Desert Research Institute

Science Environment Solutions

Assessment of Drought Resiliency in Rural Northern Nevada – Additional Studies

Wells, NV

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Presented to: Nevada Division of Emergency Management

Date: September 23, 2016

Contents

Introduction

Unusually severe to exceptional multi-year droughts are not an uncommon occurrence in Nevada. Although groundwater sources tend to be more resilient to short-term droughts than surface water sources, the intensity and length of the recent drought and the increase in population in recent decades have led to questions about the vulnerability of all of the state's municipal water systems. This includes those serving areas outside of urban centers. In 2013, the Nevada Drought Response Committee (DRC) held a strategic planning workshop during which the workgroup identified a goal of strengthening the resiliency of municipal water systems. The DRC recommended the development of public water supply vulnerability studies in the 2014 strategic plan.

The Nevada Division of Emergency Management (NDEM), in accordance with its mission of providing guidance to the state of Nevada and local jurisdictions on pre-disaster mitigation issues, desires to survey public water supply systems and domestic wells in rural northern Nevada to determine the vulnerability of those systems and sources to the effect of long-term drought. The NDEM also desires to develop guidelines to promote drought resiliency for municipal water systems and develop drought mitigation recommendations for rural water systems.

Most rural communities rely on groundwater to serve their customers. Generally, groundwater systems provide more resiliencies during drought periods because groundwater storage is typically much larger than surface water systems (e.g. reservoirs). Although the groundwater does allow small communities a certain amount of relief during short drought periods, groundwater levels can be depleted during long periods of drought. This study assesses the occurrence of drought and the potential effects on groundwater systems in northern rural Nevada.

This drought resiliency analysis focuses on small communities in northern Nevada. This includes communities north of highway 50 including Gerlach, Wadsworth, and Vya. This analysis also includes a general assessment of the potential impact drought may have on domestic wells. The domestic well analysis focuses on the expected shallow water table declines within each hydrographic basin in northern Nevada.

Objectives

This report presents the results a study designed to complete the following tasks:

1. Survey northern rural Nevada municipal/community water supply systems
2. Determine criteria for drought vulnerability of public water supply systems
3. Determine drought vulnerability for domestic wells
4. Develop municipal/community water system drought resiliency recommendations
5. Review and update the NV State Hazard Mitigation Plan's Drought Risk Assessment.

Background

Three or four major droughts occurred in the U.S. during the more than 100-year period for which records are available, not including the extreme and exceptional drought currently affecting Nevada and California. Two of the major droughts in that interval include the Dust Bowl of the 1930's and another drought during the 1950's. Both of those events persisted for a duration lasting between five and seven years, and both affected very large geographic areas (NOAA, 2008).

Medieval-era (1100-1300 CE) droughts were no more severe than modern droughts, but they persisted longer than any recent drought event, lasting 30-50 years (http://www.nasa.gov/press/2015/february/nasa-study-finds-carbon-emissions-could-dramatically-increase-risk-of-us). The likelihood of such persistent mega-droughts in the second half of this century may be exacerbated in the Southwest and Central Plains (Cook et al., 2015).

In designing a drought scenario for this study, a 15-year period of 50 percent recharge was selected as it represents a more severe and more persistent drought than has been recorded for the region, but still represents a fairly realistic scenario. There are several means by which drought is identified and its severity quantified, including the Palmer Drought Severity Index (Palmer, 1965), which is a comparison of current soil moisture to average soil moisture. For the present study, annual precipitation totals from each basin (wrcc.dri.edu) were compared to the mean total. In general, annual totals on the order of 50 percent of normal precipitation constitute some of the driest years on record.

Methods

The study presented here was conducted primarily through numerical modeling. While a previous report (Pohll et al., 2016) focused on more populated areas, the NDEM requested that three additional towns be included in the study: Gerlach, Wadsworth, and Vya (Figure 1). Estimations of the perennial yields for these basins are shown in Table 1. However, it should be noted that although these basins were selected based on the state's estimation of perennial yield, these values were further researched and re-evaluated, and generally served only as a starting point for calibration of mountain block recharge and interbasin flow.

Modeling Methods

MODFLOW-NWT (Niswonger et al., 2011) was used to simulate the groundwater system within the selected hydrographic areas. MODFLOW is considered the industry standard and has been extensively tested and verified by numerous hydrogeologists. The model was developed within the Groundwater Modeling System (GMS) environment (version 10.0). GMS acts as a database for all of the hydrogeologic information and provides an easy to use pre- and post-processor to MODFLOW.

Model domains were defined by a 1-layer mesh of 0.386 mi^2 (1 km^2) grid cells fit to the shape of the hydrographic basin. Surface elevations were defined by a DEM, and grid cell thicknesses were determined by the difference between the surface elevation and a uniform bottom elevation. All models use the convertible layer option in MODFLOW, which allows for a variable saturated thickness as defined by the simulated water table position.

While the design of the individual basin models will be discussed later in this document, in general, models were developed to include zones of mountain block groundwater recharge, evapotranspiration (ET) over phreatophyte zones, rivers and streams, and interbasin flow where applicable. Hydraulic conductivities were determined by physical properties of the formations, analysis of aquifer test results where available, and use of the parameter estimation (PEST) function in GMS. With the exception of the municipal wells in some basins, the functionality and pumping rates of wells in these basins were not available. Therefore, each well with existing water rights as stated by the NDWR was assumed to be active and pumping at the full water right issued to that well, including those wells with only supplementary water rights.

For all modeled hydrographic basins, three simulation periods were developed. First, a steady-state model was created to represent pre-development water levels. Steady state models were calibrated to observed water levels, such that the ratio of the mean absolute error to the total simulated head drop was less than 10%. These water levels were then used as the initial conditions for two sets of transient models – one set modeling normal mountain block recharge conditions, and one set modeling drought conditions, for which recharge was reduced by 50% from normal. Each transient simulation was run for 15 years. All wells were modeled as pumping at their full water right, with the exception of domestic wells which were pumped at 0.7 AFA, in contrast to their associated water right of 2.0 AFA. Additionally, the municipal wells in the Dodge Flat/Tracy Segment/Fernley Area (Wadsworth) model were pumped at rates as reported by the local municipalities. Note that the 2013 estimated pumping rates shown in Table 1 are in many cases simply a percentage of the total water rights, and because their accuracy was unknown, these numbers were not used. Comparisons of water level difference plots between the transient and steady state simulations show the basin-wide drawdown effects of simple pumping versus the effects of lost recharge due to drought conditions. Plots of drawdown over time were also created for selected municipal wells and springs to assess drought vulnerability for the public water supply and to better inform recommendations for drought resiliency.

Dodge Flat / Tracy Segment / Fernley Area (Wadsworth)

The town of Wadsworth lies at the junction of three hydrographic basins – Dodge Flat (Basin 82), Tracy Segment (Basin 83), and Fernley Area (Basin 76). These basins are bound by the Pah Rah Mountains to the west, the Virginia Range to the south, the Truckee Range to the north, and the Hot Springs Mountains to the east. The Truckee River flows east through the Tracy Segment, then bends to the north to flow through Dodge Flat, ultimately terminating in Pyramid Lake, north of the Dodge Flat basin. At the eastern end of the Tracy Segment, river water is diverted into the Truckee Canal, which flows parallel to the river within the Tracy Segment, then bends to the southeast to flow through the Fernley Area. Water in the canal is used for irrigation purposes in the southern Fernley Area. The town of Wadsworth and the surrounding area obtain water from 4 municipal wells and several quasimunicipal wells located in the Dodge Flat and Tracy Segment (Figure 2).

Steady-State Model Design

The Dodge Flat / Tracy Segment / Fernley Area model uses the results of a previously designed model as its initial condition (Pohll, 2015). It should be stated that the model incorporates only the sections of these three basins that are hydrologically relevant to the Wadsworth/Fernley area, and most notably omits a sizable portion of the Tracy Segment. This model is significantly more complicated than the others described in this report, and consists of 29,376 200 m x 200 m grid cells in 3 layers. Layers 1 and 2 are 110 m (360 ft) and 190 m (620 ft) thick, respectively. The bottommost layer (Layer 3) is defined by the bedrock surface. Surface elevations were determined by a DEM. Briefly summarized here, the model design is described in detail in Pohll, 2015.

The Pohll model was designed to simulate a steady-state condition representing the period 2000-2005. The head resulting from this simulation was then used as the initial condition for a transient model representing 2006-2010. This period was used to calibrate the storage parameters (specific yield and specific storage) and to validate the ability of the model to simulate water level trends. Groundwater sources and sinks in the Elko Segment include mountain block recharge, agricultural recharge, evapotranspiration, interbasin flow, and well pumping. Unlike the other models described in this report, both the steady state and transient calibration periods do include well pumping. The Truckee River and Truckee Canal also act as sources and sinks of groundwater.

Recharge was modeled as several specified flow arcs in layers 1 and 2 along the base of the mountain ranges bounding the basins, and was estimated to be approximately 3300 AFA. Interbasin flow was assumed to move into the model domain along the Truckee River canyon and exit in the north toward Pyramid Lake, and to the southeast toward Hazen. The hydraulic head values along these boundaries were determined by interpolation of measured water levels, or estimated from land surface elevations if no water level data were available. The head values were assumed to remain constant during all simulations and were applied to layers 1 and 2.

Evapotranspiration zones were applied to areas populated by phreatophytes, which fall primarily along the banks of the Truckee River and in irrigated areas along the Truckee Canal. The maximum groundwater ET rates were 0.0016, 0.016, and 0.016 ft/day for greasewood, playa, and cottonwood areas, respectively. The extinction depths were specified as 23, 3.3, and 16 ft for greasewood, playa, and cottonwood areas, respectively.

Interactions between the aquifer and the Truckee River and Truckee Canal were simulated using the streamflow routing package (SFR2; Niswonger and Prudic, 2005). The SFR2 package calculates flux between the surface water body and the aquifer using a number of parameters, including geometric parameters, topology of the stream network, streambed elevations, and width for each reach. Seepage from lateral canals was estimated to be approximately 3300 AFA, based on conveyance efficiencies and diversion rates. The flow budget for the steady-state model is detailed in Table 2.

Most of the hydraulic conductivity measurements within the study area were taken from Pohll et al., 2001, with a few additional measurements taken in the Wadsworth area as presented in Epstein, et al. 2007. Hydraulic testing included pumping, recovery, and packer testing and was performed from 1997 -

2006. The model was calibrated using the pilot point method, with final hydraulic conductivities ranging from 0.3 ft/d to 164 ft/d in isolated areas of the basins.

Transient Model Design

Two transient models were run – one with recharge rates set to 50% of those used in the steady-state model and using Truckee River and Truckee Canal drought condition flow rates as predicted by Pohll, 2016, and one with 100% of the steady-state recharge, to assess the effect of lost mountain block recharge as opposed to simple pumping. Truckee River and Truckee Canal flow rates for the model using 100% of normal recharge were taken from the transient predictive model described in Pohll, 2015. Heads calculated by the 2006-2010 transient simulation presented in Pohll, 2015 were used as the initial condition for the transient drought model, which was run to 15 years. For both models, municipal and quasimunicipal wells were pumped at rates reported by the local municipalities. All other well types were allowed to pump at their full water right, with domestic wells pumping at a rate of 83.5 ft^3/d (0.7 AFA). Heads calculated by the steady-state simulation were used as the initial condition for the transient models, and both models were run to 15 years.

Results

A comparison of drawdown resulting from transient models run at 50% and 100% of steady-state recharge does indicate a decline in groundwater levels in zones of mountain block recharge when under drought conditions. Interestingly, isolated regions in the Fernley Area show a small increase in groundwater levels under drought conditions. This occurs as a result of increased flow volumes in the Truckee Canal - while the steady state and 2006-2010 transient models were run using historical flow values, the drought model used estimated flow values for a drought under the new Truckee River Operating Agreement (TROA) regulations, which increased the volume allocated to the canal.

Two municipal wells in the Wadsworth area were selected to show the effects of drawdown over time (Figures 3 and 4). Results show a relatively insignificant effect of drought on the municipal supply. PLPT Municipal Well 3 shows an average decline of 0.1255 ft/yr (1.88 ft total) over 15 years of drought conditions, while the Stampmill 1 well actually shows an average increase of 0.0079 ft/yr (0.12 ft total) over the same time period. Fluctuations in these wells result from changes in river and canal flow volumes and seepage rates and are minimal. However, domestic wells located in or near the mountain block, where drawdown due to lost mountain block recharge is greater, may experience up to 14 feet of drawdown as a direct result of a 15-year severe drought (Figure 5).

Conclusions

- Municipal supply wells are resilient to the impact of a 15-year severe drought.
- The most significant impact of drought occurs in the mountain block.
- Domestic wells located in or near the mountain block may be impacted by a 15-year severe drought.
- Changing water regulations may result in increased groundwater elevations relative to the present, even during drought conditions.

Smoke Creek Desert (Gerlach)

The Smoke Creek Desert, referred to as basin 021, is located primarily in northwestern Nevada in Washoe County, and extends to the west into Lassen County, California. The town of Gerlach is located just east of the basin in the San Emidio Desert, but obtains its water from two mountain springs in the Granite Range at the northeastern boundary of the Smoke Creek Desert. Stream and groundwater flow discharges to the southwest-northeast trending playa located on the southeast side of the basin. The basin is sparsely populated, with no active municipal wells (Figure 6).

Steady-State Model Design

The Smoke Creek Desert model consists of 2902 1 km x 1 km grid cells. Cell elevations were determined by a DEM, and the base of the model was set at 2000 ft AMSL. Groundwater sources and sinks in the Smoke Creek Desert include mountain block recharge, spring flow, evapotranspiration, interbasin flow, and well pumping – though pumping was not included in the steady-state model. Mountain streams also act as head dependent sources and sinks of groundwater.

Recharge was modeled as several zones covering higher elevation areas in the hills and mountains bounding the basin. Previous studies have estimated the total mountain block recharge in the basin during non-drought years to be between 13,000 and 19,000 AFA (Glancy and Rush, 1968). The average value of 16,000 AFA was used in the initial model design, then adjusted manually to improve steady-state model calibration. The same study also estimated a 200 AFA underflow from the San Emidio Desert to the east and a 180 AFA underflow from Dry Valley to the southwest, which were applied to the model as specified flow boundaries.

Evapotranspiration zones were applied to the playa and areas populated by phreatophytes, and were calibrated such that basin-wide ET fell between the estimated values of 13,000 and 19,000 AFA (Glancy and Rush, 1968). The mountain streams of Smoke Creek, Buffalo Creek, and Squaw Creek are in communication with the underlying aquifer, and were modeled as head-dependent boundaries using the River (RIV) Package in MODFLOW.

The primary focus of this model was to determine the potential effects of drought on the two mountain springs providing water to Gerlach. A recent modeling study (Aqua, 2009) attempted to determine the effect of pumping on spring flow volumes in the Smoke Creek Desert. As part of that study, data loggers were placed in the springs to determine flow volumes. From November 2007 to February 2009, the flow in Garden Spring fluctuated between 37 and 53 gpm (59.7 and 85.5 AFA), while the flow in Railroad Spring held constant at 200 gpm (322.6 AFA). The springs were modeled using the Drain (DRN) Package in MODFLOW, and the model was calibrated to the measured spring flows. Though not a source of water for the town of Gerlach, a third un-named spring in the playa south of Garden and Railroad Springs was also modeled to more accurately calibrate the model, using a flow rate equal to the water rights for that spring. The flow budget for the steady-state model is detailed in Table 3.

As little data was available to indicate the hydraulic conductivities of the basin materials, zonal values for the mountains and basin sediments were estimated based on rock and sediment types, then calibrated using the PEST function in GMS. The final hydraulic conductivities used in this model range from 0.015 ft/d in the Granite Range to 30 ft/d in the stream alluvium.

Transient Model Design

Two transient models were run – one with recharge rates set to 50% of those used in the steady-state model, and one with 100% of the steady-state recharge, to assess the effect of lost mountain block recharge as opposed to simple pumping. All well types were allowed to pump at their full water right, with domestic wells pumping at a rate of 83.5 ft^3/d (0.7 AFA). Heads calculated by the steady-state simulation were used as the initial condition for the transient models, and both models were run to 15 years.

Results

The model run with 100% of normal recharge and all wells pumping at the full water right showed no change in the flow rate of either spring servicing Gerlach. This model therefore indicates that the current rates of pumping in this basin will not affect spring flow, a finding corroborated by the 2009 Aqua study.

A comparison of drawdown resulting from transient models run at 50% and 100% of steady-state recharge does indicate a decline in spring flow when under drought conditions. After 15 years of drought conditions, Garden Spring showed a decline of approximately 31.1 AFA (Figure 7), while Railroad Spring showed a decline of only 1.6 AFA (Figure 8). The model also indicated that wells located in Smoke Creek Basin may experience drawdown as a result of an extended drought, but that this drawdown would be less than 2 feet (Figure 9).

Conclusions

- The most significant impact of drought occurs in the mountain block.
- Springs providing water to Gerlach may be impacted. The model indicates an approximate flow reduction of 8% after 15 years of severe drought.
- Pumping in the Smoke Creek Desert does not appear to impact springs providing water to Gerlach.

Long Valley (Vya)

Long Valley, referred to as basin 009, is located in northwestern Nevada in Washoe County. The basin trends south to north, and is bound by the Hays Canyon Range to the west and various individual mountains and hills to the north, south, and east. Stream and groundwater flow discharges to playa lakes located primarily in the north basin. The basin is sparsely populated, with no active municipal wells (Figure 10).

Steady-State Model Design

The Long Valley model consists of 1161 1 km x 1 km grid cells. Cell elevations were determined by a DEM, and the base of the model was set at 4500 ft AMSL. Groundwater sources and sinks in Long Valley include mountain block recharge, evapotranspiration, interbasin flow, and well pumping – though pumping was not included in the steady-state model.

Recharge was modeled as several zones covering higher elevation areas in the mountains bounding the basin. Previous studies have estimated the total mountain block recharge in the basin during non-drought years to be approximately 6,000 AFA (Sinclair, 1963). This study also estimated evapotranspiration in the basin to be approximately 11,000 AFA. The study resolved this imbalance by suggesting that Long Valley may receive a significant amount of interbasin flow from Massacre Lake Valley to the east, Boulder Valley to the southwest, and Surprise Valley to the west. However, a separate study of Surprise Valley has stated that it is a closed basin (California Department of Water Resources, 1986). Additionally, Sinclair's estimated recharge rates in Massacre Lake Valley and Boulder Valley are quite low (3500 AFA and 2000 AFA, respectively), and they are therefore unlikely to contribute the apparent 5000 AFA difference between estimated recharge and evapotranspiration. As the Sinclair study provided no other evidence for this assertion beyond a mass balance error, it is likely that the estimate of evapotranspiration is high, and the perennial yield of the basin is in fact less than 11,000 AFA.

Evapotranspiration zones were applied to playas and to areas populated by phreatophytes. A maximum ET rate of 0.002 ft/d was applied to the playas with an extinction depth of 5 ft below the surface, while phreatophyte zones were assigned a maximum ET rate of 0.0007 ft/d with an extinction depth of 30 ft. A constant head boundary was placed in the largest playa zone to serve as a point of reference for the heads calculated in the steady state model, and the model was calibrated such that this boundary condition would not act as a significant source or sink of water. This boundary condition was removed before the transient simulations were performed. The flow budget for the steady-state model is detailed in Table 4.

As little data was available to indicate the hydraulic conductivities of the basin materials, zonal values for the mountains and basin sediments were estimated based on rock and sediment types, then calibrated using the PEST function in GMS. The final hydraulic conductivities used in this model range from 0.01 ft/d in the Hays Canyon Range to 3.5 ft/d in the alluvium of the central basin.

Transient Model Design

Two transient models were run – one with recharge rates set to 50% of those used in the steady-state model, and one with 100% of the steady-state recharge, to assess the effect of lost mountain block recharge as opposed to simple pumping. All well types were allowed to pump at their full water right, with domestic wells pumping at a rate of 83.5 ft^3/d (0.7 AFA). Heads calculated by the steady-state simulation were used as the initial condition for the transient models, and both models were run to 15 years.

Results

Transient models show the development of cones of depression surrounding irrigation wells along the western side of the basin, with a maximum drawdown of approximately 66 ft over 15 years (Figure 11).

A comparison of drawdown resulting from transient models run at 50% and 100% of steady-state recharge shows does indicate a decline in groundwater levels in zones of mountain block recharge when under drought conditions. Irrigation and domestic wells located in or near the mountain block may experience up to 10 feet of drawdown as a direct result of a 15-year severe drought (Figure 12).

Conclusions

- The currently accepted value of perennial yield for this basin may be an overestimate.
- Irrigation and domestic wells located in or near the mountain block may be impacted by a 15-year severe drought.
- The majority of the simulated drawdown is concentrated in the area of irrigation wells, indicating that irrigation well pumping exerts a dominant influence on water level decline in Long Valley.
- Water level decline due to pumping presents a more significant threat to resilience than a 15-year severe drought.

Conclusions

In this study, the effects of persistent, severe drought on groundwater levels in three hydrographic basins in Northern Nevada were assessed. This was carried out by running two transient groundwater flow simulations: one in which the mountains receive the full volume of normal recharge, and one in which the mountains received only 50 percent of normal recharge. In each simulation, domestic wells were pumped at 0.7 AFA, which is smaller than the 2 AFA water right, but represents a more realistic value. All other wells were pumped at their full water right duty, with the exception of municipal and quasimunicipal wells in the Dodge Flat/Tracy Segment/Fernley Area (Wadsworth) model, which were pumped at rates as reported by local municipalities. The simulations were run over a period of 15 years, and the difference in water levels at year-15 was interpreted as the effect of the reduction in recharge in the mountains, as all other features of the simulations – besides recharge – were identical. Differences in water level between the two scenarios in year-15 were measured at the location of municipal wells, and the difference in water level was also mapped throughout the model domain to show region of greater and lesser sensitivity.

The differences in water levels between the 50 percent (drought) and 100 percent (normal) recharge scenarios in year-15 was generally small compared to the net decline in water level at a given location due to pumping. The largest difference in water level between the drought and normal recharge simulations in year-15 usually occurred in the mountains, where recharge is delivered to model. This result is not surprising because the reduction in recharge propagates through the model at a rate governed by the hydraulic diffusivity, which is the ratio of the hydraulic conductivity to the specific storage parameter (or the ratio of transmissivity to storativity). As a result regions near the recharge zone "feel" the effects of a sudden reduction in recharge much earlier than points farther from the recharge zone. A corollary to this observation is that wells located near the mountain block tend to be less resilient than wells near the center of the valley.

The reduction in recharge is not instantaneously communicated to all locations in the basin. As a result, the effect of the reduction in recharge is not evident at any of the municipal wells during the 15-year simulation period. With the values of hydraulic conductivity, K, and specific storage, S_s, used in the transient simulations, the time delay, t_{delay}, between the onset of a reduction in recharge and its expression as additional drawdown in a pumped well is approximated by:

$$t_{delay} = \frac{S_s}{K} d^2$$

where d is the shortest horizontal distance between the recharge zone and the well in question. A well located 10,000 feet from the recharge zone, for example, would respond to a sudden change in the recharge rate in the mountain block after approximately 5.5 years.

In the Dodge Flat/Tracy Segment/Fernley Area (Wadsworth) simulations, water levels were reduced at most by 14 feet in the 50 percent recharge scenario after 15 years, relative to the full recharge case. This difference is interpreted as an effect of the drought. However, these levels of drawdown are seen only in domestic wells located near mountain block recharge zones. Municipal wells are located at a sufficient distance from recharge zones, and are primarily affected by flow rates in the Truckee River and Truckee Canal. Assuming predicted flow rates are accurate, models indicate that municipal and quasimunicipal wells in this area are resilient to an extended drought.

Similarly, the Long Valley (Vya) simulations yielded a difference in water levels of up to 10 feet at domestic and irrigation wells located near the mountain block under the 50 percent recharge drought scenario.

In the Smoke Creek Desert, flow rates in the two springs providing water to Gerlach in the 50 percent recharge case were reduced by approximately 8%, relative to the 100 percent recharge case after 15 years of simulation. The effects of pumping in the basin did not affect spring flow.

On balance, the influence of a persistent, severe 15-years drought on groundwater elevation in the three modeled basins is relatively minimal, at least when compared to the rate of decline due to pumping.

Recommendations

The most significant impacts of the simulated drought occur first in the mountains, where groundwater is recharged. Wells and springs in and near the mountain block tend to be affected earlier and more severely by a sudden reduction in recharge. For that reason, it is recommended that new wells be drilled as close to the center of the valley as possible.

Water level records are available at varying temporal resolution for some wells. Additional water level monitoring in more extant wells and flow rate monitoring in springs would provide valuable high-resolution feedback on aquifer and well performance.

While the effects of a simulated drought were small compared to the effect of pumping, the decline due to pumping alone is cause for concern, as it poses the greatest present threat to the resilience of municipal water resources.

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Tables

Table 1. Groundwater pumping by basin, *from* Nevada Statewide Assessment of Groundwater Pumpage, 2013. Volumes in acre-feet.

Hydrographic Area	Basin / Municipality	MM	IND	ENV	IRR	STK	MUN	QM	DOM	REC	COM	OTH	TOTAL	PY	% of PY
82 & 83	Dodge Flat & Tracy Segment / Wadsworth	657	1,175	0	0	0	66	1,030	4,506	727	0	845	9,005	13,600	66.2
21	Smoke Creek Desert / Gerlach	0	0	0	4,576	89	0	0	12	449	8	0	5,134	16,000	32.1
9	Long Valley / Vya	0	0	0	107	70	0	0	5	0	0	0	182	12,000	1.5

MM = Mining and Milling, IND = Industrial and Construction, ENV = Environmental, IRR = Irrigation, STK = Stock, MUN = Municipal, QM = Quasi-municipal, DOM = Domestic, REC = Recreation and Wildlife, COM = Commercial, OTH = Other, PY = Perennial Yield

Table 2. Flow budget for the Dodge Flat/Tracy Segment/Fernley Area (Wadworth) steady-state simulation.

	Rate (ft^3/d)	Rate (AFA)
Sources		
Mountain Block Recharge	391993	3285
Interbasin Flow	176840	1482
River/Canal Seepage	1967474	16486
Agricultural Recharge	292169	2448
Sinks		
Evapotranspiration	-769389	6447
Interbasin Flow	-706305	5918
River/Canal Seepage	-1065022	8924
Pumping Wells	-680984	5706

Summary	**Sources-Sinks (ft^3/d)**	**Percent Difference**
	-1.90	-0.000059

Table 3. Flow budget for the Smoke Creek Desert (Gerlach) steady-state simulation.

	Rate (ft^3/d)	Rate (AFA)
Sources		
Mountain Block Recharge	1773270	14859
Creek Seepage	32395	271
Interbasin Flow	45351	380
Sinks		
Evapotranspiration	-1591526	-13336
Creek Seepage	-117249	-983
Drains (Springs)	-142239	-1192

Summary	**Sources - Sinks (ft^3/d)**	**Percent Difference**
	1.20	0.000065

Table 4. Flow budget for the Long Valley (Vya) steady-state simulation.

	Rate (ft^3/d)	Rate (AFA)
Sources		
Mountain Block Recharge	714194	5984
Constant Head	9447	79
Interbasin Flow	298356	2500
Sinks		
Evapotranspiration	-1012802	-8487
Constant Head	-9196	-77
Summary	**Sources - Sinks (ft^3/d)**	**Percent Difference**
	0.005859375	5.7332578e-007

Figures

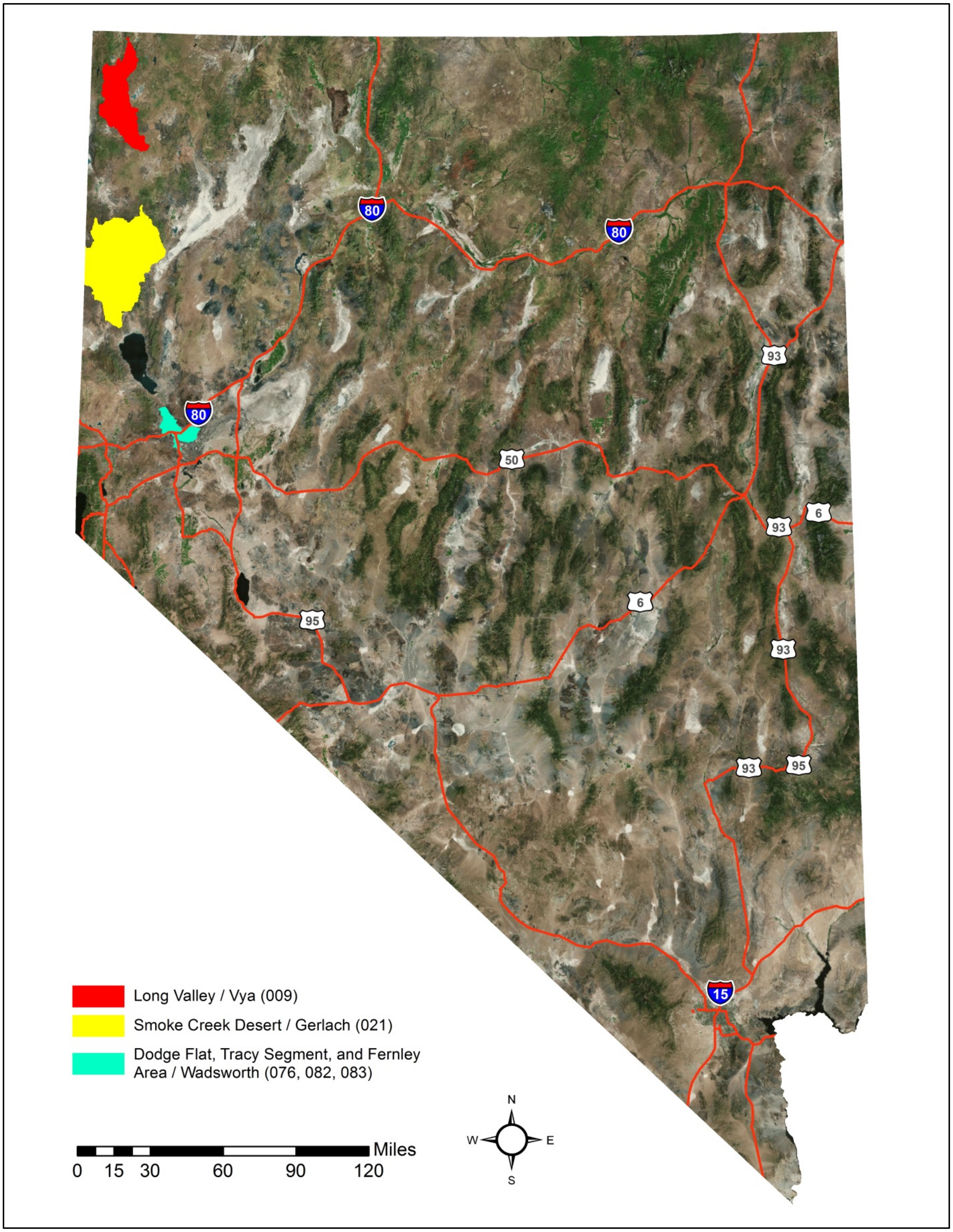

Figure 1. Hydrographic areas modeled for the study presented in this report.

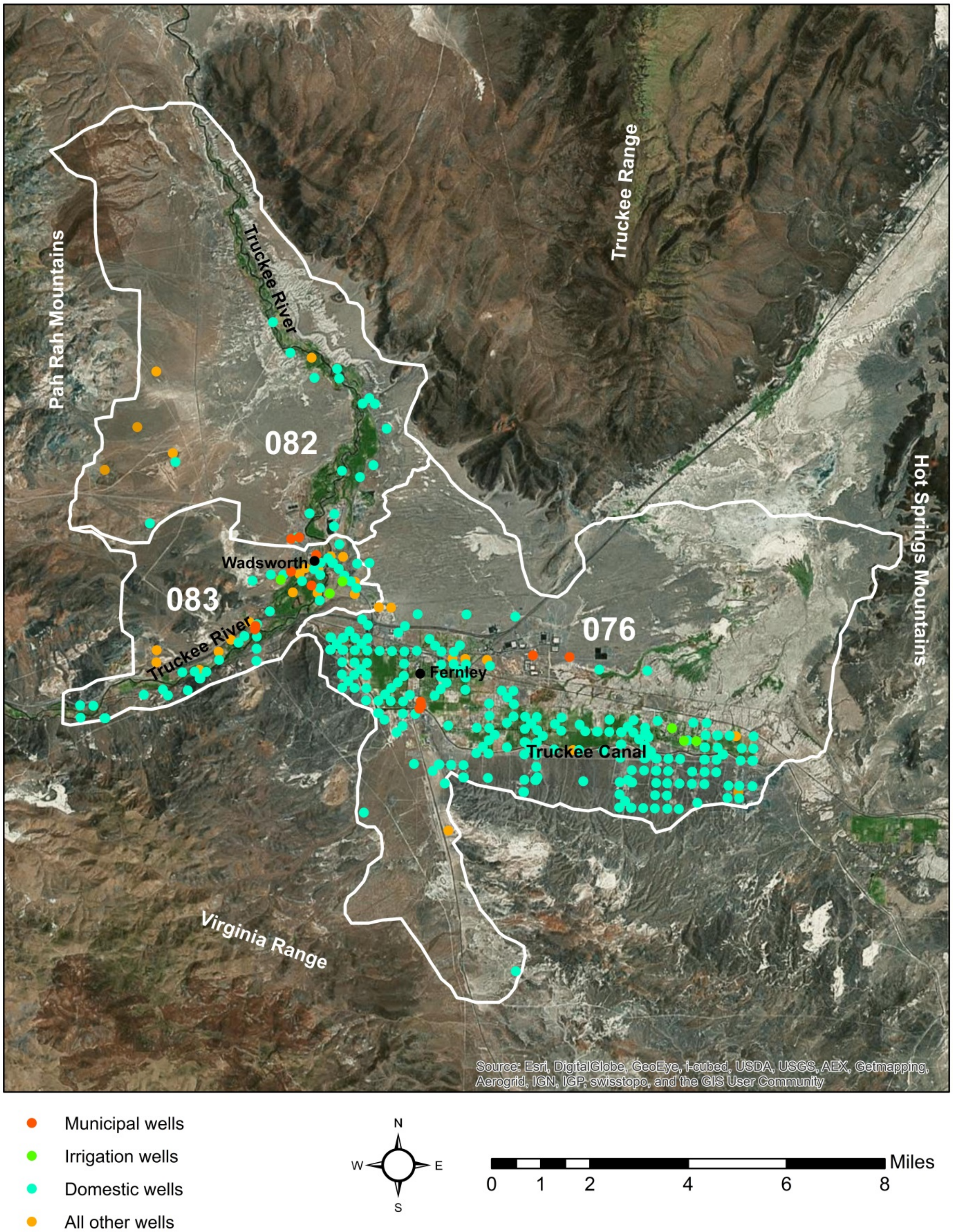

Figure 2. Dodge Flat (82), Fernley Area (76) and Tracy Segment (83) and locations of wells used in transient simulations.

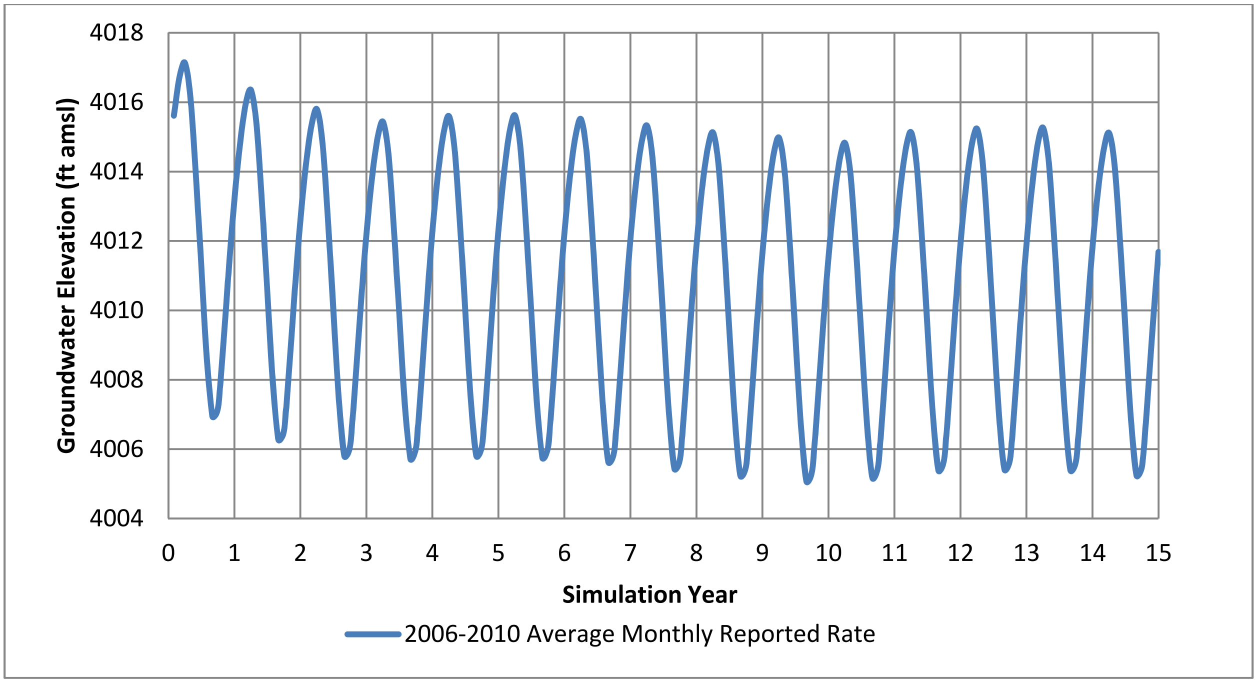

Figure 3. Groundwater levels at PLPT Municipal Well 3 over model duration.

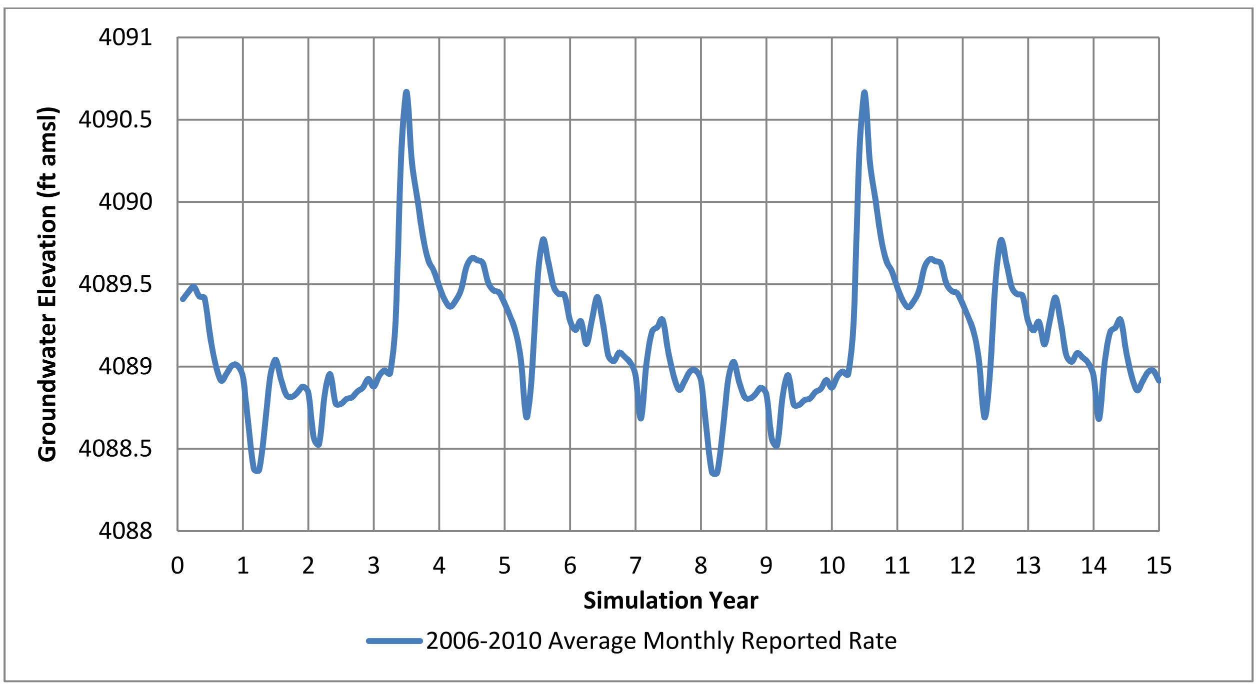

Figure 4. Groundwater levels at Stampmill 1 over model duration.

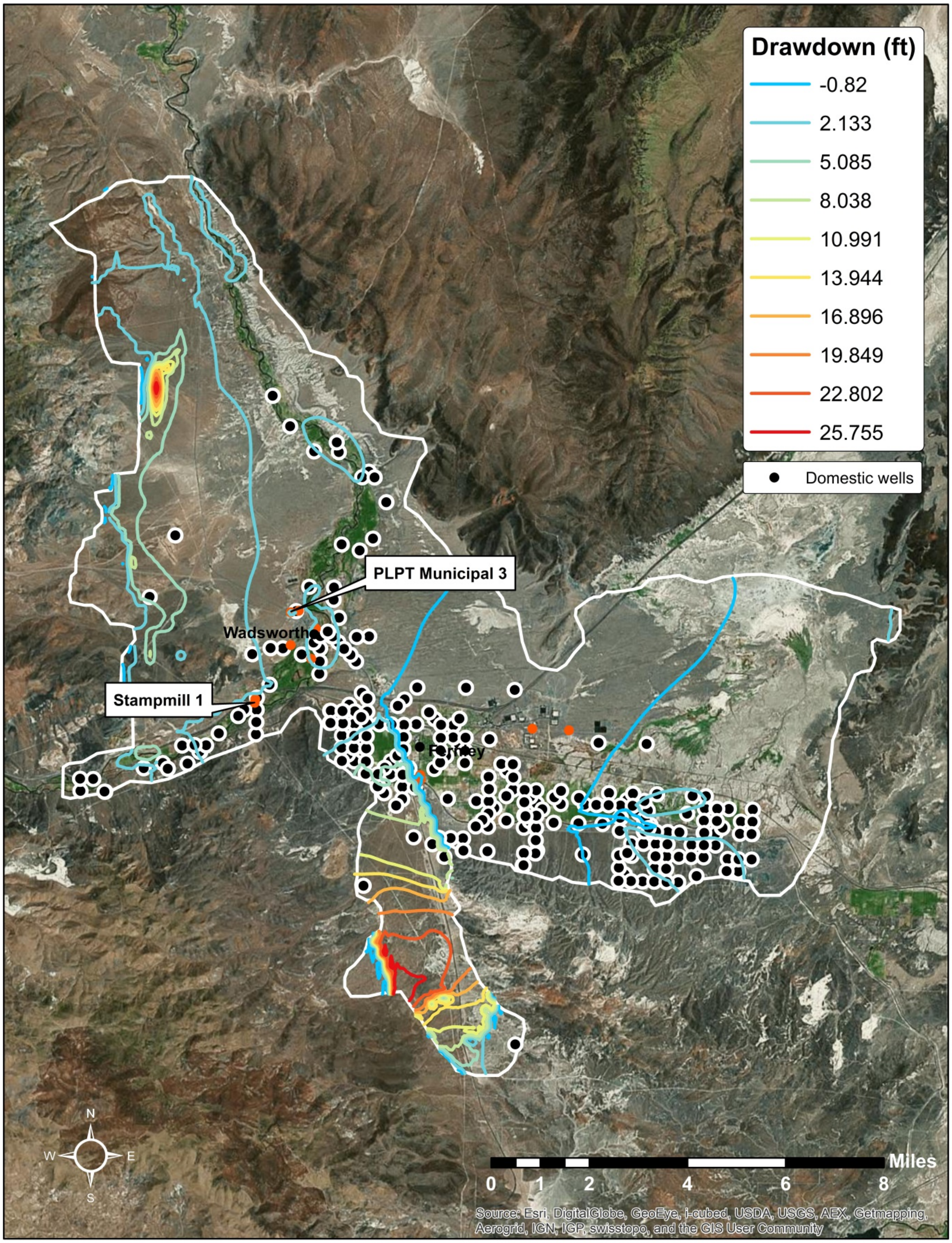

Figure 5. Difference in Dodge Flat / Fernley Area / Tracy Segment drawdown between simulation using 100% of normal recharge and simulation using 50% of normal recharge, all wells pumping at full water right.

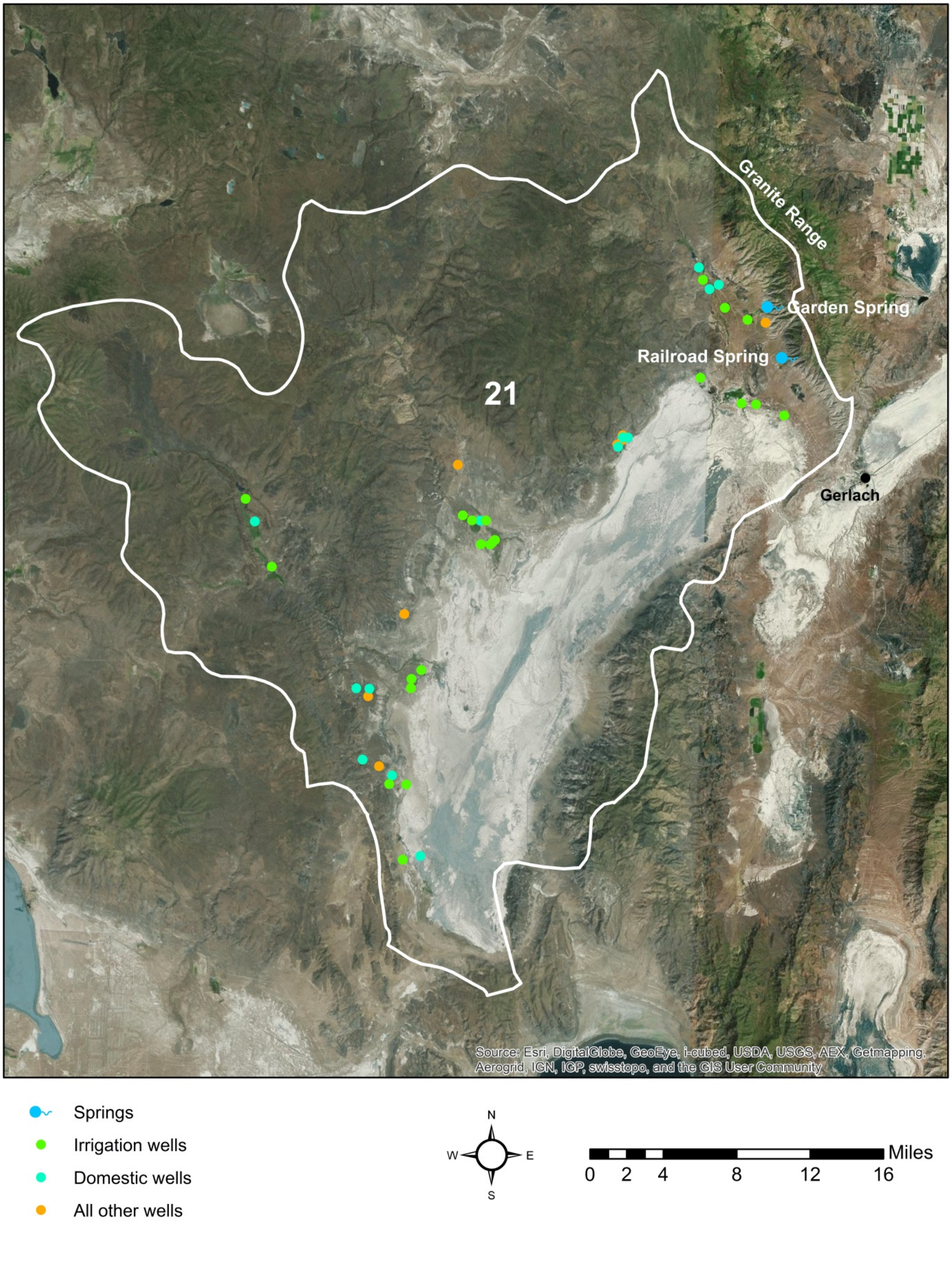

Figure 6. Smoke Creek Desert (21) and locations of wells and springs used in transient simulations.

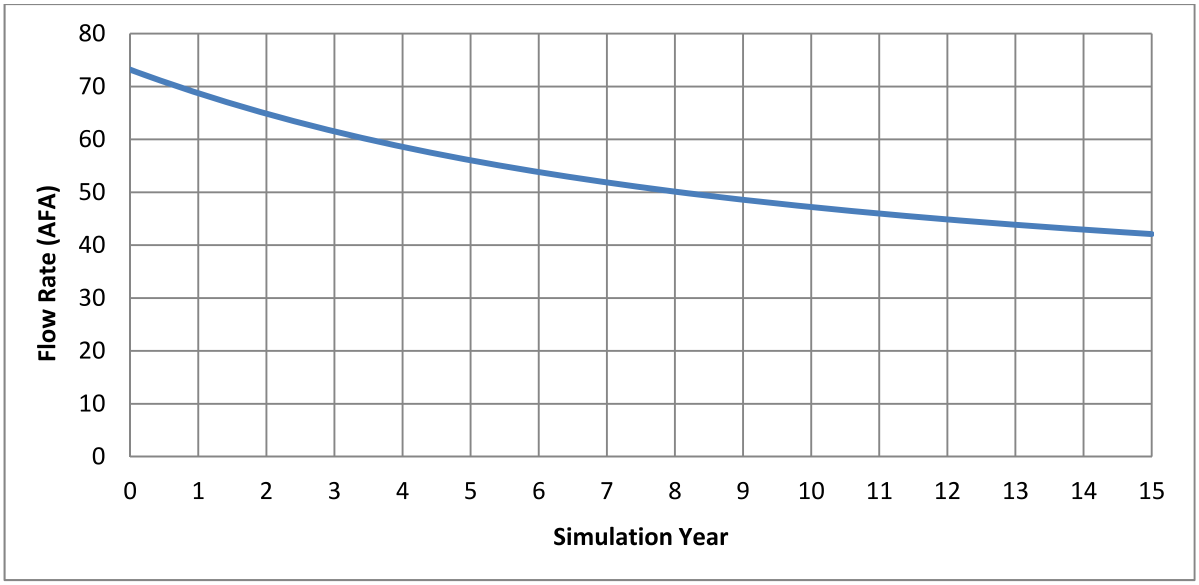

Figure 7. Declines in flow rates for Garden Spring over 15 years of drought conditions.

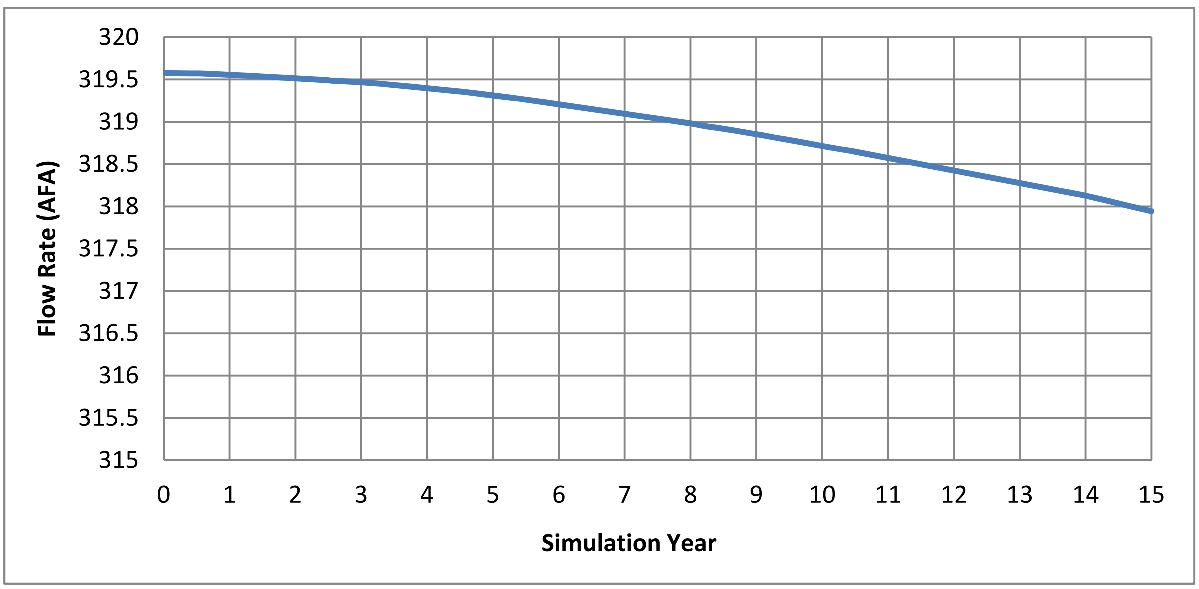

Figure 8. Declines in flow rates for Railroad Spring over 15 years of drought conditions.

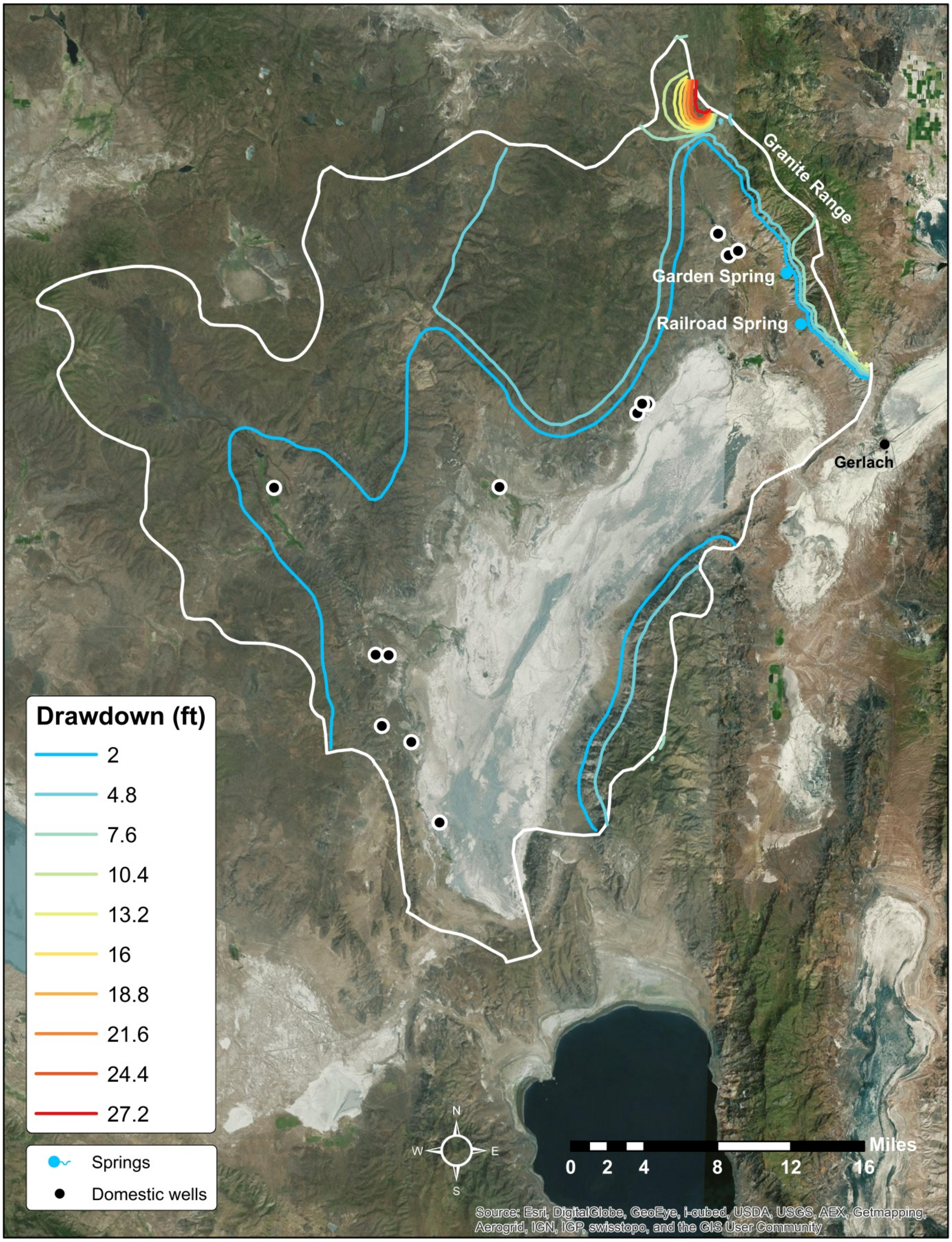

Figure 9. Difference in Smoke Creek Desert drawdown between simulation using 100% of normal recharge and simulation using 50% of normal recharge, all wells pumping at full water right.

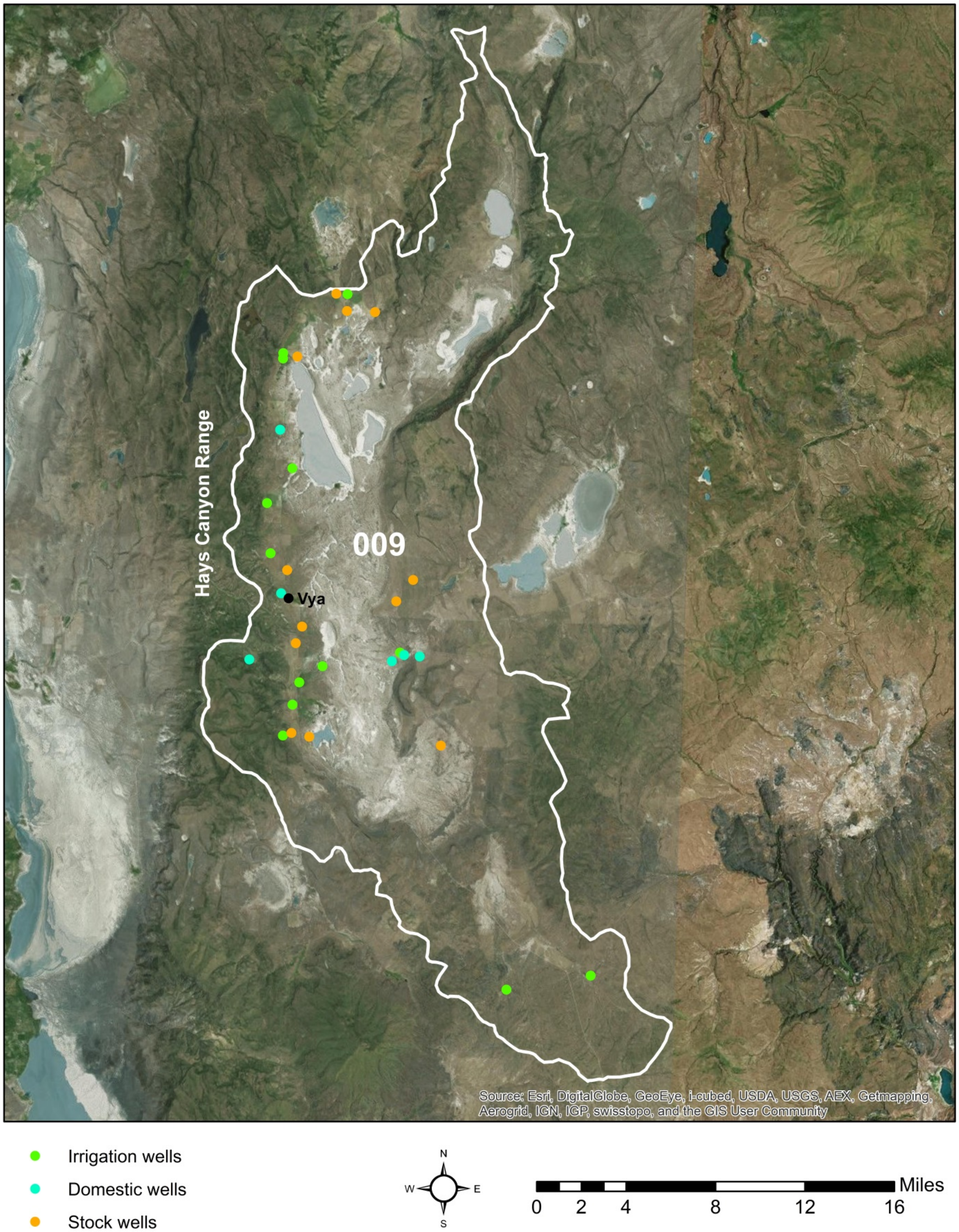

Figure 10. Long Valley (009) and locations of wells used in transient simulations.

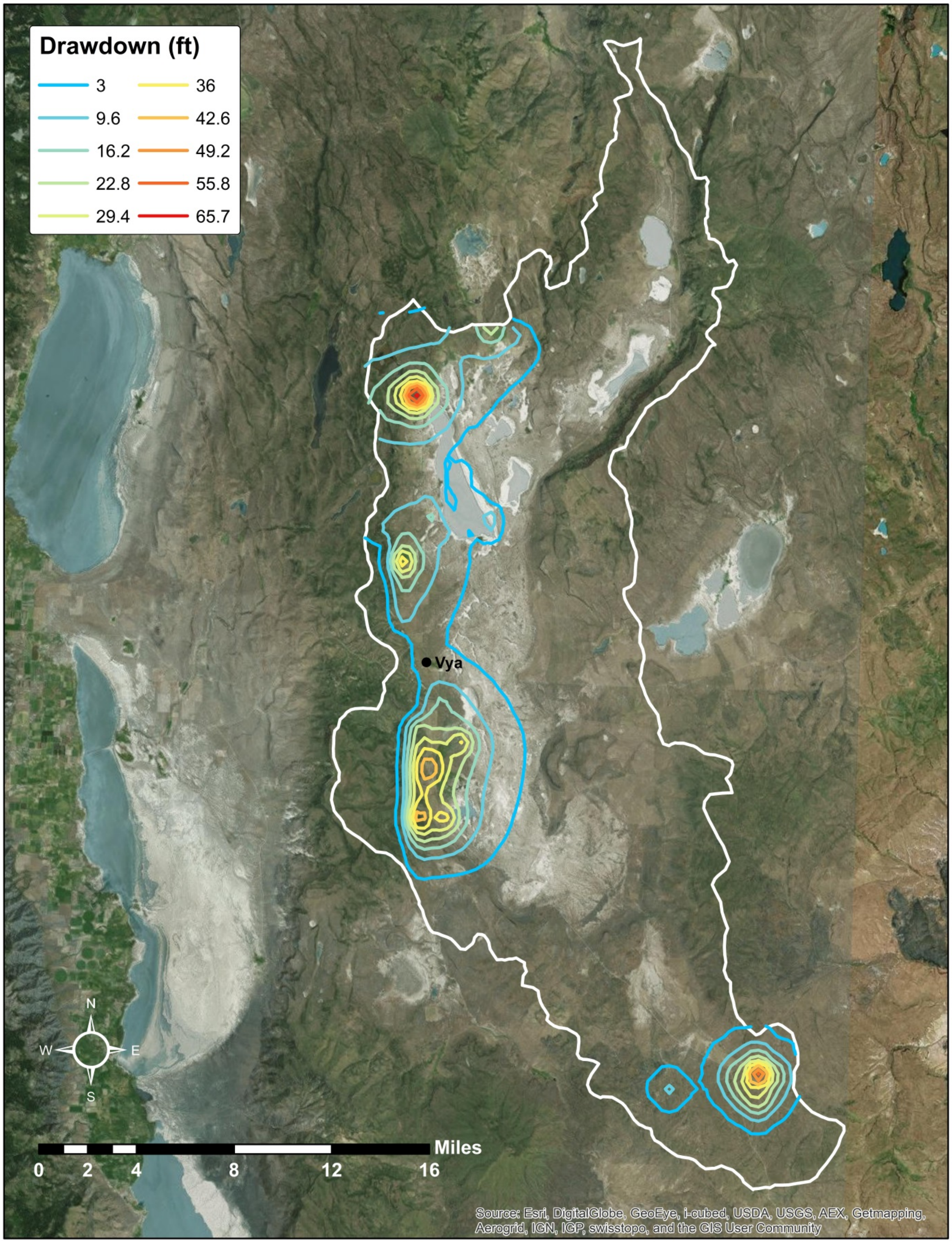

Figure 11. Drawdown in Long Valley after 15 years of mountain block recharge set to 100% of normal, all wells pumping at full water right.

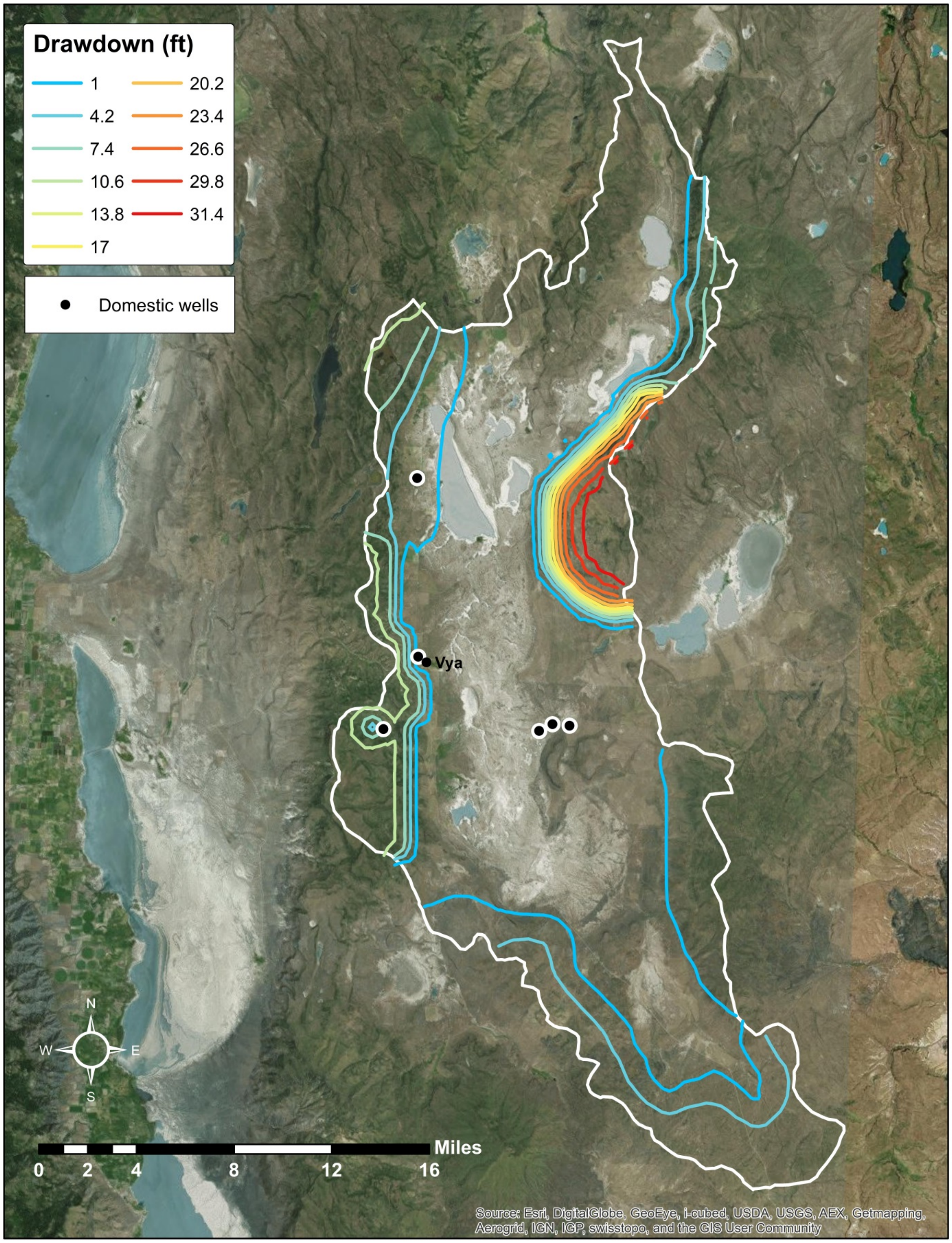

Figure 12. Difference in Long Valley drawdown between simulation using 100% of normal recharge and simulation using 50% of normal recharge, all wells pumping at full water right.