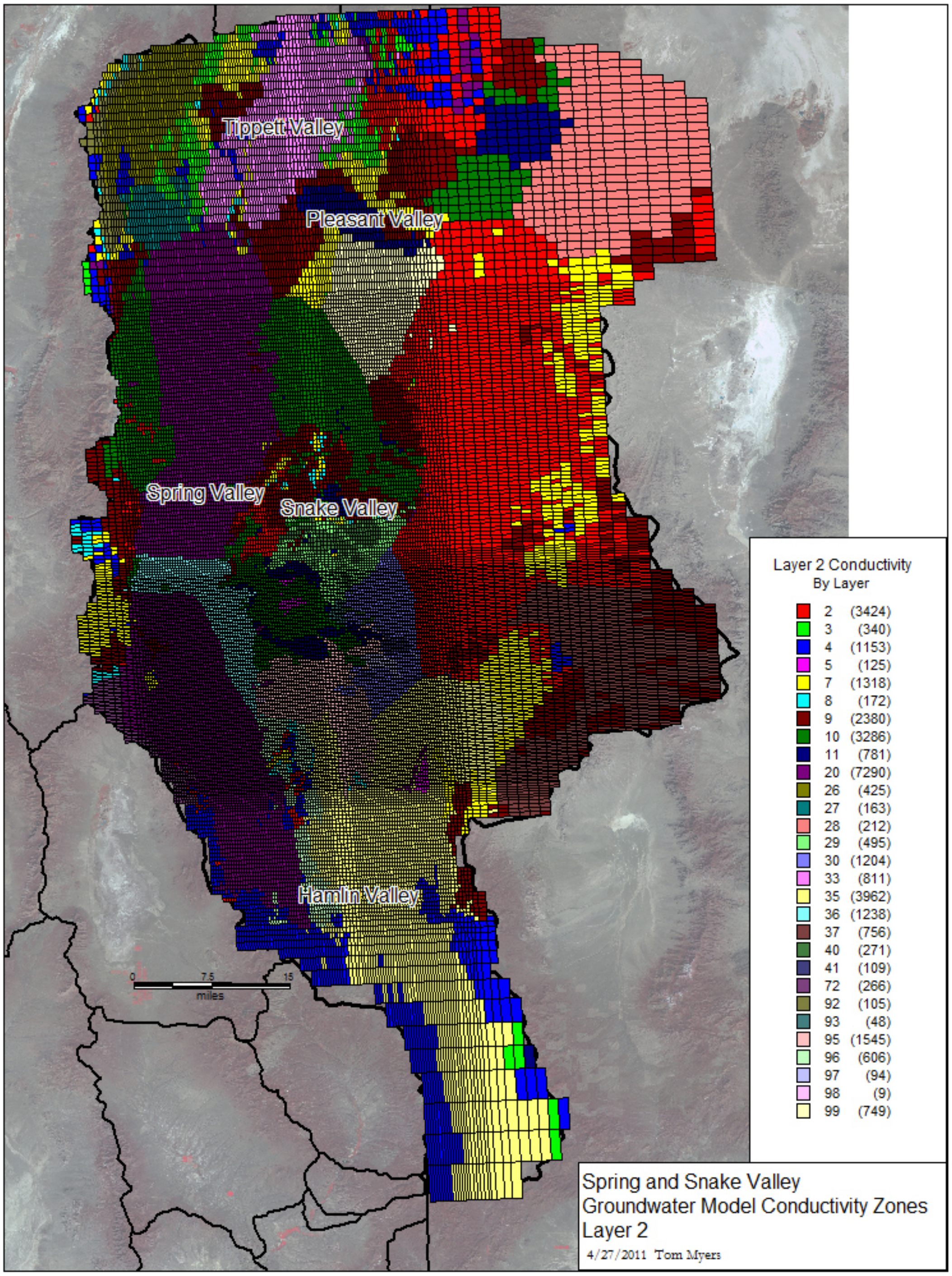

Figure 4: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 2.

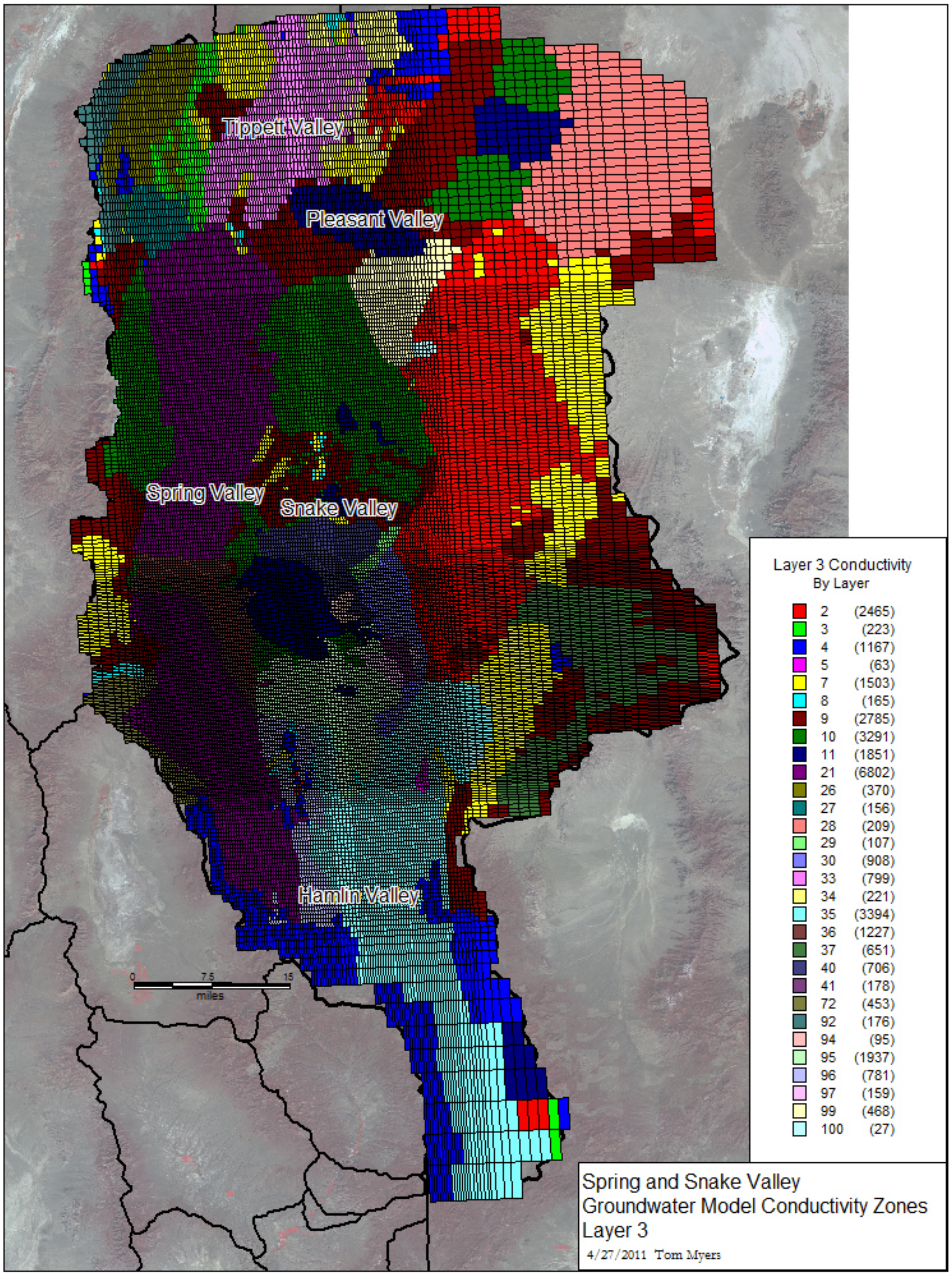

Figure 5: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 3.

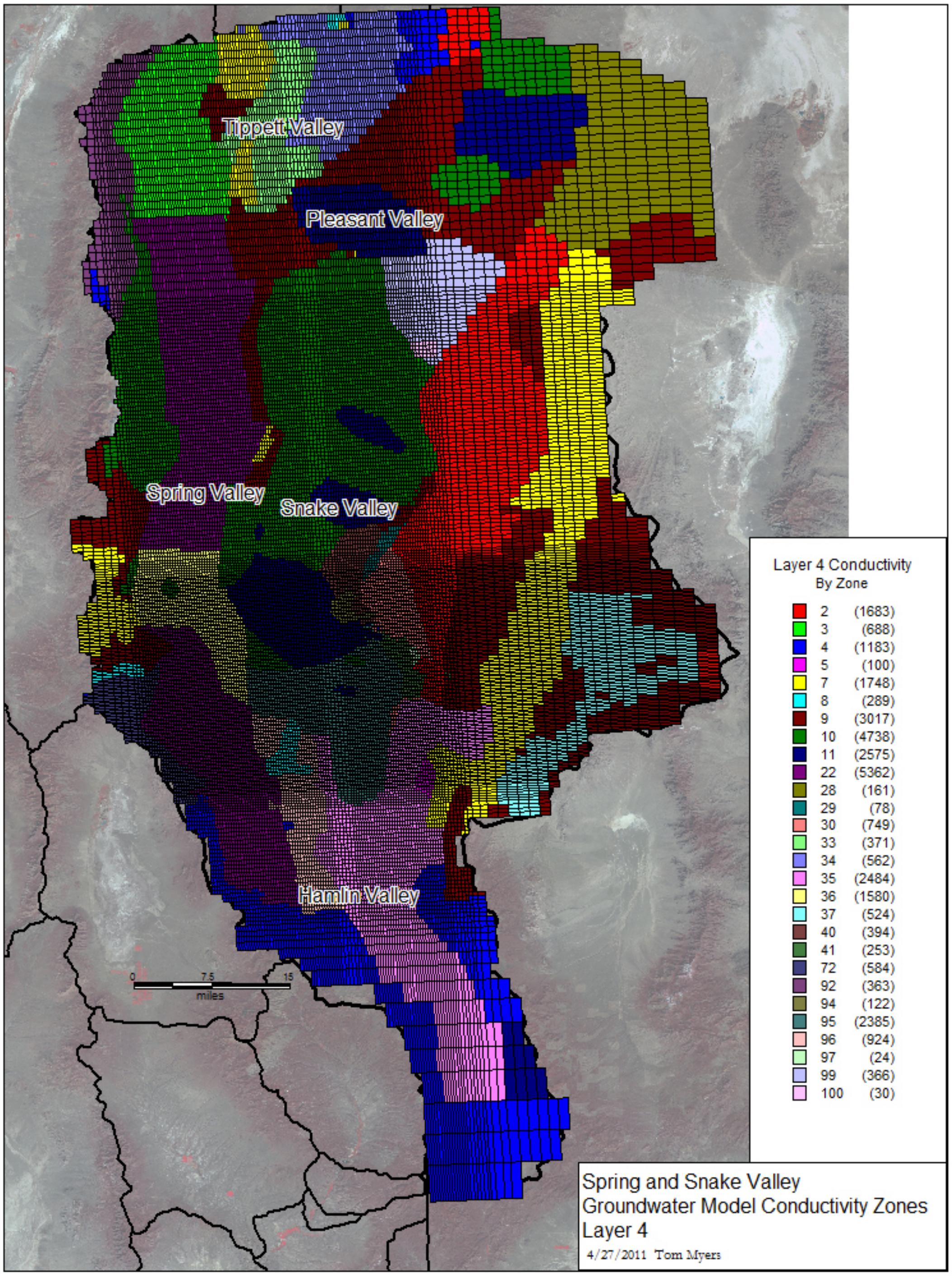

Figure 6: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 4.

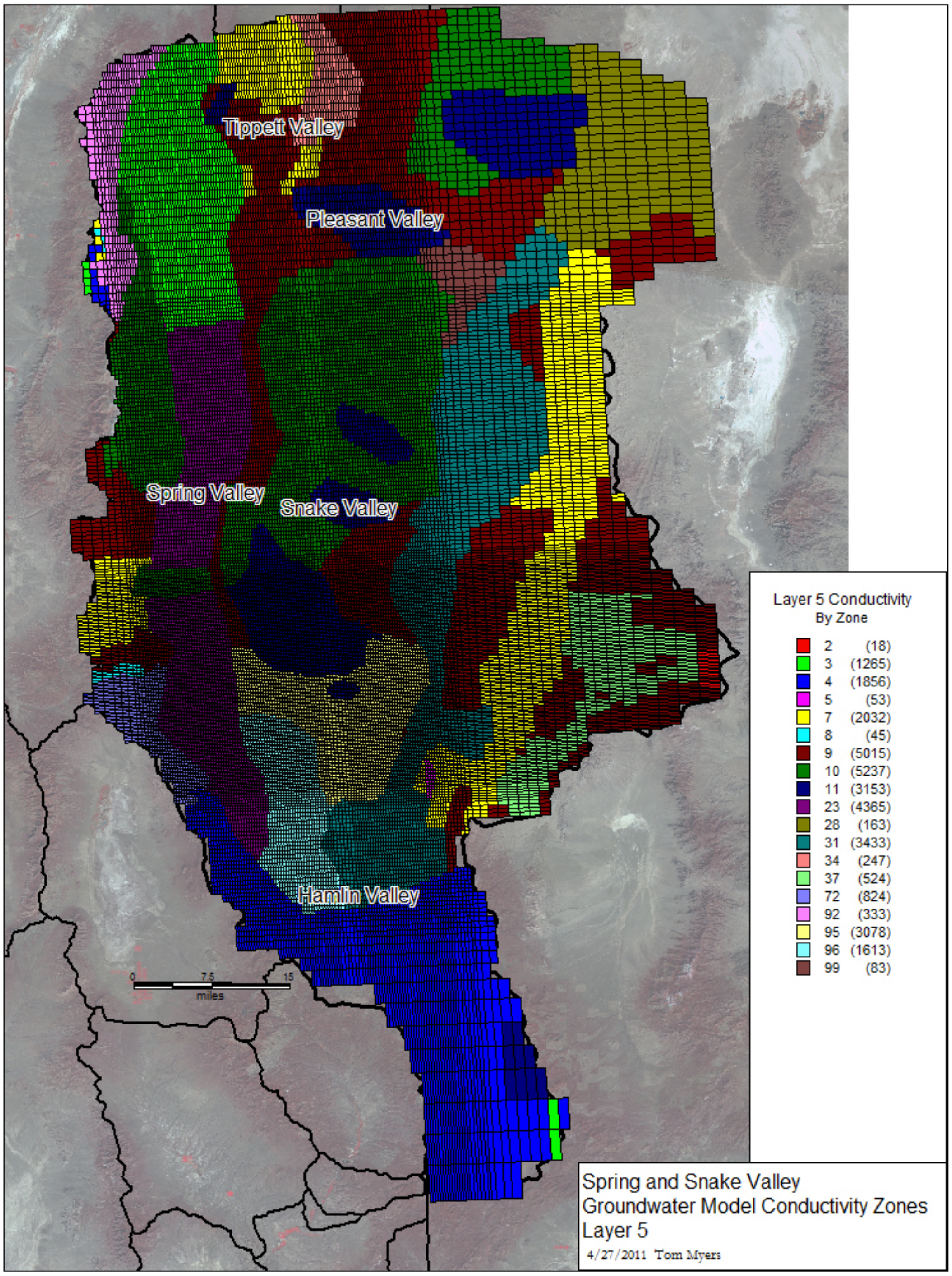

Figure 7: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 5.

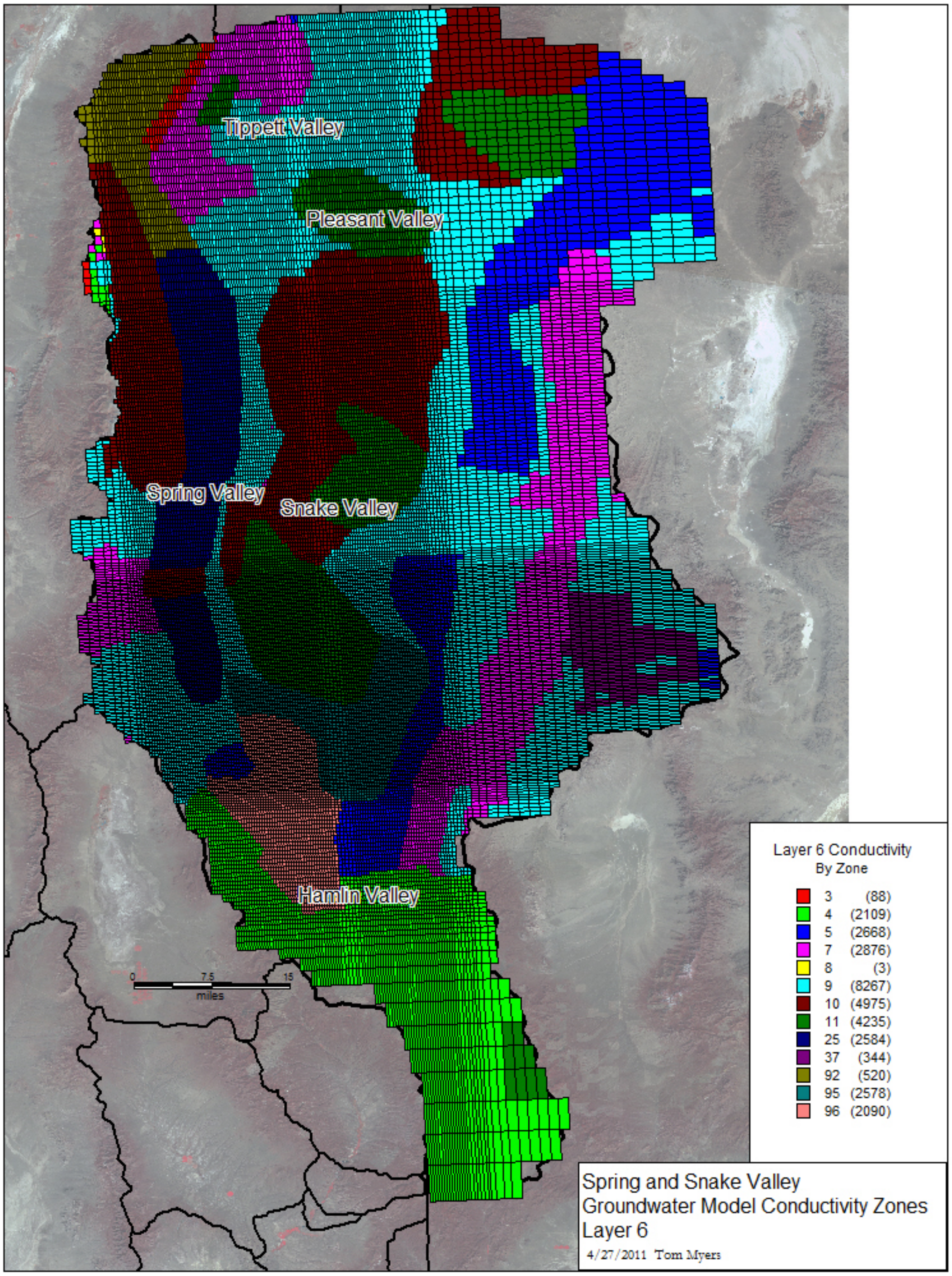

Figure 8: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 6.

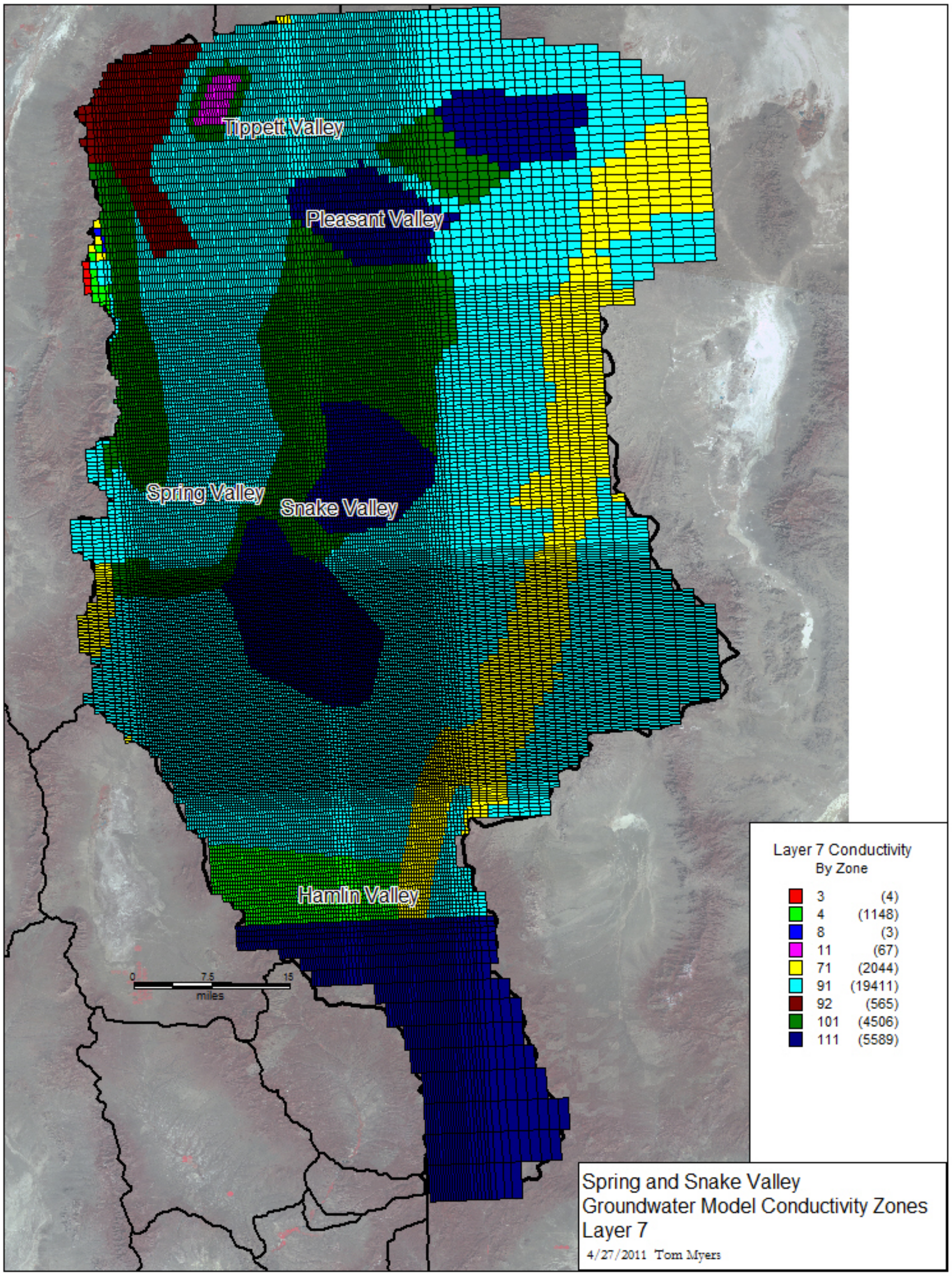

Figure 9: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 7.

Model Boundaries

Recharge

Recharge is a specified flux boundary in the model simulated with zones. It is the driving input for the groundwater model. Part A described the estimated basinwide recharge for each valley, which are used for model targets, and described the hydrogeology of mountain block and mountain front hydrology. Part A also described secondary recharge from several perennial streams.

The distribution of total recharge estimated for a basin depends on precipitation, geology and soils around the basin (Stone et al, 2001; Flint and Flint, 2007; Flint et al, 2004). Distribution of the recharge among model cells was based on these principles. The actual in-place recharge depends on the amount of precipitation which passes the soil zone which depends on the infiltration capacity of the soil, the moisture holding capacity of the soil, the potential evapotranspiration (PET) and the underlying geology. Meteoric water that exceeds the sum of those four things runs off and may become recharge further downhill or at the mountainfront. PET is the upper limit to ET that would occur if water was not limiting; because summer is the period with the most evaporative capacity and much precipitation occurs in winter, much of the PET goes unsatisfied. Only in areas with deep soils that hold lots of moisture would ET be close to the PET. Much of the recharge and runoff occurs in the spring when water is most available and heating is low.

I distributed the estimated basinwide recharge (Part A) around the basins based on precipitation and geology. First, I obtained PRISM (Daly et al, 1994; http://www.prism.oregonstate.edu/docs/overview.html#reference) annual precipitation estimates for the western United States and selected the contours for Spring and Snake Valley (Figure 10). Precipitation by model cell was determined based on polygons associated with these contours. I then determined Maxey-Eakin-like recharge efficiencies based on precipitation zones, with the highest efficiency being assumed to occur where potential evapotranspiration (PET) is lowest. I utilized efficiencies based on the recharge distribution determined by Flint and Flint (2007). In their distribution, the amount of recharge depend only on precipitation where the geology does not limit infiltration. The lowest PET, 1.3 ft/y, occurs at the highest elevations where precipitation is highest (Flint and Flint, 2007; Figure 10). In the valleys where there is no recharge the PET approaches 3.0 ft/y. Flint and Flint (2007) calculated that recharge equals about 1.0 ft/y on the high carbonate outcrops south of Wheeler Peak, and at other high elevation carbonate outcrops in the Schell Creek and Deep Creek Range, at points with approximately 2.5 feet or more of precipitation (Figure 10). The analogous recharge efficiency is therefore 0.4. Where precipitation is less than 8 in/y, there is essentially no recharge (Maxey and Eakin (1949) mostly due to high ET rates, and the recharge efficiency is 0. The recharge efficiency between 30 and 8 in/y where geology is not limiting may be described with a power function - $a(P-8)^b/P$ - with greater than 30 in/y having efficiency equal to 0.4.

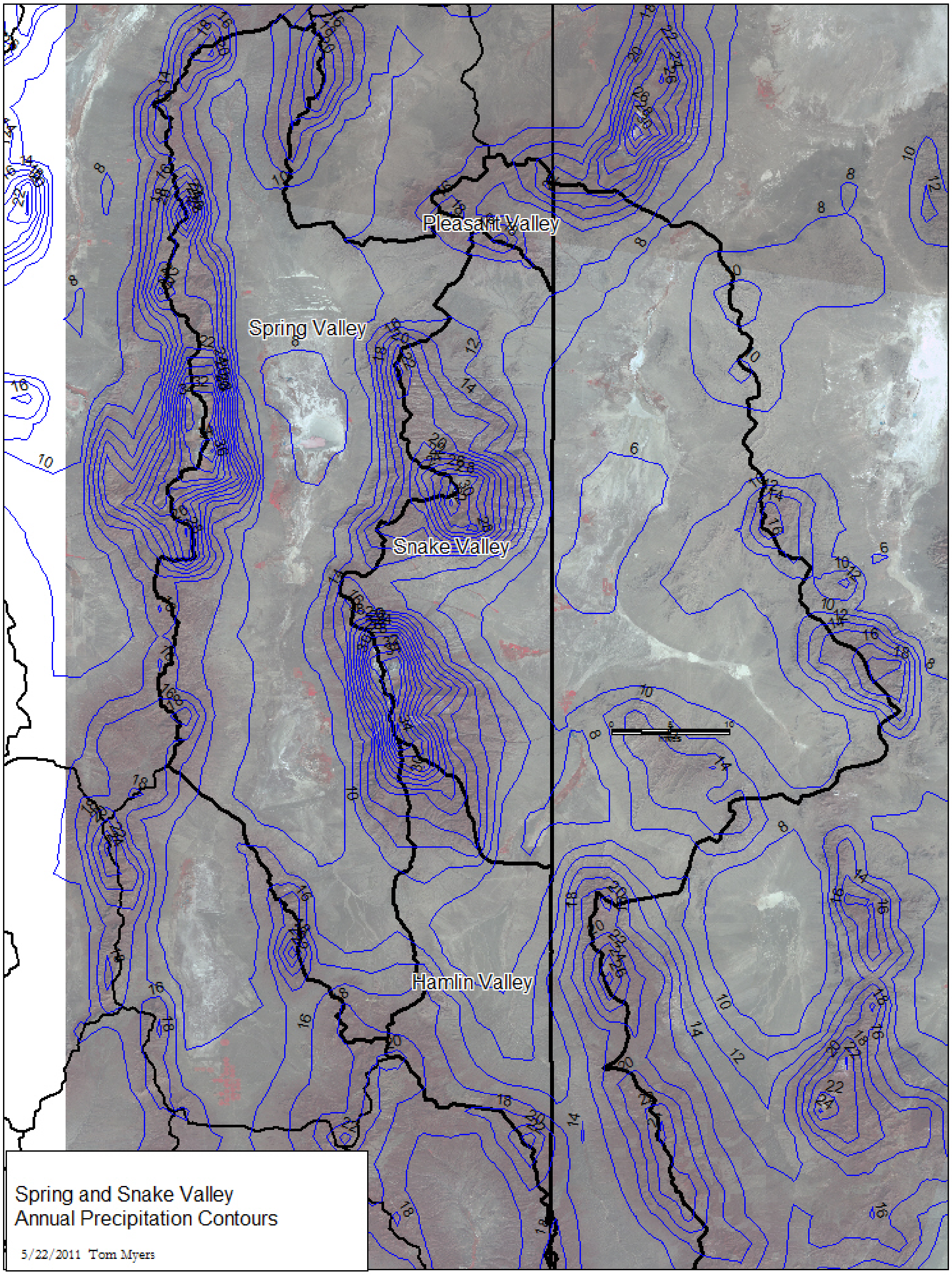

Figure 10: Annual precipitation for Spring and Snake Valley in 2 in/y contours.

The potential recharge was based on the recharge efficiencies just described. I adjusted this potential recharge for geology by multiplying by an assumed factor based on geology (Flint et al, 2004; Flint and Flint, 2007). The factor is 1.0 for upper or lower carbonate or coarse or fine-grained basin fill, 0.0 for intrusive rock, 0.1 for upper or lower siliciclastic rock, and 0.5 for volcanic tuff or fill. The difference between potential recharge (that without geology being limiting) and the actual recharge after having been adjusted for geology was considered runoff. Runoff may become recharge downgradient. The total runoff recharge was summed and applied evenly to cells containing CYSU (alluvium) with TOP elevation between 6000 and 6400 ft amsl. This elevation zone coincides consistently through the model domain with the alluvial fan subject to run-on. I assumed recharge would occur only in alluvium because rock outcrops on the valley floor would not be subject to run-on. This assumption is a reasonable simplification that does not account for the actual area above a cell that produces runoff. During calibration, runoff recharge was redistributed to areas primarily above observed discharge points. The total recharge estimated for each basin was adjusted so that the sum would equal the targeted rate by basin (Part A). The potential recharge was adjusted to maintain the targeted recharge volume by basin.

Estimated runoff recharge also does not include secondary recharge from the streams that were perennial emerging from the mountain front. The recharge of perennial stream baseflow is secondary because by definition groundwater discharge supports perennial stream baseflow. These streams result in additional recharge near their outlet from the mountains and explain why the model recharge below does not equal the recharge specified in Part A. Specifically these include Baker, Lehman, Snake, Strawberry, and Silver Creek in Snake Valley and Cleve Creek in Spring Valley. This recharge increases the total recharge by a few percent.

Percolation from other perennial streams below springs on the valley floor, such as Big Springs Creek, Lake Creek, or the streams below Millick Spring or Gandy Warm Springs, is secondary recharge. In the model, the discharge from the springs (DRAIN cells) is from recharge to the model. much of the ET that occurs downstream from those springs is groundwater discharge even though it is from these streams because the springs are a groundwater discharge (Halford and Plume, 2011). Some of the discharge from DRAIN (springs) is returned to the model with the drain return routine.

PRISM precipitation for the south half of Hamlin Valley is very high (Flint and Flint, 2007, Figure 4; Halford and Plume, 2011), with many cells having precipitation from 13 to 17 in/y which resulted in very high recharge rates over a large area (Figure 10). This caused Hamlin Valley to have over 80,000 af/y recharge, which is more than 80% of the target recharge for all of Snake Valley – an unrealistic amount. I removed runoff recharge in the south end of Hamlin Valley from the model; prior to this adjustment, total recharge south of model row 247 equaled 34,500 af/y. After the adjustment, the final recharge for this zone was 9660 af/y, which is very close to the BARCAS estimate. Flint and Flint (2007) had predicted very high runoff in Snake Valley subbasin 5, but there is little evidence of this runoff in the field.

Figure 11 shows the final recharge distribution around the model domain.

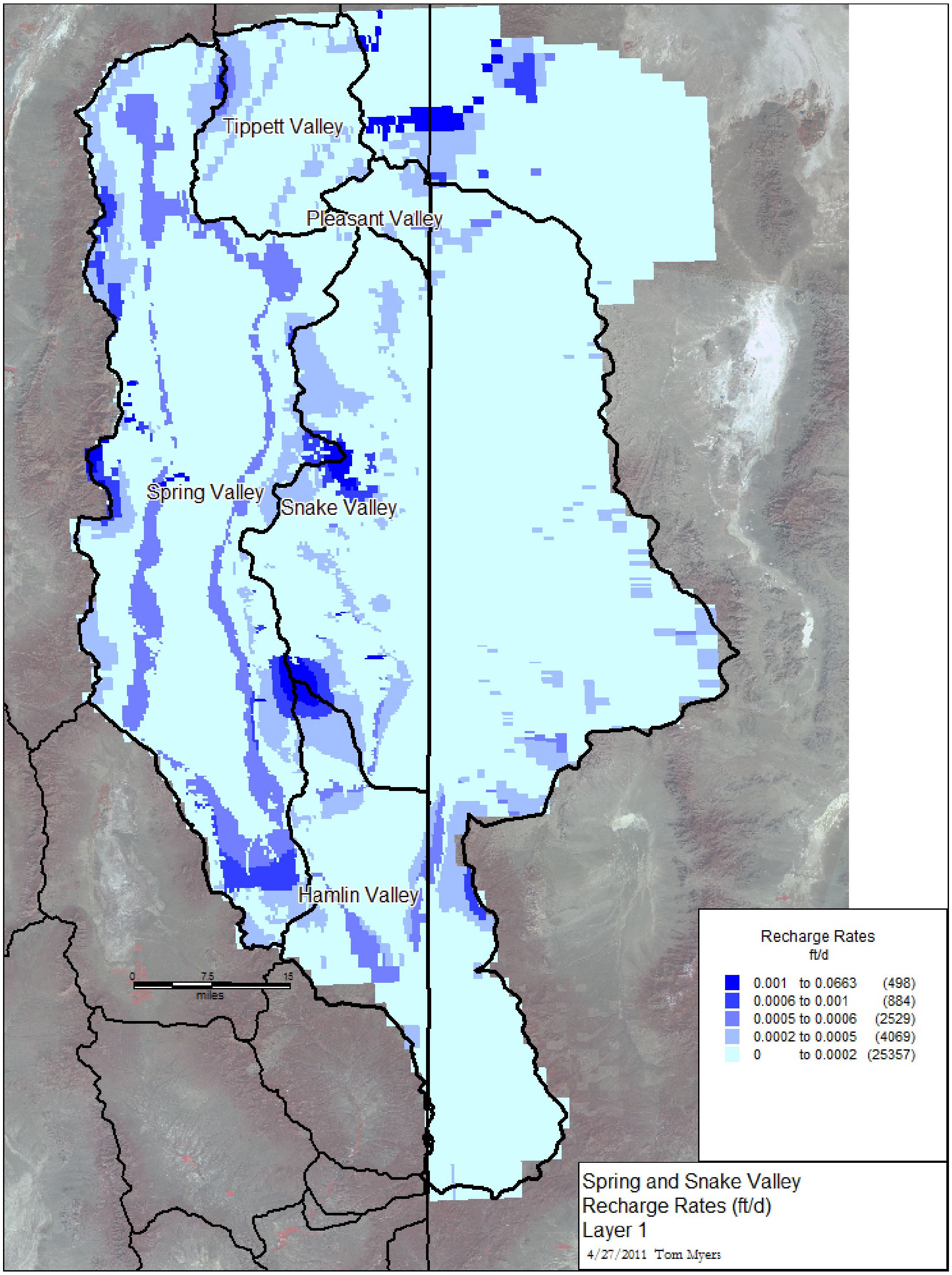

Figure 11: Recharge rates for the Spring and Snake Valley Groundwater Model, layer 1.

Groundwater Discharge

Groundwater discharges through both springs and directly through phreatophytic ET, but the difference can be difficult to discern (Part A, Halford and Plume, 2011). This is because water discharging from springs supports phreatophytes just as groundwater directly transpiring without having gone through a spring. Halford and Plume (2011) decreased GWET downstream from Big Springs assuming that spring flow in Big Springs Creek and Lake Creek would support that discharge.

The two primary valleys differ in this regard. In Spring Valley, there are literally hundreds of springs along the edge of the playa, as may be seen on any USGS topographic map. During a site visit on April 1, 2011, I observed seeps all along the east side of the Spring Valley playa south of Hwy 50 and along the west side of the playa north of Cleve Creek; both playas had ponded water. This water is a mixture of direct runoff and spring discharge – surface and groundwater. Evaporation of this water would partially be evaporation of groundwater that had discharged from the springs. During dry periods when there is no ponded water, evaporation continues through the ground surface, in a process of exfiltration.

In Snake Valley, there are fewer but more prominent springs, including Big Springs, Spring Creek spring, Rowland Springs, Gandy Warm Springs, and Twin Springs. These all discharge into a channel or pond where the water flows as surface water. They support primarily riparian phreatophyte transpiration, although some of this water becomes secondary recharge. This secondary recharge from Lehman Creek and Gandy Warm Springs supports groundwater seeps near Baker and springs and marshlands in the Gandy Salt Marsh area, respectively.

The groundwater model utilized two types of boundaries for simulating this discharge – the DRAIN and ET boundaries. Both are head-controlled flux boundaries with thresholds beyond which they cease discharging. Because of the difficulty in distinguishing spring discharge from simple ET discharge, the targeted discharge rates were usually for a sum of the two. ET was directly modeled in each valley with areas and rates based on Moreo et al (2007) (Table 3 and Figure 12) with fine-tuning based on aerial photographs and site visits. More wet meadow was simulated between Big Springs and Prues Lake (Figure 13). As was the case in BARCAS (Moreo et al, 2007), riparian areas currently being irrigated were modeled according to their pre-irrigation vegetation type.

In Spring Valley, both playas have drain and ET boundaries (Figure 12 and 14). The drain boundaries also controlled the water level on the edge of the playas and simulate the seeps which are apparent on the playa edges. Specifically modeled springs along the edge of the playa included Millick, Keegan, and Cleve Creek springs (Figure 14). Swallow and Swallow Canyon springs were also included in the modeling due to their flow rate and carbonate sourcing.

In Snake Valley, Big Springs, Spring Creek, Rowland, Gandy Warm, and Caine, were directly modeled with DRAIN boundaries. The first four springs in that list had 50% of their discharge returned to the aquifer using the drain return routine. Table 4 lists the springs along with other boundaries specifying their reach number and targeted flow rates.

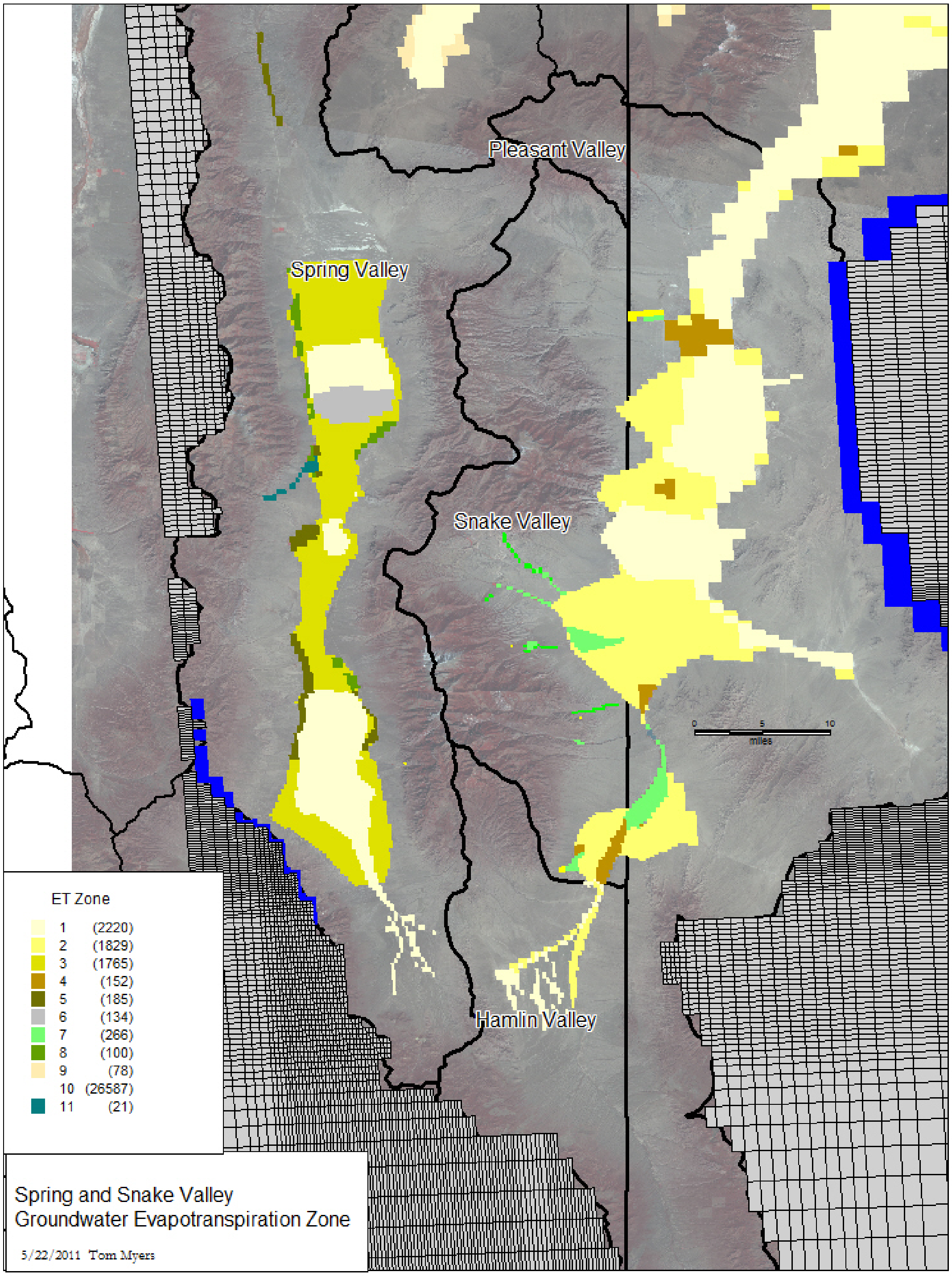

Figure 12: ET zones for the Spring and Snake Valley Groundwater Model, layer 1.

Figure 13: Aerial photo from google earth (4/25/2011) showing Big Springs area to Prues Lake. The total distance from Big Springs, located in the green on the southwest portion of the phreatophyte area, to the lake at the top is 15.4 miles.

Table 3: Evapotranspiration rates from the BARCAS study (Moreo et al, 2007) and as adjusted during calibration.

			ET Rates (ft/d)		
Model ET Zone	Type	Valleys	BARCAS	Calibrated	Extinction Depth (ft)
1	Playas	All	0.00197	0.00073	30
2	Sparse shrub	Snake	0.00236	0.00236	50
3	Sparse shrub	Spring	0.00258	0.00040	50
4	Moderate shrub	Snake	0.00288	0.00288	50
5	Moderate shrub	Spring, Tippett	0.00201	0.00301	50
6	Moist bare soil	Spring	0.00548	0.00548	20
7	Avg of marsh and meadowland		0.00908	0.00908	20
8	Avg of marsh and meadowland		0.00933	0.00738	20
9	Sparse shrub	Tippett	0.00271	0.00271	50
11	Riparian marshland	Spring	0.01123	0.01140	20

Table 4 : Head-controlled Flux Boundaries to and from the Spring/Snake Valley Groundwater Model. Targets are shown where used.

			Targeted Flows		
	Boundary Type	Reach #	Inflow (af/y)	Outflow (af/y)	Outflow ft3/d
Steptoe In	GHB	32	4000		
Lake Valley	GHB	31	29,000		
Outflow	GHB	21-25		29,000	
Tippett/Deep Creek Valley	GHB	12			
Rowland Springs	Drain	14			172000
Big Springs	Drain	13			443000
Stateline Spring	Drain	19			
Gandy Warm Springs	Drain	16			693000
Spring Creek	Drain	11			86000
Caine Spring	Drain	17			100
Keegan Spring	Drain	3			100
Millick Springs	Drain	1			75000

Cleve Creek Spring	Drain	4			1100000
Swallow Springs	Drain	30			110000
East Side Spring Valley	Drain	2			
Lehman Crk	River	13	5800		950400
Baker Crk	River	14			
Snake Crk	River	15			
Strawberry Crk	River	12			43200
Silver Creek	River	11			

Basinwide GWET estimates discussed in Part A are not considered calibration targets in part because those estimates depend on the BARCAS recharge estimates. However, the general trend of significantly more GWET in Snake Valley is expected and qualitatively considered during calibration, discussed below.

Interbasin Flow Boundaries

Interbasin flow to or from the model domain is simulated using general head boundaries (GHB), which are also head-controlled flux boundaries. The flux through the boundary depends on the gradient from the boundary into the model domain and the conductance. Both head and conductance are adjusted during calibration, although the head values were constrained by prior estimates of head in the adjoining valleys (Welch et al, 2008, Plates 2 and 3). Conductance was adjusted to calibrate the flux so that it was similar to values observed in BARCAS.

The model domain has potential inflow and outflow through four primary boundaries. The only inflow could be from Steptoe to Spring Valley, partly by way of Lake Valley. The BARCAS estimate was 4000 af/y from Steptoe to Spring and 29,000 af/y from Lake to Spring Valley. This flow was simulated with GHB reaches 31 and 32. The primary outflow from domain is the flow to the Great Salt Lake (GSL) Desert and to Fish Springs Flat; the BARCAS outflow is 29,000 af/y. This flow was simulated with GHB reaches 22 through 25. There is also outflow north from Tippett and Deep Creek Valley to the north, at a rate approximately 12,000 af/y, simulated as GHB reach 12. Figure 14 shows these boundaries.

The outflow reach 22 to GSL through the basin fill is designed to reflect the artesian pressure observed historically in the area, especially near Callao as reported by local residents and shown on USGS 1:100000 scale maps as flowing wells. The specified head increased from 4250 in layer 1 to 4270 in layer 4. Reaches 23 through 25 represent the Fish Springs Range, which actually lies about four miles east of the grid cells in column 28 (Figure 14) and south into the Confusion Range. It has variable steady state head values, starting at 4250 ft msl in the north and increasing to 4800 ft msl in the south. The conductance varies according to calibrated values targeting the head in surrounding valleys.

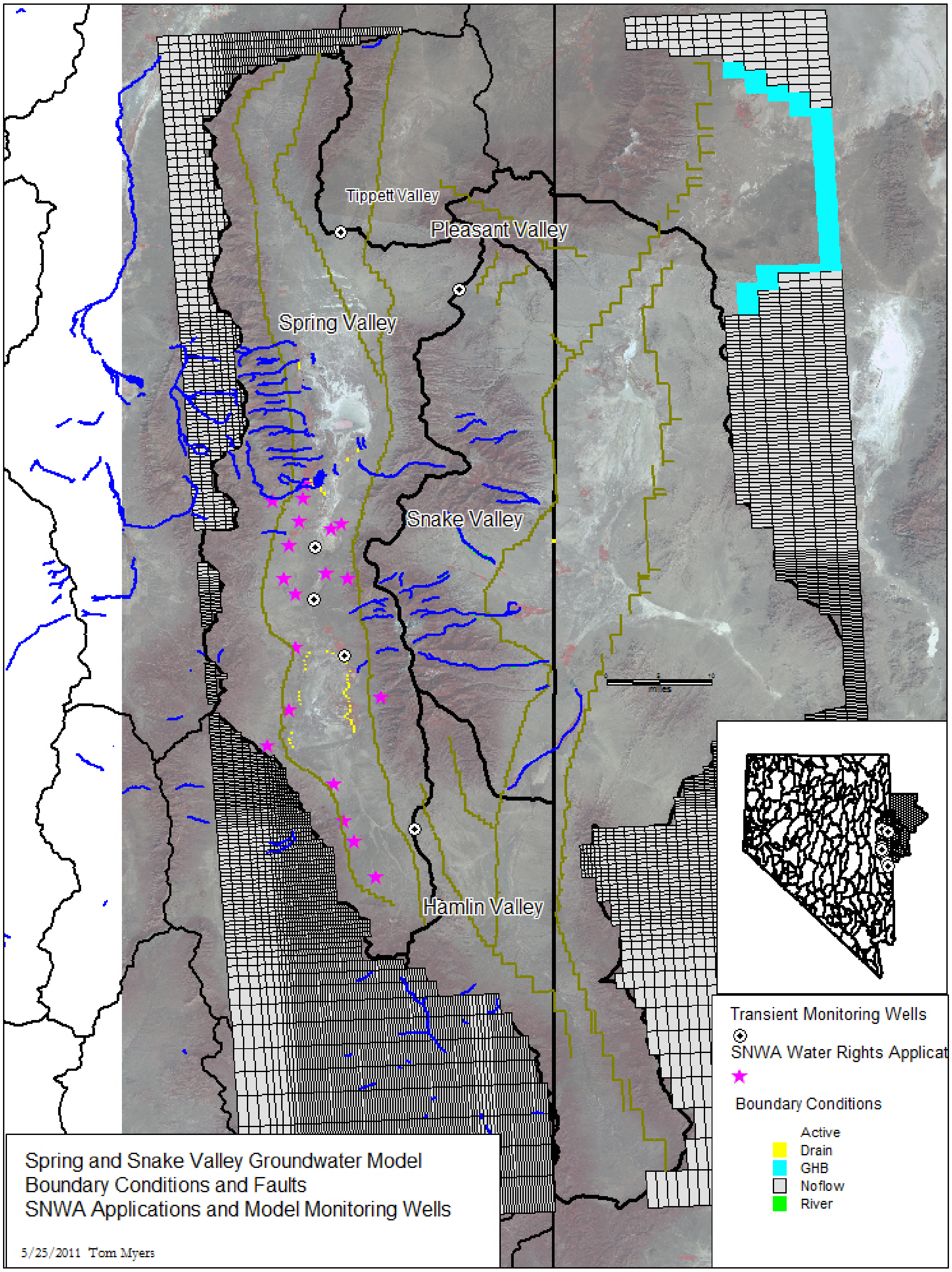

Figure 14: MODFLOW boundaries used in the Snake Spring Valley model. See Table 4 for model layers that apply to each boundary. The olive-brown line represents location of modeled faults in layer 4.

Steady State Calibration

Calibration required several steps. The initial calibration was completed by trial and error, just adjusting the starting parameters and zone boundaries to test and improve the conceptual model. The sensitivity of individual conductivity and ET zones were tested with the idea of selecting the values which led to the minimum SSR. This involved using an internal utility of GWVistas to alter the parameter values by a user-specified multiplier. Automated parameter estimation was completed for the sensitive parameters with PEST (Doherty, 2004).

Calibration Targets

There are two types of targets used for calibration. These are heads and fluxes as described in Part A. The head values recorded in wells throughout the study area and the measured baseflow or loss from springs and streams and the estimated interbasin flows were included.

Flux targets were also used, although not in automated calibration. The calibration goal was to accurately match the heads while the water balance for the model domain and specific reaches (springs, streams, and interbasin flow) approximated the estimates from Part A. By approximated, the goal was to match the magnitude; more accuracy is not justified because the measurements are usually too infrequent to be certain of the amount of flow that is groundwater discharge and because interbasin flows are broad estimates.

Some wells were removed from the calibration because during calibration it became obvious they were completed in perched aquifers, not part of the system being simulated. Specifically, these were wells less than 80 feet deep, so they were in layer 1, located in areas where layer 1 was dry. These wells would only be neglected if their target elevation was more than 100 feet different from target elevations in wells in layers 2 or higher. Care was taken in eliminating a well because a dry cell may represent a bad conceptualization. Only if the observed water level was far higher than water levels at nearby deeper wells were the wells discarded, and the conceptualization that caused the cell to be dry accepted.

Appendix A lists the wells, their target elevation, and their final residual. Figure 15 maps the targets. The final water balance is discussed separately.

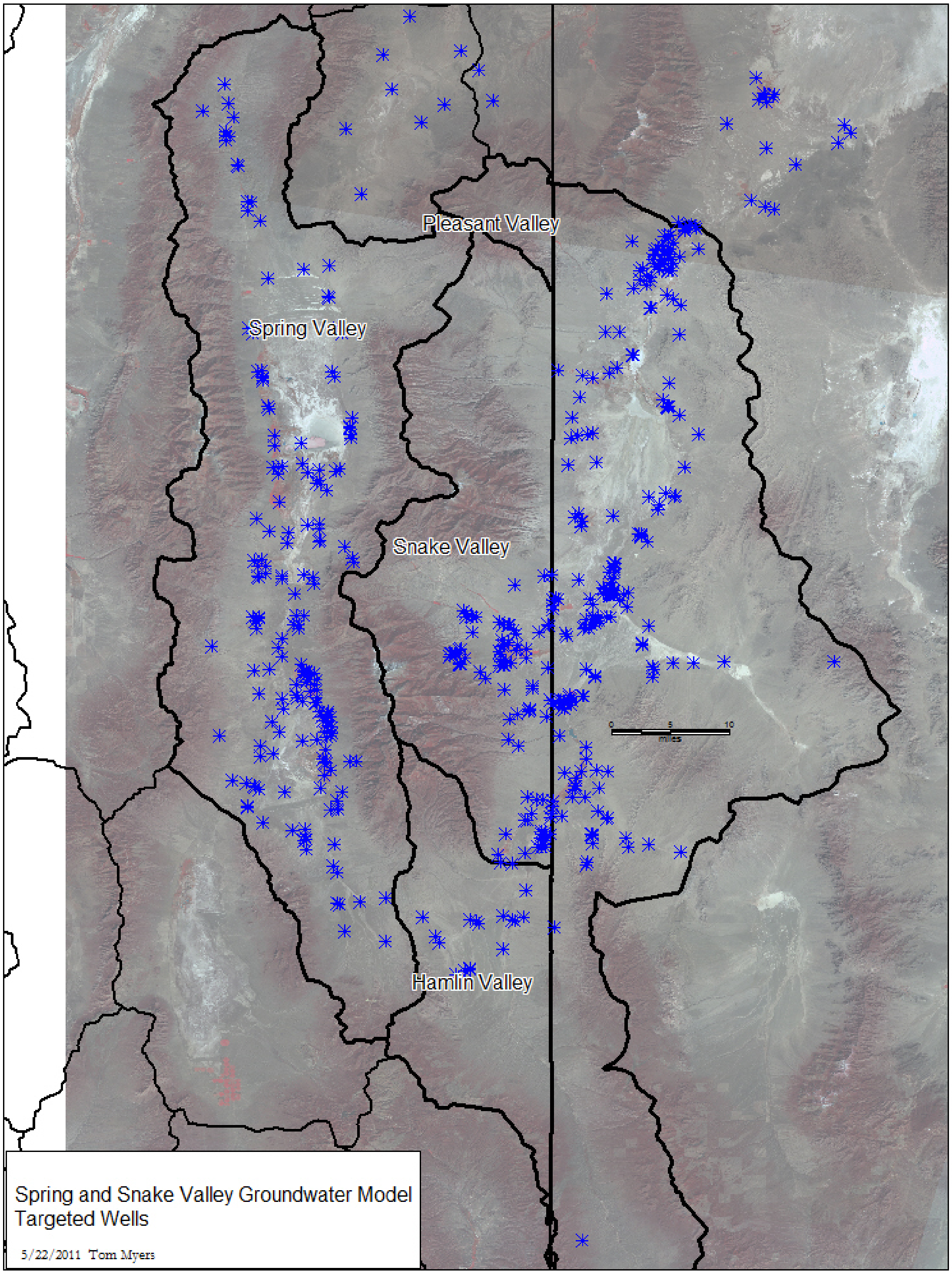

Figure 15: Locations of wells used for steady state calibration.

Changes to the Conceptual Model

During the initial trail-and-error calibration, I made numerous changes to the conceptual model. The most obvious conceptual model change is that I amended the conductivity for most zones and subdivided some zones so that instead of 11 there were 45 zones (Table 2). Immediately obvious was that conductivity for LSCU was much too low because water levels above layers with this material were thousands of feet too high. Also immediately obvious was the fact that the VFU conductivity was much too high because it outcrops in northern Spring Valley, and was conceptualized to consist of much of layer 3 in that region, where its lower conductivity causes the higher water levels observed in wells in that area (layer 2).

The far north end of Spring Valley differs from the southern four-fifths of the valley in several ways that affect the model calibration; these differences required changes to the numerical model conceptualization. The valley slopes steeply to the south, dropping five hundred or more feet in just a few miles. The central drainage which has many springs conceptualized to be regional is in a significant drainage channel. The depth of the channel is near the thickness of layer 1, so the layer is barely saturated (in the numerical model) near the springs in that channel. The parameter values were set lower for both the carbonate rock on the west side of the valley (zone 92) and the valley fill (zone 26). These changes forced the water level in the fill, layers 1 through 3, to match the observed water levels.

However, the water levels in the fill in northern Spring Valley are also much higher than the water levels and ground surface in Tippett Valley to the east. The difference results in a gradient for flow to Tippett Valley at an interbasin flow rate commensurate to expected values, but there is no groundwater divide or rise due to recharge in the Antelope Range.

Gandy Warm Springs was a challenge to model because it discharges more water than the near-uphill watershed would seemingly produce as recharge. Carbonate outcrops just north of the springs and the higher EC and temperature indicate a carbonate source with a substantial flowpath to reach the springs. Two water sources are apparent – interbasin flow from Spring Valley and recharge into the carbonate outcrops on the north end of the North Snake Range. Most of the springs east of the Gandy Warm Springs discharge from basin fill and are apparently sourced by secondary recharge from Gandy Warm Springs; this means that the two sources to Gandy Warm Springs are not needed for water to reach these salt marsh springs. The modeling therefore requires that flow from these two sources reach the Gandy Warm Springs, simulated as a DRAIN in layer 4. This was done using the range-front fault just east of the springs, assuming a fault runs northwest north of the springs, assuming a north-south anisotropy of 100:1 in the carbonate north of North Snake Range, and a small section of highly conductive carbonate in layers 3 and 4 west of the spring which effectively gathers flow to the spring (Dettinger et al, 1995). Sensitivity analyses of this conductivity zone found that the chosen conductivity resulted in both the maximum discharge rate and minimum SSR. Water for the marshes east of the warm springs is returned to the domain with the drain return routine with water discharged back into layer 1 east of the springs.

Big Springs is another example of a large spring with seemingly too little near-uphill watershed to support the springs. In this case, however, the gradient in the carbonate rock draining from the south end of the Snake Range and interbasin flow from Spring Valley sufficed, along with the range-front fault, to cause flow from the spring. Half of the water discharging from the spring was returned to layer 1 northeast of the spring in Big Springs Creek; a DRAIN for Stateline Spring in layer 1 was added because this spring provides much of the water to the marshland area along Big Springs and Lake Creek, into Pruess Lake.

Swallow Springs in Spring Valley discharges water that had recharged into carbonate rock in Swallow Canyon and along the front range of the west side of the Snake Range. Its' orifice point is on the top of the alluvial fan, west of the carbonate outcrops and far above the valley floor. The DRAIN for this spring was actually simulated to be to the east, near the carbonate outcropping. Because the stream percolates into the fan as it flows westward toward the playa, half of the DRAIN discharge was returned through the drain return routine.

There are many shallow wells at the edge of the valleys and the toe of the fans. During calibration they often were in dry cells, but right at the edge of saturation. This suggests the conceptual flow model at this point is not adequately defined due to the coarseness in the model.

Parameter Estimation Routine

After utilizing trial and error calibration and sensitivity analysis for individual parameters to minimize the sum of the squared residuals (SSR), I utilized the parameter estimation package, PEST (Doherty, 2004) to adjust hydraulic conductivity parameters automatically and jointly, to find a global minimum in the objective function. The objective function was the SSR. The final sensitivity for a set of horizontal conductivity parameters shows only about an order of magnitude variation (Figure 16). This figure however shows only the most sensitive, because the inclusion of other parameters caused the parameter estimate to yield unreasonable values. As Doherty (2004) emphasizes, the modeler must interpret the results and attempt to estimate only parameters that vary within reasonable means and do cause unexpected results on the conceptual model or other unincluded-in-PEST aspects of the model. Vertical conductivity was not considered because of instability in the estimated parameters.

Parameters with the highest sensitivity include zone 9, the LCU unit and zone 35. Kh35 covers the fill in southern Snake Valley controls the water level near many wells. Zone 9 is the higher layer carbonate rock with very high conductivity. Other carbonate zones were chosen wherever lower K was obviously required, as may be seen with conductivity values in zones 90 through 98 being less than zone 9. Three of the other carbonate zone parameters (91, 95, and 96) have relatively high parameter sensitivity. Zones 3 and 10, representing volcanic flow and clastic rocks, also have relatively high sensitivity because of the important role that these two formations play in controlling flow, mostly as a barrier, around the model domain.

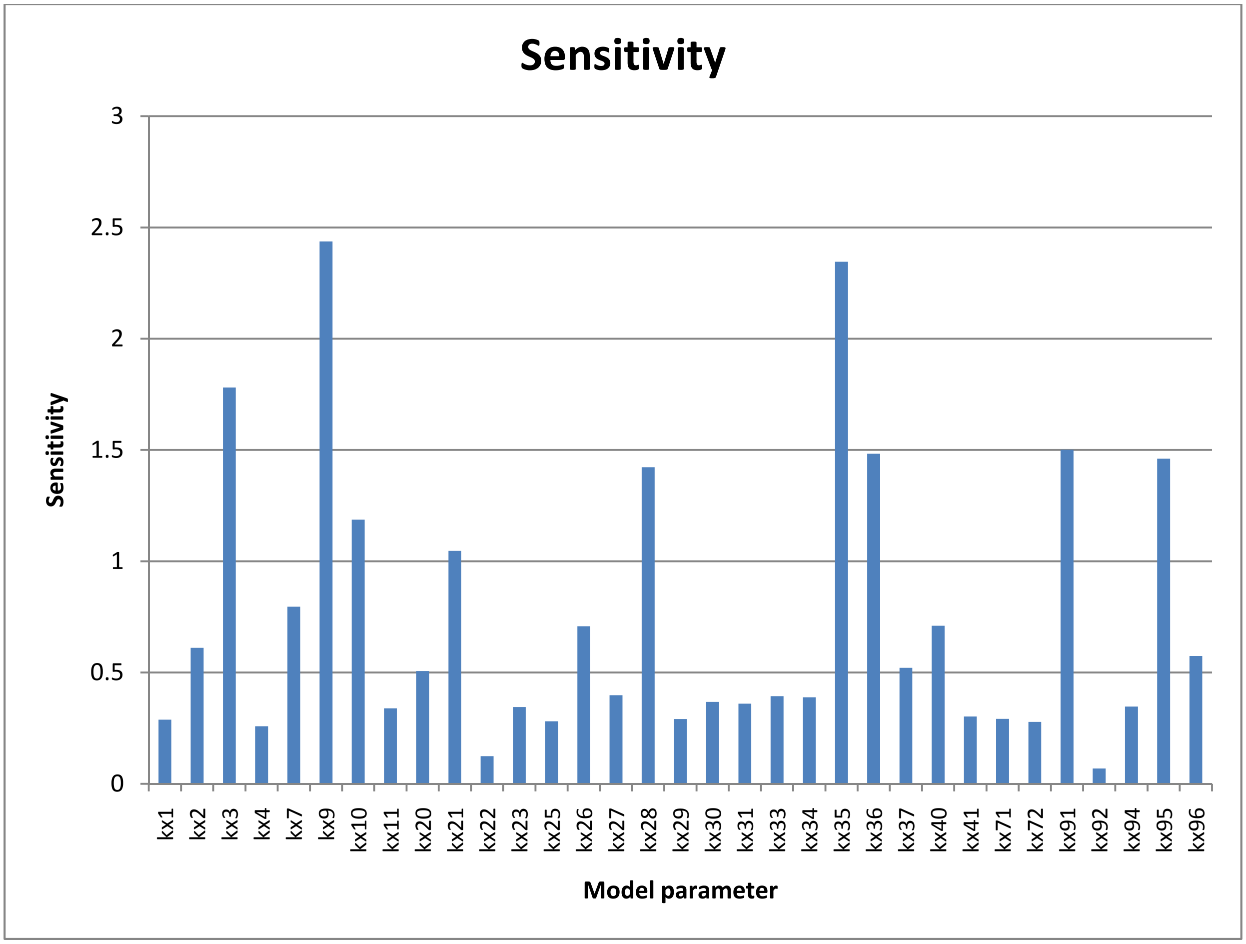

Figure 16: Sensitivity of Spring/Snake model parameters.

Steady State Calibration Statistics

Table 5 presents the final calibration test statistics for residuals over the entire data set and by layer through layer 4. The scaled mean and standard deviation, just 0.017 and 0.025, indicate a very good fit. Only 25% of the residuals have absolute value exceeding 50 feet. The observed and simulated heads plot along a straight line, without more scatter obvious at any point on the line (Figure 17); there is no significant difference from the 1:1 slope in any of the layers. The residuals do not show a trend with observed head, although in layers 1 and 2 there is a slight tendency toward more negative residuals and in layers 3 and 4 the trend is toward more positive residuals (Figure 18).

Table 5: Residual goodness of fit statistic, by layer and for the entire model.

	Layer 1	Layer 2	Layer 3	Layer 4	All
Mean	-1.36	6.70	-4.26	1.07	1.01
Standard Error	3.03	3.97	7.18	11.12	2.45
Median	2.34	5.52	-5.84	-6.25	1.98
Standard Deviation	42.64	57.13	71.10	80.95	57.99
Sample Variance	1818.42	3263.57	5055.45	6553.04	3362.70
Skewness	-1.18	0.35	-0.11	2.36	0.51
Minimum	-190.6	-145.6	-253.0	-166.6	-253.0
Maximum	84.9	205.7	240.5	406.7	406.7
Count	198	207	98	53	561
Confidence (95.0%)	6.0	7.8	14.3	22.3	4.8

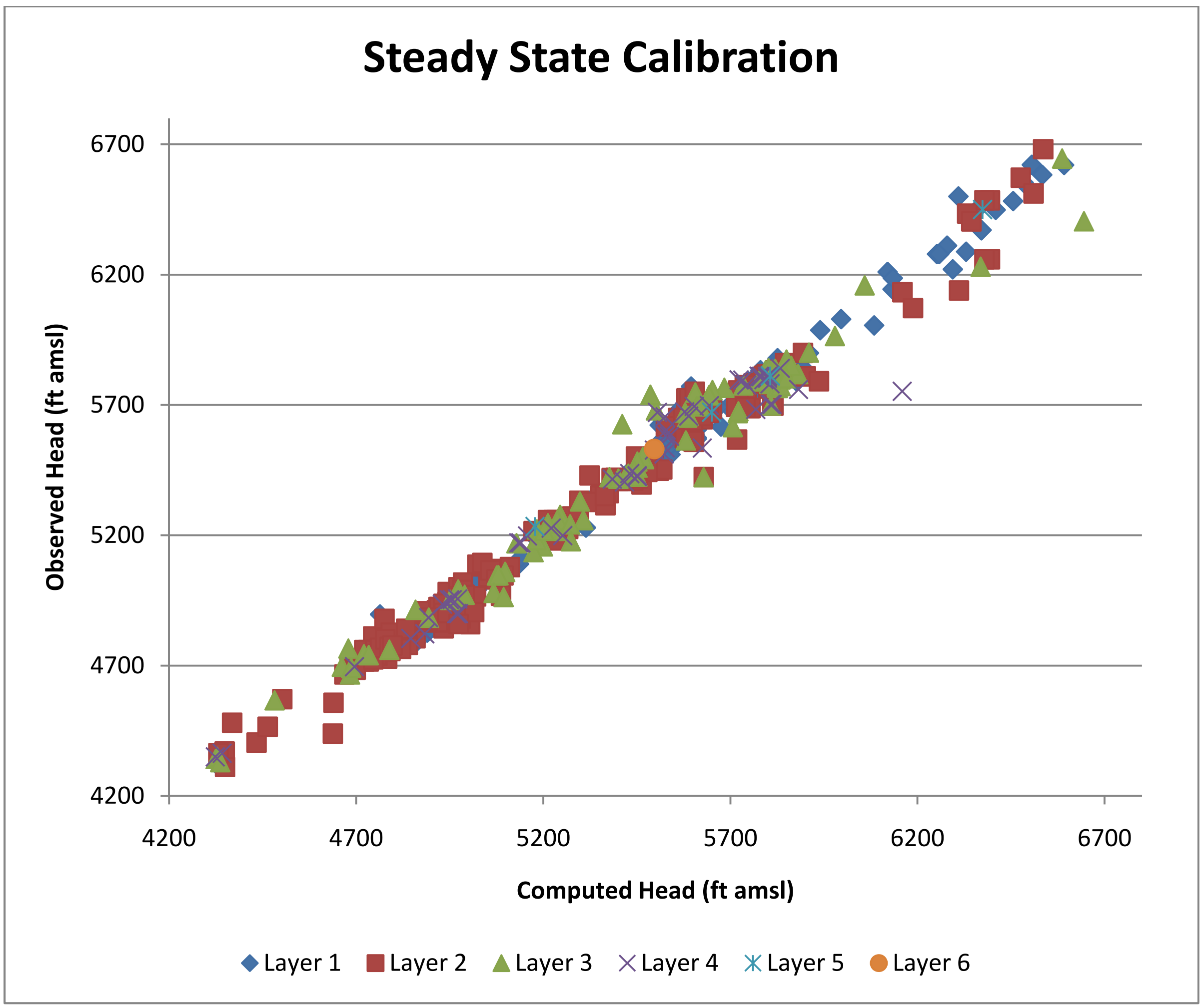

Figure 17: Scatter plot of observed to computed water levels at target well by model layer. The trend line for layers 1 through 4 were Y=1.026x-139, Y=1.06x-38.9, Y=0.976x +134, Y=0.971x+157.

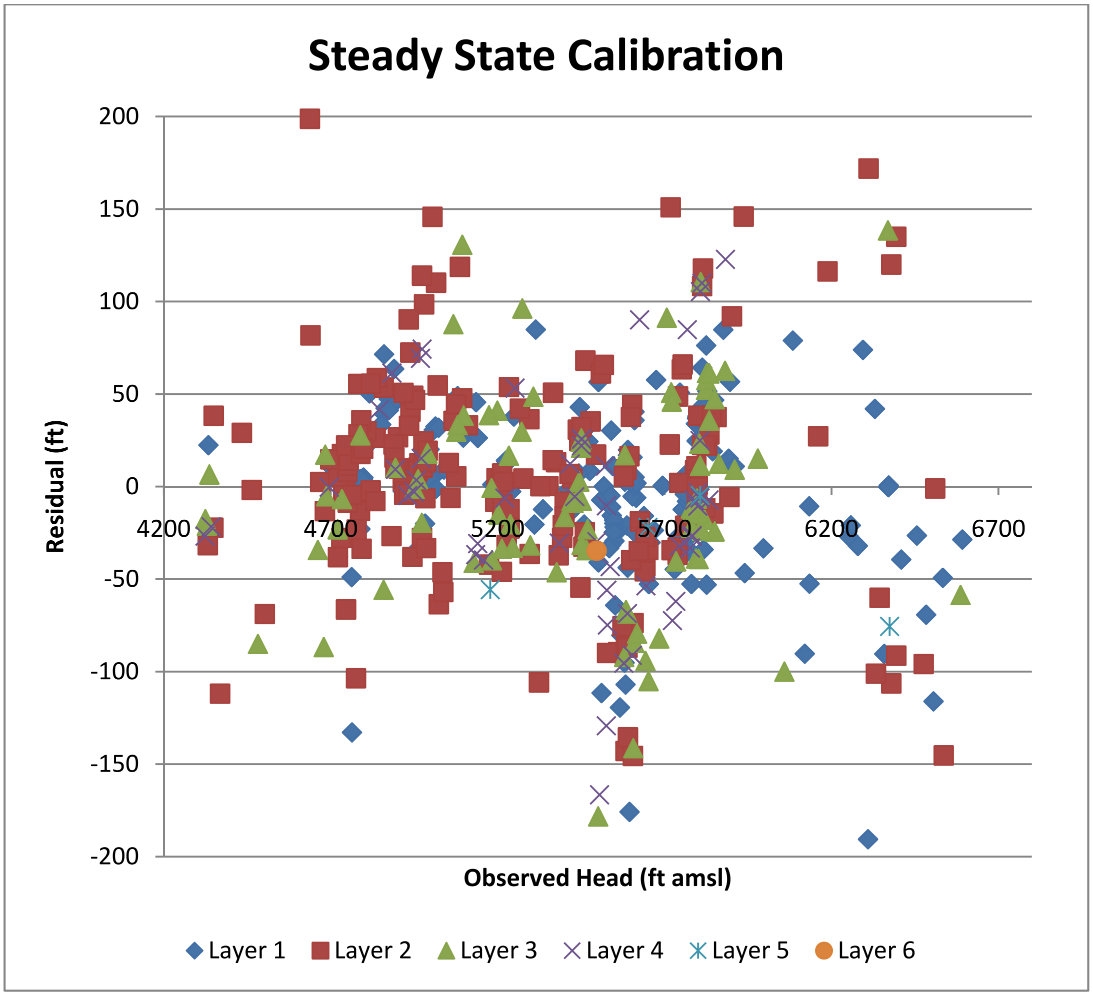

Figure 18: Scatter plot of residual and computed water level by layer. The trend for layers 1 through 4 is Y=-0.026x+139, Y=-0.0061x+38.9, Y=0.024x - 134, Y=0.029x-157

No obvious spatial trends appear in the residuals (Figure 19), other than a few areas with clusters of a few positive or negative residuals.

The steady state contours show a low point in the middle of Spring Valley (Figure 19) which corresponds with a playa and several springs; the area is an obvious groundwater ET discharge zone. A low groundwater divide between two 5800 ft contours is present in the south end of Spring Valley; the interbasin flow through the Limestone Hills area emanates from recharge in that area. At depth the divide does not exist. The contours also suggest a path for water to flow from northern Spring to Tippet Valley. The pathway continues through Pleasant Valley at a very flat gradient to northern Snake Valley. The Snake Valley water table slopes consistently toward the northeast.

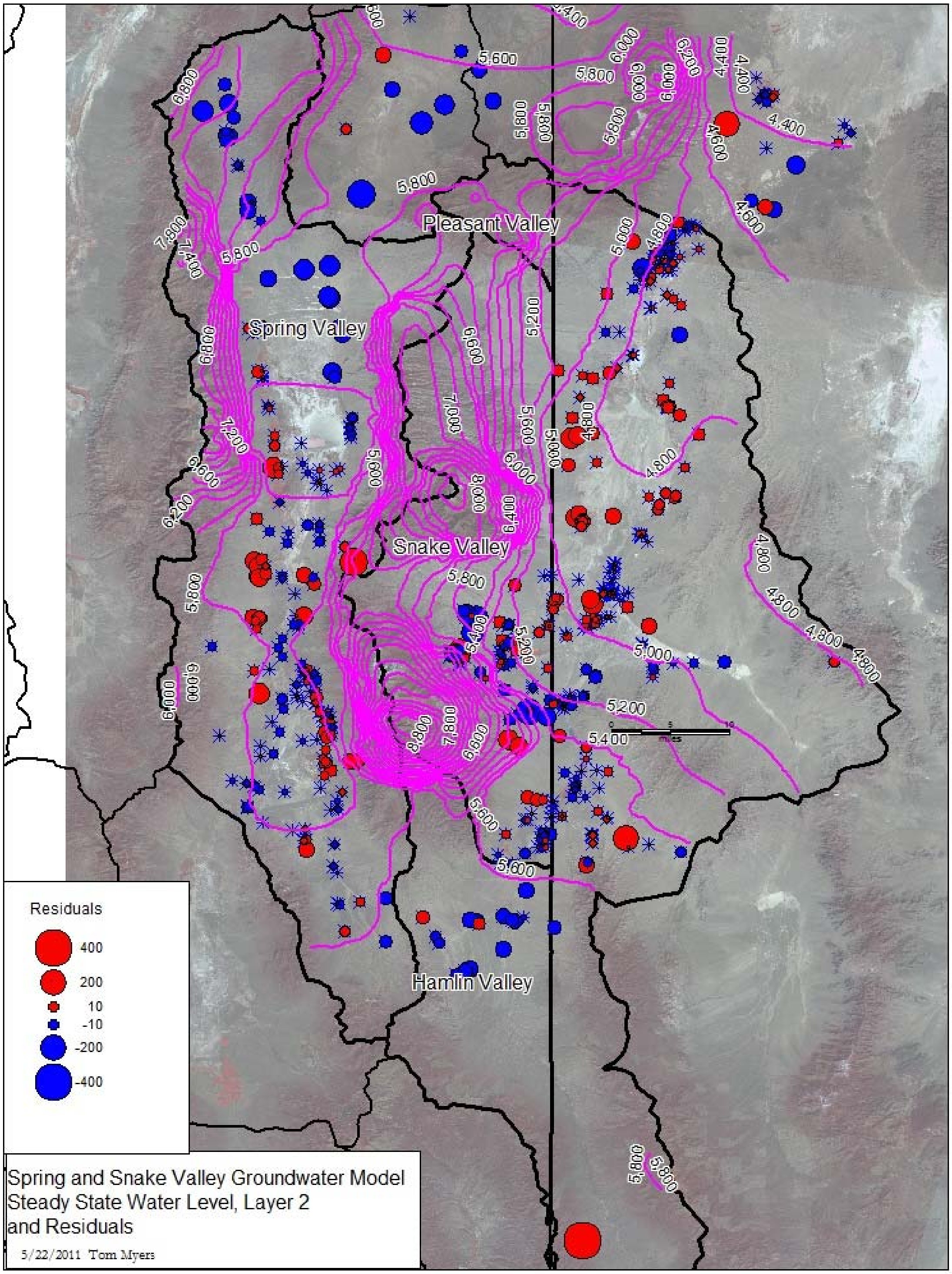

Figure 19: Snake and Spring Valley Groundwater Model, steady state groundwater level contours, layer 2, and magnitude of residuals by well.

The final steady state model has internal fluxes that correspond with the distribution of recharge and ET zones in the model, as affected by the geologic parameters. Of special interest are Spring Valley proper, Tippet Valley, and north Hamlin Valley. Recharge to Spring Valley is about 80,500 af/y (Table 6), including secondary recharge, and total discharge is about 76,000 af/y, so the interbasin flows from Spring Valley depend primarily on flows from Steptoe and Lake Valley. Interbasin flow to Snake and Hamlin Valley is about 19,800 af/y. Interbasin flow is actually a loss of 1230 af/y from Tippet Valley, although there is significant flow to Deep Creek Valley. North Hamlin Valley received almost 18,000 af/y from the west, Spring Valley. Inflow to N Hamlin from the south is from the south end of Hamlin Valley.

Table 6: Water balance fluxes for select regions of the model domain, including Spring Valley, Tippett Valley7, and the north end of Hamlin Valley. The water balance was determined by digitizing basin boundaries with GWVistas.

Spring Valley	
	Net (af/y)
West	192.8
East to Snake, Hamlin, and Tippet Valley	-19788.8
North	-1945.5
South	1631.5
Recharge	80581.6
ET	-56043.8
Spring Flow	-19966.1
Interbasin Flow (GHB 31 and 32)	15337.7
Tippett Valley	
West	9522.2
East to Deep Creek Valley	-4593.5
North	-8853.9
South	2630.4
Recharge	8964.8
ET	-7064.0
Interbasin Flow	-606.0
N Hamlin Valley	
West	17991.8
East	-6966.7
North	-30183.0
South	6065.8
Recharge	17630.7
ET	-4538.6

It is also useful to compare the targeted flux for various springs and streams and other flux boundaries with the simulated values (Table 7). Simulated and targeted interbasin flows, such as outflow to the GSL and inflow from Steptoe and Lake Valley, match well. The flow from Lake and Steptoe Valley was from BARCAS (Welch et al, 2008) and only treated as a guideline. A few springs have large residuals, but they are misleading. The most difficult springs to simulate are Gandy Warm and Rowland Springs. The residual at Gandy Warm Springs is misleading because there is substantial ET near the spring. The boundary for Rowland Spring is very near Lehman and Baker Creek so that overall the fluxes are accurate. At Big Springs, there is also substantial ET nearby and discharge from nearby Stateline Springs. Cleve Creek Springs is simulated at about half the targeted value, but because the target was based on a water right rather than measurements, the residual is acceptable. Swallow Springs, Millick Springs, and Strawberry Creek are simulated very accurately.

Table 7: Discharge at select boundaries.

			Targeted Flows				
	Boundary Type	Reach #	Inflow (af/y)	Outflow (af/y)	Discharge ft^3/d	simulated (ft^3/d)	Simulated (af/y)
Steptoe In	GHB	32	4000			274737	2302.09
Lake Valley	GHB	31	29,000			1555697	13035.57
Outflow	GHB	21-25		29,000		-3408603	-28561.5
Tippett/Deep Creek Valley	GHB	12				-1755385	-14708.8
Rowland Springs	Drain	14			172000	-11841	-99.2206
Big Springs	Drain	13			443000	-181984	-1524.89
Stateline Spring	Drain	19				-147775	
Gandy Warm Springs	Drain	16			693000	-14915	-124.977
Spring Creek	Drain	11			86000	-20154	-168.872
Caine Spring	Drain	17			100	-2543	-21.3097
Keegan Spring	Drain	3			100	0	0
Millick Springs	Drain	1			75000	-96007	-804.464
Cleve Creek Spring	Drain	4			1100000	-425668	-3566.78
Swallow Springs	Drain	30			110000	-94628	-792.91
East Side Spring Valley	Drain	2				-1858744	-15574.9
Lehman Crk	River	13	5800		950400	33652	281.9783
Baker Crk	River	14				34373	288.0228
Snake Crk	River	15				-9802	-82.1311
Strawberry Crk	River	12			43200	43213	362.0965
Silver Creek	River	11				268452	2249.429

Sensitivity of Model to Parameter Zones

The sensitivity of the model to each horizontal and vertical conductivity zone was tested by altering each zone by multiplying by 0.5, 0.7, 0.9, 1.0, 1.1, 1.3, and 1.6, running the model to solution and recording the SSR for each simulation. The SSR will vary more if the model is sensitive to the tested parameter.

The model was sensitive to about fifteen horizontal conductivity zones, defined as those for which the SSR varied by more than a few percent over the range of parameter multipliers (Figure 20). The relations suggest that increasing some of the Kh value could even marginally improve the calibration, with SSR dropping another 0.5% for parameter increases of up to 50%. There are two reasons these changes were not implemented. The most important is that when attempted, several of the springs would go dry – especially Gandy Warm Springs. The second is that increasing some of the parameters would cause their values to be higher than the conceptual model would really allow; in other words the increases would have extended the values beyond their expected range.

The model most sensitive to parameters representing basin fill – zones 2 and 20-35 (Figure 20). This reflects the large number of wells that were completed in the fill zones. The model is less sensitive to most of the carbonate parameter zones in the 90s because they represent small areas of the model. Zone 95 is an exception to the small area rule, being the primary carbonate zone in the south Snake Range. The implication is the model fit could be improved slightly by making the K even smaller, but this would have increased water levels in the mountain to unreasonable heights because there are no target wells in that area the high water level does not negatively affect the SSR.

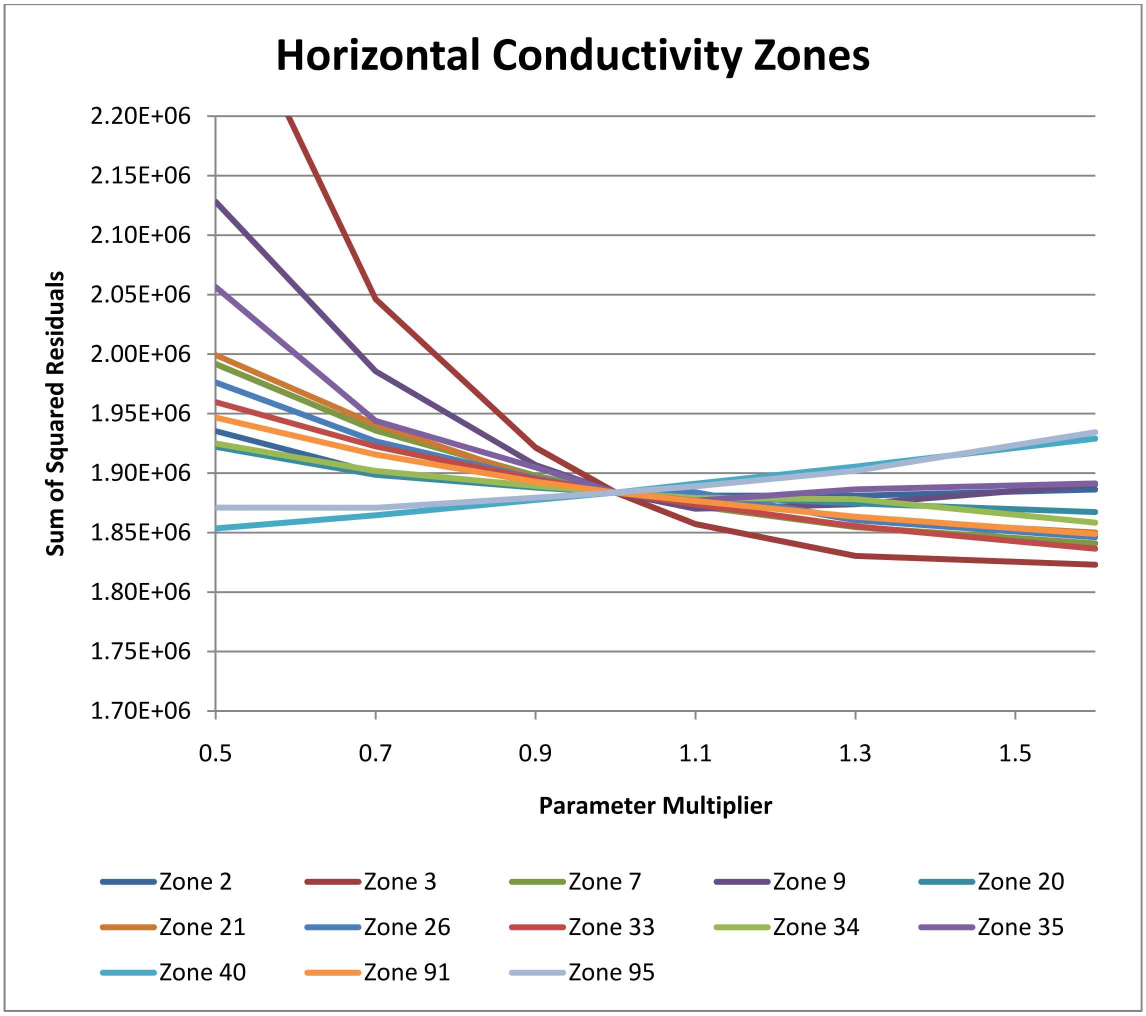

Figure 20: Sensitivity of the calibrated groundwater model to selected horizontal conductivity zones.

The model was less sensitive to vertical conductivity in general, as can be observed in the much small range of the most sensitive parameters (Figure 21). The model was sensitive to just one fill zone, number 2, which reflects that the groundwater flow in those zones is mostly horizontal. The model is sensitive to three carbonate zones, 91, 92, and 94, due to their roll in controlling the vertical movement of recharge through the bedrock.

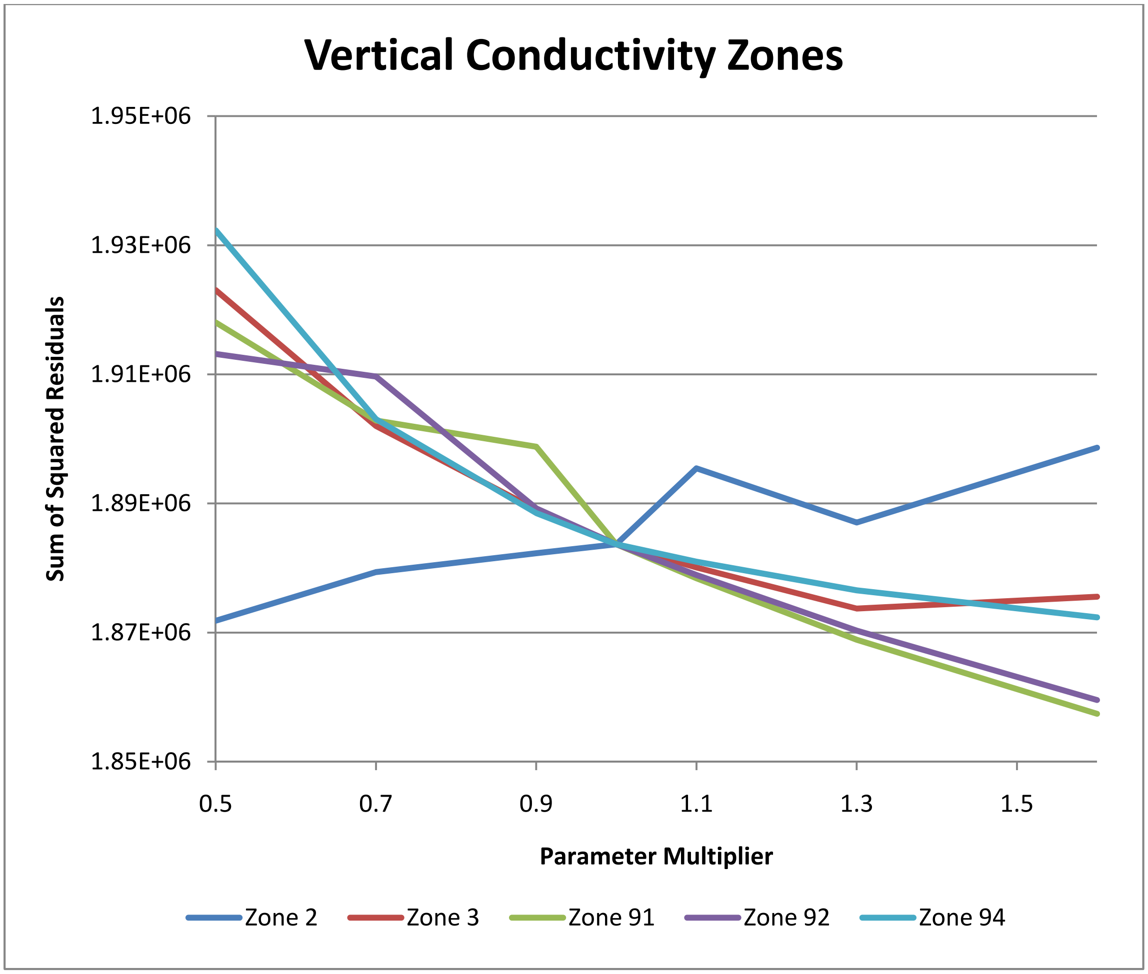

Figure 21: Sensitivity of the calibrated groundwater model to selected vertical conductivity zones

No-Fault Simulation

Faults were utilized around the model domain, according to the Spring/Snake Valley conceptual model (Figure 14). To test the overall impact and sensitivity of the faults, after all calibration was complete, all faults were removed to test their overall impacts. The final SSR had been 1.88×10^{-6} and scaled root mean squared error is 0.025. Removing the faults increased the SSR to 2.7×10^{-6} and the SRME to 0.03. Faults are important for controlling the discharges as well. With faults, discharge from Big Springs and Gandy Warm Springs is 1524 and 125af/y, respectively. Without faults it is 2002 and 0, respectively. Gandy Warm Springs goes dry without faults.

Transient Calibration

Transient calibration is used to set the storage parameters so that the model responds to stress correctly (Anderson and Woessner, 1992). The storage parameters, specific yield for unconfined aquifers and specific storage (L^{-1}) for confined aquifers when using MODFLOW-2000, establish how much the water level or potentiometric surface changes due to the removal or injection of an amount of water. Transient calibration involves setting the storage parameters so that simulated water level hydrographs match observed hydrographs.

Two current stresses cause water level and discharge changes within Snake and Spring Valleys: seasonal changes, which affect recharge and GWET, and pumping, primarily for irrigation. Neither stress approaches the magnitude of stress expected to be caused by SNWA because the proposed applications exceed the amount currently pumped from Spring Valley (Welborn and Moreo, 2007) by four times. Also, data concerning the existing stresses is sparse and subject to much interpretation because there are no direct measurements. The water level hydrographs presented in Part A had seasonal variations and some trends and ostensibly could be used for transient calibration if seasonal recharge or ET could be estimated. Estimates of pumping rates, however, are coarse both spatially and temporally (Halford and Plume, 2011; Welch et al, 2008) because they are limited to estimates based on irrigated acreage. Both recharge and GWET rates are annual estimates although the amounts obviously vary over the year.

Specific yield for the basin fill reasonably could range from 0.05 to 0.25 (Anderson and Woessner, 1992). Clay layers complicate the estimate and interpretation because clay lenses may prevent the release of groundwater or increase its flow paths; both effects would alter the results of pump tests. This would not be relevant on long-term temporal scales, thus the use of short-term pump test data for long-term models may yield inaccurate results. For Spring Valley, Myers (2006) used 0.10 for the basin fill. Hood and Rush (1965) assumed the specific yield for the upper 100 feet of the Snake Valley aquifer was also at least 0.10 based on their estimate that for 1,200,000 acres 12,000,000 af of water could be removed from the top 100 feet. SNWA (2009 and 2010) used 0.18 for upper valley fill. Halford and Plume (2011) used 0.15, but noted that studies indicate a range of 0.12 to 0.18. Clearly, there has been no consensus from previous studies.

The specific yield of fractured rock is lower because it primarily is the release of water from secondary porosity – the bulk media might simply not even drain. The value is likely to be highly variable at a small scale, but at the scale of a model cell is probably more constant. SNWA (2009 and 2010) used 0.05 for upper and lower carbonate and 0.01 for all other unconfined bedrock aquifers. Halford and Plume (2011) used 0.02 but suggested the range could be 0.01 to 0.04. Anderson and Woessner (1992) suggest a much higher range, with estimates as high as 0.36 for limestone and 0.47 for tuff.

For this model, the initial, for transient calibration, specific yield values for testing are 0.15 and 0.01 for fill and bedrock specific yield, respectively. These apply mostly to layer 1 because it is unconfined. It could also apply to layer 2 where layer 1 is dry. However, the model treated this layer as confined, which makes no difference for steady state simulations, but which causes the model to use a constant transmissivity and to use a specific storage value when specific yield would be necessary. This can be accommodated by using specific storage in layer 2 that reflects a blend of specific yield and specific storage. The specific storage in the layer-2 mountain-zone bedrock was set equal to 100 times the specific storage for completely confined layers.

Specific storage values for carbonate, clastic, volcanic, and intrusive rock, zones are also more complicated because storage depends on the location, size, density and interconnection of fractures. As described by Belcher et al (2001), there are two sources of water draining from the bedrock – the fractures and the bulk matrix. Groundwater drains quickly from the fractures and much more slowly from the bulk matrix. This dual sourcing of groundwater drainage complicates the interpretation of pump tests for determining storativity and the modeling of groundwater being released from storage. Water is most available from the primary fracture system, but if the system is extensive only a small drawdown may result in large amounts of water being released. In most systems, the matrix storativity is ultimately more important because it represents a much larger volume, as indicated by the database of hydraulic test data completed by Belcher et al (2001). Many matrix storativity values are an order of magnitude higher than the fracture storativity values, and the overall storativity is the same as the matrix value.

Literature estimates of storage for the carbonate layers can vary over several orders of magnitude. SNWA (2009 and 2010) used 2.4×10^{-5} and 6.1×10^{-8} ft^{-1} for upper valley fill and all other materials, respectively. Schaeffer and Harrill (1995) used a dimensionless storage coefficient equal to $6x10^{-4}$, because they modeled using the original version of MODFLOW. Converting to specific storage based on an average 5000-foot-thick aquifer, the specific storage for carbonate aquifers is 1.2×10^{-7} ft^{-1}. This is at the low end of the range, 4.6×10^{-9} to 0.019 ft^{-1}, reported by Faunt et al (2004) in their study of the carbonate aquifer in the Death Valley flow system (DVFS). Belcher et al (2001, page 19) indicated that storativity equaled 0.003, which when converted to specific storage using the average screen length of 81 m, yields $1.1x10^{-5}$ ft^{-1}. McDonald Morrissey Associates (1998) used $3x10^{-6}$ ft^{-1} for carbonate aquifers in the Carlin Trend and assumed that water levels would not be sensitive to the value. Myers (2006) used $3x10^{-5}$ ft^{-1} because he assumed that because SNWA will screen its wells in fracture zones where the effective storage would be much greater. Based on the difference between matrix and fracture storativity discussed above, this may have overestimated the storage coefficient for Spring Valley. Halford and Plume (2011) used 2×10^{-6} ft^{-1} for all bedrock in Spring and Snake Valleys.

To complete a transient calibration, it was necessary to find some water level changes over time that reasonably correspond to known pumping. Drawdown has ranged to 30 feet in Snake Valley (Halford and Plume, 2011), although none of the well hydrographs presented in Part A show quite that much drawdown. They documented that 13,000 af/y is the average pumpage between 1945 and 2004 and during 2000, 2002, and 2005, they pumped 19,000 af/y. The estimated pumpage is based on average consumptive use of 2.5 ft/y, so the pumpage is a net value that accounts for return flow. Apparently they assume no surface water irrigation either, although Welborn and Moreo (2007) had included both sources in their estimate. Welch et al (2008) had estimated that wells and springs source 70% of the irrigation water. The amount of supplemental water rights in Spring Valley suggests the proportion is probably less in a wet year and much more, as much as 100% in some ranching operations, during dry years.

Transient calibration herein was completed by pumping 2.5 af/a/y from five different areas in Snake Valley for 40 years with a goal of simulating a drawdown of from 12 to 28 feet (0.3 to 0.7 ft/y) at the center of these areas (Figure 22). Pumping drew from layers 2 and 3, from 80 to 400 feet bgs according to well depth analysis completed in Part A. For testing, there were five parameter zones which could be adjusted to match the targeted drawdown. The initial specific yield in fill, carbonate, and other bedrock was 0.15, 0.03, and 0.01 ft^{-1}, respectively. Initial specific storage for fill was 0.00001 and for all bedrock was 2×10^{-6} ft^{-1}. Bedrock in layer 2 has specific storage equal to 2×10^{-4} ft^{-1}. This allowed a fine-tuning of the specific yield and specific storage for valley fill in Snake Valley; the calibrated values will be assumed applicable to Spring Valley. Zone 1 represented all fill. Zone 2 represented layer-2 bedrock. Zone 3 was non-carbonate rock. Zone 4 was carbonate rock. Zone 5 was set to represent zone1 in layer 2 to accommodate layer 2 being modeled as confined when it could be unconfined. Zone 7 was added to simulate hydraulic conductivity zone 30, a very low conductivity zone east of the Snake Range near Baker.

The final calibrated specific yield values were 0.15, 0.0002, 0.01, 0.02, 0.15, and 0.15 for zones 1, 2, 3, 4, 5, and 7 (fill, layer 2 bedrock, non-carb bedrock, carbonate, layer 2 fill, and near-Baker fill). The final specific storage is 0.0001, 0.0002, 0.000002, 0.000002, 0.001, and 0.001 for the same parameter values.

Because the pumping occurs all in fill, this calibration was not expected to be sensitive to the values in the bedrock. To verify this, sensitivity simulations with the storativity in the bedrock altered by an order of magnitude in each direction was completed.

Conclusion

The numerical groundwater model developed and documented in this report is an accurate implementation of the conceptual model developed in Part A. The model is adequately parameterized to simulate SNWA's proposed water rights' pumping from either Spring or Snake Valley. It will accurately estimate the effects of pumping SNWA proposed water rights applications from either valley, or estimate the effects of moving those applications around the valleys.

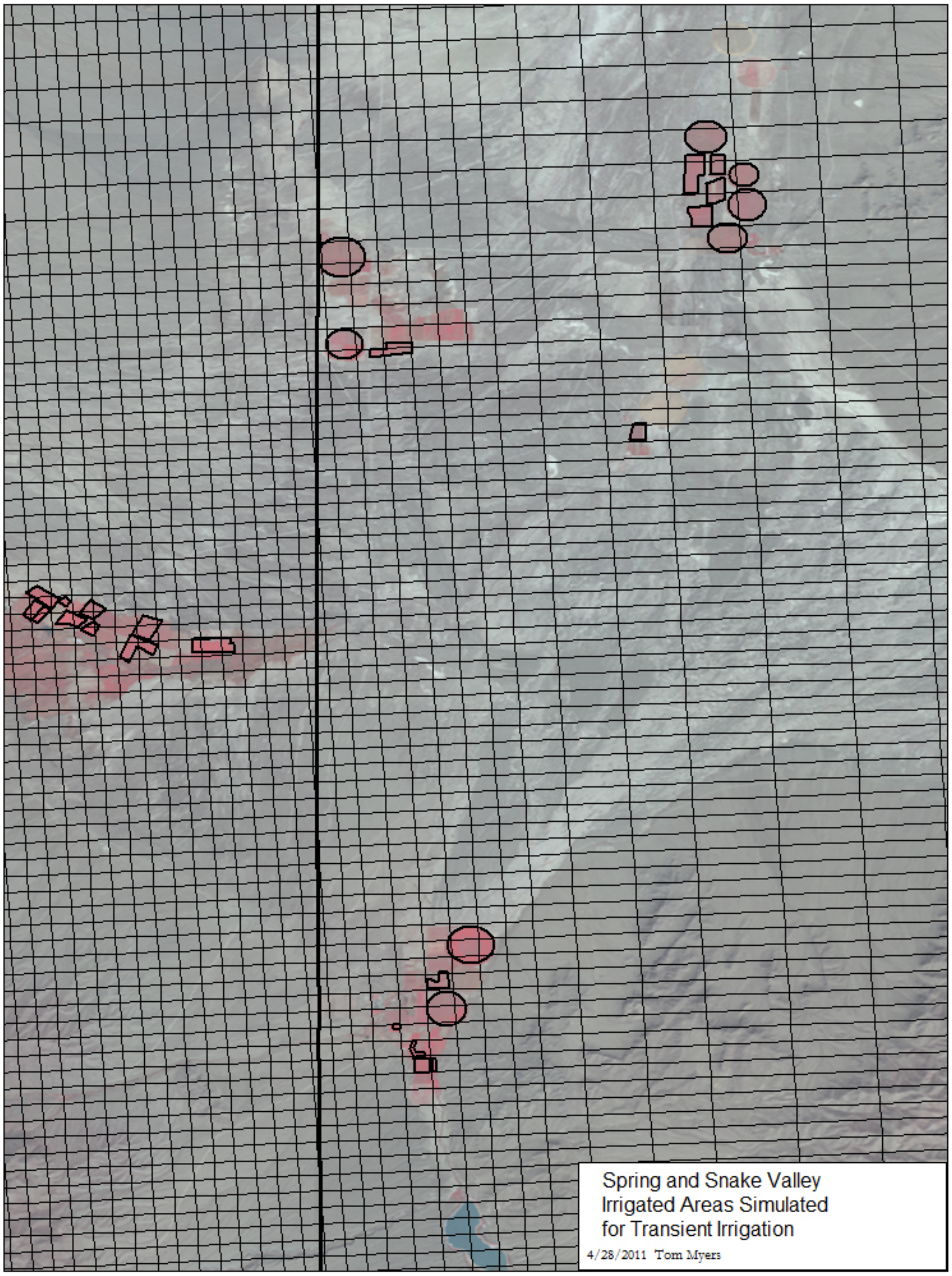

Figure 22: Irrigated areas near Baker in Snake Valley used for transient calibration. The lake at the bottom is Pruess Lake, the irrigated areas on the west side (left side) are east of Baker.

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Appendix A: Wells and Residuals

	Nevada State Eastern Zone					
Well Name: From Log # or Nevada or Utah Naming Convention, USGS Name, or spring name, or UGS name	X	Y	Model Layer	Obs. Water Level	Comp. Water Level	Residual
79	1078039	27648740	1	5570.6	5651.0	-80.4
1483	1091241	27818277	1	5097.0	5070.5	26.5
2335	1091378	27691598	1	5545.0	5533.9	11.1
2338	1081921	27706743	1	5459.0	5479.5	-20.5
3077	1082967	27769396	1	5613.0	5637.0	-24.0
4103	1056020	27823485	1	5604.0	5588.1	15.9
4337	1047261	27801167	1	6533.5	6582.8	-49.3
9391	1071326	27781136	1	5826.0	5879.0	-53.0
19237	1090473	27692500	1	5510.0	5517.3	-7.3
72740	1075347	27841935	1	5502.0	5445.5	56.5
74596	1091293	27698906	1	5472.0	5447.6	24.4
74597	1091404	27698860	1	5469.0	5447.6	21.4
103634	1082514	27687254	1	5502.0	5542.9	-40.9
103865	1086747	27814349	1	5135.4	5089.8	45.6
108852	1083105	27770168	1	5615.0	5621.0	-6.0
108854	1051215	27796294	1	6371.4	6370.8	0.6
108855	1051545	27795649	1	6370.5	6370.8	-0.3
108856	1051064	27795712	1	6370.5	6370.8	-0.3
(C-11-16)_6CC	1184992	28124311	1	4333.4	4311.0	22.4
(C-13-18)_14DDC	1147360	28046927	1	4705.5	4695.7	9.8
(C-13-18)_22Acc	1141020	28044130	1	4762.6	4811.5	-48.9
(C-13-18)_22CBB	1138024	28043230	1	4788.6	4811.5	-22.9
(C-13-18)_33BCD	1134396	28032678	1	4770.6	4774.8	-4.2
(C-13-18)27DCC	1141145	28035843	1	4721.5	4759.3	-37.8
(C-13-18)28ccc1	1134600	28035144	1	4792.6	4774.8	17.8
(C-13-18)33CCC	1133321	28030103	1	4796.6	4774.8	21.8
(C-14-18)_4BDB	1134275	28027589	1	4770.6	4767.7	2.9
(C-14-18)_4DBB	1135959	28025828	1	4770.6	4767.7	2.9
(C-14-18)_5C	1128782	28024477	1	4763.6	4896.4	-132.8
(C-14-18)17ACC	1131045	28015407	1	4797.9	4793.0	4.9
(C-14-18)8CCC	1128062	28017861	1	4796.6	4793.0	3.6
(C-14-18)9CBC	1133279	28019312	1	4785.6	4757.3	28.3
(C-16-19)_4ADD1	1107937	27961299	1	4908.0	4858.9	49.1
(C-18-18)10AAD	1146004	27894285	1	4873.6	4826.2	47.4
(C-19-19(35DCB	1118973	27837088	1	4957.6	4953.0	4.6

(C-19-19))23ACD	1119692	27849702	1	4923.6	4923.0	0.6
(C-19-19)14ACD	1119548	27855013	1	4917.6	4910.5	7.1
(C-19-19)14DCC	1118978	27852424	1	4915.6	4918.0	-2.4
(C-19-19)14DCD	1119725	27852431	1	4921.6	4918.0	3.6
(C-19-19)29ABD	1103639	27845261	1	4957.6	4957.7	-0.1
(C-19-19)35ACC	1119142	27839122	1	4957.6	4949.4	8.2
(C-19-19)35ACD	1119938	27839045	1	4954.6	4949.4	5.2
(C-19-19)35BDD	1118535	27838992	1	4964.6	4949.4	15.2
(C-19-19)35CDC	1117618	27836335	1	4953.6	4953.4	0.2
(C-19-19)35DBC	1119287	27837637	1	4958.6	4953.0	5.6
(C-19-19)35DCC	1119240	27836402	1	4975.6	4955.4	20.2
(C-20_19)15CAA	1113388	27821843	1	4995.6	4975.5	20.1
(C-20-19)15BDB	1112670	27823332	1	4989.6	4971.9	17.7
(C-20-19)15CBA	1112329	27821902	1	4995.6	4975.5	20.1
(C-20-19)15CCC	1111716	27819925	1	5008.6	4978.0	30.6
(C-20-19)16BDC	1107445	27822579	1	5013.6	4981.2	32.4
(C-20-19)21AAB	1110145	27819114	1	4956.6	4990.9	-34.3
(C-20-19)21B	1107270	27818082	1	5022.7	4990.9	31.8
(C-20-19)21BCC	1106276	27817178	1	5005.7	5000.8	4.9
(C-21-18)10CDD1	1146644	27798326	1	4982.5	5002.5	-20.0
(C-21-19)31D	1100800	27777476	1	5183.7	5182.6	1.1
(C-22-19)6bca2	1098140	27774425	1	5248.5	5210.6	37.9
(C-22-19)6bca3	1098429	27774544	1	5222.5	5210.6	11.9
(C-22-19)6bca4	1098277	27774583	1	5224.7	5210.6	14.1
(C-22-19)6ccb	1097251	27771669	1	5240.2	5242.9	-2.7
(C-22-19)6ccd	1098413	27770957	1	5227.5	5226.8	0.7
(C-32-19)22DCB	1124028	27434153	1	6309.4	6500.0	-190.6
01AABB2	962376	27741868	1	5791.9	5783.6	8.3
04C1_Swallow_Spring	1005738	27738863	1	6294.3	6220.4	73.9
08ACAB1	971490	27799042	1	5760.7	5796.5	-35.8
10adb1	1145931	27893447	1	4889.8	4826.2	63.6
12B_1	1084774	27710114	1	5476.0	5467.5	8.5
13A1	992647	27767673	1	5892.0	5876.9	15.1
184_N11_E66_24A1	959794	27724728	1	5770.5	5798.0	-27.5
184_N11_E66_24BDAC1	960613	27724080	1	5763.2	5792.1	-28.9
184_N11_E66_24D1	962355	27722298	1	5750.0	5788.6	-38.6
184_N11_E67_01BC1	990695	27740439	1	5794.0	5760.0	34.0
184_N11_E67_01C1	992111	27738749	1	5806.8	5771.6	35.2
184_N11_E67_13B1	991206	27730965	1	5797.0	5760.1	36.9
184_N11_E68_31C1	997144	27712148	1	5770.9	5795.5	-24.6
184_N12_E67_08A1	972490	27768644	1	5744.2	5770.6	-26.4

184_N12_E67_11A1	988413	27767551	1	5798.1	5760.1	38.0
184_N12_E67_12D2	993733	27765028	1	5910.1	5899.2	10.9
184_N12_E67_13A1	992842	27761586	1	5896.1	5839.4	56.7
184_N12_E67_27B1	981247	27750965	1	5754.0	5766.4	-12.4
184_N13_E66_05ACAB1	939805	27804172	1	6455.7	6482.2	-26.5
184_N13_E67_15D2	982765	27791394	1	5844.1	5825.0	19.1
184_N13_E67_22D1	982920	27786052	1	5809.1	5786.6	22.5
184_N13_E67_33D1	978056	27776844	1	5766.9	5774.9	-8.0
184_N13_E67_33DDA1	978655	27775252	1	5767.3	5760.1	7.2
184_N16_E67_03A1	985872	27899342	1	5580.9	5578.3	2.6
184_N16_E67_11AB1	990319	27894576	1	5603.9	5609.2	-5.3
184_N16_E67_18A1	969380	27887956	1	5587.2	5608.2	-21.0
184_N16_E67_27D1	981834	27874453	1	5589.2	5633.0	-43.8
184_N16_E67_27DADD1	987125	27875872	1	5607.9	5632.2	-24.3
184_N17_E67_28A1	979445	27909890	1	5541.8	5557.4	-15.6
184_N23_E66_07C1	943760	28116824	1	6505.5	6621.6	-116.1
184_N23_E66_19A1	946385	28108680	1	6483.7	6553.0	-69.3
184_N23_E66_31B!	943085	28098123	1	6358.0	6448.4	-90.4
195_N13_E69_11A1	1051551	27804170	1	6279.0	6311.0	-32.0
195_N13_E70_09B1	1068734	27803542	1	5335.8	5348.1	-12.3
195_N13E70_09C1	1069405	27802093	1	5310.1	5330.6	-20.5
19B1	1090779	27793835	1	5140.5	5114.2	26.3
19dcd-1	1098734	27813992	1	5039.1	5029.8	9.3
20bac-2	1104767	27730845	1	5395.0	5412.5	-17.5
21acc-1	1108554	27817127	1	4997.7	4993.4	4.3
22bcd-1	1114774	27725797	1	5411.1	5412.7	-1.6
24a1	1052475	27826576	1	5653.0	5705.7	-52.7
24A1BLM	961116	27820664	1	5824.7	5748.5	76.2
24aaBB1	961259	27821768	1	5812.7	5748.5	64.3
25B1	958218	27821431	1	5876.0	5791.2	84.8
25BADD1	959731	27815317	1	5814.0	5778.8	35.2
25D1	1087933	27691130	1	5518.0	5517.9	0.1
31C	1056542	27814471	1	5595.0	5770.8	-175.8
35DABC2	957032	27712546	1	5780.4	5833.0	-52.6
391327114255901_elev_adj_to_	981499	27905010	1	5549.0	5568.8	-19.8
4B2	955009	28059996	1	6133.3	6144.0	-10.7
6bdc-1	1098505	27773413	1	5204.7	5210.6	-6.0
AG14a	1110516	27824741	1	4983.6	4966.4	17.2
AG1A	1104173	27724310	1	5396.8	5416.7	-19.8
Big_Spgs	1070241	27686895	1	5540.0	5551.1	-11.1
Blind_Spring	989964	27723774	1	5772.0	5774.2	-2.2

Blind_Spring	996425	28102413	1	5848.4	5801.6	46.8
Caine_Spring	1091689	27847588	1	5016.0	5017.1	-1.1
Cedars	987155	27772767	1	5796.0	5771.3	24.7
Clay_Spring	1108921	27748673	1	5446.0	5403.1	42.9
Cold_Spring	1115520	27963797	1	4859.6	4788.1	71.5
Coyote_Spring	1113151	28009877	1	5080.0	5031.1	48.9
Foote_Res_Spg	1139272	27949074	1	4816.0	4765.6	50.4
Four_Wheel_Dr_Spg	963828	27846564	1	5746.0	5695.2	50.8
Keegan_Spg	961297	27958606	1	5610.0	5605.0	5.0
Keegan_Spg_N	961316	27959920	1	5610.0	5609.6	0.4
Keegan_Spg_S	961379	27957408	1	5610.0	5605.0	5.0
Kell_Spring_	1110227	27912424	1	4860.0	4820.8	39.2
Kious_Spring	1060615	27791599	1	5940.0	5986.7	-46.7
Knoll_Spg	1138506	27885963	1	4884.0	4839.9	44.1
Layton_Spg	976775	27834867	1	5694.0	5693.5	0.5
Lime_Spring	1124353	28039640	1	5314.0	5229.1	84.9
Miller_Spring	1139976	28009635	1	4770.0	4746.4	23.6
Minerva_Spring	991664	27745284	1	5806.0	5769.8	36.2
Minerva_Spring	994422	27733765	1	5828.0	5776.5	51.5
N_Knoll_Spg	1141632	27895450	1	4864.0	4821.6	42.4
N_Millick_Spg	996096	27907427	1	5590.0	5570.2	19.8
N17_E68_06A_1_USBLM	1000349	27931708	1	5550.2	5572.1	-21.9
N17_E68_06D_1_USGS	1000719	27924761	1	5548.7	5566.8	-18.1
N18_E66_01B1	960222	27963129	1	5616.0	5614.2	1.8
N18_E66_24DC1	963749	27943148	1	5556.6	5581.4	-24.8
N18_E67_01C1	991969	27962895	1	5511.1	5622.7	-111.6
N18E6602A1	958631	27962339	1	5674.7	5617.1	57.6
N18E68_31A2	1000985	27936295	1	5550.0	5579.4	-29.4
Needle_Pt_Spg	1098543	27708726	1	5468.0	5436.2	31.8
North_Spring	967570	27761578	1	5770.0	5773.0	-3.0
Osbourne_Springs	953058	28054939	1	6120.0	6210.3	-90.3
Rock_Spring	998780	27862145	1	6330.0	6288.0	42.0
Rowland_Spg	1046783	27799800	1	6592.0	6620.6	-28.6
S_Bastian_Spg	970816	27845182	1	5658.0	5688.2	-30.2
S_Bastian_Spg_2	970812	27843650	1	5668.0	5691.6	-23.6
S_Millick_Spg	994000	27906079	1	5590.0	5573.1	16.9
SG23B	1098279	27709069	1	5443.2	5436.2	7.1
SG24a	1141602	27945404	1	4816.7	4762.7	54.0
SG24b	1141493	27945396	1	4817.2	4762.7	54.6
SG25a	1132533	28001685	1	4786.1	4784.4	1.7
SG25b	1132533	28001685	1	4786.5	4784.4	2.0

SG25d	1133051	28001830	1	4788.6	4784.4	4.2
SG26b	1125577	27974891	1	4795.2	4774.5	20.8
SG27a	1118645	27967466	1	4817.4	4793.7	23.7
SG27a	1125686	27974898	1	4793.3	4774.5	18.8
Shoshone_Spring	992273	27737994	1	5815.0	5771.2	43.8
South_Little_Spg	1076662	27681298	1	5540.0	5571.6	-31.6
spg_E_of_Cleve_Crk	973359	27870361	1	5638.0	5653.9	-15.9
Spg_N_of_Big_Spring	1073540	27698574	1	5540.0	5509.7	30.3
Spring_Crk_shallow_wells	1077402	27767205	1	5817.0	5851.0	-34.0
Spring_Crk_Spg	1074164	27764412	1	6134.0	6186.5	-52.5
Stateline_Spring	1094420	27714974	1	5425.0	5437.7	-12.7
Stonehouse_Spring	948785	28080578	1	6252.0	6278.9	-26.9
Stonehouse_Spring_Cmplx	948384	28081645	1	6258.0	6279.0	-21.0
Swallow_Springs	1002871	27738873	1	6084.2	6005.3	78.9
The_Seep	987467	27751437	1	5760.5	5764.6	-4.1
Twin_Springs	1141617	27945186	1	4818.0	4762.7	55.3
unnamed	1138852	27888965	1	4874.0	4832.7	41.3
unnamed_5_spring	972905	27864202	1	5638.0	5664.7	-26.7
Unnamed_spg	1134381	27893477	1	4851.0	4817.5	33.5
unnamed_spring	942816	28100631	1	6409.0	6448.4	-39.4
USGS_3919081142708	978866	27922009	1	5537.9	5542.8	-4.9
USGS_3921371142228	1000530	27926871	1	5534.3	5567.6	-33.3
USGS_3922341142228	1000370	27931132	1	5547.4	5572.1	-24.7
USGS_3930591142215	996138	27984869	1	5566.2	5685.5	-119.4
USGS3844031142723	977364	27699194	1	5792.0	5799.8	-7.8
USGS3846041142343	994489	27711471	1	5798.8	5792.9	5.9
USGS3846401142880	973869	27721093	1	5766.4	5782.6	-16.2
USGS3851081143026	962375	27747737	1	5788.0	5781.7	6.3
USGS3855261142907	972129	27774829	1	5730.0	5774.7	-44.7
USGS3856231142725	981004	27773540	1	5766.1	5760.1	6.0
USGS3900521142914	970029	27804435	1	5765.1	5797.9	-32.8
USGS3903361142727	978913	27815096	1	5787.8	5789.4	-1.6
USGS3918351142820	970133	27908653	1	5573.3	5564.4	8.9
USGS3927031142305	992966	27959706	1	5552.0	5616.2	-64.2
USGS3927501143106	959808	27987291	1	5580.0	5675.2	-95.2
USGS3931281142332	994602	27987706	1	5583.2	5690.2	-107.0
W_Spring_V_Cmplx_5	968756	27904022	1	5610.0	5574.2	35.8
W_Spring_V_Complex_1	968314	27907274	1	5610.0	5569.6	40.4
Willard_Springs	971302	27809326	1	5740.0	5770.3	-30.3
Willow_Spring	959131	28049336	1	5996.0	6029.3	-33.3
2	1142267	28023639	2	4742.5	4739.3	3.2

296	1083911	27782035	2	5236.0	5258.5	-22.5
650	1071778	27796464	2	5296.0	5332.4	-36.4
1730	1072704	27819103	2	5227.0	5258.6	-31.6
2219	1070522	27795330	2	5352.0	5351.7	0.3
9379	1056716	27823056	2	5607.0	5680.8	-73.8
13888	1069107	27795138	2	5375.0	5361.8	13.2
13889	1070543	27818669	2	5277.0	5272.7	4.3
13938	1076147	27813337	2	5193.0	5201.2	-8.2
13939	1051259	27803468	2	6311.0	6139.1	171.9
14697	1089616	27700399	2	5461.0	5485.6	-24.6
22314	1049138	27801581	2	6394.0	6485.4	-91.4
22314	1049402	27801846	2	6394.0	6259.0	135.0
22315	1049138	27801581	2	6379.0	6485.4	-106.4
22315	1049397	27801912	2	6379.0	6259.0	120.0
23540	1072704	27819103	2	5295.0	5258.6	36.4
25917	1071586	27797879	2	5328.0	5327.8	0.2
36072	1068631	27820157	2	5366.0	5315.3	50.7
72993	1089608	27698951	2	5457.0	5489.5	-32.5
83692	1091254	27818087	2	5076.0	5070.5	5.5
92847	1047705	27801644	2	6476.0	6571.9	-95.9
103131	1090152	27818869	2	5111.0	5077.8	33.2
3.85348E+12	989844	27764420	2	5791.4	5782.5	8.9
3.85504E+12	992348	27765885	2	5846.0	5860.5	-14.5
3.85659E+14	977962	27782645	2	5761.7	5782.8	-21.1
3.85906E+14	982380	27784287	2	5795.1	5784.1	11.0
(C-11-15)_30dcb1	1219704	28104480	2	4348.3	4370.5	-22.2
(C-11-16)_36_cdb1	1214449	28098006	2	4433.6	4404.6	29.0
(C-11-16)_6CBC1	1185054	28125427	2	4349.4	4311.1	38.3
(C-11-17)_12acc1	1182166	28120921	2	4331.7	4363.4	-31.7
(C-11-17)_21_cca1	1164554	28108208	2	4637.6	4438.8	198.8
(C-12-16)_17_aab1	1195870	28085198	2	4368.5	4480.4	-111.9
(C-12-17)_1abc1	1182553	28094987	2	4463.5	4465.3	-1.8
(C-12-17)_35cac1	1176419	28064827	2	4502.5	4571.4	-68.9
(C-13-17)_1bd1	1182809	28060817	2	4639.3	4557.5	81.8
(C-13-18(_35C	1145261	28031546	2	4733.5	4715.8	17.7
(C-13-18)_13ACC	1151625	28049581	2	4668.5	4666.0	2.5
(C-13-18)_14bba1	1144114	28051707	2	4782.6	4727.1	55.5
(C-13-18)_14DDB	1146998	28048153	2	4682.5	4695.7	-13.2
(C-13-18)_22CAA	1139960	28043362	2	4745.6	4812.0	-66.4
(C-13-18)_28da1	1137687	28037125	2	4731.9	4759.7	-27.8
(C-13-18)_28DCC	1135749	28035742	2	4775.6	4879.2	-103.6

(C-13-18)_34BCC	1138614	28032729	2	4737.6	4741.6	-4.0
(C-13-18)27ADB	1142201	28039353	2	4721.5	4716.0	5.5
(C-13-18)27CDD	1140302	28035831	2	4721.5	4759.7	-38.2
(C-14-18)_3CD1	1140093	28023688	2	4753.5	4739.3	14.2
(C-14-18)_3CD2	1140176	28023615	2	4753.5	4739.3	14.2
(C-14-18)_4ADC	1137073	28026686	2	4756.6	4738.0	18.6
(C-14-18)8ACC	1130688	28020620	2	4787.6	4800.8	-13.2
(C-17-18)_1DA	1155975	27929348	2	4858.6	4805.1	53.5
(C-17-18)26ab1	1149847	27910402	2	4834.5	4808.2	26.3
(C-17-19)_5CC	1099014	27926676	2	5004.7	4858.9	145.8
(C-18-18)31ADB	1131191	27871803	2	4901.6	4874.9	26.7
(C-18-19)20ABD	1103083	27882852	2	4979.6	4881.1	98.5
(C-18-19)20dad1	1104611	27878952	2	4938.7	4898.2	40.5
(C-18-19)20ddd1	1104374	27878995	2	4947.3	4898.2	49.1
(C-18-19)23ACC	1118197	27881759	2	4933.6	4843.2	90.4
(C-19-18)5abb1	1134156	27867901	2	4903.6	4893.8	9.8
(C-19-19(34ABA	1114405	27840864	2	4943.6	4944.3	-0.7
(C-19-19(35CAC	1117571	27837651	2	4963.6	4953.0	10.6
(C-19-19)14ADC	1119986	27855043	2	4915.6	4912.3	3.3
(C-19-19)34ADB	1114962	27839803	2	4955.6	4950.1	5.5
(C-19-19)34dac1	1114736	27837325	2	4977.6	4953.0	24.6
(C-19-19)35CAD	1118278	27837612	2	4965.6	4952.9	12.7
(C-19-19)35dcb1	1119265	27837328	2	4961.6	4952.9	8.7
(C-19-19)36cda1	1123825	27837508	2	4953.5	4952.4	1.1
(C-20-19)30ABD	1098961	27812911	2	5067.7	5032.2	35.5
(C-21-18)12CCD1	1155928	27798566	2	4944.6	4982.6	-38.0
(C-21-18)17AD!	1138047	27796006	2	4973.2	5001.0	-27.8
(C-21-18)20DAB	1137695	27789600	2	5053.7	5040.9	12.8
(C-21-19)16cbd1	1107937	27793882	2	5034.4	5080.8	-46.4
(C-21-19)21AD	1111994	27790314	2	5023.6	5087.1	-63.5
(C-21-19)21daa1	1111967	27789297	2	5037.1	5094.1	-57.0
(C-22-19)6aad	1102088	27775289	2	5196.7	5192.1	4.6
(C-22-19)6bac2	1098539	27775095	2	5208.4	5204.7	3.7
(C-22-19)6bbb	1097139	27776038	2	5213.4	5206.4	7.0
(C-22-19)6bbd1	1097853	27774999	2	5203.8	5204.7	-0.9
(C-22-19)6bcc1	1097126	27774059	2	5213.3	5225.2	-11.9
(C-22-19)6dab2	1101431	27773315	2	5174.0	5216.1	-42.1
(C-22-20)1aba1	1095577	27775733	2	5214.9	5224.4	-9.5
(C-22-20)24DD	1096735	27755407	2	5462.8	5394.7	68.1
(C-23-19)7CD	1099453	27734149	2	5382.8	5419.9	-37.1
(C-23-19)8D	1106986	27734665	2	5400.8	5409.0	-8.2

(C-24-19)3DBA	1119512	27708872	2	5423.8	5419.4	4.4
10baa-1	1142333	27958482	2	4807.2	4777.3	29.9
10dda-1	1119074	27734989	2	5440.2	5409.4	30.8
11bcc-1	1113050	27987801	2	4882.0	4908.8	-26.8
12aab-1	1125965	27829844	2	5020.4	4965.7	54.7
12acc-1	1092319	27829793	2	5093.6	5045.8	47.8
12bdc-1	1119606	27987981	2	4819.6	4821.7	-2.1
12CAAD1	992051	27765911	2	5855.7	5818.1	37.6
12CCD1	1053417	27799585	2	6159.9	6132.7	27.2
14bad1	1118563	27823760	2	4976.0	4965.7	10.3
14bad-1	1116927	27823726	2	4976.0	4965.7	10.3
14bbc-1	1116619	27823912	2	4978.9	4965.7	13.2
14DBBD1	1002247	27856125	2	6510.5	6511.5	-1.0
15bcc-1	1111602	27822568	2	4987.0	4973.8	13.2
16C1	1069443	27797575	2	5364.8	5350.5	14.3
17aaa-1	1132674	28017216	2	4780.6	4758.5	22.1
17dac-1	1138207	27794034	2	4985.5	5018.7	-33.2
17dba-1	1102172	27949648	2	4888.0	4865.3	22.7
184_N09_E68_21DC1	1008464	27658646	2	5834.0	5805.8	28.2
184_N10_E67_15DA1	983208	27695884	2	5797.8	5803.0	-5.2
184_N10_E67_22AA1	982917	27693755	2	5827.4	5805.3	22.1
184_N10_E67_26BB1	984008	27688275	2	5901.6	5809.6	92.0
184_N10_E68_31CD1	996310	27678693	2	5790.2	5812.1	-21.9
184_N11_E66_15CA1	949809	27727566	2	5821.5	5833.0	-11.5
184_N11_E66_23AB1	956412	27725764	2	5796.8	5818.0	-21.2
184_N11_E68_19DCDC1	999334	27721308	2	5812.5	5790.1	22.4
184_N12_E67_12D3	993810	27765118	2	5894.1	5899.7	-5.6
184_N12_E67_20BD1	971047	27755867	2	5739.0	5771.9	-32.9
184_N12_E67_20BD1	968206	27742843	2	5739.0	5775.9	-36.9
184_N13_E67_15DCDC1	982407	27790454	2	5796.6	5792.5	4.1
184_N14_E67_16DD2	977671	27822614	2	5744.0	5742.0	2.0
184_N14_E67_21DC1	976454	27817248	2	5721.0	5755.4	-34.4
184_N15_E67_02DA1_USGSMX	987844	27866172	2	5622.9	5657.7	-34.8
184_N15_E67_35BD1	985266	27841302	2	5751.4	5688.0	63.4
184_N16_E67_02BC1	987612	27898616	2	5585.6	5576.4	9.2
184_N16_E67_03AAAA1	987156	27900424	2	5585.9	5576.4	9.5
184_N17_E67_30CB1	966447	27907607	2	5718.0	5567.1	150.9
184_N23_E65_14C1	932847	28111821	2	6536.0	6681.3	-145.3
184_N23_E66_31AB1	944755	28097663	2	6333.0	6434.1	-101.1
185_N23_E68_04B	1015948	28125791	2	5560.6	5650.0	-89.4
18dcc-1	1125376	28013080	2	4792.4	4826.0	-33.6

195_N10_E70_11D1	1082914	27706876	2	5494.9	5477.6	17.3
195_N12_E70_13AC1	1090429	27766180	2	5323.8	5429.6	-105.8
195_N12_E70_34_1	1078624	27749362	2	6188.0	6071.7	116.3
195_N13_E70_04D1	1071348	27807107	2	5266.7	5224.6	42.1
195_N13_E70_10A1	1076329	27804370	2	5233.8	5180.0	53.8
195_N15_E70_25DD1	1088008	27847278	2	5058.9	5065.0	-6.1
195_No9HE70_33C	1071390	27682536	2	5577.9	5572.4	5.5
196_N08_E69_09DA1	1042714	27639276	2	5642.3	5685.4	-43.1
196_N08_E69_15B1	1044661	27635509	2	5640.2	5686.0	-45.8
196_N08_E70_06B1	1060764	27648150	2	5584.2	5670.3	-86.1
196_N09_E69_32DA1	1036728	27649885	2	5753.9	5687.9	66.0
196_N09_E70_35_1	1082494	27650853	2	5626.2	5645.0	-18.8
19dd-1	1097892	27911168	2	4938.3	4865.8	72.5
20A	1083137	27666148	2	5527.8	5617.7	-89.9
20bcd-1	1104077	27726563	2	5395.1	5415.8	-20.7
20ca-1	1101293	27880718	2	5015.5	4905.2	110.2
20cac-3	1102873	27720506	2	5393.3	5421.0	-27.7
21A_1	1073135	27632466	2	5588.9	5675.9	-87.0
23abd-1	1119318	27850833	2	4920.0	4924.5	-4.5
23bdc	1117488	27849620	2	4922.0	4924.5	-2.5
24B1USGS	958608	27854084	2	5814.9	5697.1	117.8
25ddd-1	1153826	28036153	2	4698.6	4683.8	14.8
26BB_USGS-MX	983592	27694149	2	5842.8	5804.2	38.6
26bdd1	1118029	27844039	2	4933.0	4936.8	-3.8
26cba-1	1146938	27940163	2	4838.1	4779.5	58.6
26dbc-1	1146539	28003587	2	4791.4	4755.6	35.8
27aaa-1	1143034	28007037	2	4783.1	4754.7	28.4
27c1	1072704	27819103	2	5212.5	5258.6	-46.1
28bcc-1	1104496	27875890	2	4952.3	4905.4	46.9
28cbb-1	1108765	27720172	2	5400.1	5416.0	-15.9
28dab-1	1137185	28038066	2	4751.0	4759.7	-8.7
29cb-1	1099278	27938343	2	4918.0	4867.4	50.6
31adb1	1129928	27871678	2	4890.6	4874.9	15.7
31C1	943204	28094967	2	6344.0	6404.1	-60.1
32aba-1	1133175	27808325	2	4983.5	4989.7	-6.2
33AC	1073082	27651138	2	5574.0	5649.4	-75.4
33ddc-1	1137443	28030292	2	4749.4	4741.6	7.8
34ccc-1	1138737	28029237	2	4749.4	4738.0	11.4
35A1	1084044	27783579	2	5235.5	5247.6	-12.1
35ABLM	961434	27777680	2	5936.9	5791.0	145.9
35AD1	1086638	27718728	2	5509.0	5447.9	61.1

35BA	1082612	27719785	2	5518.0	5452.2	65.8
36bd	1089495	27718733	2	5478.4	5443.1	35.3
3cad-1	1118716	27708285	2	5444.5	5419.9	24.6
3CDA	1140396	28024346	2	4753.5	4739.3	14.2
3ddc-1	1142748	28027740	2	4746.0	4723.8	22.2
4aab1	1114698	27712243	2	5451.3	5419.1	32.2
4ACA	1136563	28027811	2	4763.6	4768.1	-4.5
4bba-1	1103621	27962681	2	4934.4	4901.5	32.9
4bdd-1	1106038	27928956	2	4833.3	4841.1	-7.8
5CCC	1128065	28023310	2	4777.6	4800.8	-23.2
5dc1	1101551	27927889	2	4973.5	4859.5	114.0
6bc-1	1094533	27833997	2	5075.4	5030.8	44.6
6bcc-1	1108781	27834205	2	5087.0	4968.3	118.7
9dad-1	1113367	27735600	2	5415.3	5408.5	6.8
AG14b	1110257	27824342	2	4990.1	4970.7	19.4
AG15A	1093357	27699042	2	5447.8	5502.4	-54.6
AG16B	1104166	27724405	2	5395.7	5417.0	-21.2
MX_Spring_V_Central	982991	27699729	2	5822.0	5799.6	22.4
N17_E67_18BCAA1	966708	27920001	2	5602.9	5558.7	44.2
N18_E66_25A2	964111	27941286	2	5594.7	5578.3	16.4
N20_E67_26A2	989982	28005322	2	5582.8	5725.7	-142.9
N20_E67_26ABBD1	989557	28005974	2	5590.2	5725.7	-135.5
Project	959975	27844941	2	5812.3	5703.9	108.4
PW06a	1131261	27870746	2	4893.8	4883.8	10.0
PW8A	1127406	27697441	2	5628.8	5423.1	205.7
SG24c	1142241	27945213	2	4819.8	4764.2	55.6
SG25c	1133435	28001746	2	4789.1	4771.5	17.6
SG26c	1125686	27974898	2	4796.9	4776.4	20.4
USBLM	1074879	27816094	2	5216.2	5213.6	2.6
USGS_3902811142903	966732	27926120	2	5599.0	5561.4	37.6
USGS_3934421142318	989686	28023669	2	5605.0	5750.6	-145.6
USGS3840391142327	996419	27691013	2	5787.0	5808.0	-21.0
USGS3844481143009	964037	27703582	2	5799.2	5798.2	1.0
USGS3859201142940	965737	27791583	2	5796.1	5796.6	-0.5
USGS3903521143054	959470	27819132	2	5801.0	5762.7	38.3
USGS3908031142510	984678	27844554	2	5651.0	5685.3	-34.3
USGS3909361143058	963486	27851162	2	5715.5	5692.7	22.8
USGS3909401143020	961804	27854557	2	5740.0	5691.3	48.7
USGS3911311142447	987486	27872624	2	5600.0	5639.7	-39.7
USGS3912241142936_Cleve_Creek	964814	27870735	2	5642.3	5669.5	-27.2
USGS-MX	958796	27790897	2	5841.1	5803.4	37.7

USGS-MX	987369	27865217	2	5622.9	5657.7	-34.8
548	1062019	27647040	3	5720.0	5669.1	50.9
1420	1070091	27809970	3	5307.0	5258.4	48.6
3373	1074338	27796639	3	5245.0	5278.1	-33.1
9299	1070364	27805988	3	5238.0	5258.4	-20.4
9663	1053973	27822773	3	5684.0	5766.1	-82.1
10936	1053906	27825150	3	5652.0	5757.1	-105.1
40151	1072843	27808729	3	5183.0	5222.8	-39.8
43528	1071572	27795306	3	5298.0	5329.8	-31.8
49244	1073650	27752450	3	6369.0	6230.6	138.4
74561	1080901	27799565	3	5199.0	5158.0	41.0
76368	1090459	27698260	3	5469.5	5492.6	-23.1
78758	1088908	27696653	3	5466.0	5500.3	-34.3
94995	1080822	27804894	3	5174.0	5135.4	38.6
107478	1058550	27822706	3	5501.0	5679.3	-178.3
108853	1082885	27769200	3	5411.0	5626.1	-215.1
109586	1093296	27707884	3	5452.0	5459.7	-7.7
3.85259E+12	992701	27759442	3	5820.0	5838.0	-18.0
3.85259E+14	993687	27753399	3	5833.7	5798.1	35.6
3.85314E+14	990936	27755731	3	5827.0	5765.6	61.4
(C-11-16)_24DD	1216930	28108460	3	4324.3	4341.9	-17.6
(C-11-17)_1bdc1	1181420	28125734	3	4328.9	4350.1	-21.2
(C-11-17)_26ddc1	1177041	28134884	3	4336.4	4329.9	6.5
(C-13-16)_6C1	1186786	28059561	3	4481.9	4566.9	-85.0
(C-13-18)_13BCC	1148730	28049244	3	4661.5	4695.8	-34.3
(C-13-18)_13D	1152292	28047959	3	4683.5	4666.3	17.2
(C-13-18)_23AAB1	1147288	28046296	3	4686.5	4691.7	-5.2
(C-13-18)34CDD	1140553	28032944	3	4720.5	4743.6	-23.1
(C-14-18)_4DCC	1136102	28023741	3	4788.6	4760.9	27.7
(C-20-19)_1BC2	1122268	27833927	3	4961.6	4957.6	4.0
(C-20-20)12acc1	1092355	27827921	3	5098.0	5059.7	38.3
(C-21-17)8dcc1	1169598	27798909	3	4858.5	4914.3	-55.8
(C-21-19)31acd1	1101025	27778531	3	5181.6	5182.4	-0.8
(C-22-20)1aab1	1096096	27775373	3	5233.7	5217.0	16.7
(C-22-20)1bdc1	1093621	27773225	3	5271.7	5242.0	29.7
(C-24-18)20BCC1	1137795	27693280	3	5421.6	5429.2	-7.6
(C-24-18)27A1	1152221	27689593	3	5376.7	5423.0	-46.3
13bcd-2	1128620	27691865	3	5444.5	5441.8	2.7
16bdb-1	1112764	27693721	3	5449.8	5428.8	21.0
184_N11_E66_35DBAC1	957170	27712645	3	5794.2	5833.1	-38.9
184_N11_E67_01C1	991391	27738514	3	5824.0	5771.7	52.3

184_N11_E68_31CDCD1	997796	27710855	3	5782.9	5796.7	-13.8
184_N12_E67_12D1	993798	27765103	3	5910.1	5901.0	9.1
184_N12_E67_13B1	990261	27762254	3	5804.1	5780.9	23.2
184_N12_E67_13DD1	994556	27759029	3	5850.1	5874.3	-24.2
184_N12_E67_24CDDD1	992283	27753296	3	5824.6	5767.1	57.5
184_N13_E67_15CDAA1	981218	27791359	3	5780.7	5802.9	-22.2
184_N13_E67_15D1	982770	27791324	3	5881.1	5818.5	62.6
184_N13_E67_22ADBB!	982877	27788725	3	5796.9	5803.4	-6.5
184_N13_E67_26BADC1	986148	27789301	3	5812.0	5835.9	-23.9
184_N13_E67_26BADC1	986276	27783323	3	5801.3	5815.9	-14.6
184_N13_E67_26DCCB1	987061	27786265	3	5802.0	5841.2	-39.2
184_N13_E67_35D1	987106	27775561	3	5834.1	5773.0	61.1
184_N15_E68_17DD1	1002996	27853927	3	6645.2	6404.7	240.5
184_N16_E66_26A1	959326	27877981	3	5720.0	5669.4	50.6
184_N20_E66_13AB1	962871	28016289	3	5643.0	5737.2	-94.2
184_N20_E67_08D1	978689	28021183	3	5606.3	5747.7	-141.4
184_N24_E66_31CB1	941927	28127656	3	6586.8	6645.4	-58.6
185_N22_E67_36DBAC1	1003409	28065368	3	5486.4	5739.4	-253.0
185_N24_E68_17_1	1011993	28144977	3	5706.6	5615.3	91.3
195_N10_E70_24AB1	1091393	27700360	3	5451.4	5483.0	-31.6
195_N13_E70_03D1	1077042	27806793	3	5273.8	5177.5	96.3
195_N13_E70_30AA1	1062569	27788105	3	5979.5	5964.4	15.1
196_N09_E70_34D	1077340	27649286	3	5584.4	5651.1	-66.7
1aba-1	1093434	27834756	3	5076.0	5046.3	29.7
1baa-2	1092407	27832823	3	5080.0	5046.8	33.2
21bab-1	1135871	27819379	3	5067.2	4979.5	87.7
22CCCA1	978998	27817348	3	5734.6	5775.0	-40.4
24DAD	994500	27754997	3	5862.7	5850.4	12.3
26DCCB1	987048	27780113	3	5806.6	5795.3	11.3
27C1	1073193	27818803	3	5212.5	5246.2	-33.7
2ada-1	1093890	27710390	3	5443.0	5448.0	-5.0
32aba-2	1133166	27808452	3	4972.6	4992.2	-19.6
34dcc-1	1141364	28030191	3	4733.5	4740.3	-6.8
36A1_Rosencrans_Well	1058668	27619959	3	5610.0	5694.5	-84.5
6B_1	1058259	27649041	3	5579.0	5671.1	-92.1
6bdc1	1098806	27773585	3	5202.6	5217.7	-15.1
7bbd-1	1110049	27831271	3	5094.0	4963.3	130.7
AG14c	1110529	27824551	3	4989.7	4971.8	17.9
AG16C	1104166	27724405	3	5400.9	5417.3	-16.5
Confusion_Well	1146320	27986410	3	4679.0	4765.7	-86.7
N19_E66_11B1	954273	27987397	3	5721.6	5675.7	45.9

PW02A	1094194	27717976	3	5427.4	5436.2	-8.8
PW03a	1106903	27778228	3	5128.3	5169.6	-41.3
PW04A	1096116	27645035	3	5588.7	5657.3	-68.6
PW06b	1131067	27870846	3	4894.0	4883.9	10.1
PW06c	1131213	27870907	3	4893.9	4883.9	10.0
PW09a	1125997	27838221	3	4951.2	4952.4	-1.2
PW11a	1112474	27698950	3	5448.9	5424.8	24.1
PW11b	1112106	27699046	3	5450.8	5424.8	26.0
PW11c	1112482	27698830	3	5451.2	5425.6	25.6
PW11c	1112482	27698830	3	5451.2	5425.6	25.6
PW8b	1127406	27697441	3	5628.7	5423.1	205.5
Rosencrans_Well	1056219	27619363	3	5617.7	5697.2	-79.5
USGS_3917131142447	986961	27906417	3	5581.0	5564.0	17.0
USGS3845581142305	997312	27716666	3	5778.9	5790.6	-11.8
USGS3847311142245	1001959	27641385	3	5850.0	5802.8	47.2
USGS3908071143041	960028	27850999	3	5808.3	5697.8	110.5
USGS3932111143207	953214	28060408	3	6059.0	6159.0	-100.0
1	943900	27752786	4	5833.3	5840.5	-7.2
76369	1089891	27691525	4	5497.0	5526.7	-29.7
3.85852E+14	980158	27794651	4	5777.0	5810.2	-33.2
(C-11-17)_11aaa1	1178705	28122769	4	4341.7	4363.4	-21.7
(C-11-17)_1bdc3	1180948	28126536	4	4323.4	4350.1	-26.7
(C-13-18)_13cba1	1149780	28050150	4	4695.5	4695.8	-0.3
(C-18-19)20DDD2	1104086	27878916	4	4968.6	4899.3	69.3
(C-18-19)21CCC	1104978	27878743	4	4973.6	4899.3	74.3
(C-19-19)34ADD	1115593	27838923	4	4956.6	4953.0	3.6
(C-19-19)35cdd1	1118359	27836430	4	4971.1	4955.9	15.2
(C-21-19)31DDC	1101163	27776512	4	5157.7	5197.4	-39.7
(C-31-19)20CD1	1111727	27465420	4	6159.2	5752.5	406.7
16bdb-2	1112636	27693712	4	5451.0	5428.9	22.1
184_N08_E68_14A	1020440	27635988	4	5733.4	5795.4	-62.0
184_N09_E68_30AB1	997778	27657257	4	5799.5	5810.0	-10.5
184_N12_E67_31DD1	968131	27742908	4	5744.0	5776.2	-32.2
184_N13_E67_15CDAA2	981288	27791363	4	5781.0	5808.0	-27.0
184_N13_E67_15CDDD1	981445	27790106	4	5799.4	5802.7	-3.3
184_N13_E67_22BADD1	981461	27788840	4	5789.6	5796.9	-7.3
184_N14_E67_15C1	981058	27822529	4	5882.3	5759.5	122.8
185_N23_E68_23DDBB1	1029761	28106730	4	5505.1	5671.7	-166.6
185_N23_E69_07DCBD1	1039343	28116976	4	5525.3	5654.6	-129.3
185_N24_E69_17aaaa1	1046121	28147875	4	5526.8	5582.8	-56.0
185_N25_E68_26B1	1023361	28167713	4	5525.7	5536.1	-10.4

193_N23_E69_11_1_G_E	1061004	28119293	4	5578.0	5673.5	-95.5
195_N10_E70_25AB1	1091350	27694729	4	5522.9	5511.8	11.1
196_N08_E69_36AAA1	1058406	27621259	4	5603.3	5694.5	-91.2
20bcd-1	1104682	27726640	4	5384.5	5415.0	-30.5
253_N24_E69_27baab1	1054478	28137469	4	5528.5	5603.3	-74.8
26aba1	1119289	27846297	4	4930.5	4935.3	-4.8
32dbd	1109936	27681175	4	5625.0	5534.9	90.1
35DC	1052129	27617164	4	5644.0	5697.7	-53.7
4add2	1108623	27929508	4	4883.4	4822.0	61.4
4bcd-1	1109121	27742065	4	5417.0	5404.7	12.3
8dcc-1	1219172	27799924	4	4846.0	4804.2	41.8
Gandy_Warm_Spg	1092252	27965064	4	5252.0	5198.8	53.2
N18_E68_31A1	1001301	27936317	4	5537.0	5580.2	-43.2
NPA-1B	1112491	27698710	4	5451.4	5425.6	25.8
PW01b	1092328	27775507	4	5221.3	5227.5	-6.2
PW02B	1094202	27717865	4	5431.1	5436.5	-5.4
PW03b	1107045	27778015	4	5134.2	5171.0	-36.8
PW03z	1106739	27778359	4	5140.2	5171.0	-30.8
PW04b	1096116	27645035	4	5588.7	5657.3	-68.6
PW06d	1131263	27870710	4	4893.6	4884.3	9.3
PW09b	1125910	27838298	4	4949.6	4952.5	-2.9
PW11E	1112747	27698487	4	5451.2	5425.6	25.6
USGS3833511141802	1019913	27660633	4	5723.5	5795.9	-72.4
USGS3837041142250	999450	27656978	4	5783.0	5809.5	-26.5
USGS3837071142312	997859	27675243	4	5806.0	5812.2	-6.2
USGS3856131142504	986975	27772793	4	5806.1	5781.2	24.9
USGS3904481142744	980671	27845843	4	5768.0	5683.2	84.8
USGS3908021143030	960685	27844305	4	5811.8	5701.8	110.0
USGS3908021143039	960877	27844502	4	5807.2	5701.8	105.4
184_N23_E66_31B2	942840	28097849	5	6374.0	6449.6	-75.6
N19_E66_14AB1	956063	27984634	5	5650.0	5672.1	-22.1
PW01c	1092320	27775635	5	5177.8	5233.5	-55.7
USGS3857151142545	984184	27779172	5	5806.7	5811.5	-4.8
(C-24-19)32ad	1110503	27683014	6	5496.5	5531.1	-34.6